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ANALYSIS OF THE IMPACT OF ECONOMY DIGITALIZATION ON LABOR PRODUCTIVITY IN RUSSIA

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Digital economy is viewed as a tool to provide competitiveness of the state and high standards of living. The economic basis for improving the welfare of all citizens and the growth of the state's economy as a whole is an increase in labor productivity. At the same time, one of the main factors of labor productivity growth is scientific and technical progress in general, as well as the introduction of digital technologies and computerization of labor in particular. This article is concerned with the research of the key factors of digitalization affecting the level of labor productivity in the regions of the Russian Federation, and assessing their significance. The methodological basis of the research is the econometric model building. Data on labor productivity and digital factors were considered for the regions of the Russian Federation. The control variables used were the number of employees in the regional economy and the share of depreciation of fixed assets, which reflected the impact on productivity of factors such as labor and capital. The development of digitalization in the last decade has led to an expansion of the range of indicators of the digital economy covered by statistical observation. Therefore, the models were built with the use of two sets of numerical indicators: in the period from 2011 to 2017 and from 2006 to 2017. Panel regression models with random and fixed effects were developed. The Hausman specification test showed significant differences in models with random and fixed effects. We revealed a significant positive impact of such factors as computerization of workplaces, use of server equipment, appliance of mobile subscriber devices and the broadband Internet connection to workplaces in organizations which require a high degree of automation. Whether or not the companies had a website or the majority of their PCs had Internet connection posed practically no impact on the level of labor productivity.

Keywords: digital economy, digitalization, labor productivity, digital factors

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АНАЛИЗ ВЛИЯНИЯ ЦИФРОВИЗАЦИИ ЭКОНОМИКИ НА ПРОИЗВОДИТЕЛЬНОСТЬ ТРУДА В РОССИИ

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Цифровая экономика рассматривается как средство повышения конкурентоспособности государства и качества жизни его граждан. Экономической основой повышения благосостояния всех граждан и роста экономики государства в целом выступает возрастание производительности труда работников. При этом одним из основных факторов роста производительности труда выступает научно-технический прогресс в целом, а также внедрение цифровых технологий и компьютеризация труда в частности. Данная статья посвящена выявлению ключевых факторов цифровизации, влияющих на уровень производительности труда в регионах Российской Федерации, и оценке их значимости. Методологической основой исследования выступает эконометрическое моделирование. Рассматривались данные по

регионам Российской Федерации о производительности труда и цифровых факторах. В качестве контрольных переменных использовались численность занятых в экономике региона и доля износа основных производственных фондов, которые влияют на производительность труда и капитала. Развитие процесса цифровизации в последнее десятилетие привело к расширению круга показателей цифровой экономики, охваченных статистическим наблюдением. Поэтому модели были построены с применением двух наборов числовых показателей: за 2011–2017 гг. и за 2006–2017 гг. В данной работе предлагаются модели панельной регрессии со случайными и фиксированными эффектами. Модели панельной регрессии с фиксированными эффектами признаны статистически значимыми и более подходящими к применению с теоретической точки зрения. Тест Хаусмана показал существенные различия в моделях со случайными и с фиксированными эффектами. Выявлено значимое положительное влияние компьютеризации рабочих мест, использования серверного оборудования, применения абонентских устройств мобильной связи и подключения к широкополосному интернету рабочих мест организаций, требующих высокой степени автоматизации. Наличие собственного веб-сайта у организаций и подключение к сети интернет большинства их ПК практически не отражается на уровне производительности труда.

Ключевые слова: цифровая экономика, цифровизация, производительность труда, цифровые факторы

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Introduction

Nowadays the current state and further development of digital economy receives special attention. The digital economy is viewed as a tool to increase competitive qualities of the state and the standards of living [1]. In this study, the term “digital economy” refers to “a state of economic activity characterized by ubiquity and application of digital technologies, which therefore requires availability of the appropriate infrastructure and the Internet. Distribution and application of these elements is ... digitalization of economy, i.e. the process of its formation” [2].

Successful functioning of the digital economy is ensured with the development of infrastructure (access to the Internet, software and telecommunications), e-business (economic activity through computer networks) and e-commerce (distribution of goods via the Internet) [3, 4].

Digitalization of economic sectors and of the whole country is becoming an inescapable fact. There is a gradual introduction of digital platforms for controlling enterprises of engineering business, artificial intelligence technologies in industry, finance, medicine and etc. [5–8].

A vast majority of Russian organizations use personal computers in their activities (Fig. 1). By now, their implementation has been completed almost everywhere. This is also the case of the use of the global information resources and the broadband Internet connection. At the same time, the local area networks and proprietary servers are not applied in all organizations yet.

Impact assessment of digital technologies implementation is carried out in terms of the ratio of results to costs. The criterion for the effectiveness of the digitalization process is the acceleration of economic growth in the regions and the country as a whole [9, 10]. In this case, various indicators can be used as a result indicator. One of them is the level of labor productivity.

The purpose of the study is to identify key factors of the economy digitalization and assessment of their impact on the level of labor productivity in the regions of Russia.

Research methods

The instrumental basis of the research is the method of econometric model. The authors used panel regression models that have an advantage over conventional regression models, since they consider the specifics of development of the particular regions of the country.

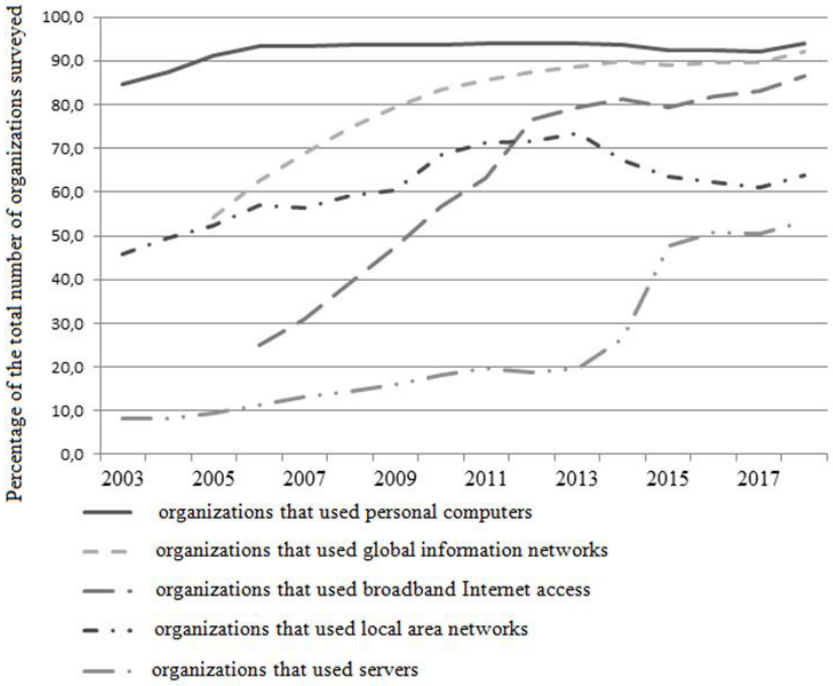

Figure 1. The use of digital technologies in the activities of organizations of the Russian Federation in 2003–2018

Source: Done by the authors based on Rosstat data [11, 12]

In relation to this study, the following models were constructed [13–15]:

1. Panel regression with random effects (PRRE):

$$Y_{i,t} = X_{i,t}\beta + u_i + \varepsilon_{i,t}. \quad (1)$$

2. Panel regression with fixed effects (PRFE):

$$Y_{i,t} = a_i + X_{i,t}\beta + \varepsilon_{i,t}. \quad (2)$$

In the presented models the following notations are used:

$Y_{i,t}$ — values of the effective variable in the i region in the t year;

$X_{i,t}$ — row-vector of values of independent variables in the i region in the t year;

β — column-vector of the model parameters;

$\varepsilon_{i,t}$ — a random component that characterizes the impact of other factors, which are not included into the model on the effective feature in the i region in the t year;

u_i — random effect for the i region;

a_i — fixed effect for the i region.

It is assumed that u_i means manifestations of a random variable that is subject to the normal distribution law, and a_i means constants that characterize the specificity of the i region.

The information base for the analysis is the official statistical data for 77 regions of Russia [11, 12].

The effective indicator is the level of labor productivity, which is represented in the models by the volume of GRP per a person employed in the region's economy at constant prices in 2017. In this study, the logarithmic values of this indicator are used as an endogenous variable, since their distribution within the year follows the normal law (Fig. 2).

Dynamic analysis of the distribution density function shows that since 2003 there has been an increase in labor productivity in the regions. In addition, since 2011, there has been a trend towards regional convergence. The graph represents this trend in the growth of the maximum of the density function. Thus, we can draw a conclusion about the convergence of Russian regions in terms of labor productivity in recent years.

Exogenous variables of models express the influence of both innovative factors of production caused by the process of digitalization, and basic ones [16–18].

The development of digitalization in the last decade has led to an expansion of the range of indicators of the digital economy covered by statistical observation. Therefore, with the use of two sets of numerical indicators certain models were built: in the period from 2011 to 2017 and from 2006 to 2017.

At the first stage of the study, panel regression models were obtained, which were based on the initial data for a relatively short period (from 2011 to 2017). However, from a theoretical point of view, they are of scientific interest, since they contain an extended list of variables that characterize digitalization.

Due to the inevitability of the process of the economy digitalization, it is necessary to expand onwards the list of indicators of the digital economy registered by the state statistics service, both at the national and regional levels. The identification of the most promising areas of development and implementation of digital technologies that save working time is of particular interest.

Currently, Rosstat evaluates the application areas of specialized software by all organizations of the Russian Federation, without specifying their territorial affiliation. In this regard, the retrospective dynamics of these values has no noticeable fluctuations over the years of the study (Fig. 3). While information about specialized software which was designed to support sales, planning the resource potential of the enterprise and other goals, recorded in the context of Russian regions, could reveal additional drivers of labor productivity growth.

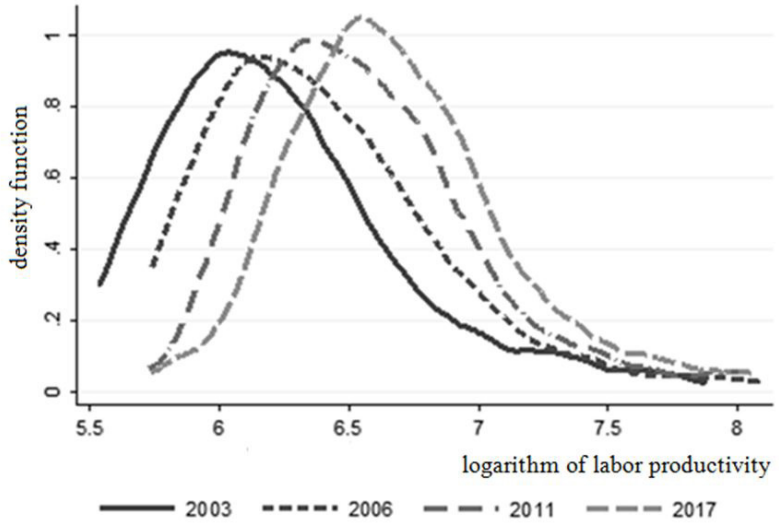

Figure 2. Distribution of Russian regions by labor productivity in 2003, 2006, 2011 and 2017.

Source: Done by the authors based on Rosstat data [11]

The models use the logarithm of a number of people employed in the regional economy and the coefficient of depreciation of fixed assets of enterprises and organizations in the region as control variables. Logarithmic numbers of the employed in the economy characterize the use of labor as a factor of production. The degree of depreciation of fixed assets expresses the influence of the quality of the applied labor resources on the results of production.

Basic variables additionally assume a logical control function over the models. In accordance with the law of decreasing marginal productivity, the growth of the number of employees in the economy of the

region should cause a decrease in productivity, all other things being equal. The amount of depreciation of fixed assets should have the opposite effect on the effective indicator. So, from a theoretical point of view, we should expect negative values of regression coefficients with these control variables.

At the second stage of the study, panel regression models were constructed based on the data for the period from 2006 to 2017.That led to a reduction of a number of factors that characterize the digitalization of the regional economy, since some indicators were not registered by Rosstat until 2011.

The following factors were excluded: share of organizations that used electronic document management systems; share of organizations that used electronic data exchange between their own and external information systems, and the number of active subscribers to the mobile broadband Internet per 1000 people.

On the other hand, the list of control factors was supplemented with an additional variable "crisis". It reflects the impact of the global financial crisis of 2008 with a time lag of 1 year on the economy of Russian regions.

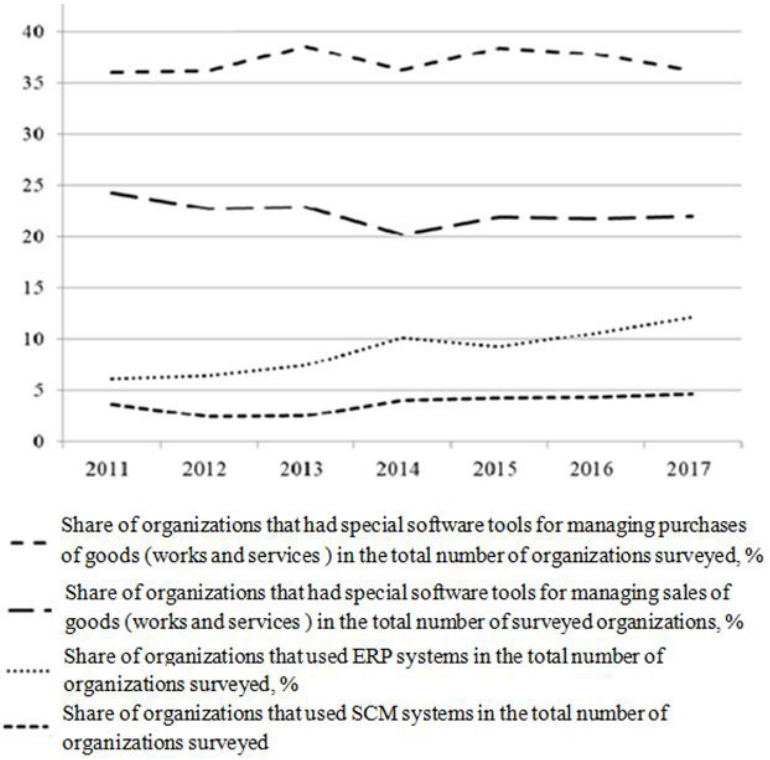

Figure 3. Organizations of the Russian Federation using specialized software in 2011–2017.

Source: Done by the authors based on Rosstat data [11, 12]

Obtained results

All panel regression models obtained at the first and second stages of the study were statistically significant with a high confidence probability. The sample size (77 regions of Russia) slightly differed from the size of the total population. The Hausman specification test showed significant differences in models with random and fixed effects. This indicates a preference for the models with fixed effects over the models with random effects [13, 19, 20]. In addition, panel regression models with fixed effects allowed identifying a greater number of factors (among the studied ones) that have a significant impact on the level of labor productivity in the regions of Russia.

The use of periods with different duration at different stages of the study did not affect the significance of regression coefficients for control variables. This means that traditional factors of production, such as

labor and capital, show the significance of their impact on labor productivity at any level of study (columns 3 and 5 of the table). According to theoretical expectations, the numerical values of the coefficients by the control variables in both models were negative. This means that with 1% growth in the number of employees in the regional economy, we can expect a decrease in labor productivity by 0.74%, all other things being equal. If the state of the fixed assets decays, the level of labor productivity in the region will fall. The coefficient for the control variable "crisis" also assumed the expected negative value (column 5 of the table), which indicates negative reaction of the level of labor productivity to the occurring and/or development of crisis phenomena in the economy of regions.

Checking the dependence of the effective indicator on the factors of digital economy revealed the following pattern: in a short period of time, it is not possible to prove the significant impact of most factors of digitalization on the dynamics of labor productivity in the regions. According to the values presented in column 3 of the table, four digital economy factors out of nine, which were included in the panel regression model with fixed effects, had a significant impact on the effective indicator. At the same time, a high level of significance is characterized by a positive coefficient for only one digitalization factor which is the share of organizations that had broadband Internet access. However, the numerical values of coefficients for other factors of the digital economy that characterize the degree of infrastructure development and e-business (the share of organizations that used servers; the logarithm of the number of connected mobile subscriber devices per 1000 people; the share of organizations that used electronic data exchange, etc.) were either of low or no significance.

Results of econometric modeling of the impact of economy digitalization on the level of labor productivity in the regions of Russia

Variables	Values of coefficients (size of standard deviations) in models based on source data			
	from 2011 to 2017		from 2006 to 2017	
	PRRE	PRFE	PRRE	PRFE
1	2	3	4	5
Constant	6.500*** (0.356)	9.553*** (0.578)	8.241*** (0.218)	10.62*** (0.242)
Control factors				
Logarithm of the number of employees	-0.0230 (0.0383)	-0.510*** (0.0876)	-0.361*** (0.0297)	-0.736*** (0.0355)
Depreciation of fixed assets at the end of the year, %	-0.00106 (0.000738)	-0.00125* (0.000699)	-0.00152** (0.000666)	-0.00249*** (0.000589)
Crisis phenomena in the economy	-	-	-0.0270*** (0.00926)	-0.0354*** (0.00807)
Factors of the digital economy				
Percentage of organizations that used broadband Internet access, %	0.00126*** (0.000413)	0.00134*** (0.000385)	0.00211*** (0.000415)	0.00178*** (0.000364)
Number of personal computers per 100 employees	0.000217 (0.00129)	-0.000253 (0.00120)	0.00125 (0.00141)	0.00340*** (0.00124)
Percentage of organizations that used servers, %	0.000274 (0.00029)	-0,0000481 (0.00028)	0.00151*** (0.000332)	0.00108*** (0.000291)
Logarithm of the number of connected mobile subscriber devices per 1000 people	-0.00999 (0.0419)	0.00525 (0.0398)	0.0659*** (0.0148)	0.0651*** (0.0129)
Number of personal computers with the Internet access per 100 employees	0.00406** (0.00164)	0.00392** (0.00153)	-0.000754 (0.00174)	-0.00158 (0.00152)
Percentage of organizations that had a website, %	0.000188 (0.00064)	0,0000379 (0.00060)	0.0000589 (0.000727)	0.000252 (0.000634)

Logarithm of the number of active mobile broadband Internet subscribers per 1000 people	0.0480*** (0.0167)	0.0327** (0.0159)	-	-
Percentage of organizations that used electronic data exchange between their own and external information systems, %	0.000320 (0.000231)	0.000377* (0.000215)	-	-
Percentage of organizations that used electronic document management systems, %	-0.000663* (0.000402)	-0.000257 (0.000381)	-	-

Note: the factors marked *** are significant at the significance level p<0.01, ** at the significance level p<0.05, * at the significance level p<0.1.

On the one hand, the use of panel data for a long period of time (from 2006 to 2017), led to reduction of the digitalization factors included in the model, and on the other hand, it allowed to prove the significant impact most of them have on the level of labor productivity in the regions of Russia. Thus, four out of six exogenous variables of the digital economy included in the panel regression model with fixed effects, were significant: share of organizations having used broadband Internet access; number of personal computers per 100 employees; share of organizations that used servers; logarithm of the number of connected mobile subscriber devices per 1000 people (column 5 of the table). It is proved that all of the abovementioned factors have direct impact on the effective feature. At the same time, it is noteworthy that the inconsistency of trends in the distribution density functions of these exogenous features and the resulting variable did not affect the decrease in the significance of the regression coefficients for the corresponding factor variables. For example, Fig. 4 shows a noticeable increase in the degree of stratification of Russian regions by the number of organizations that used their own server in the period from 2011 to 2017. While the convergence of the most subjects of the Russian Federation was observed according to the labor productivity level in the same period (Fig. 2). This may be due to the gradual transition to the use of cloud technologies and the lease of computing power from large IT service providers.

Contrary to expectations, the panel regression model with fixed effects demonstrated the opposite insignificant impact on the level of labor productivity of the number of personal computers provided with the Internet access per 100 employees of organizations (column 5 of the table). This may be due to the increasing unproductive use of working time when installing a PC in places where a high degree of automation of work procedures is not required.

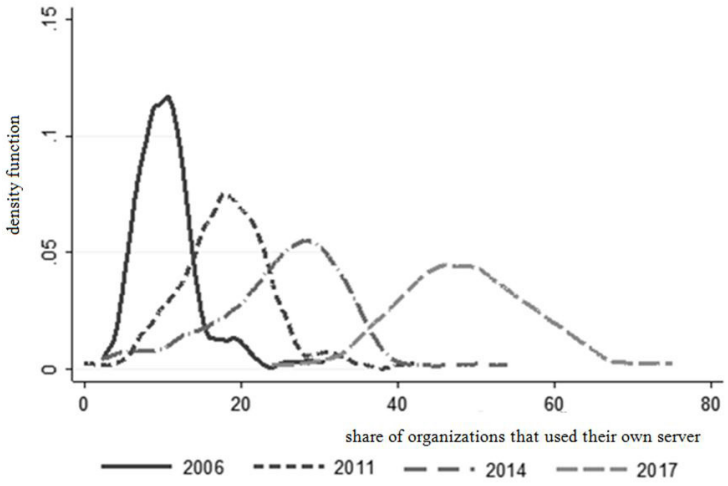

Figure 4. Distribution of regions of the Russian Federation by the share of organizations using their own server in 2003, 2006, 2011 and 2017.

Source: Done by the authors based on Rosstat data [11, 12]

The regression coefficient was also insignificant for such a variable model as the share of organizations that had their own website. To verify the reliability of the obtained result, the study conducted a counter analysis of the dynamics of the density function of the distribution of Russian regions by factor and effective characteristics. Thus, the analysis of the dynamics of the density functions of the distribution of Russian regions by this exogenous factor shows that in 2006 most of the Russian regions were close in this feature and had a small share of organizations that invested in the development of their own websites (Fig. 5).

Over the next five-year period (from 2006 to 2011), Russian regions were "stratified" by this indicator: both regions with a high share of organizations having a website (75% or higher) and regions with a low share of this indicator (less than 20%) began to occur. In 2011 and subsequent years, those regions where the share of organizations with their own web page increased to 30-50% were dominating. The lower limit of the numerical values of the studied feature increased (from 18 to 30%), while the regional stratification became stable. The analysis of the distribution density functions of Russian regions by the level of labor productivity over the same period (Fig. 2) showed a tendency to similarity of regions on this basis. The contradictory dynamics of the density of the distribution of Russian regions by exogenous and endogenous factors was one of the possible reasons for the insignificance of the regression coefficient in the corresponding variable model.

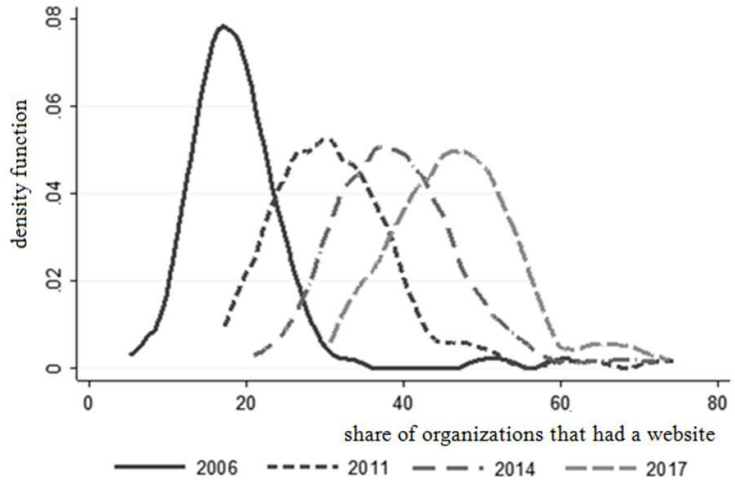

Figure 5. Distribution of regions of the Russian Federation by the share of organizations having a website in 2003, 2006, 2011 and 2017.
Source: Done by the authors based on Rosstat data from [11, 12]

Additional reasons could be the following:

– For many regional companies in Russia, the website is only a mean of publishing business information, and not an effective tool for interacting with customers and increasing sales.

– The companies update information on the websites rarely, which reduces the users' trust to the content and the organization as a whole.

– Organizations allocate insufficient financial resources to promote their websites, etc.

Together, these reasons do not lead to the expected growth in sales and production volumes and, consequently, the level of labor productivity. And in some cases (for example, when placing false information on the website), they entail financial sanctions, which may ultimately affect the growth of production volumes in a negative way.

Conclusion

As a result of the research, the authors found out that the basic factors of production (labor and capital) have significant impact on the growth of labor productivity. This effect is detected at any modeling horizon.

Along with the basic factors and factors of the macroeconomic environment, the level of labor productivity in the regions of modern Russia is also affected by the factors of the digital economy. However, their significant impact can only be tracked when using baseline data for a long retrospective period.

The computerization of workplaces (with controlled access to the Internet), use of server equipment and mobile subscriber devices, and connection of workplaces that require a high degree of automation to the broadband Internet have a significant positive impact on the growth of labor productivity in Russian regions. However, providing access to the Internet for the most PCs of an organization affects the level of labor productivity negatively, which can be explained by the increase in unproductive use of working hours. Whether the companies possessed a website or not had little impact on productivity, which indicates that organizations use other ways to interact with suppliers and consumers.

Directions for further research

This paper considers only some aspects of the impact of digitalization of the economy on labor productivity in the regions of the Russian Federation. We see prospects for further research in the study of the impact of the use of specialized software designed to support sales, planning the resource potential of the enterprise and other goals on the dynamics of labor productivity. In addition, the analysis of the impact of factors on labor productivity on the materials of a large number of specific enterprises in the regions of Russia can reveal the most effective factors of digitalization.

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