ATLANTIS PRESS
Advances in Economics, Business and Management Research, volume 156
2nd International Scientific and Practical Conference on Digital Economy (ISCDE 2020)

Modeling the Influence of Intellectualization Factors on Labor Productivity in Russian Regions

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ABSTRACT
The article analyses the intellectualization processes and their impact on labor productivity both at the national level and in relation to the situation in Russian regions. The study proves that labor intellectualization can be considered not only as an objectively occurring in society process of changing the content of labor in favor of intellectual activity and increasing the share of intellectually intensive operations, but also as a certain form of control action, as a model of economic transformation that ensures economic growth.
The use of digital solutions and information and communication technologies (ICT), training and retraining of personnel, research and development (R&D) were theoretically justified as factors of influence on labor productivity related to its intellectualization. As a result of econometric modeling, the significant impact of digital solutions and ICT, as well as training and retraining of personnel on labor productivity in Russian regions was confirmed. R&D factor was excluded from the final model due to the low level of influence.
Based on the modeling results, the rating of Russian regions by the level of expenditures on the labor intellectualization was compiled.
Keywords: *Intellectualization of labor, labor productivity, regions of Russia, digital economy, ICT, R&D, economic development*

1. INTRODUCTION

The post-industrial model of the modern economy development and new factors caused by the foreign policy and epidemiological restrictions at the end of the second decade of the XXI century have increased attention to the processes of labor intellectualization. The role of intellectual capital in generating added value and increasing labor productivity has become so significant that investors and entrepreneurs began to focus their attention in business development on the so-called "knowledge-intensive" technologies. Earlier scholars and practitioners agreed that only the functioning of high-tech and knowledge-intensive production is based on advanced knowledge, highly educated and highly qualified labor [1, 2]. Now it is intellectual labor that determines the potential for business development and its competitiveness in almost any industry and sphere of economic activity.
Despite a large number of scholarly works devoted to the evaluation of intellectual capital level [3-7] and the study of the relationship between intellectual capital (for the most part, between its elements, namely, human capital) and labor productivity [8-12], at present, the issue of evaluating labor productivity in the process of its intellectualization is still unresolved. Traditionally, when making decisions about increasing labor productivity, the main and primary factor of influence is considered to be an increase in the labor capital ratio, which requires investment in fixed assets. However, it is already becoming clear that in addition to this main factor, there are other secondary factors affecting labor productivity associated with its intellectualization.
Thus, the issues of studying the factors of labor intellectualization and their influence on labor productivity require more detailed consideration.
Research hypothesis: In a post-industrial model of modern economy development and the emergence of new factors, including those caused by epidemiological restrictions and foreign economic pressure, the dynamics of labor productivity in addition to the primary factor – the increase in the capital-labor ratio – is influenced by secondary factors associated with labor intellectualization.
The purpose of the study is to identify the most significant factors of labor intellectualization, in addition to investment in fixed assets, and to model their impact on the dynamics of labor productivity in Russian regions.

2. METHODOLOGY

Increasing labor productivity is one of the main vectors of the Russian economy development [13]. However, in the context of accelerated development of new production and related technologies, digital transformation of the Russian economy and new realities caused by foreign policy pressure and the use of restrictive measures related to preventing the spread of epidemiological threats, specific mechanisms for ensuring labor productivity growth require more detailed study. This issue becomes especially

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important when it is considered in relation to the specific socio-economic situation in the Russian regions.

In our opinion, the management of labor intellectualization processes both at the national level and in relation to the situation in Russian regions is the effective mechanism for influencing the dynamics of labor productivity in modern conditions.

The main features of the labor intellectualization processes at the present stage are:

– changing the content of material production and logistics processes in the direction of reducing human participation in actions that require physical effort, in favor of activities related to receiving, processing and transmitting information;

- increase in the general level of remuneration for intellectual labor, both due to structural changes in the employment market and supported at the legislative level by the Decree of the President of the Russian Federation Vladimir Putin [14] and the corresponding regional action plans ("road maps") in the field of culture, education and science, healthcare, etc.;

– development of technologies for telecommuting, which has become especially important during the growing global epidemiological threats, such as the 2019-2020 coronavirus infection (COVID-19);

– the widely spread concept of lifelong learning, which allows a person to raise intellectual level rather quickly and often on-the-job through the system of advanced training and retraining of personnel;

– digitalization of the economy as a key trend in the development of socio-economic systems at the turn of the second and third decades of the 21st century, when, without the necessary knowledge and skills in the field of ICT, a person is not in demand for a significant part of employers.

Taking into account the selected features, we considered the essence of labor intellectualization in the new economic conditions. Several definitions and interpretations are given in the academic literature.

The intellectualization of labor is a process that is constantly enriched with knowledge and is in a dynamic state, the main factors of its development are education, readiness to improve it, genetic abilities and learning from the experience of previous generations; this is the increase in the share of intellectual labor in human activity [15,16].

The intellectualization of labor is understood as a multifaceted process of increasing the role of intellectual creative work, saturation of all types of labor with functions of creative nature; accompanying all stages of the process of creating innovative products [17].

The intellectualization of the economy is the process of enriching labor with knowledge and increasing the share of the intellectual component in the activities of the individual and human capital as a whole through the generation and accumulation of knowledge and the development of science-intensive principles in economic activity [18].

The essence of intellectual labor is that its results find an objective form of expression, "materialize" in the objects of intellectual property [19].

Without entering into polemics with the above authors about the comprehensive nature of particular definition and largely agreeing with them, we would like to reveal a slightly different aspect of the intellectualization of labor. In addition to the fact that this is an objectively ongoing in society process of changing the content of labor in favor of intellectual activity and increasing the share of intellectually intensive operations, the intellectualization of labor can be considered as a certain form of control action, as a model of economic transformation that ensures economic growth. This perspective is especially relevant at the regional level, when, in the context of resource constraints and increased competition, local decision-makers have no time to wait for the economic order to change and highly intelligent technologies for production and service delivery to become widespread. We need proactive actions to ensure that the regional labor market is ready for such a transformation. And most importantly, people themselves must be ready for such changes.

Regional management systems require specific proportions of the use of resources aimed at increasing labor productivity. In practice, the need for resources is most often estimated in terms of value, which requires financial measurement of the resource indicators used in models.

Regression modeling conducted by HSE researchers in 2020 showed that the main factors for higher labor productivity are the size of the enterprise, investment activity, employee training, export, and the use of digital technologies [20]. The size of the enterprise, investment activity, and exports are not the indicators of labor intellectualization, and therefore, in our study, we will move them beyond modeling.

The size of the enterprise has a positive effect on the output indicator due to the economies of scale, since large orders, and as a result, production programs, are mainly concentrated in large enterprises. Their capital and labor organization levels are significantly higher than those of small enterprises. A sharp drop in labor productivity in large enterprises arises with a decrease in the size of orders and the need to constantly convert facilities for a changing product range.

Investment activity is the main and primary factor influencing the increase in capital-labor ratio and, as a consequence, labor productivity. But when planning decisions on the distribution of regional resources, the volume of private investment does not directly fall within the zone of influence of regional authorities. Of course, in most regions of the Russian Federation, investment attraction programs are being implemented, but their influence on the size of capital investments of private investors is still indirect.

The high export potential of the enterprise has a positive effect on labor productivity, including through the additional foreign exchange margin income and the territorial diversification of sales markets. However, in the context of emerging political, epidemiological and other restrictions, the export orientation of an enterprise can negatively affect labor productivity and even lead to reduction in jobs.

It turns out that the secondary factors affecting labor productivity associated with its intellectualization are:

– the use of digital solutions and ICT;
– training and retraining of personnel;
– R&D.

The third factor "R&D" was added to the model by the authors of this study to test the hypothesis that highly intelligent work in this area can have any significant effect on labor productivity.

All three identified factors of intellectualization are presented in the model by specific cost indicators per one employed in the regional economy according to official statistics for 2017–2018. The volume of gross regional product (GRP) per one employed in the regional economy was used as an indicator of labor productivity.

Regression analysis was used to study the relationship between labor productivity and factors of intellectualization. The following hypothesis was to be tested:

H0: The higher the cost of intellectualization, the higher is the labor productivity.

3. RESULTS

The study includes data on 85 constituent entities of the Russian Federation for 2017–2018. We chose this time period for analysis, since some of the indicators included in the study are collected by the Federal Statistics Service of the Russian Federation since 2017.

The model of labor productivity dependence on three groups of costs for the intellectualization of labor is presented as follows:

$$LP = f(RD, E, ICT), \quad (1)$$

where LP – GRP per person employed in the region's economy, RD – unit costs for R&D (calculated as costs for R&D divided by the average annual number of people employed in the economy), E – unit investment in fixed assets in the education sector (calculated as investment in fixed assets in the education sector divided by the average annual number of people employed in the economy), ICT – unit costs for ICT (calculated as costs for ICT divided by the average annual number of people employed in the economy).

The values of the indicators used in the model for 2018 are shown in table 1.

Table 1 Labor productivity and its factors in the regions of the Russian Federation in 2018, thousand rubles per person

Region of the Russian Federation	GRP per person employed in the region's economy *(LP)*	Internal R&D costs per person employed in the region's economy *(RD)*	Investment in fixed assets in the education sector per person employed in the region's economy *(E)*	ICT costs per person employed in the region's economy *(ICT)*
Altai region	537.4	1.8	1.8	4.5
Amur region	776.1	1.5	1.9	7.2
Altai Republic	610.8	1,2	7.1	8.4
Arkhangelsk region	1030.8	3.2	2,3	7.8
Astrakhan region	1175.8	1.1	1.6	6.5
Belgorod region	1150.7	2.8	2.4	6.1
Bryansk region	628.7	2.7	3	11.4
Chechen Republic	371.4	0.6	8	2.7
Chelyabinsk region	839.2	12.2	2	8
Chukotka Autonomous District	2346.5	0	4	22.2
Chuvash Republic	576.2	4,3	3.9	5.6
Irkutsk region	1284.1	4,3	3.9	15.5
Ivanovo region	444.6	1.6	2	3.8
Jewish autonomous region	855.7	0	2.6	4.9
Kabardino-Balkar Republic	391.6	1.9	3.6	1.6
Kaliningrad region	960.3	2.5	3.1	7.1
Kaluga region	926.4	14.1	1.6	17.8
Kamchatka Krai	1443.2	8.5	9.5	12.7
Karachay-Cherkess Republic	441.1	2.9	4	3.4
Kemerovo region	1039	1.3	2.8	6
Khabarovsk region	1027.3	3.3	3	9.6
Khanty-Mansi Autonomous District	4096.6	3	3.1	25.7
Kirov region	568.1	3.6	3.7	5.1
Komi Republic	1628.3	4.9	1.9	17.7
Kostroma region	638.8	0.7	3	6.4
Krasnodar region	900.7	2.4	4	8.8
Krasnoyarsk region	1621.1	16.1	4.5	11.7
Kurgan region	653.5	1,2	1.8	4.9

Continuation of Table 1

Region of the Russian Federation	GRP per person employed in the region's economy *(LP)*	Internal R&D costs per person employed in the region's economy *(RD)*	Investment in fixed assets in the education sector per person employed in the region's economy *(E)*	ICT costs per person employed in the region's economy *(ICT)*
Kursk region	838.8	5.3	3.1	6,3
Leningrad region	1418.9	9.5	4.2	7.9
Lipetsk region	1025.4	0.9	3	7.4
Magadan region	1863.9	8.7	2	18.6
Mari El Republic	631.6	0.7	1.8	5.1
Moscow city	2023.2	39,7	2.9	103.2
Moscow region	1241	36.7	6.2	43.6
Murmansk region	1326.1	7.1	1.9	12.9
Nenets Autonomous District	9585.6	0	22.5	33
Nizhny Novgorod region	837.4	47.3	2.8	13.9
Novgorod region	921.2	7	1.8	8.2
Novosibirsk region	943.7	17.9	4.6	15.4
Omsk region	764.4	6.5	1.6	6.5
Orenburg region	1086.9	1	0.9	6.4
Oryol region	733.5	1.9	2.7	5.8
Penza region	662.3	8.4	3.1	4.4
Perm region	1140.9	12.5	2.8	14.6
Primorsky Krai	858.9	8.2	3.3	9.5
Pskov region	580.9	0.7	1.3	4.9
Republic of Adygea	715.4	2	3	6
Republic of Bashkortostan	993.1	6.5	3.5	11.3
Republic of Buryatia	591.5	2.1	5.1	5.5
Republic of Crimea	465	1.8	8.7	8.6
Republic of Dagestan	559	1.1	6.6	1,2
Republic of Ingushetia	306.3	0.6	30.3	2.9
Republic of Kalmykia	682.4	0.9	7.8	3.8
Republic of Karelia	1037.8	4.1	1.4	8
Republic of Khakassia	1022.7	0,4	3.4	8.2
Republic of Mordovia	598.2	2.6	4.1	3.5
Republic of North Ossetia-Alania	436.5	1	7,7	2.7
Republic of Sakha	2182.1	5.8	6.8	13.2
Republic of Tatarstan	1270	9.2	5.4	12.6
Rostov region	747.1	6,7	3.3	6.4
Ryazan region	768.8	4	3.2	6.4
Saint Petersburg city	1330.6	39.4	5.4	22.8
Sakhalin region	4218.3	3.9	11.4	37.9
Samara region	913.8	8.5	2,3	11.9
Saratov region	677.7	4,3	3.7	17.7
Sevastopol city	398.8	4	15.4	8.7
Smolensk region	723.4	3.9	1.4	5.8
Stavropol region	572.5	1.7	1.9	4,3
Sverdlovsk region	1117.6	14.8	2.9	15.1
Tambov region	711.7	1.9	7	5.6
Tomsk region	1138.9	32	4,3	11
Tula region	889.6	9.4	1,2	7,7
Tver region	730	7.3	1,2	7.2
Tyumen region	1726.5	18.6	6.4	19.7
Tyva Republic	668.2	2.9	8.9	6,3
Udmurtia	901	3.3	3.2	6.5
Ulyanovsk region	609.3	21.2	6.2	8.9
Vladimir region	701.2	8	1.9	6.9
Volgograd region	747	3.1	2.6	6.6
Vologda region	1098.7	1.1	6.8	14.5
Voronezh region	850	7.3	5.5	5.1
Yamalo-Nenets Autonomous District	7381.5	0.7	6,3	23.2
Yaroslavl region	901	8.4	1.5	6.9
Zabaykalsky Krai	699.9	0.9	2.1	7.1

Descriptive statistics for the above indicators are presented in Table 2 below.

Table 2 Descriptive statistics

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
E, thous.rubles per person	4.032524	3.049103	30.29203	0.535499	3.796614	170
LP, thous.rubles per person	1090.551	814.7076	9585.553	293.761	1187.151	170
ICT, thous.rubles per person	11.0092	7.281354	103.2358	0.829919	12.28645	170
RD, thous.rubles per person	6.767204	3.27932	47.27197	0	9.215714	170

Since the input data for the analysis has a panel data structure, panel regression models with fixed or random effects are applicable to them. We applied the logarithm method followed by the change of variables to estimate the parameters of the regression, which is non-linear in the estimated parameters. Taking the log-linear form of Eq. (1), we obtain:

$$\ln LP = \ln \alpha_1 + \alpha_2 \cdot \ln RD + \alpha_3 \cdot \ln E + \alpha_4 \cdot \ln ICT$$

We tested all the variables using the Levin, Lin and Chu unit root test for panel data. The studied variables are stationary at the statistical significance level of 5%. The resulting models are panel regression models with random effects. The random effects models are appropriate according to the Hausman test. Estimated econometric models are presented in Table 3.

Table 3 Model table

Variable / Model	Model 1	Model 2	Model 3
Dependent variable	ln*LP*	ln*LP*	ln*LP*
ln*RD*	0.027882		
	(0.029729)		
ln*E*	**0.048153****	**0.061094****	
	(0.024354)	(0.023539)	
ln*ICT*	**0.358279*****	**0.374616*****	
	(0.043849)	(0.041702)	
$\ln E_{-1}$			**0.09301***
			(0.055799)
$\ln ICT_{-1}$			**0.598562*****
			(0.052124)
Constant	**5.899209*****	**5.915891*****	**5.494957*****
	(0.093513)	(0.095857)	(0.12066)
R-squared	0.327462	0.315756	0.635802
Adjusted R-squared	0.314852	0.307562	0.626919
F-statistic	25.96825	38.53257	71.5762
Observations	170	170	85
Note: Standard Errors are in parentheses. *** stat. significance on 1%, ** stat. significance on 5%, * stat. significance on 10%.			

R&D costs do not have statistically significant effect on the resulting indicator in Model 1. Eliminating this indicator, we built Model 2, in which all the variables have statistically significant effect on labor productivity. We obtained the following dependence:

$$\ln LP = 5.92 + 0.06 \cdot \ln E + 0.37 \cdot \ln ICT .$$

Model 3 showed that there is the relationship between the unit investment in fixed assets in the education sector, the unit costs for ICT made a year ago, and labor productivity in the current period. The lag dependency has the form:

$$\ln LP = 5.49 + 0.09 \cdot \ln E_{-1} + 0.60 \cdot \ln ICT_{-1} .$$

We can conclude from Model 2 and Model 3 that investment in education and spending on ICT have statistically significant effect on labor productivity. This dependence increases over time. ICT spending has stronger impact on labor productivity than investment in education.

Based on the results of modeling, we have compiled the rating of the regions of the Russian Federation in terms of their expenses for the intellectualization of labor. Model 2 showed that investment in education and ICT costs affect labor productivity in a ratio of 0.06 (α_2) to 0.37 (α_3). We calculated the following indicators to rank regions:

sE – share of investment in education development in GRP; $sICT$ – share of ICT costs in GRP.

We calculate the regional rating using the formula:

$$R = w_1 \cdot sE + w_2 \cdot sICT ,$$

where w_1 и w_2 – weights that are proportional to the elasticities in the model, $w_1 + w_2 = 1$. $w_1 = \alpha_2 / (\alpha_2 + \alpha_3)$ and $w_2 = \alpha_3 / (\alpha_2 + \alpha_3)$.

The results of ranking the regions of the Russian Federation are shown in table 4.

Table 4 Rating of Russian regions by the level of expenditures on the intellectualization of labor

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

The first place in the rating of regions in terms of expenditures on the intellectualization of labor was expectedly taken by the capital of the Russian Federation – the city of Moscow. The top ten intellectually-oriented regions of the Russian Federation also include the Moscow region and the city of St. Petersburg, which are also considered centers of attraction for intellectual capital. The bottom position of the rating was taken by the Yamalo-Nenets Autonomous District, which in 2018 had one of the highest GRP per employee in the country, which is associated not with the high degree of labor intellectualization in the region, but with its commodity dependence. Also, in the lower part of the rating you can find other leading regions in oil production – the Khanty-Mansi Autonomous District and the Krasnoyarsky Krai.

It should be noted that the main contribution to getting a high rating was made by the efforts of regional authorities and major business representatives to develop and implement digital solutions and modern ICT.

4. DISCUSSION

Analyzing the ratio of the weight coefficients in the constructed model 2 (0.06 and 0.37), we find that the allocation of regional resources for the digital transformation of the economy has a six-fold higher

positive effect on the dynamics of labor productivity than investment in education. The main reason for this result can be recognized as the ratio of the ICT commercialization and educational projects terms.

In modern conditions, taking into account the level of ICT development and the availability of ready-made digital solutions for business development on the market, investments in digital transformation give a positive effect quite quickly, the result is often noticeable within the first year of implementation. Investments in educational projects have a longer period of return: in the system of professional and higher education from 4 to 6 years, depending on the chosen level: secondary vocational education, bachelor's degree, specialty, master's degree, postgraduate study. The effects of professional development and retraining can be obtained most quickly, but only if the program that best suits the profile of future employment is selected.

Nevertheless, the obtained ratio does not mean that the regions definitely need to redistribute allocated resources from the education system to the digitalization of the economy. The long-term impact of investment in education is as important as the quick results of digital transformation. Moreover, digital solutions make educational projects themselves more effective. And the use of modern ICT also requires appropriate training of specialists.

5. CONCLUSION

As a result of the study, using the example of secondary factors of influence, we confirmed that the effective mechanism for influencing the labor productivity dynamics in modern conditions is the management of labor intellectualization processes both at the national and regional level.

The study proves that the intellectualization of labor can be considered not only as an objectively occurring in society process of changing the content of labor in favor of intellectual activity and increasing the share of intellectually intensive operations, but also as a certain form of control action, as a model of economic transformation that ensures economic growth.

The study results confirmed that investment activity is the main and primary factor influencing the increase in labor productivity.

The use of digital solutions and ICT, training and retraining of personnel, R&D were theoretically justified as secondary factors of influence on labor productivity associated with its intellectualization.

As a result of economic and mathematical modeling of the relationship between labor productivity and intellectualization factors using regression analysis, the factor "R&D" was considered insignificant and excluded from the final model.

Based on the modeling results, the rating of Russian regions by the level of expenditures on the intellectualization of labor was built. The ratio of the weighting factors in the constructed final model (0.06 and 0.37) showed that the allocation of regional resources for the digital transformation of the economy has a six-fold higher positive effect on the dynamics of labor productivity than investment in education.

In the future, analyzing the influence of secondary intellectualization factors on labor productivity, it is possible to prepare more effective management decisions aimed at both the digital transformation of the economy and the allocation of additional investments in the training and retraining system.

ACKNOWLEDGMENT

The reported study was funded by RFBR, project number 20-010-00877.

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