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PRODUCTIVITY PARADOX IN REGIONAL DIMENSION

The next industrial revolution is expected to give new impulse to productivity growth. In practice, the macroeconomic growth rate of this indicator decreases in developed countries and in Russia. However, productivity paradox, when technological innovations are accompanied by a slowdown in productivity growth, is observed only in parts of the constituent entities of the Russian Federation. The article is aimed to determine the reasons of a significant divergence of regions in the dynamics of labour productivity. For this purpose I identified two groups in the plurality of the constituent entities of the Russian Federation. The first one groups subjects with the most significant decrease in the labour productivity index. The second group covers the subjects of the Russian Federation where such decrease did not occur or it was small. The scientific contribution of the article consists in the results of a comparative analysis of the selected groups of regions. This analysis has revealed significant differences in the dynamics of expenditures on technological innovations and the share of these costs in the investments in fixed assets, in the share of investments to reconstruction and modernization, in the ratio of spending on research and development to the gross regional product. Thus, average annual costs of technological innovations during 2014–2016 in comparison with the period of 2010–2013 in the group of regions with a paradox of productivity grew by 1.82 times. However, and in the second group of regions these costs only increased by 1.03 times. The research has confirmed that, at the regional level, the productivity paradox is caused by the gradual exhaustion of reserves for improving previously mastered technologies. Furthermore, another reason of the productivity paradox is the diversion of resources from current production for its reconstruction and modernization or for research and development.

Keywords: labour productivity, productivity paradox, technological innovations, general purpose technologies, territorial subjects of the Russian Federation, indicators of executive authorities performance, industrial revolution, reconstruction, modernization, investment

Introduction

It is expected that widespread introduction of robotics, Internet of things and artificial intelligence as a part of the next industrial revolution would boost labour productivity. The current level of labour productivity in Russia is half of the USA level, even taking into account the purchasing power parity. There is a risk such situation may persist in case of Russia's fall into the "middle income trap", which threatens any country, when it attains an income of 40 to 60 percent per capita of the U.S. income level. The strategic guideline to get Russia out of the trap is to ensure the annual 5-percent increase in labour productivity at medium-sized and small enterprises in non-resource industries[1].

According to the assessments made by the Ministry of Industry and Trade of the Russian Federation, "a system-wide transition to a digital development model can boost labour productivity in manufacturing industries by over 30 percent by 2024 and increase the contribution to the GDP of the sectors based on advanced manufacturing technologies up to 15 percent"[2].

However, along with many other national economies, the Russian economy is now following a downward trend in labour productivity growth rates [1]. A pictorial presentation of the trend is shown in Figure 1.

[1] "O natsionalnykh tselyakh i strategicheskikh zadachakh razvitiya Rossiyskoy Federatsii na period do 2024 goda", Ukaz Prezidenta Rossiyskoy Federatsii ot 07.05.2018. №204 ["On National Goals and Strategic Objectives of the Russian Federation through to 2024", The Executive Order of the President of the Russian Federation No. 204 of May 7, 2018. As amended July 19, 2018]. Retrieved from: http://www.kremlin.ru/acts/bank/43027 (Date of access: 01.10.2018).

[2] Na zasedanii Soveta pri Prezidente po strategicheskomu razvitiyu i prioritetnym proektam obsudili programmu "Tsifrovaya ekonomika" [The Digital Economy program was discussed at the meeting of the Presidential Council for Strategic Development and Priority Projects]. Retrieved from: http://minpromtorg.gov.ru/press-centre/news/?_escaped_fragment_=na_zasedanii_soveta_pri_prezidente_po_strategicheskomu_razvitiya_i_prioritetnym_proektam_obsudili_programmu_cifrovaya_ekonomika (Date of access: 17.10.2018).

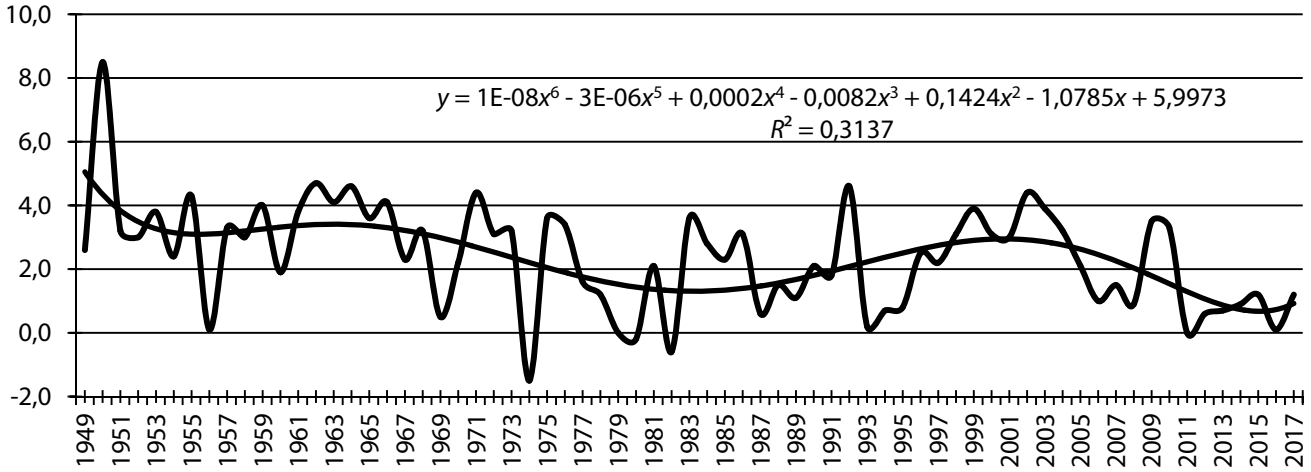

Fig. 1. *Rates of labour productivity dynamics for the U.S. business sector (the graph is plotted based on the data of the Bureau of Labour Statistics USA. Table Net Multifactor Productivity and Cost, 1948-2017 Retrieved from: https://www.bls.gov/mfp/#data (Date of access: 08.10.2018))*

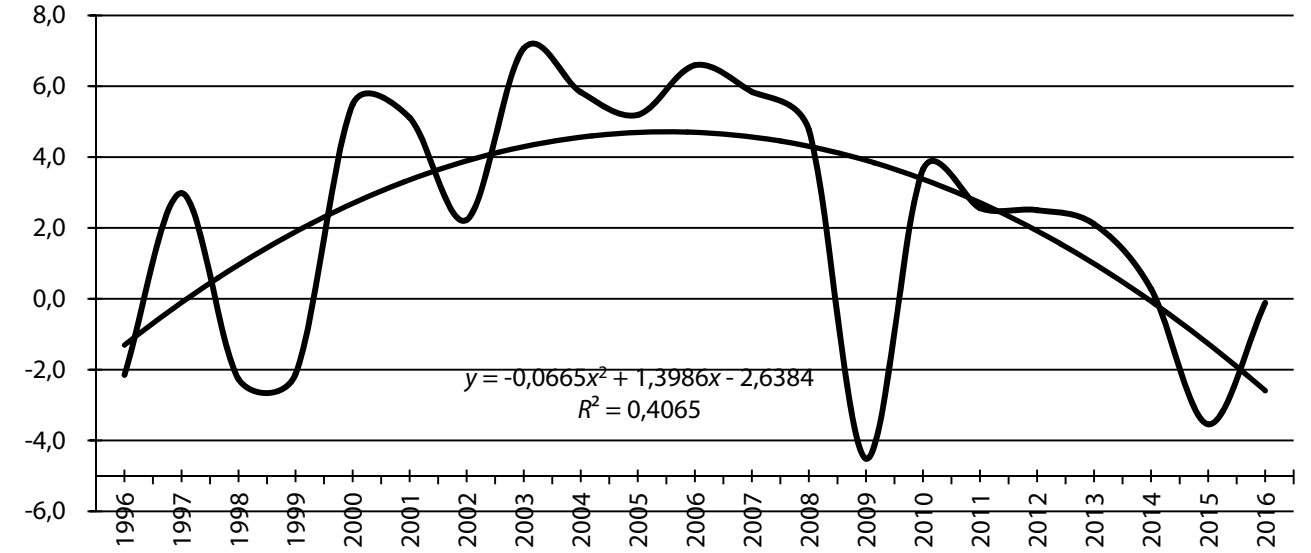

Fig. 2. *Rates of labour productivity dynamics for the Russia economy as a whole (plotted based on OECD Growth in GDP per capita, productivity and ULC data Retrieved from: https://stats.oecd.org/Index.aspx?DataSetCode=PDB_GR (Date of access: 08.10.2018))*

Moreover, the downward trend in yields of the capital investments in the U.S. private industry sectors has been reported by the U.S. Bureau of Economic Analysis[3] since 2000[4]. The similar situation occurred in the USA in 1970-s, when many organizations introduced computers into their operations.

R. Solow noted that for a long time computerization (or "programmable automation", as he put it in 1987) had seemed unable to make any positive impact on the labour productivity dynamics: "You can see the computer age everywhere but in the productivity statistics"[5]. Since then, the very phenomenon, when introduction of the new technologies is inevitably accompanied by a long-term slowdown in resource productivity, has become referred to as the Solow paradox, or the productivity paradox. As the vast body of studies report, the previous industrial revolutions used to provoke the same effects. As for

[3] Bureau of Economic Analysis. Retrieved from: https://www.bea.gov/ (Date of access: 02.10.2018).

[4] Gross Output by Industry. Retrieved from: https://apps.bea.gov/iTable/iTable.cfm?ReqID=51&step=1; Table 3.1ESI. Current-Cost Net Stock of Private Fixed Assets by Industry. Retrieved from: https://apps.bea.gov/iTable/iTable.cfm?ReqID=10&step=2 (Date of access: 11.10.2018).

[5] Solow R. (1987, 12 July) We'd better watch out. Book Review. New York Times Retrieved from: http://www.standupeconomist.com/pdf/misc/solow-computer-productivity.pdf (Date of access: 03.09.2018).

the Russian economy, the downward trend in labour productivity dynamics became obvious even before the 2008 crisis (Figure 2).

According to the Federal State Statistics Service (Rosstat) reports, beginning with 2010[6], the downward trend in labour productivity indices has already evolved in the majority of the RF subjects. Thus, improving the dynamics of the gross regional product (GRP) per capita has become a serious challenge for many subjects of the Russian Federation. The said dynamics is considered as one of the measures for assessing executive authorities' performance efficiency by the Presidential Executive order No. 548 of November 11, 2017 and the Decree of the Russian Federation government No. 472 of April 19, 2018.

With that, based on the average figures for the period from 2010 to 2016, we can see that the Russian Federation subjects differ significantly by labour productivity growth rates. 15 subjects can be ranked as top leaders (Table 1). Presented comparative analysis covers the Russian Federation subjects, for which the correspondent statistical data are available for the period covered.

Table 1

Russian Federation subjects with the highest labour productivity growth rates, 2010–2016, %*

RF subject	Growth rates of labour productivity
Bryansk Oblast	105,7
Tambov Oblast	105,5
Belgorod Oblast	105,3
Astrakhan Oblast	105,2
Mari El Republic	105,1
Republic of Mordovia	105,1
Kaluga Oblast	105,0
Voronezh Oblast	104,8
Novgorod Oblast	104,8
Sverdlovsk Oblast	104,8
Tula Oblast	104,7
Kursk Oblast	104,5
Irkutsk Oblast	104,5
Nizhny Novgorod Oblast	104,2
Orel Oblast	104,1

* Calculated based on the Rosstat data: Indeks proizvoditelnosti truda [Labour productivity index]. Retrieved from: http://gks.ru/free_doc/new_site/effect/macr2.xls (Date of access: 28.09.2018).

In exploring the causes of the decline in labour productivity growth rates in some of the Russian regions and their significant differences, it is helpful to refer to the current interpretations of the regional economic growth factors and to the insights on the factors triggering the Solow paradox.

Background studies review

Regional development disparity traditionally receives much attention in research community, and the brief, yet insightful outline of the studies in the field is presented, for example, in [3]. Among the most important factors of the regional economic growth modern researchers usually mention a region's scientific and technological potential [4, 5, 6] and efficiency of its use in the framework of a regional innovation system [7, 8]. Given that, in recent years innovation agenda at the regional level is frequently discussed in terms of transition to "Industry 4.0." [9, 10, 11]

As for the regional disparity in labour productivity levels, in [12] it is attributed to the specifics of a region's specialization and to the development level of a region's high-technology and knowledge-intensive sectors. The leadership of certain regions in labour productivity growth rates is explained by high concentration of the economic activity in the concerned regions in [13], where the author used the relative gross regional product (the ratio of a region's GRP to the average GRP for a set of regions under consideration) as a measure of economic activity concentration. Such explanation feels consistent with considering a region's investment climate as an important factor of the regional growth (see, for instance, [14]). The Agency for Strategic Initiatives has provided the National rating of investment climate in the Russian regions for several years, drawing on regional comparisons based on the wide spectrum of aspects. The National Research University Higher School of Economics (NRU-HSE) also provides its own assessments concerning the levels of the regions' innovation-driven development [15].

[6] Indeks proizvoditelnosti truda [Labour Productivity Index]. Retrieved from: http://gks.ru./free_doc/new_site/effect/macr2.xls (Date of access: 28.09.2018).

The list of the regions, presented in Table 2, differs up to 50 percent with the lists of the Russian Federation subjects, featured as leaders in the ratings of investment climate[7], investment potential and investment risks[8] in 2016 and 2017.

To a certain extent this fact confirms that "innovation mechanisms have not yet acted upon to their full extent as a major economic development leverage in Russia and that a range of pressing issues, concerning the guidelines for innovation-driven development of the RF regions as well as methodologies for its assessment and analysis, do still persist, waiting to be properly addressed" [16]. The similar point of view is presented in [17].

Given that background, some additional research and analysis of the factors, influencing the regional dynamics of labour productivity, is required. The very character of the dependence between labour productivity growth rates and availability of high-performance workplaces in a region also calls for such an analysis. In accordance with the Rosstat methodology, the term "high-performance workplace" relates to all occupied job positions at an enterprise (or in an organization), where a worker's average monthly wage (or average revenue for a self-employed entrepreneur) equals or exceeds the established criterion (threshold value)[9].

The number and percentage of such workplaces are considered in [18] as an integrated indicator, which reflects how material and technical, organizational and socio-economic factors impact the dynamics of labour productivity. It is shown, "that the capability of an economy to create high-performance workplaces, that provide relatively higher increase in value added, and the correspondent saturation of a regional labour market with such jobs cause no direct unequivocal effect on labour productivity growth in a medium-term (five-year) perspective" [18, p. 32].

In searching for the insights concerning the specifics of labour productivity dynamics, observed across the Russian regions, it is relevant to look at the current explanations of the productivity paradox. To date, there is an extensive body of studies in the field, published by both domestic and foreign researchers. The correspondent reviews are presented in [1, 19, 20, 21].

Some authors question the very existence of the productivity paradox. The point is that when measuring the impacts of new technologies, part of the effects is ignored [22, 23]. The labour productivity indicators are designed to capture return on investments, gained by manufacturers themselves, in the first place. Such approach ignores the fact that relatively inexpensive new products and services tend to satisfy consumers more. Many people cannot even imagine getting along without the Internet or social networks that are so inexpensive to use. Therefore, the new technologies, being very useful to consumers, may not be appropriately measured and included in the GDP estimates.

However, mismeasurement cannot account entirely (or almost so) for the productivity slowdown [24]. In fact, adoption of new technologies is accompanied by the increasing labour productivity divergence between firms. This trend is discussed in [25, p. 18–22, 26]. When a small fraction of firms benefits from new technologies in terms of enhancing their market power, total averaged indicators of labour productivity may show negative dynamics [27, 28]. As [29, p. 6–8] notes, information technologies have contributed heavily to the divergence across the U.S. states in terms of total factor productivity.

Some researchers consider the productivity paradox as related to laying the groundwork for further transition to a higher stage of economic development, and this explanation is worthy of special attention. It can also be considered as a mismeasurement, since such groundwork is not accounted in the assessments of current performance.

Investments in the development of new general purpose technologies (GPT) take away the resources required to maintain the already mastered technologies of goods production [30]. The model simulating

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[7] Natsionalnyy reiting sostoyaniya investitsionnogo klimata v subektakh RF [National Rating of the investment climate in the subjects of the Russian Federation]. Agenstvo strategicheskikh initsiativ [Agency for strategic initiatives]. Retrieved from: http://asi.ru/investclimate/rating/ (Date of access: 28.09.2018).

[8] Tablitsa 2. Investotsionnyy risk rossiyskikh regionov v 2017 godu [Table 2. Investment risks in the Russian regions in 2017]. Retrieved from: https://raexpert.ru/rankingtable/region_climat/2017/tab2/ (Date of access: 28.09.2018).

[9] Prikaz Rosstata ot 17.11.2013 №449 (red. ot 26.08.2014) "Ob utverzhdenii metodilk rascheta pokazateley "Prirost vysokoproizvoditelnykh rabochikh mest, v protsntakh k predydushchemu godu", "Dolya produktsii vysokotekhnologichnykh i naukoemkikh otrasley v valovom vnutrnnem produkte" i " Dolya produktsii vysokotekhnologichnykh I naukoemkikh otraskey v valovom regionalnom produkte rossiyskoy Federatssii" [The methodology for calculating the indicator of "highly efficient jobs increase, as a percentage over the previous year", Appendix to the Rosstat order No. 449 of November 14, 2013. Amended Rosstat Orders No 21 of January 14, 2014, No 115 of February 18, 2014, No 532 of August 26, 2014]. Retrieved from: http://www.consultant.ru/document/cons_doc_LAW_154564/ (Date of access: 27.09.2018).

such effects is presented in the renowned paper by Helpman and Trajtenberg [31]. Those authors have shown that the adoption of a new GPT is being may result in a temporary drop of production output. The adoption of a new technology requires an input of new resources (supplementary components). As a result, some portion of available resources is directed towards the development of the necessary components (intermediate products). Until a certain volume (e.g., a critical set) of such components is accumulated, the new GPT cannot be employed. In such situations certain components that have been produced are not marketable and, consequently, cannot generate any profit. But once the whole set of required components is in place, the new GPT comes into operation, with the resultant increase of production output.

The efficiency of a new technology usually depends on the development of the related technologies as well as on labour arrangements. It may take a substantial time to develop related technologies up to a necessary level as well as to train the workforce properly, therefore causing a delay in realizing the fullest potential of economy's new technological base. For instance, "the whole new complex of related assets, such as electronic digital networks for data transfer and processing, new labour arrangements and the proper human capital had to be developed and fostered, for the economy to benefit from information and communications technologies (ICT). The whole new techno-economic system for enterprises, employing ICT in their operations, had to be created, and it took a long time for that task to be completed" [32, p. 3].

Just another explanation of the productivity paradox is related to the character of interconnections between new and old technologies. At the initial development stage, new general-purpose technologies are usually considered as incremental innovations for mature economic sectors. It is the exhausted development potential within the current technological base that forces the mature economic sectors to make risky investments in new GPTs. The improving role of steam engines can be exemplified by their installation on sailing ships. However, the efficiency of such improvements is definitely limited. As a result, through adopting new technologies the mature sectors can only suppress further drop of return on investments, and at best achieve a temporal improvement in growth rates of labour productivity. The transition period from domination of old technologies to prevailing of new ones, that is, the productivity paradox persistence, may last for quite a long time. In the USA., for instance, the downward trend in labour productivity growth rates, that evolved in 1960-s, changed to the upward one only in 1980-s (see Figure 1).

To explore the productivity paradox at the regional level, that is, across the RF subjects we are to draw on the Rosstat data. My general research approach involves the descriptive statistics analysis across two groups of the regions: those with the marked productivity paradox and those, where such paradox is almost absent.

Factors contributing to labour productivity dynamics in the Russian Federation regions

From the productivity paradox viewpoint, the relation between labour productivity dynamics and changes in spending on technological innovation are of certain interest. Comparisons between labour productivity indices for a given year and growth rates of the aforementioned spending for that same year or for the previous one across the Russian regions (for which the correspondent data for 2010–2016 is available) do not detect any close relationship. The resultant scatter diagram is presented in Figure 3.

Similar patterns, demonstrating the absence of any strong correlation between the variables, would show up in the diagrams, when labour productivity indices for the Russian subjects are compared to: a) respective shares of high-technology and knowledge-intensive products in GRP; b) respective relative shares of organizations that have introduced technological, organizational or marketing innovations in the year under review, in the total number of organizations reviewed; c) respective degrees of fixed assets' wear and tear; d) respective indices of actual monthly average gross payroll.

Still, it is quite reasonable to compare the regions with the marked labour productivity decline to the regions with no labour productivity decline (or those, where such a decline is less than 1 %). To ensure comparability, we firstly have to rank the Russian subjects by the rate of changes in labour productivity indices. Since the indices change non-monotonically, ranking should be based on the relationship between the averaged growth rates of labour productivity for 2010–2013 and those for 2014–2016. The Russian Federation subjects with the most significant decline in labour productivity, constituting the first group for the purposes of the analysis, are presented in Table 2.

Translation

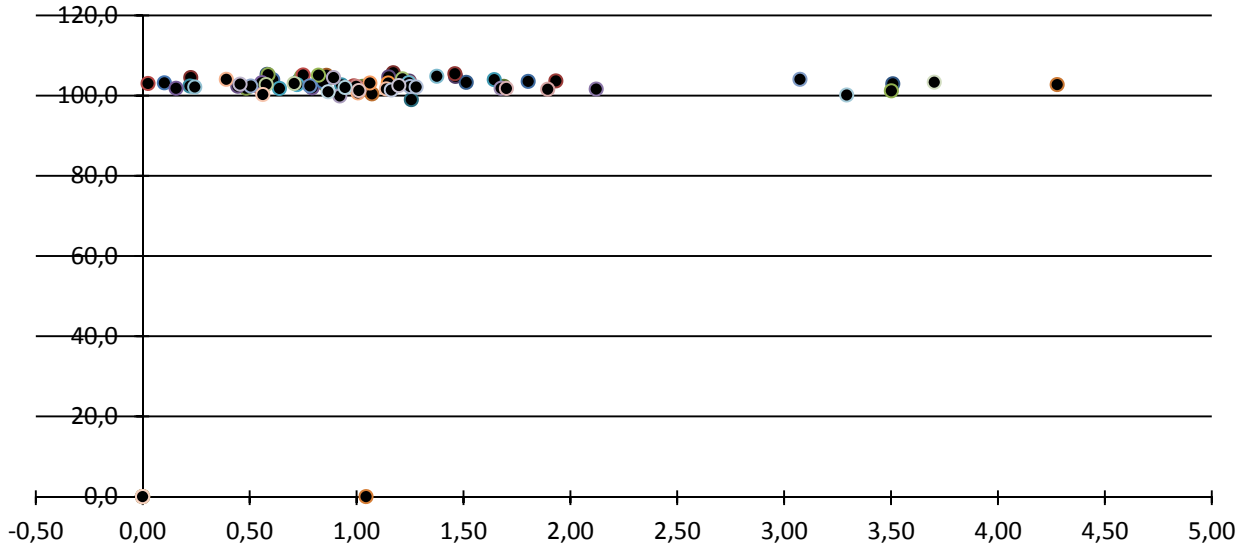

Fig. 3. *Relationship between labour productivity indices in 2016 (Y axis) and growth rates of spending on technological innovation in 2015 (X axis) (plotted based on the Rosstat data: Regiony Rossii. Sotsialno-ekonomicheskie pokazateli — 2017 [Regions of the Russian Federation. 2017 Socio-economic indicators]. Retrieved from: http://www.gks.ru/bgd/regl/b17_14p/Main.htm (Date of access: 27.09.2018))*

Table 2

Russian regions with the most significant decline in labour productivity indices*

Region	Averaged index for 2010–2013	Averaged index for 2014–2016	Relationship between the averaged indices
Kaluga Oblast	108,1	100,9	0,933
Sverdlovsk Oblast	107,6	101,1	0,940
Astrakhan Oblast	108,0	101,5	0,940
Ryazan Oblast	104,9	99,3	0,947
Samara Oblast	105,5	100,0	0,948
Krasnodar Krai	104,4	99,7	0,955
Kostroma Oblast	104,9	100,3	0,956
Orenburg Oblast	103,6	99,1	0,957
Belgorod Oblast	107,2	102,8	0,959
Smolensk Oblast	105,1	100,8	0,959
Perm Krai	104,2	100,1	0,961
Republic of North Ossetia-Alania	103,5	99,6	0,962
Moscow Oblast	105,3	101,4	0,963
Zabaikal (Trans-Baikal) Krai	103,2	99,4	0,963
Omsk Oblast	103,8	100,0	0,964

* Calculated based on the Rosstat data: Regiony Rossii. Sotsialno-ekonomicheskie pokazateli — 2017 [Regions of Russia. 2017 Socio-economic indicators]. Retrieved from: http://www.gks.ru/bgd/regl/b17_14p/Main.htm (Date of access: 27.09.2018).

The regions with minor or absent signs of the productivity paradox are featured in Table 3 as the second group of regions for our analysis.

Through comparing the identified groups by changes in spending on technological innovation we can find out, whether its dynamics contributes to the paradoxical dynamics of labour productivity. The resultant differences between the two groups of regions are shown in Table 4.

As evidenced by the table data, up to 2013 inclusive, both groups demonstrated the rapid growth of spending on technological innovation. However, while the level of spending on technological innovation in the group with declining labour productivity indices has considerably grown by 2016 as compared to 2013, the correspondent spending for the second group has plummeted and stuck at the diminished level.

Table 3

Russian regions with insignificant decline in labour productivity indices*

Region	Averaged index for 2010–2013	Averaged index for 2014–2016	Relationship between the averaged indices
Tomsk Oblast	102,2	101,3	0,991
Novgorod Oblast	105,1	104,3	0,992
Republic of Mordovia	105,4	104,7	0,993
Leningrad Oblast	103,7	103,3	0,996
Sakhalin Oblast	102,7	102,2	0,995
Lipetsk Oblast	103,0	102,7	0,997
Sakha (Yakutia) Republic	102,9	102,8	0,999
Amur Oblast	100,8	101,8	1,010
Kamchatka Krai	101,3	103,0	1,017
Arkhangelsk Oblast	101,5	103,4	1,019
Murmansk Oblast	101,0	103,0	1,020
Kemerovo Oblast	99,2	101,4	1,022
Tula Oblast	103,4	106,4	1,029
Altai Republic	101,3	104,6	1,033
Chukotka Autonomous District	97,3	107,1	1,101

* Calculated based on the Rosstat data: Regiony Rossii. Sotsialno-ekonomicheskie pokazateli — 2017 [Regions of Russia. 2017 Socio-economic indicators]. Retrieved from: http://www.gks.ru/bgd/regl/b17_14p/Main.htm (Date of access: 27.09.2018).

Table 4

Year by year changes in spending on technological innovation (total costs), RUB bn.*

Group of regions	Changes in total spending on technological innovation, by year						
	2010	2011	2012	2013	2014	2015	2016
With declining labour productivity indices	91	127	238	295	326	361	339
Without any significant decline in labour productivity indices	64	97	100	162	102	117	109

* Calculated based on the Rosstat data: Regiony Rossii. Sotsialno-ekonomicheskie pokazateli — 2017 [Regions of Russia. 2017 Socio-economic indicators]. Retrieved from: http://www.gks.ru/bgd/regl/b17_14p/Main.htm (Date of access: 27.09.2018).

Table 5

Share of spending on technological innovation in investments made by both groups in fixed capital, %*

Group of regions	Share of spending on technological innovation in investments in fixed capital, by year						
	2010	2011	2012	2013	2014	2015	2016
With declining labour productivity indices	4,03	4,76	7,76	8,67	10,07	11,62	11,41
Without any significant decline in labour productivity indices	4,95	5,95	5,67	9,92	6,47	6,85	5,84

* Calculated based on the Rosstat data: Regiony Rossii. Sotsialno-ekonomicheskie pokazateli — 2017 [Regions of Russia. 2017 Socio-economic indicators]. Retrieved from: http://www.gks.ru/bgd/regl/b17_14p/Main.htm (Date of access: 27.09.2018).

The similar pattern can be seen if we compare the two groups of the regions by shares of spending on technological innovation in investments made in fixed capital (Table 5).

Moreover, we see even greater and more obvious divergence in the dynamics of the groups' spending on technological innovation, when comparing their annual average spending on technological innovation over two time periods, that is, in 2010–2013 versus 2014–2016 (Table 6).

Additionally, significant differences show up when we compare the two groups by respective investments in reconstruction and modernization as a percent of their total investments in fixed capital (Table 7).

With that, the two groups show different patterns in what concerns investments in fixed capital (Table 8).

Translation

Table 6

Growth of annual average spending on technological innovation by the groups of regions*

Group of regions	Growth of annual average spending on technological innovation by period, RUB bn.		Spending growth rate, %
	2010–2013	2014–2016	
With declining labour productivity indices	188	342	1,82
Without any significant decline in labour productivity indices	106	109	1,03

* Calculated based on the Rosstat data: Regiony Rossii. Sotsialno-ekonomicheskie pokazateli — 2017 [Regions of Russia. 2017 Socio-economic indicators]. Retrieved from: http://www.gks.ru/bgd/regl/b17_14p/Main.htm (Date of access: 27.09.2018).

Table 7

Average shares of investment in reconstruction and modernization by the groups, %*

Group of regions	Averaged shares of investment in reconstruction and modernization, by year									
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
With declining labour productivity indices	226,0	223,2	226,1	228,3	228,9	229,4	224,5	221,2	222,1	220,3
Without any significant decline in labour productivity indices	220,1	119,4	118,1	119,2	117,7	119,4	116,0	116,8	113,9	114,3

* Calculated based on the Rosstat data: Regiony Rossii. Sotsialno-ekonomicheskie pokazateli — 2017 [Regions of Russia. 2017 Socio-economic indicator]. Retrieved from: http://www.gks.ru/bgd/regl/b17_14p/Main.htm (Date of access: 27.09.2018).

Table 8

Dynamics of investments in fixed capital, group totals*

Group of regions	Dynamics of groups' total investments in fixed capital by period, fold		
	2013 to 2010	2016 to 2014	2016 to 2010
With declining labour productivity indices	1,51	0,92	1,31
Without any significant decline in labour productivity indices	1,25	1,19	1,44

* Calculated based on the Rosstat data: Regiony Rossii. Sotsialno-ekonomicheskie pokazateli — 2017 [Regions of Russia. 2017 Socio-economic indicators]. Retrieved from: http://www.gks.ru/bgd/regl/b17_14p/Main.htm (Date of access: 27.09.2018).

In 2010–2013, the group of regions with the marked productivity paradox maintained a relatively high spending on technological innovation as well as spending on reconstruction and modernization, combined with the rapid growth of investments in fixed capital. While the group retains its advantage over the second group by the share of aforementioned spending, this advantage comes at the expense of the diminished growth rates of investing in fixed capital (see Table 8). If in 2016 fixed assets value for the first group (with the marked productivity paradox) has increased in 1.8 times compared to 2010, fixed assets value in the second group has grown in 2.1 times.

Given all that, we can name two causes of the emergence of the productivity paradox. First, after 2013 the first group invested in reconstruction and modernization at the expense of the reduced investments in fixed capital, and it indeed took its toll on the assets' wear and tear and, thus, on current production. The degree of the assets' wear and tear was higher for the first group even in the period, when the group's total investments in fixed capital rapidly increased (Table 9). This fact implies that the older production assets were still used and demanded higher expenditures for maintaining their proper operating condition.

The share of high-technology and knowledge-intensive industries in the total GRP of the first-group regions prompts that investments in fixed capital were not accompanied by any structural shifts towards the said industries. The averaged shares of high-technology and knowledge-intensive industries' products in total group's GRP for both groups are quite similar. For the group with the marked productivity paradox this share hovers around 20 % for the whole period of 2010–2016, while the correspondent figure for the second group of regions is about 18 %, as seen in Table 10.

Second, any improvements of the current technological base clearly have their limits. The innovation activities, that took place until 2014 and comprised both reconstruction and modernization and technological innovation, have pushed the current technological base towards its limits, and

Table 9

Average degree of fixed assets' wear and tear for two groups of regions by year end, %*

Group of regions	Average degree of fixed assets' wear and tear by year end, by year						
	2008	2009	2010	2011	2012	2013	2014
With declining labour productivity indices	47,8	47,9	48,3	49,3	48,8	49,0	49,4
Without any significant decline in labour productivity indices	42,9	43,5	44,7	44,4	44,5	44,4	46,2

* Calculated based on the Rosstat data: Regiony Rossii. Sotsialno-ekonomicheskie pokazateli — 2017 [Regions of Russia. 2017 Socio-economic indicators]. Retrieved from: http://www.gks.ru/bgd/regl/b17_14p/Main.htm (Date of access: 27.09.2018).

Table 10

Averaged shares of high-technology and knowledge-intensive industries' production in GRP by the groups, %*

Group of regions	Averaged shares of high-technology and knowledge-intensive industries' production in a group's total gross regional product, by year, %						
	2010	2011	2012	2013	2014	2015	2016
With declining labour productivity indices	19,5	19,9	20,0	20,0	20,0	20,1	20,2
Without any significant decline in labour productivity indices	17,8	17,7	17,8	19,0	18,7	18,5	18,1

* Calculated based on the Rosstat data: Regiony Rossii. Sotsialno-ekonomicheskie pokazateli — 2017 [Regions of Russia. 2017 Socio-economic indicators]. Retrieved from: http://www.gks.ru/bgd/regl/b17_14p/Main.htm (Date of access: 27.09.2018).

Table 11

Yield of capital investments by the groups of regions*

Group of regions	Yield of capital investments, by year						
	2010	2011	2012	2013	2014	2015	2016
With declining labour productivity indices	0,41	0,43	0,44	0,43	0,42	0,42	0,39
Without any significant decline in labour productivity indices	0,41	0,42	0,39	0,36	0,36	0,36	0,35

* Calculated based on the Rosstat data: Regiony Rossii. Sotsialno-ekonomicheskie pokazateli — 2017 [Regions of Russia. 2017 Socio-economic indicators]. Retrieved from: http://www.gks.ru/bgd/regl/b17_14p/Main.htm (Date of access: 27.09.2018).

Table 12

Research-and-development spending as a ratio of GRP, by the groups of regions, %*

Group of regions	Research-and-development spending as a percent of GRP, by year						
	2010	2011	2012	2013	2014	2015	2016
With declining labour productivity indices	1,47	1,45	1,43	1,45	1,52	1,48	1,39
Without any significant decline in labour productivity indices	0,52	0,50	0,55	0,56	0,56	0,56	0,54

* Calculated based on the Rosstat data: Regiony Rossii. Sotsialno-ekonomicheskie pokazateli — 2017 [Regions of Russia. 2017 Socio-economic indicators]. Retrieved from: http://www.gks.ru/bgd/regl/b17_14p/Main.htm (Date of access: 27.09.2018).

eventually impacted the dynamics of labour production. Therefore, the yield of capital investments (the ratio of a group's total GRP to a group's total assets) in the first group tended to grow until 2012 inclusive (see Table 11), and then began to decline.

The duration of the decline in labour productivity and its low growth rates in the first group depend on the rate of formation of a production complex (regional-wide of interregional) that either embraces general-purpose technologies or facilitates their adoption. This, in turn, depends on the willingness of the currently existent industries to rather draw on new GPTs and invest in the relevant research and development while reconstructing and modernizing their facilities, than improve the already mastered technologies. The first-group regions are likely to be better positioned in this respect, as evidenced by the ratio of research-and-development spending to GRP (total research-and-development spending of a group as a percent of a group's total GRP) (Table 12).

Conclusion

The comparisons between the two identified groups of regions allow drawing conclusions relevant for the theoretical insights into the origins of the productivity paradox. The regions committed to pursue more proactive innovation policy may experience a certain period of decline in labour productivity rates or the Solow paradox. It is caused by both the gradually diminishing scope for further improvement of the previously mastered technologies and the diversion of resources from current production to either its improvement and modernization or research and development activities.

At the same time, the regions focused on mobilizing available resources for boosting their current production through building-up the production assets of their already obsolescent technological bases may become the temporary leaders in labour productivity growth. If, as a result, these regions succeed in enhancing their investment potential, such regional policy seems quite reasonable not only in terms of assessing the efficiency of the executive authorities' performance. However, the tendency towards decline in the yield of capital investment, observed in the second group of regions, imposes an additional burden on the economy related to the maintaining of the production capacities. Such situation highlights that even in the second group of regions the growth in labour productivity indices is only temporary.

However, the existent production facilities in the context of creative destruction are neither a worthless stuff for the renovating economy nor an object to be resuscitated with the new wave technologies. The well-being of the industries constituting the old technological mode actually matters in terms of both leadership-oriented and catching-up development. The existent industries not only contribute heavily to accumulating knowledge and human capital, but create the initial demand for emerging technologies of the new technological mode. If we do not pay attention to the traditional industries in the old industrial regions, but rather wait for the next industrial revolution to come, we can hamper demand for the new evolving industries and stand in the way of their development.

The analysis of the productivity paradox presented here within the regional dimension is based on quite averaged assessments of the two identified groups of regions. Each group comprises a very heterogeneous mix of the subjects of the Russian Federation, with economic parameters diverging greatly from the group averages. Tomsk Oblast, for instance, is included in the second group, i. e., as experiencing no significant decline in its labour productivity index, while its spending on research and development makes up more than 2 % of the correspondent gross regional product. That figure is much higher than the second group's average, which is less than 0.6 %.

The role of the region's industrial structure and such factors as interregional economic ties, foreign economic cooperation and labour resources dynamics have remained beyond the scope of the present productivity paradox analysis. This study can be taken a step forward by examining the above-mentioned factors and employing sophisticated econometric tools. However, the most important path for further research is examination of the productivity paradox, based on exploring the specific circumstances of its emergence in the particular regional contexts and analyzing the real life economic processes. Such deep examination can help to avoid strategic errors in devising regional policies, when long-term development opportunities are sacrificed for the sake of current and medium-term well-being.

Up to now, the economists have spent most of their time figuring out various explanations of the productivity paradox. It seems that the crucial task for further research should be an attempt to optimize a time period and a degree of decline in labour productivity growth rates.

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References

1. Brynjolfsson, E., Rock, D. & Syverson, C. (2017). *Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics.* NBER Working Paper, w24001. Retrieved from: https://www.nber.org/papers/w24001.pdf (date of access: 29.09.2018).

2. Franke, R. H. (1987). Technological Revolution and Productivity Decline: Computer Introduction in the Financial Industry. *Technological Forecasting and Social Change, 31,* 143–154.

3. Gubanova, E. S. & Kleshch, V. S. (2017). Metodologicheskie aspekty analiza urovnya neravnomernosti sotsialno-ekonomicheskogo razvitiya regionov [Methodological aspects in analyzing the level of non-uniformity of socio-economic development of regions]. *Ekonomicheskie i sotsialnyye peremeny. Fakty, tendentsii, prognoz [Economic and social changes: facts, trends, forecast], 10(1),* 58–75. DOI: 10.15838/esc/2017.1.49.4. (In Russ.)

Translation

4. Kurbatova, M. V., Kagan, U. S. & Vshivkova, A. A. (2018). Regionalnoye razvitie: Problemy formirovaniya i realizatsii nauchno-tekhnicheskogo potentsiala [Regional development: addressing the problems of building and realization of scientific and technological capacities]. *Terra Economicus, 16(1),* 101–117. DOI: 10.23683/2073–6606–2018–16–1-101–117. (In Russ.)

5. Volchik, V. V. & Krivosheeva-Medyantseva, D. D. (2013). Institutsionalnyye usloviya innovatsionnogo razvitiya rossiyskoy ekonomiki [Institutional circumstances for innovative development of the Russian economy]. *Terra Economicus, 11(4-3),* 18–26. (In Russ.)

6. Itskovits, G. (2011). Model troynoy spirali [Triple Helix Model]. *Innovatsii [Innovations], 4,* 5–10 (In Russ.).

7. Lau, A. K. W. & Lo, W. (2015). Regional innovation system, absorptive capacity and innovation performance: An empirical study. *Technological Forecasting and Social Change, 92,* 99–114. DOI: 10.1016/j.techfore.2014.11.005. (In Russ.)

8. Doloreux, D. & Parto, S. (2005). Regional innovation systems: Current discourse and unresolved issues. *Technology in society, 27(2),* 133–153.

9. Maslennikov, M. I. (2017). Tekhnologicheskie innovatsii i ikh vliyanie na ekonomiku [The Technological Innovations and Their Impact on the Economy]. *Ekonomika regiona [Economy of Region], 13(4),* 1221–1235. DOI: 10.17059/2017–4-20. (In Russ.)

10. Romanova, O. A. (2018). Prioritety promyshlennoy politiki Rossii v kontekste vyzovov chetvertoy promyshlennoy revolyutsii. CH. 1 [Industrial Policy Priorities of Russia in the Context of Challenges of the Fourth Industrial Revolution. Part 1]. *Ekonomika regiona [Economy of Region], 14(2),* 420–432. DOI: 10.17059/2018–2-7. (In Russ.)

11. Romanova, O. A. (2018). Prioritety promyshlennoy politiki Rossii v kontekste vyzovov chetvertoy promyshlennoy revolyutsii. CH. 2. [Industrial Policy Priorities of Russia in the Context of Challenges of the Fourth Industrial Revolution. Part 2]. *Ekonomika regiona [Economy of Region], 14(3),* 806–819. DOI: 10.17059/2018–3-9. (In Russ.)

12. Rastvortseva, S. N. (2018). Proizvoditelnost truda i fondovooruzhennost v obespechenii ekonomicheskogo rosta rossiyskikh regionov [Labour Productivity and Capital to Labour Ratio in Ensuring the Economic growth of the Russian Regions]. *Sotsialnoye prostranstvo [Social Area], 1(13).* Retrieved from: http://sa.isert-ran.ru/article/2545 (date of access: 9.10. 2018). DOI: 10.15838/sa/2018.1.13.1. (In Russ.)

13. Bufetova, A. N. (2017). Prostranstvennyye aspekty dinamiki proizvoditelnosti truda v Rossii [Spatial aspects of labour productivity dynamics in Russia]. *Mir ekonomiki i upravleniya [World of Economics and Management], 17(4),* 142–157. DOI: 10.25205/2542–0429–2017–17–4-142–157. (In Russ.)

14. Khodos, D. V., Parshukov, D. V. & Zelezinskiy, A. L. (2018). Innovatsionnoye razvitie regionov: modeli analiza i otsenki perspektiv [Innovation development of regions: models of analysis and assessment of the prospects]. *Innovatsionnoye razvitie ekonomiki [Innovative development of economy], 44(2),* 9–88. (In Russ.)

15. Abdrakhmanova, G. I, Bakhtin, P. D., Gokhberg, L. M. et al. (2017). *Reyting innovatsionnogo razvitiya subektov Rossiyskoy Federatsii. Vyp. 5. [Russian Regional Innovation Scoreboard. Issue 5].* In: L. M. Gokhberg (Ed.). National Research University Higher School of Economics. Moscow: HSE, 260. (In Russ.)

16. Ilina, I. E., Zharova, E. N., Agamirova, E. V. & Kamenskiy, A. S. (2018). Innovatsionnoye razvitie regionov Possii [Innovative Development of the Regions of Russia]. *Regionologiya [Regionology], 26(2),* 230–255. DOI: 10.15507/2413–1407.103.026.201802.230–255. (In Russ.)

17. Trifonov, E. (2013). O vybore modeli rossiyskoy ekonomiki [Theoretical concepts of models the Russian economy]. *Obshchestvo i ekonomika [Society and economy], 9,* 86–91. (In Russ.)

18. Sychev, S. A. (2017). Statisticheskaya otsenka vliyaniya faktorov "tekhnologicheskogo liderstva" na dinamiku proizvoditelnosti truda v subektakh RF [Statistical estimation of the infl uence of the factors of "technological leadership" on the dynamics of labor productivity in the subjects of the Russian Federation]. *Statistika i ekonomika [Statistics and Economics], 14(2),* 29–38. (In Russ.)

19. Dedrick, J. & Kraemer, K. L. (2001). *The productivity paradox: is it resolved? Is there a new one? What does it all mean for managers?* Center for Research on information technology and organizations, Paper 118. Retrieved from: https://ru.scribd.com/document/264599700/The-Productivity-Paradox-is-It-Resolved-is-There-a-New-One-What-Does-It-All-Mean-for-Managers (date of access: 17.03.2018).

20. Platonov, V. V. (2007). "Paradoks Solou" dvadtsat let spustya ili ob issledovanii vliyaniya innovatsiy v informatsionnykh tekhnologiyakh na rost proizvoditelnosti [The Solow paradox twenty years later, or about the study of the impact innovations in information technologies on productivity growth]. *Finansy i Biznes [Finance and Business], 3,* 28–38. (In Russ.)

21. Skripkin, K. G. (2015). Paradoks proizvoditelnosti informatsionnykh tekhnologiy: sovremennoye sostoyanie v mire i v Rossii [IT productivity paradox: present state of research in the world and in Russia]. *Vestnik Tomskogo gosudarstvennogo universiteta [Tomsk State University Journal], 395,* 172–178. (In Russ.)

22. David, P. (1990). The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox. *The American Economic Review, 80(2),* 355–361.

23. Basu, S., Fernald, J. & Kimball, M. (2006). Are technology improvements contractionary? *American Economic Review, 96,* 1418–1448.

24. Syverson, Ch. (2017). Challenges to Mismeasurement Explanations for the US Productivity Slowdown. *Journal of Economic Perspectives, 31(2),* 165–86. DOI: 10.1257/jep.31.2.165.

25. Andrews, D., Criscuolo, Ch. & Gal, P. (2016). The Best versus the Rest: The Global Productivity Slowdown, Divergence across Firms and the Role of Public Policy. *OECD Productivity Working Papers, 5,* 77.

26. Furman, J. & Orszag, P. (2015). *A Firm-Level Perspective on the Role of Rents in the Rise in Inequality.* Presentation at "A Just Society" Centennial Event in Honor of Joseph Stiglitz at Columbia University. Retrieved from: http://gabriel-zucman.eu/files/teaching/FurmanOrszag15.pdf (date of access: 29.09. 2018). (In Russ.)

27. De Loecker, J. & Eeckhout, J. (2017). *The Rise of Market Power and the Macroeconomic Implications.* NBER Working Paper, w23687. Retrieved from: https://www.nber.org/papers/w23687.pdf (date of access: 29.09. 2018).

28. Gutiérrez, G. & Philippon, T. (2017). *Declining Competition and Investment in the U.S.* NBER Working Paper, w23583. Retrieved from: https://www.nber.org/papers/w23583.pdf (date of access: 29.09. 2018).

29. Cardarelli, R. & Lusinyan, L. (2015). U.S. Total Factor Productivity Slowdown: Evidence from the U.S. States. *IMF Working Paper, WP/15/116,* 24.

30. Jacobs, B. & Nahuis, R. (2002). A General Purpose Technology Explain the Solow Paradox and Wage Inequality. *Economics Letters, 74(2),* 243–250.

Translation

31. Helpman, E. & Trajtenberg, M. (1998). A Time to Sow and a Time to Reap: Growth Based on General Purpose Technologies. In: Helpman Elhanan (Ed.). *General Purpose Technologies and Economic Growth.* Cambrigde, MA: MIT Press, 55–83.

32. Akaev, A. A. & Rudskoy, A. I. (2017). Konvergentnyye IKT kak klyuchevoy faktor tekhnicheskogo progressa na blizhayshie desyatiletiya i ikh vliyanie na mirovoye ekonomicheskoye razvitie [Convergent ICT as a key factor of technological progress in the coming decades and their impact on world economic development]. *International Journal of Open Information Technologies, 5(1),* 1–18. (In Russ.)

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