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The Impact of Scientific Activity of Universities on Economic and Innovative Development[1]

Universities play a crucial role in local economies, providing educational services and participating in research and development. This is particularly important for Russia where regions are highly differentiated in terms of both socio-economic development and technological progress and innovations. However, many regional universities in Russia have traditionally focused primarily on teaching, with less emphasis on research activities. In this paper, we aim to deepen the understanding of the impact of scientific activities of universities on regional economic and innovative development. For this purpose, we estimate different specifications of a fixed-effects model using panel data from Russian regions for 2010–2016. We aggregate the number of universities' publications per researcher at the sub-national level to incorporate regional scientific activity in our model. Considering other important socio-economic characteristics of regions, we revealed that the association between the publication activity of universities and innovative development of the region remains significant, while the relationship between economic development of the region and the scientific activity of universities disappeared completely. A number of robustness checks demonstrated that statistically significant results remain only when the relative number of publications indexed in international citation databases (Scopus and Web of Science) is used as an explanatory variable. Simultaneously, the publications indexed in specific Russian lists and databases as well as publications in regional scientific organisations that are not universities do not contribute to innovative development of the region. The results can be used for planning the funding of research activities in universities and setting performance targets for universities.

Keywords: universities, innovation, economic growth, regional economy, Russian regions, scientific activity, publication activity, regional innovation system

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ИССЛЕДОВАТЕЛЬСКАЯ СТАТЬЯ

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Влияние научной деятельности университетов на экономическое и инновационное развитие

Университеты играют значительную роль в региональной экономике, поскольку они предоставляют образовательные услуги и принимают участие в научно-исследовательской работе. Это особенно важно для России, где регионы существенно различаются с точки зрения как социально-экономического, так и технического и инновационного развития. Традиционно сложилось, что многие региональные университеты в России занимаются только преподаванием, не уделяя должного внимания исследовательской деятельности. Данная статья анализирует влияние научной деятельности университетов на экономическое и инновационное развитие регионов. Для достижения этой цели была проведена оценка различных спецификаций модели с фиксированными эффектами на основании панельных данных по регионам России за 2010–2016 гг. Для анализа региональной научной деятельности в модель был включен показатель количества публикаций университетов на одного исследователя на субнациональном уровне. Анализ важных социально-экономических характеристик регионов позволил выявить, что связь между публикационной активностью университетов и инновационным развитием региона остается значимой, в то время как взаимосвязь между экономическим развитием региона и научной активностью университетов полностью исчезла. Проверка правильности расчетов продемонстрировала, что результаты статистически значимы только тогда, когда в качестве объясняющей переменной выступает относительное количество публикаций, проиндексированных в международных системах цитирования (Scopus и Web of Science). При этом публикации, проиндексированные в российских списках источников и базах данных, а также публикации в региональных научных организациях, не являющихся университетами, не способствуют инновационному развитию региона. Результаты исследования могут быть применены для планирования финансирования исследовательской деятельности в университетах и формирования целевых показателей для университетов.

Ключевые слова: университеты, инновации, экономический рост, региональная экономика, регионы России, научная деятельность, публикационная активность, региональная инновационная система

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1. Introduction

Recent studies of economic growth and development often focus on knowledge economy and the diffusion of innovations. Innovations are considered as one of the main competitive advantages of the national economy.

According to neoclassical models of economic growth, innovations or research and development (R&D) are believed to affect total factor productivity and to be one of the main determinants of economic growth, along with the capital accumulation, even taking precedence over it. However, both physical and human capital accumulation remains an essential component of economic growth. Certainly, finding ways to accelerate economic growth and increase welfare at the expense of both presented elements remains current agenda.

The role of universities in the development of the economic system is commonly known. On the one hand, these organisations provide educational services to the population creating a high level of human capital. On the other hand, they are engaged in research and development participating in the innovation process and contributing to technological progress and productivity growth.

Such a logic is not only applicable at the country level, but also at the regional level. To a certain extent, the regions can be considered as quasi-states. This idea has a special meaning for the Russian Federation, because it consists of many highly differentiated regions. It should be noticed that the large number of these regions' economies are comparable with some European and other countries in the world.

This study seeks to advance understanding concerning the impact of scientific activity of universities on regional economic and innovative development. We develop a new approach for measuring the scientific activity of universities and their impact on regional economy.

The rest of paper is organised as follows. It begins with literature review and theoretical framework of the research through formulating key hy-

potheses regarding universities' role in regional economy. Then we introduce an econometric model and discuss suitable estimation methods. Then we describe collected data and give main variables' definitions. We conclude by presenting the results of our research, pointing out some policy implications and discussing the limitations of the study.

2. Literature Review and Theoretical Framework

Nowadays, universities are undoubtedly an essential part of the subnational economic landscape, in particular, playing an important role in the development of regional innovation systems. However, it is quite difficult to separate and analyse potential effects of universities as a part of a regional economy from universities as a part of an innovation system. In this regard, the specific tasks that modern universities can and should address remain the subject of debate both in theory and in practice.

Previous studies of universities' impact can be divided into three groups: (1) theoretical and empirical studies of all the variety of functions that universities perform in a regional economy; (2) research of the role played by universities for the economic development of the region as a whole, without the separating specific regional subsystems; (3) more specific studies of the place and role of universities in regional innovation systems, including the formation of theoretical concepts such as the ''triple helix'', the estimation of the knowledge production function, and others [1, 2, 3].

The multi-faceted influence of universities on regional development, which has long been recognised as extending beyond purely educational activities, is widely accepted. Thus, what matters for subnational development is not the presence and number of universities in the region, but how effectively they perform their multiple functions. Hence, modern researchers no longer study single universities or theorise about their role, but rather quantify their impact on both the economic and innovative development in cross-country or cross-regional comparisons [4, 5].

As part of this research approach, we formulate two main hypotheses that will be addressed in our paper.

H1. Universities have a significant impact on the economic development of the region.

It is obvious that universities have a fundamental territorial linkage. But the crucial question is whether these institutions have a real impact on regional economies, their growth and development. Can it be measured and forecasted? What channels of interconnection do we have?

Brown and Heaney explored the economic impact of institutions of higher education via the analysis of universities' influence on regional economy through labour market. Considering two main approaches for such analysis (economic-based approach and skill-based approach) authors have justified the overestimation of second one [6].

Martin, using Canadian universities' data, concluded that universities make a significant contribution to GDP and employment growth through the stream of new ideas and technologies [7].

Talking about other educational organisations, Hanushek & Woessmann investigated the impact of school education on economic growth. Using cognitive skills as an indicator measured by students' test results instead of traditionally implemented years of schooling data, authors have proved that this approach is the most suitable way for assessing human capital in growth models. The main result obtained by these authors is that school activities have a direct significant causal effect on variations in long-run growth rates across countries [4].

There are three well-known roles of universities (teaching, research, and entrepreneurship), based on which researchers analyse their impacts on regional economies. So, Guerrero, Cunningham, and Urbano found that all three types of university activities have positive impact on regional economic performance, however, the influence of entrepreneurial activities is the biggest one [8].

Hanushek demonstrated that economic growth is highly related to the knowledge capital of the country. In this case, the role of universities is one of the central parameters to any empirical considerations of human capital and growth not only on country, but on regional level as well [9].

Drucker analysed the impact of different types of university activities on entrepreneurship and concluded that this impact varies with the selected variable measures and remains positive, although not as strong as in previous studies [10].

Egorov, Leshukov, and Gromov analysed the contribution of universities in Russia to gross regional product growth and concluded that the development of regional higher education systems would lead to a positive effect on regional economic development [11].

Valero & Van Reenen assessed the economic impact of universities in the broad historical and global context. Authors revealed both the direct impact of the increase in the number of universities on economic growth and the indirect impact

through the contribution of universities to regional human capital and innovation [12].

H2. Universities have a significant impact on the innovative development of the region.

The conceptual framework for studying the impact of universities on regional innovative development is provided by the "triple helix of innovation" concept, which recognises universities, public authorities, and industry as equal participants in the innovation process (see Leydesdorff & Etzkowitz [1], Etzkowitz & Leydesdorff [2]).

Mansfield afforded theoretical support and empirical evidence for the hypothesis explaining the key role of the university research in stimulating both product and process innovations [13].

Gunasekara admitted that universities, with help of their resource base of people, skills and knowledge, play a significant role in regional networking and institutional capacity building. At the same time their staff, both in formal and informal way, may act as ''regional animators'' [14].

Laredo considered the set of university activities. Common approach supposes consideration of three missions of universities, including mass tertiary education, professional specialised higher education and research and academic training. Considering the third mission, Laredo proved that it is closely associated with a concept of entrepreneurial university as well as traditionally mentioned functions of fundamental and applied research and transfer of technology. The third mission is widely recognised by scientists as a main channel connecting universities with the external world [15].

Nowadays, as Goldstein admitted, universities are experiencing so-called "entrepreneurial turn". It means that they are becoming actively involved in the development and commercialisation of technology stemming from university-based research; and "changing the internal regulations, rewards and incentives, norms of behaviour, and governance of universities to remove barriers to individual faculty, other researchers, and research centres/institutes engaging in behaviour that leads to the commercialisation of university-generated knowledge" [16].

Smith and Bagchi-Sen [17] concentrated on the evidence provided by Martinelli, Meyer, and Von Tunzelmann [18], which illustrated that even becoming more entrepreneurial, did not necessarily mean a stronger regional impact. They showed that, "the university is at the centre of a dense network of relations with non-academic partners". Such faculty relationships were described as indicators of entrepreneurialism.

Rücker Schaeffer, Fischer, and Queiroz studied the role of research universities in the development of local and regional innovation systems, using the Brazilian state of São Paulo as an example. The authors concluded that the presence of a leading university in the city or micro-region has a positive impact on innovation activities. There is also a positive effect on human capital development [19].

The study of the so-called knowledge production function stands apart in this matter. The basic equation of such functions, introduced by Jaffe [20], inspired by Griliches [21], and developed by many others. Such functions usually include knowledge output and universities' expenditures on research and development as one of inputs.

3. Model, Methods, Estimation Issues

The empirical research, relied on regional level data, is obviously constrained by the limited number of regions within one country (Russia, in our case, consists of 85 regions). That problem can be solved by using the within-region variation to multiply the number of observations. Such a solution is available within the framework of the panel data approach.

The basic model of innovations for econometric estimation of universities' impact using panel data approach can be written as following:

$$inno_{it} = \beta x_{it} + \gamma controls_{it} + \delta_i + \mu_t + \varepsilon_{it}, \qquad (1)$$

where i and t are indices used for regions and time, correspondingly; $inno_{it}$ is innovations per person (this indicator can be replaced with gross regional product (*GRP*) per capita for the economic development equation); x_{it} denotes to university variable; $controls_{it}$ denotes to control variables; δ_i is a region-specific effect and μ_t is a time-specific effect; ε_{it} is the error term.

The inclusion of time-specific effects is important because the innovative activity is assumed to increase over time. The inclusion of a region-specific effect allows to take into account permanent differences in the level of innovative development between regions that are not captured by $x_{i,t}$, or $controls_{i,t}$.

However, do not forget about the possible presence of the problem of endogeneity of the studied variables. For example, the close relationship between quantitative indicators of university performance and economic indicators (the gross regional product) can be explained by the impact of science, education, and business activities of universities on economic growth, and the reverse impact of the scale of economic development that determine the demand for educational services and research work.

Similarly, the relationship between universities and innovative indicators is ambiguous. The results and effectiveness of the activities of universities can influence the development of the regional innovation system through several channels. At the same time, the regional innovation system itself can, during its expansion and development, lead to an increase in demand for educational services and research. Moreover, both presented indicators may be dependent on the third variable, which also complicates the analysis process and distorts the results.

One way to solve the problem of the reciprocal inverse causal relationship between the indicators in econometrics is to lag all regressors by one year. This means that regressors are measured at $t - 1$, whereas the dependent variable is measured at t. This approach solves the problem of inverse causality, but it is worth recognising that it does not completely solve the more general problem of endogeneity, which needs to be addressed in further research.

4. Data and Variable Definitions

4.1. Data

Data from different sources were used. The main source of information about the economic and innovative performance of Russian regions is a publicly available database provided by Russian Federal State Statistics Service, the statistical yearbook called ''Russian regions'' (issues of 2016, 2017, 2018). This yearbook consists of 25 chapters, including several chapters related to the needs of our research. Chapter 21 ''Science and Innovations'' contains data about important measures for the effectiveness of a regional innovation system. Chapter 5 ''Education'' provides useful information about educational system characteristics. Another important data relevant to the research can be found in chapters 2 ''Population'', 3 ''Employment and unemployment'', 10 ''Gross Regional Product'', 23 ''Investment'', 24 ''Prices and Tariffs'' and others.

Additional information about scientific activity was obtained from the Scientific Electronic Library (eLIBRARY). eLIBRARY is the largest online library with open access in the Russian Federation, which contains the biggest storage of scientific publications, which authors are mainly from Russia. The main feature of this library is co-integration with the Russian Science Citation Index, which was created by the Ministry of Education and Science of the Russian Federation. The Russian Science Citation Index accumulates more than 2 million publications of Russian authors, as well as information about citing these publications from more than 3000 scientific journals and other editions. eLIBRARY collects a lot of different information and indicators about publication activity. The available information makes it possible to aggregate data on publication activity at the regional level.

However, this library includes data on both the publication activity of universities and the characteristics of other organisations, including scientific centers. To exclude performance indicators of all organisations, except for universities, the following algorithm was used. Firstly, the list of universities for each region was collected from the portal "National Center for Monitoring the Innovation Infrastructure of Scientific and Technical Activities and Regional Innovation Systems" which was designed to provide an integrated approach to monitoring of the regional innovation systems of the Russian Federation and, in general, the national innovation system. The portal is managed by the Ministry of Education and Science of the Russian Federation. Thus, the study will only consider universities officially recognised as part of the national innovation system. In addition, this approach allows focusing on the indicators of scientific activity of universities, excluding the indicators of scientific centres and other organisations. Secondly, the values of indicators of publication activity of listed universities were obtained from Scientific Electronic Library. Thirdly, the values of the obtained indicators were aggregated at the regional level to measure the publication activity of each region and to be comparable with the official statistics.

The final sample covers almost all Russian regions in the quantity of 83 from 85 available for the period 2010–2016 (the Republic of Crimea, Sevastopol are not included due to the lack of data). Since there is no data for some indicators in some regions, the study uses an unbalanced data panel. In addition, the data were cleared of outliers by relative indicators of innovative activity of the regions and their economic development. Thus, the set of regions under study changes according to the dependent variable under consideration and the regressors included in the model.

Values for monetary indicators were deflated by the index capturing the price of consumer basket for each specific region in each year.

4.2. Dependent Variables

According to Griliches, "The dream of getting hold of an output indicator of inventive activity is one of the strong motivating forces for economic research in this area" [22, p. 1669].

Table 1

Descriptive statistics of dependent variables

variable	decomposition	mean	sd	min	max	*n*
vig	overall	13.16	35.91	0.00	469.05	575.00
	between		28.56	0.02	245.70	83.00
	within		21.79	–232.42	236.51	6.93
grp	overall	548.69	398.20	214.19	3437.91	575.00
	between		393.86	264.05	3020.87	83.00
	within		63.61	–40.70	965.73	6.93

Source: Authors' calculations.

The Russian specificity is that the indicators of the number of patents and their citations may not reflect the real innovation activity in the regions, since the procedure for their registration is relatively cheap and simple, while their role in protecting intellectual property rights is minimal. Patents serve rather as a means of confirming compliance with KPIs, contractual and grant obligations, and have little relevance for real innovations. Thus, the patent citation statistics are not consistent for purposes of our research.

A reasonable strategy in this case would be to look for an indicator more realistically reflecting the results of innovation activities. Fortunately, the yearbook "Regions of Russia" includes several innovative indicators. Among them is the indicator "Value of innovative goods, works and services". Innovative goods, works and services are defined as "goods, works and services that are new or have been subject to various technological changes over the last three years". This indicator of R&D output seems to be consistent with approach applied in Acs et al. [23, 24], Anselin et al. [25], Varga [26]. The indicator is taken on a per capita basis dånoted in the following text as vig.

GRP per capita (grp) was used to measure the economic development of the region, which corresponds to many studies on economic growth.

A first look at both innovative and economic indicators reveals significant heterogeneity across regions and time (see Table 1). At the same time, the fraction of dispersion between indicators is high (especially for *GRP* per capita), which indicates the presence of unobserved individual effects that do not change over time. However, the general time effects should not be excluded from consideration either. This all speaks in favour of choosing a model with fixed individual and time effects. It does not contradict the economic intuition either, since when analysing data by regions, there are reasons to believe that there are important regional characteristics that do not change over time, as well as time effects that are identical for all regions in each period, related to different aspects of the state economic and innovation policy, business cycles, etc.

4.3. Variable of Interest

The measurement of universities' results is quite an important question. Their role in regional and innovative development can be represented as a many-sided process. This process includes educational, scientific, consultative, entrepreneurial, and other functions. A common approach is to use various publication performance indicators to assess the research output of universities at different levels, including departments, universities, regions, and countries. (See such research as Teodorescu [27], Hu et al. [28], Evdokimov et al. [29], Ivanov et al. [30], Turko et al. [31], Tereshchenko & Shcherbakov [32]).

There are several widespread publication activity indices in absolute values as well as in relative numbers, for example, the h-index and others. So Tereshchenko & Shcherbakov provided some motivation for using indicators of publications in relative numbers on the regional level [32].

Simultaneously, eLIBRARY gives an opportunity to differentiate Scopus and Web of Science publications from publications recommended by Higher Attestation Commission, so-called VAK publications, and the Russian Science Citation Index (RSCI) ones.

It should be noted that, on the one hand, there are much more serious requirements for papers to be accepted for publication in Scopus and Web of Science compared to RSCI. It is therefore not surprising that there is a large list of predominantly Russian publications included in the RSCI, which is constantly growing and expanding. On the other hand, the process of publication in the RSCI requires a much smaller amount of labour and time, which leads to an exponential increase of papers of relatively poor quality.

Due to industry standards, to get candidate or doctor degrees, Russia postgraduate students have to make several publications in the journals included in the VAK list, i. e., journals recommended by Higher Attestation Commission. Thus,

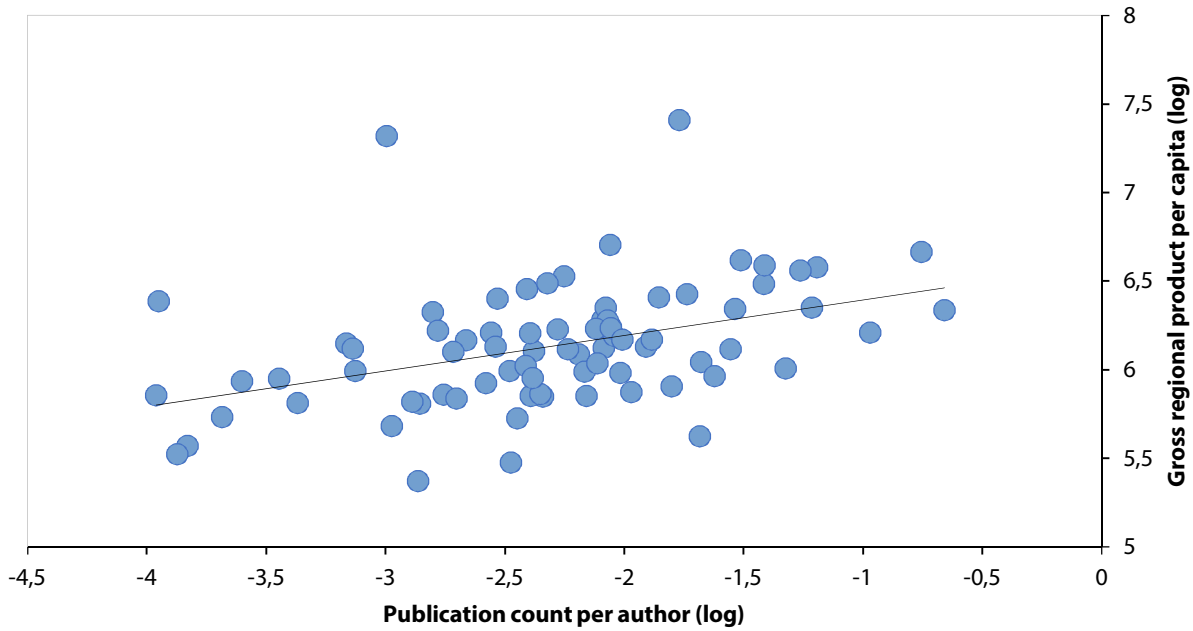

Fig. 1. *Relationship between publication activities in regions and their economic development*

sometimes, these publications fulfil some prerequisites and formal requirements but do not connected to any scientific results directly.

Therefore, we argue that total number of universities' publications per researcher indexed in Scopus and Web of Science during 1 year time period could be regarded as the most appropriate indicator for measurement of regional universities' results. Henceforth we use the notation pub for this indicator.

Scatter plots showing some relations between the mentioned above indicator and dependent variables connected with innovative and economic development of the regions of the Russian Federation in 2015 are presented in Figures 1, 2. Pearson correlation coefficients estimates between pub indicator and value of regional innovative products and GRP are 0.35 and 0.41 accordingly. These coefficients are significant on the 1 % level.

4.4. Control Variables

The main objective of this study is to identify the effect of scientific activities of universities on the innovative and economic development of the region. In order to obtain an unbiased estimate of the regression coefficient for a variable of interest, a set of control variables should be added to the regression.

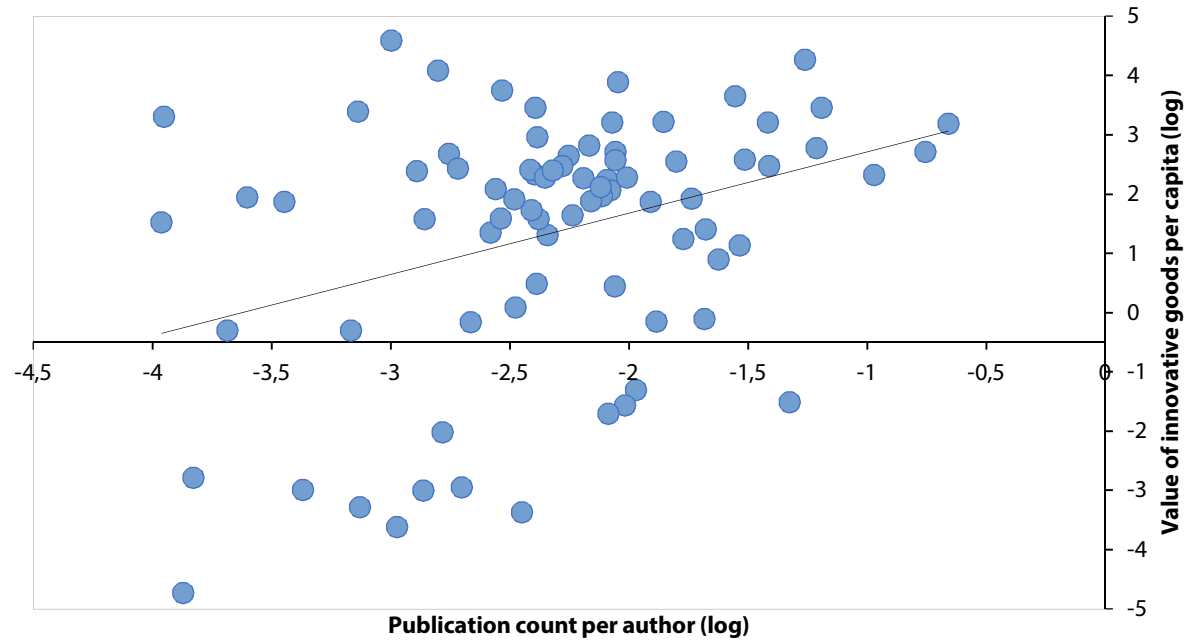

Fig. 2. *Relationship between publication activities in regions and their innovative development*

Table 2

Justification of inclusion of control variables in the regression

Variable	Pairwise correlation coefficient with:			Theoretical support
	vig	*grp*	*pub*	
Stud	0.12	0.22	0.32	[11], [33]
Hei	0.12	0.20	0.34	[12], [19]
Rdc	0.30	0.30	0.60	[8]
Inv	0.23	0.47	0.41	[11], [12], [19], [33]
Dens	0.16	0.18	0.26	[11], [19], [33]
Birth	–0.15	–0.06	–0.03	[4]
unempl	–0.32	–0.33	–0.32	[10], [11], [33]
Urb	0.34	0.44	0.46	[11], [34]

Source: Authors' analysis.

It should be noted that our work focuses on two research issues: (1) whether universities influence the innovative development of the region and (2) whether universities influence the economic development of the region. This may raise some doubts about the set of control variables: should it be the same for regressions with different dependent variables? Strictly speaking, no. However, the use of the identical set in our study is still justified. Firstly, control variables associated with important regional characteristics for innovation activity equation definitely can play the same role for GRP equation in terms of omitted variables bias. Variables correlated with regional innovations are often correlated with GRP as well. Secondly, such approach would lead to more visibility and comparability of results when assessing different models.

Taking into account the economic intuition, the experience of previous researchers working on this topic, as well as available data, a set of control variables was formed, and the following notations were chosen:

— stud — the number of current students enrolled in programmes of higher education, including Bachelor's, Specialist's and Master's programmes, per 1000 people in region;

— hei — the number of functioning higher education institutions per 1000 people in the region;

— rdc — intra-company research and development costs per capita in the region;

— inv — investment in fixed assets per capita in the region;

— dens — population density in the region;

— birth — birth-rate in regions (%);

— unempl — unemployment rate in the region (%);

— urb — share of urban population in the region (%).

Justification of inclusion of control variables in the regression is presented in Table 2.

Almost all variables (see estimated correlation coefficients in the table), can be related to both innovation and economic subnational characteristics as well as to scientific activities of universities in the region, so not including them in the regression may result in an omitted variable bias. Moreover, their inclusion in the regression equation is based on the accumulated experience of previous studies on this topic.

5. Results

Table 4 presents the results of the main regressions. Regressions (1)–(4) are designed to identify the relationship between the scientific activity of universities and regional innovations, and regressions (5)–(8) express the relationship between the scientific activity of universities and the economic development of the region.

Regressions (1), (5) are baseline regressions. They represent pooled regressions and allow estimating the association between scientific activity of universities and innovative and economic indicators of regions at first glance. In both cases, the estimated regression coefficients are positive and significantly different from zero.

Regressions (2), (6) are also pooled regressions, but extend the baseline specification by including control variables in the regression equations. In both cases, the significance of the estimated coefficient on the publication activity disappears.

Regressions (3), (7) extend the baseline regressions by including fixed regional and time effects into it. In regression (3), the estimated coefficient on scientific activity of universities remains statistically significant at least at 10 % level, but the absolute value of the estimated coefficient decreases. In the regression (7), the statistical significance of the coefficient on variable of interest is lost.

Regressions (4), (8) include both a full set of control variables and regional and time fixed effects. In regression (4), the estimated coefficient

Table 3

Regression results

Regressors	Dependent variable							
	vig				*Grp*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pub	0.906***	0.204	0.495*	0.513*	0.116**	−0.015	−0.012	−0.011
	(0.255)	(0.239)	(0.275)	(0.291)	(0.047)	(0.039)	(0.016)	(0.014)
Control variables	No	Yes	No	Yes	No	Yes	No	Yes
Fixed individual and year effects	No	No	Yes	Yes	No	No	Yes	Yes
Observations	357	357	357	357	371	371	371	371
R^2	0.097	0.491	0.913	0.915	0.066	0.589	0.951	0.956
Adjusted R^2	0.094	0.477	0.888	0.888	0.064	0.579	0.937	0.942

Note 1: all variables, except for stud, hei, birth, urb are taken in natural logarithms; the first lags of regressors are taken in the right-hand side of the equations.
Note 2: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.
Note 3: Standard errors of coefficient estimates clustered at regional level are in parentheses.
Note 4: R^2 and adjusted R^2 in columns (3), (4), (7), (8) are calculated for LSDV (least squares dummy variable) model.

on the indicator of university research activity remains statistically significant at least at the 10 % level, but the absolute value of the estimated coefficient decreases in comparison with the baseline regression. In regression (8), the coefficient on variable of interest becomes insignificant.

Thus, both in the case of the analysis of the innovative development of the region and in the study of economic development, the initially strong and significant effect of the scientific activity of universities is delayed by other regional and temporal characteristics to a large extent. However, the relationship between the publication activity of universities and the innovative development of the region remains significant, while the relationship between the economic development of the region and the scientific activity of universities disappears completely.

5.1. Robustness Check

The results allow us to provide some conclusions and recommendations to be made in the area of public policy, but they must first be tested for sensitivity and robustness to various changes in the regression model and data used. Table 4 presents the results of regressions that make it possible to do so.

Regressions (9), (13) reproduce the results of regressions (4), (8) from Table 3 and are inserted into Table 4 for comparison with the results of modified models. The rest of the regressions are designed to reveal some additional aspects of the study of the relationship between the scientific activity of universities and subnational innovation and economic development, connected with the peculiarities of science functioning in Russia.

First, in the basic regressions of this paper, we adhered to the standard of Western studies and analysed the impact of university science on regional development. However, in Russia, in addition to universities, scientific activities are carried out directly in scientific organisations, such as institutes and departments of the Russian Academy of Sciences. This organisation plays a crucial role in the development of fundamental science. But in many cases, it is quite difficult to measure direct effects of fundamental research on process of innovations' creation because of time lags. Universities in turn have relatively more applied research. Therefore, our research has focused on the publication activity of universities. Nevertheless, the potential role of other scientific organisations should also be examined.

The regressions (10), (14) take into account other explanatory variable, namely the number of publications indexed in Scopus and Web of Science per one author, considering the publications and authors related to scientific organisations in the region according to the portal "National Center for Monitoring the Innovation Infrastructure of Scientific and Technical Activities and Regional Innovation Systems". In both regressions, the estimated coefficient on this variable is statistically insignificant. This may serve as indirect evidence that Russia is gradually switching to modern Western models of scientific systems development with the leading role of university research.

Second, as mentioned at the beginning of this paper, in addition to the international indices of scientific citation, Russia has a national index, namely the Russian Science Citation Index (RSCI). There are a lot of high-quality publications which have fundamental as well as practice-centered na-

Table 4

Robustness check

Regressors	Dependent variable							
	viq				*grp*			
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Pub	0.513*	0.324	–0.022	0.497*	–0.011	–0.015	0.056	–0.012
	(0.291)	(0.201)	(0.675)	(0.267)	(0.014)	(0.201)	(0.062)	(0.014)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed individual and year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	357	366	361	365	371	380	375	376
R^2	0.915	0.897	0.897	0.922	0.956	0.956	0.955	0.955
Adjusted R^2	0.888	0.863	0.863	0.896	0.942	0.943	0.941	0.941

Note 1: all variables, except for stud, hei, birth, urb are taken in natural logarithms; the first lags of regressors are taken in the right-hand side of the equations.
Note 2: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.
Note 3: Standard errors of coefficient estimates clustered at regional level are in parentheses.
Note 4: R^2 and adjusted R^2 in all columns are calculated for LSDV (least squares dummy variable) model.

tures. At the same time, they have some peculiarities. For instance, the majority of RSCI's publications are made in Russian. This fact may lead to relatively smaller diffusion of ideas made by Russian-speaking scientists within international professional and business communities. This in turn could not be the crucial factor for innovations' appearance based on them. So, regressions (11), (15) consider the number of publications in RSCI editions per one author as a dependent variable. In both regressions, the estimated coefficient on this variable is statistically insignificant. This means that it is the scientific activity, the results of which are published in international publications, that has a significant effect on the innovative development of the region.

Third, it is necessary to check the sensitivity of the obtained results to outliers. Regressions (12), (16) are estimated at the total population of regions for which there are no missed values. In both regressions, the estimated coefficient on the scientific activity changes slightly in absolute terms, and the status of significance of the coefficient estimate remains unchanged. The scientific activity of universities is still significantly associated with regional innovation development and is not associated with economic development of the region.

Thus, the results obtained can be considered quite reliable and robust.

6. Conclusions and Implications

To sum up, the following main conclusions can be drawn in the context of the hypotheses stated at the beginning of the paper.

Based on the econometric analysis, we obtained following results: Scopus and Web of Science papers affect regional innovations, but are not associated with GRP. The result obtained can be interpreted as follows. Publication of articles in journals indexed in Scopus and Web of Science is one of the intermediate steps in creating new knowledge and products, obtaining qualitatively different results since it allows researchers to present their own vision and to initiate scientific discussions and, more importantly, to be the first to enshrine the results obtained before the world scientific community.

Obviously, in view of this, there is a positive effect of such publications on innovation. The lack of influence on GRP, in turn, may indicate that not all innovations resulting from such publications are implemented or applicable in their own region, and that even if they are implemented, there can be a significant time lag between the publication itself and its practical application in the regional economy.

Overall RSCI publications do not affect regional innovations. Considering the rapidity and low-quality requirements for the published material in some proceedings indexed in the RSCI, this fact may indicate that the purpose of such a publication is not the creation of new knowledge, but the fulfilment of some quantitative goals on publications. In other words, publications begin to appear for the sake of the publications themselves, which certainly does not lead to the creation of new knowledge and innovations.

Our findings created a basis for further analysis in different directions. For instance, one of questions, which have a high priority in this sphere, is funding of universities' research programmes. It is necessary to have some indicators to measure the effectiveness of funding. In this case our results can provide some arguments. Clearly, targets

and benchmarks should be based on publications indexed in international citation databases rather than in Russia-specific lists and indices.

There should be two simultaneous ways in the development of scientific activity. On the one hand, government and universities should promote additional motivation for researchers to publish in the appropriate Scopus and Web of Science journals. On the other hand, it is needed to raise quality standards and ethical approaches within RSCI and VAK journals.

However, the interpretation of the results obtained in this study is not free from some limitations. For example, there are Russian journals in various fields, which are included in the list of VAK, but also included in Scopus and/or WoS. Such kind of publications' impact on innovative development certainly requires additional clarification.

References

1. Leydesdorff, L. & Etzkowitz, H. (1998). The triple helix as a model for innovation studies. *Science and Public Policy, 25(3),* 195–203.

2. Etzkowitz, H. & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. *Research Policy, 29(2),* 109–123. DOI: https://doi.org/10.1016/S0048–7333(99)00055–4.

3. Bania, N., Randal, W. & Fogarty, M. (1993) Universities and the Startup of New Companies: Can We Generalize from Route 128 and Silicon Valley? *The Review of Economics and Statistics, 75(4),* 761–766.

4. Hanushek, E. A. & Woessmann, L. (2012). Do better schools lead to more growth? Cognitive skills, economic outcomes, and causation. *Journal of Economic Growth, 17(4),* 267–321. DOI; https://doi.org/10.1007/s10887–012–9081-x.

5. Tereshchenko, D. S. & Shcherbakov, V. S. (2017). Innovation systems in the regional economic development in Russia: experience of econometric research of the role of universities. *Innovatsii [Innovations], 5,* 75–83. (In Russ.)

6. Brown, K. H. & Heaney, M. T. (1997). A note on measuring the economic impact of institutions of higher education. *Research in Higher Education, 38(2),* 229–240.

7. Martin, F. (1998). The economic impact of Canadian university R&D. *Research Policy, 27(7),* 677–687.

8. Guerrero, M., Cunningham, J. A. & Urbano, D. (2015). Economic impact of entrepreneurial universities' activities: An exploratory study of the United Kingdom. *Research Policy, 44(3),* 748–764. DOI: https://doi.org/10.1016/j.respol.2014.10.008.

9. Hanushek, E. A. (2016). Will more higher education improve economic growth? *Oxford Review of Economic Policy, 32(4),* 538–552.

10. Drucker, J. (2016). Reconsidering the regional economic development impacts of higher education institutions in the United States. *Regional Studies, 50(7),* 1185–1202.

11. Egorov, A. A., Leshukov, O. & Gromov, A. D. (2017). The Role of Universities in Economic Development of Russian Regions (SSRN Scholarly Paper No. ID 2968356). Rochester, NY: Social Science Research Network. Retrieved from: https://papers.ssrn.com/abstract=2968356 (Date of Access: 10.06.2019).

12. Valero, A. & Van Reenen, J. (2019). The economic impact of universities: Evidence from across the globe. *Economics of Education Review, 68,* 53–67.

13. Mansfield, E. (1995). Academic research underlying industrial innovations: sources, characteristics, and financing. *Review of Economics and Statistics, 77(1),* 55–65.

14. Gunasekara, C. (2005). Reframing the Role of Universities in the Development of Regional Innovation Systems. *The Journal of Technology Transfer, 31(1),* 101–113. DOI: https://doi.org/10.1007/s10961–005–5016–4.

15. Laredo, P. (2007). Revisiting the third mission of universities: Toward a renewed categorization of university activities? *Higher Education Policy, 20(4),* 441–456.

16. Goldstein, H. A. (2010). The 'entrepreneurial turn' and regional economic development mission of universities. *The Annals of Regional Science, 44(1),* 83–109.

17. Smith, H. L. & Bagchi-Sen, S. (2012). The research university, entrepreneurship and regional development: Research propositions and current evidence. *Entrepreneurship & Regional Development, 24(5–6),* 383–404. DOI: https://doi.org/10.1080/08985626.2011.592547.

18. Martinelli, A., Meyer, M. & Von Tunzelmann, N. (2008). Becoming an entrepreneurial university? A case study of knowledge exchange relationships and faculty attitudes in a medium-sized, research-oriented university. *The Journal of Technology Transfer, 33(3),* 259–283.

19. Rücker Schaeffer, P., Fischer, B. & Queiroz, S. (2018) Beyond Education: The Role of Research Universities in Innovation Ecosystems. *Foresight and STI Governance, 12(2),* 50–61. DOI: 10.17323/2500–2597.2018.2.50.61.

20. Jaffe, A. B. (1989). Real effects of academic research. *The American Economic Review, 79(5),* 957–970.

21. Griliches, Z. (1979). Issues in assessing the contribution of research and development to productivity growth. *The Bell Journal of Economics, 10(1),* 92–116.

22. Griliches, Z., 1990. Patent statistics as economic. Indicators: a survey. *Journal of Economic Literature, 18(4),* 1661–1707.

23. Acs, Z. J., Audretsch, D. B. & Feldman, M. P. (1992). Real effects of academic research: comment. *The American Economic Review, 82(1),* 363–367.

24. Acs, Z. J., Audretsch, D. B. & Feldman, M. P. (1994). R & D Spillovers and Recipient Firm Size. *The Review of Economics and Statistics, 76(2),* 336–340. DOI: https://doi.org/10.2307/2109888.

25. Anselin, L., Varga, A. & Acs, Z. (1997). Local Geographic Spillovers between University Research and High Technology Innovations. *Journal of Urban Economics, 42(3),* 422–448. DOI: https://doi.org/10.1006/juec.1997.2032.

26. Varga, A. (2000). Local academic knowledge transfers and the concentration of economic activity. *Journal of Regional Science, 40(2),* 289–309.

27. Teodorescu, D. (2000). Correlates of faculty publication productivity: A cross-national analysis. *Higher Education, 39,* 201–222.

28. Hu, G., Carley, S. & Tang, L. (2012). Visualizing nanotechnology research in Canada: evidence from publication activities, 1990–2009. *The Journal of Technology Transfer, 4(37),* 550–562.

29. Evdokimov, V. I., Goryachkina, T. G. & Leonov, B. I. (2014). Analysis of Publication Activity in the Field of Biomedical Engineering in 2003–2012. *Biomedical Engineering, 1(48),* 1–8.

30. Ivanov, V. V., Libkind, A. N. & Markusova, V. A. (2014). Publication activity and research cooperation between higher education institutions and the Russian Academy of Sciences. *Vestnik Rossiiskoy akademii nauk [Herald of the Russian Academy of Sciences], 1(84),* 28–34.

31. Turko, T., Bakhturin, G., Began, V., Poloskov, S. & Gudym, D. (2016). Influence of the program "5-top100" on the publication activity of Russian universities. *Scientometrics, 2(109),* 769–782.

32. Tereshchenko, D. S. & Shcherbakov, V. S. (2019). Statistical Analysis of Differentiation Between Russian Regions by Level of Publications. *EKO [ECO], 9,* 132–154. DOI: 10.30680/ÅÑÎ0131–7652–2019–9-132–154. (In Russ.)

33. Rodríguez-Pose, A. & Wilkie, C. (2019). Innovating in less developed regions: what drives patenting in the lagging regions of Europe and North America. *Growth and Change, 50(1),* 4–37.

34. O'Huallachain, B. & Leslie, T. F. (2007). Rethinking the regional knowledge production function. *Journal of Economic Geography, 7(6),* 737–752.

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