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The Impact of Research Collaboration on Academic Performance: An Empirical Analysis for Russian Universities

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Abstract

The aim of this paper is to investigate the impact of external research collaborations on the scientific performance of academic institutions. Data are derived from the international SCOPUS database. We consider the number of citations of publications to evaluate university performance in Russia. To this end, we develop a non-overlapping generations model to evidence the theoretical idea of research externalities between academic institutions. Moreover, we implement different empirical models to test for the effect of external scientific collaborations on the institutional research quality. The results confirm an important positive impact of co-authoring process.

Keywords: Academic institutions; Productivity; Research externalities.

Jel Codes: I21; D2.

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1. Introduction

As observed in most countries, scientific performance has become the most important topic for science policy. There is an increasing trend in collaborations between individuals and organizations ([Beaver, 2001](#); [Rosenblat and Mobius, 2004](#); [Grayal et al., 2006](#); [Carillo, Papagni and Sapio, 2013](#)). This collaboration considers researchers belonging to the same department and between institutions ([Katz and Martin, 1997](#); [Adams et al., 2005](#)).

As recalled in [Katz and Martin \(1997\)](#) and [Bonaccorsi and Daraio \(2005\)](#), policy makers have supported initiatives to favor collaborations among researchers and academic institutions.

In this paper, our research question is what forms of collaboration are more effective at raising scientific Universities in Russia. In particular, we select top 50 Russian Universities according to National Ranking of Universities 2016 prepared by Interfax for two years 2015 and 2016 to identify formal collaborations instead of informal ones. In this way, we try to learn whether the investigation of a single researcher is better than the University, as the unity of analysis.

In order to satisfy our goal, we implement both econometric models for count data, and panel data model with clustered errors. Finally, we run also an instrumental variable model, where the number of students in mobility is used as an instrument for collaborations variable. The findings are particularly interesting: more external collaborations positively affect the Universities performance, measured by the number of citations.

The paper is structured as follows. Section 2 reviews the main findings on influence of scientific collaboration onto research performance, research productivity and citations of publications. Section 3 describes the data. Section 4 presents the theoretical framework and Section 5 deals with the empirical strategy. The results of empirical investigation are showed in Section 6, while Section 7 discusses the policy implication of analysis and deserves some remarks for further research.

2. Literature review on influence of collaboration on research performance

Collaboration in different forms supports the development of research quality and quantity of organisation or a specific research topic. There are many evidences for support this statement. [Riahi et al. \(2014\)](#) in their bibliometric study on the research performance of Iran in Immunology and Microbiology for 2000 – 2012 state that: “... scientific collaborations with researchers in other countries could play a major role in enhancing the level of knowledge of our researchers.” . [Sweile et al. \(2016\)](#) doing the worldwide overview of tramadol studies says that “ ... Collaboration among pharmaceutical industry, clinical researchers and academic institutions can improve research quantity and quality on tramadol.” . One of the findings in [Kodama, Watatani, and Sengoku \(2013\)](#) in their analysis of stem cell-related research is: “ ... we demonstrated a research assessment by proposing and introducing key performance indicators and found that a certain degree of interdisciplinarity and internal collaboration may bring about high research productivity.” . [Graue et al. \(2013\)](#) in their analysis of Diabetes research in four Nordic countries (Denmark, Iceland, Norway and Sweden) from 1979 – 2009 show that “ ... International collaborative research networks facilitate funding opportunities and contribute to further development of professional research competence.” . [Stein et al. \(2006\)](#) analyzing the brain-behaviour research in South Africa state that : “ ... Local and international collaboration may be useful in increasing research capacity in South Africa, and ultimately in improving mental health services”.

Research Collaboration in different ways: international as well as national and intraorganisational is necessary for the increase the general research productivity of organizations. The examples of positive influence of research collaboration on research productivity and capacity can be found in many bibliometric studies that cover publications of different countries and research organisation in different fields of science and topics. [Elhorst and Zigo \(2014\)](#) measuring the research productivity of academic economists employed at 81 universities and 17 economic research in Austria, Germany and Switzerland state that “...empirical results support the hypotheses that collaboration and that the existence of economies of scale increase research productivity”. [Chakravarty and Madaan](#)

(2016) in their analysis of research performance of Chandigarh city affiliations in 1964 – 2014 state: “ ... An important finding of the paper undertaken is that foreign collaborations and foreign journals have remained the epicenter of the research activity. National and international collaborations also form the basis of growth of research productivity.” . Zucker and Darby (2011) in their study on research activity or M.R. Japanese biotechnology firms show: “ ... we find that identifiable collaborations between particular university star scientists and firms have a large positive impact on firms' research productivity, increasing the average firm's biotech patents by 34 percent, products in development by 27 percent, and products on the market by 8 percent as of 1989-1990”.

Collaboration (primarily collaboration with developed countries) can also help less developed countries to build their research capacity and increase research performance. , Zdravkovic, Chiwona-Karlton and Zink (2016) measuring the research performance of five southern African Universities in fields of mathematics, physics, chemistry in 1995 – 2014 state: “ ... We conclude that supporting international and national collaboration which includes increased scientific mobility, strong scientific groups and networks, are key factors for capacity building of research in southern African Universities.” .

Collaboration also in general leads to the increase of levels of citations. Collaborated (especially internationally collaborated) publications receive higher number of citations the single-authorship papers. Evidence of positive influence of collaboration on the level of citation can be found in different studies. O’Leary et al. (2015) in their analysis of University of Toronto’s Faculty of Medicine research performance for 2008–2012 show that “ ... The academic departments with the highest levels of collaboration and interdisciplinary research activity also had the highest research impact.” . Fu et al. (2012) analyzing the Acupuncture research for 1980-2009 state that “... International collaborative papers are the most frequently cited.” . Isirdia-Lachica et al. (2015) in the analysis of research performance of Universidad de Sonora (Mexico) for 2000 – 2009 state that “... International co-authorship produced higher citation rates.”. Chuang, and Ho (2015) analyzing highly cited publications in Taiwan state that “... International collaboration was responsible for the increasing number of

highly cited papers over the years.” . Obamba and Mwema (2009) in their analysis of poli□□ of African academic partnerships state the following: “ ... This paper suggests that strategic international research collaboration between research communities located within Africa and those in developed countries, as well as regional partnerships among African universities themselves, represent the most productive framework for reinvigorating and strengthening research capacity within sub-Saharan universities.” .

Collaboration also increases the visibility of research. Collaborative publications are in general more visible than purely national or one-author papers. Geracitano, Chaves, and Monserrat (2009) studying the success of Latin America in environmental studies for 1999 – 2008 show that: “ ... the establishment of collaborative studies could be one of the strategies to improve Latin American visibility in environmental studies.” . Olmeda-Gómez et al. (2008) measure the research performance of Catalonian universities, for 2000 – 2004 and show that “... As a whole, they prefer to collaborate with institutions in the United States, the United Kingdom, France, Germany and Italy, and obtain better visibility when publishing with English-speaking authors.” .

3. Methodology

To set the best Russian universities in our model we take them from National Ranking of Universities. This Ranking is formed every year since 2009/2010 by Interfax (privately-held independent major news agency in Russia). National Ranking of Universities is a Special project of Interfax Group launched in 2009 to develop and test new mechanisms for independent Russian universities rating system. This project was initially supported by Federal Education and Science Supervision Agency (Rosobrnadzor). Since 2010 the Ranking is implemented as the own project of Interfax with the participation of radio station 'Ekho Moskvyy'. National Ranking of Universities combine six sub-indices (Educational activity rank; Research Activity rank; Research commercialization; and Innovation activity rank; Internationalisation and communications rank; Social Activity rank; Branding Rank). In 2010 National Ranking of Universities rates 51 Russian universities.

In 2016 database was expanded to 2014 universities. In our analysis we take top 50 Universities from the Ranking of 2016¹. The total Rank score of these universities varies from 501 to 1000 points.

Than main problem was the availability of comparable and reliable data on Russian universities. To ensure the comparability and reliability of data we take the data from Monitoring of efficiency of activity of educational organizations of higher education that was launched in 2013 by Information-computing Centre of Ministry of Education and Science of the Russian Federation². The purpose of Monitoring is the formation of information and analytical materials on the basis of information about the educational organizations of higher education and their branches on the basis of their performance indicators. The objects of Monitoring are educational organizations of higher education of the Russian Federation. The principles of monitoring:

- openness and publicity of events and data in Monitoring
- continuity and comparability of indicators;
- accounting of the specificities of activity of educational organizations;
- the possibility of documentary evidence of the quality of data provided by educational organizations;
- the availability of data about educational organizations from external sources.

Data in Monitoring are collected and provided on yearly basis since 2013. IN 2015 the set of data was seriously expanded. In our model we take (for top-50 universities from Interfax National Ranking of Universities) indicators for 2015 and 2016. In 2016 Monitoring encompasses 830 educational organizations of higher education and 932 their campuses in Russia and 35 organisation abroad. In 2015 and 2016 data on 121 indicators of educational organizations of higher education of the Russian Federation are available in Monitoring.

WE take bibliometric activity indicator from Russian Science Citation Index (RSCI). RSCI is the largest Russian information and analytical portal in science, technology, medicine and education/ It

¹ National Ranking of Universities for 2016 is available on http://univer-rating.ru/rating_common.asp?per=9&p=1 Website is in Russian language.

² The official web portal of Monitoring of efficiency of activity of educational organizations of higher education is available here <http://indicators.miccedu.ru/monitoring/?m=vpo> Website is in Russian language.

is electronic library of scientific publications, with rich capabilities of search and information gathering. RSCI is created by order of the Ministry of Education and Science of the Russian Federation. RSCI is a free public tool to measure and analyze the publication activity of scientists and organizations. RISC developed and supported by the company "Scientific electronic library". RSCI contains abstracts and full texts of more than 24 million scientific and technical publications (journal articles, conference proceedings, books, book series, monographs, analytical reports, scientific reports, dissertations etc.) including electronic versions of more than 5,200 Russian scientific and technical journals, including more than 3800 journals in open access³.

In our model we take the 31 indicators (from the whole sample of 121 indicators available in Monitoring) that fit our theoretical framework (list of indicator used in our model is presented in Table A.1 in Appendix. Basic indicators of Russian Universities in our model are presented in Table A.2 in Appendix). Our indicators can be spitted onto several clusters: Research activity; Internationalisation: Collaboration; Students; Personnel and Infrastructure.

4. Theoretical framework

This section, according to a significant strand of literature ([Acemoglu 1996](#), Aldieri and Vinci 2016), we present a basic Non-Overlapping Generation Model where Institutions of higher education consist of two different types of academic units both of them normalized to unity. In each university, all of academic researchers, assumed to be risk-neutral and with an inter-temporal preference rate equal to zero, live for two periods. In the first period, in order to improve their research expertise, they will choose their talents; in the second period scientific papers occur in a form of a partnership of two researchers belonging to the two different types of Schools. Benefits from the scientific partnership will be availed at the end of this second period.

A scientific research takes place according to the following functional forms:

$$P_{i,j,t} = Ae_{i,t}^{\alpha} e_{j,t}^{(1-\alpha)} \quad (1)$$

³ Russian Science Citation Index portal is available on <http://elibrary.ru/defaultx.asp> Website is in Russian language.

with: $0 < \alpha < 1$, and where $P_{i,j,t}$ stands for scientific research output, $e_{i,t}$ and $e_{j,t}$ measure respectively the talent of the i -th and j -th researchers. A may captures effects due to technological and geographical proximities, public supply of Research Funds.

Moreover the statement of randomness of the researchers' matching function, will involve for all the i -type researchers the same probability of meeting j -type researchers, and then is too costly to break it up the above co-operation in order to find a new co-author for each researcher. The consequential anonymity of contracts, will imply that $j(i)$ -type researchers' decisions, concerning talent skills, depend on the whole distribution of talent across all the $i(j)$ -type ones.

The utility functions will be the following:

$$U_{i,t} = P_{i,j,t}^e - \frac{\theta_i e_{i,t}^{(1+\gamma)}}{(1+\gamma)} \quad (2)$$

$$U_{j,t} = P_{i,j,t}^e - \frac{\lambda_j e_{j,t}^{(1+\gamma)}}{(1+\gamma)} \quad (3)$$

where θ_i and λ_j are a positive taste parameter capturing disutility of accumulating research competences. The above may be rewritten as:

$$U_{i,t} = A e_{i,t}^\alpha \int e_{j,t}^{(1-\alpha)} dj - \frac{\theta_i e_{i,t}^{(1+\gamma)}}{(1+\gamma)} \quad (4)$$

$$U_{j,t} = A e_{j,t}^{(1-\alpha)} \int e_{i,t}^\alpha di - \frac{\lambda_j e_{j,t}^{(1+\gamma)}}{(1+\gamma)} \quad (5)$$

from which we may derive:

$$e_{i,t} = \left\{ \frac{A\alpha \int e_{j,t}^{(1-\alpha)} dj}{\theta_i} \right\}^{\frac{1}{\gamma+1-\alpha}} \quad (6)$$

$$e_{j,t} = \left\{ \frac{A(1-\alpha) \int e_{i,t}^\alpha di}{\lambda_j} \right\}^{\frac{1}{\gamma+\alpha}} \quad (7).$$

From inspection of eqs. (6) and (7) we can state:

Proposition 1⁴: *Assuming $\theta_i = \theta, \lambda_j = \lambda$:*

1. *There exists a unique equilibrium, Pareto inefficient, given by: (e_j^*, e_i^*) .*
2. *Social increasing returns, in the sense that small variations in talent's investments of all agents will make every one better off. Moreover when a small group of j -type (i -type) researchers invest more in research skills, other researchers will answer back, and the equilibrium rate of return of all will improve.*

⁴ See Acemoglu (1996) for a formal proof of Prop. 1.

5. Empirical results

The model that is estimated is the following:

$$C_{i,k} = C(Coll, x_{i,k}, z_i, w_k) \quad (8)$$

Our empirical analysis aims to estimate the marginal effect of external collaborations (Coll) on quality indicator of Russian universities, measured by number of citations (C) of own papers, controlling for sources of heterogeneity across research units, research institutions and academic fields.

University-specific characteristics (vector $x_{i,k}$) include the number of PhD students (Phd) and post-doctoral fellows (Post), the amount of funds received for scientific activity (Funds) and the average age of member staff (Age_staff).

The institution-specific characteristics that affect the quality of a unit's publications (z_i) consider the "age" of an academic institution (Age), i.e. the years elapsed from its establishment up to 2010, and the number of faculty staff (staff).

Moreover, we take into account also universities potential by adding size (number of students) and the number of publications (Pub).

The input and output variables above are organized in a panel of Russian universities (years 2015 and 2016). Summary statistics for the selected variables are reported in Table 1.

Scientific fields (w_k) are grouped into 10 sectors: Chemical sciences, Engineering, Geological and chemical sciences, Medical sciences, Medical-Social-Economic sciences, Multidisciplinary, Natural sciences, Physics, Social and economic sciences and Mathematics.

Table 1. Description statistics

Variable	Mean	Std. Dev.
logC _i	5.93	0.921
logColl	3.15	0.436
logPub	5.03	0.663
logSize	9.58	0.483
logPhd	5.90	3.490
logPost	6.39	0.595
logFunds	13.52	0.914
Log_Age_staff	32.00	7.005
Log_Age	4.56	0.498
Log_staff	8.12	0.592

Note: 100 observations; variables in log terms.

As the dependent variable, the number of citations to own papers, is a count variable and not normally distributed, OLS is not opportune (Greene, 1994; Winkelmann and Zimmermann, 1995). For this reason, we should implement the Poisson model corrected for heteroskedasticity. However, there are usually some very large values that contribute substantially to overdispersion. In this case, it is difficult to specify a model with a conditional mean and variance that captures the main features of the data. For this reason, we also estimate a negative binomial (NB)⁵. Finally, we compare Poisson and NB estimates using AIC (*Akaike's* information criterion) and BIC (*Bayesian* information criterion).

6. Empirical results

In Table 2, we report the results of the analysis based on Russian Universities data. As explained in the previous section, we compute Poisson and NB estimates. In order to identify the best model, we take into account the AIC and BIC information criteria in Table 3. On the basis of this procedure, the NB model is preferred, because of lower AIC and BIC.

Table 2. Count Model results

Variable	Poisson		NB	
	Coeff.	s.e. ^a	Coeff.	s.e. ^a
logColl	0.89***	(0.339)	0.83***	(0.258)
logPub	0.30**	(0.158)	0.41***	(0.143)
logSize	-0.13	(0.261)	-0.09	(0.319)
logPhd	-0.01	(0.038)	0.01	(0.077)
logPost	0.01	(0.001)	-0.01	(0.001)
logFunds	-0.35***	(0.118)	-0.35**	(0.141)
Log_Age_staff	0.03**	(0.013)	0.03***	(0.013)
Log_Age	0.07	(0.179)	0.04	(0.211)
Log_staff	0.01	(0.001)	0.01*	(0.001)
Pseudo R ²	0.58		0.06	

a: *** Coefficient significant at the 1%, ** Coefficient significant at the 5%, * Coefficient significant at the 10%.

b: Scientific dummies are included in the estimation procedure. Chemical sciences is the reference country.

c: standard errors are corrected for heteroscedasticity.

⁵ See Cameron and Trivedi (2013) for a technical discussion of Poisson and NB models.

Table 3. Comparison based on Information criteria

Information criteria	Poisson	NB
AIC	16795.997	1426.816
BIC	16858.521	1491.945

As we may observe, the regression results confirm the importance of external collaborations on the quality academic performance. This finding shows that academic production in quality determines an important scientific externality: it leads to a higher own performance index but also to higher performance of other academic institutions. The scientific collaborations represent a relevant channel for the diffusion of externality.

Moreover, we implement also a panel model with clustered errors:

$$Y_{it} = X_{it}\beta + u_i + e_{it} \quad (9)$$

where i = universities and t = 2015 and 2016

t index could represent any arbitrary index for observations grouped along two dimensions. The usual assumption is that e_{it} is independently and identically distributed, iid, but this is clearly violated in many cases. For this reason, we may assume “clustered errors”, i.e. observations within group i are correlated in some unknown way, inducing correlation in e_{it} within i , but that groups i and j do not get correlated errors (Wooldridge, 2002).

Table 4. Panel data Model results

Variable	Coeff	s.e. ^a
logColl	0.79*	(0.481)
logPub	0.29**	(0.139)
logSize	-0.25	(0.441)
logPhd	-0.03	(0.069)
logPost	0.01	(0.001)
logFunds	-0.42***	(0.152)
Log_Age_staff	0.04**	(0.018)
Log_Age	0.09	(0.245)
Log_staff	0.01**	(0.001)
R ²	0.57	

a: *** Coefficient significant at the 1%, ** Coefficient significant at the 5%, * Coefficient significant at the 10%.

b: Scientific dummies are included in the estimation procedure. Chemical sciences is the reference country.

c: standard errors are corrected for heteroscedasticity.

The causal interpretation of the parameters could be questionable because scientific performance and collaborations are affected by authors' ability. This aspect may lead to an omitted variable or joint causation matter. In order to avoid this bias, we consider two instruments for collaborations variable (Coll) in an instrumental variable (IV) model: the number of students towards Russian Universities (MOBILITYIN) and the number of Russian students towards other universities (MOBILITYOUT). There is no reason to expect correlation with the error term, since even if more students were involved in international exchange programs, this event does not lead to better scientific performance of the research units.

Table 5. IV Model results

Variable	Coeff	s.e. ^a
logColl	2.81**	(1.293)
logPub	0.60***	(0.180)
logSize	0.11	(0.386)
logPhd	-0.03	(0.082)
logPost	0.01	(0.001)
logFunds	-0.46**	(0.233)
Log_Age_staff	0.04	(0.024)
Log_Age	-0.05	(0.253)
Log_staff	0.01	(0.001)

Sargan overid.test 0.145179 (p = 0.7032)

a: *** Coefficient significant at the 1%, ** Coefficient significant at the 5%.

b: Scientific dummies are included in the estimation procedure. Chemical sciences is the reference country.

c: standard errors are corrected for heteroscedasticity .

As we may observe from IV results, we find confirmation of the importance of external collaborations on Russian universities performance. The values of the Sargan overidentification test provide support for the null of valid orthogonal instrumental variables in the estimated model.

7. Policy implications and conclusions.

The main objective of this paper is that of investigating the effects of external scientific collaborations on the Russian Universities performance, measured by the number of citations towards the publications.

This topic has become important in any debate on policies to foster productivity in different countries. We approach this issue both theoretically and empirically. In particular, the rationale behind the model is that the scientific publications in collaboration produce positive externalities to all Universities involved in the economic process.

Moreover, we estimate different econometric models to evidence the impact of external collaborations on the universities performance. The data refer to top 50 Russian Universities according to National Ranking of Universities 2016 prepared by Interfax specialized in 10 disciplines, observed for two years 2015 and 2016. The findings of all models evidence the importance of collaborations for the academic performance. Furthermore, we show that the knowledge flows that arise among researchers from different Universities are relevant to enhance the quality research. Indeed, we use the mobility of students as instruments for endogeneity of collaborations variable.

The results of our work have relevant implications for science policy. The knowledge exchange with researchers is crucial to obtain the highest research quality.

However, further research is necessary. The weaknesses of the analysis consist in the limited number of Universities and years observed in the sample. Hence, it should be opportune to replicate the economic exploration with a sample based on better statistical features. Additionally, it should be very interesting to compare our results to those stemming from the analysis based on more developed countries.

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Appendix.

Table A.1. List of variables used in the model.

Short name	Cluster of variable	Description
age	no cluster-basic info	Year of establishment of University
year	no cluster-basic info	Year of analysis
PhDS	students	Number of PhD students per 100 students
CIT	Research activity	Number of citations on publications published in the past 5 years, indexed in the Russian Science Citation Index per 100 persons of teaching and research staff
PUB	Research activity	Number of the publications indexed in Russian Science Citation Index, per 100 persons of teaching and research staff
Grants	Research activity	Number of grants received during the reporting year, per 100 persons of teaching and research staff
ForeignS1	Internationalisation	Share of foreign students (bachelors, masters, specialists) except the Commonwealth of Independent States countries in total number of students (bachelors, masters, specialists) (all types of education)
ForeignS2	Internationalisation	Share of students (bachelors, masters, specialists) from Commonwealth of Independent States (CIS) countries in total number of students (bachelors, masters, specialists) (all types of education)
ForeignS3	Internationalisation	Share of foreign alumni (bachelors, masters, specialists) CIS countries all other countries in total number of students (bachelors, masters, specialists) (all types of education)
ForeignS4	Internationalisation	Share of foreign alumni (bachelors, masters, specialists) except the CIS countries in total number of students (bachelors, masters, specialists) (all types of education)
ForeignS5	Internationalisation	Share of alumni (bachelors, masters, specialists) from Commonwealth of Independent States countries in total number of students (bachelors, masters, specialists) (all types of education)
MobilityOut	Collaboration	Share of students (bachelors, masters, specialists) enrolled in full-time, studied abroad for at least a semester (semester), in total number of students (bachelors, masters, specialists) enrolled in full-time education
MobilityIn	Collaboration	Share of students (bachelors, masters, specialists) from foreign universities studied full-time in a given Russian university at least a semester (semester) per 100 students (bachelors, masters, specialists) enrolled in full-time education
ForeignR	Collaboration	Number of foreign leading professors, teachers and researchers working in a given Russian university for at least one semester
Posts1	Internationalisation	Share of foreign postgraduate students (excluding the CIS countries) in total number of postgraduate students
Posts2	Internationalisation	Share of foreign postgraduate students from CIS countries in total number of postgraduate students
Infra	infrastructure	Total square of teaching and laboratory space per student (the reduced contingent), including:
Computer	infrastructure	Number of personal computers per one student
Machinery	infrastructure	Share of the value of machinery and equipment not older than 5 years old in the total value of machinery and equipment
Size	students	Total number of students (bachelors, masters, specialists, masters)
Funds1	Revenues and Finance	The total amount of funds received (for the year) on the implementation of R & D performed in-house
Funds2	Revenues and Finance	The total amount of funds received (for the year) of works and services related to scientific, scientific-technical, creative and development services performed in-house
PostNumber	students	Number of postgraduate students
employees	Personnel	Total number of employees of university (without external part-time workers and personnel working under contracts of a civil law character)
teachers	Personnel	Total number of teaching staff (without external part-time workers and personnel working under contracts of a civil law character)
researchers	Personnel	Total number of research staff (without external part-time workers and personnel working under contracts of a civil law character)
teach65	Personnel	Share of teaching staff younger than 65 years

Short name	Cluster of variable	Description
teach40	Personnel	Share of teaching staff younger than 40 years
fields	no cluster-basic info	Key field of science (according to Russian Science citation Index)
Coll	Collaboration	Number of articles in collaboration with foreign organizations
coll2	Collaboration	Share of publications in collaboration with other organizations (Russian Science Citation Index database) (for 2011 - 2015)
coll3	collaboration	Share of publications in collaboration with foreign co-authors (Russian Science Citation Index database) (for 2011 - 2015)

Table A.2. Some key variables for the 50 studied Russian universities analysed in the model.

name	year	year	PUB	Grants	Size	Funds1	PostNumber	employees	coll2
Lomonosov Moscow State University	1755	2016	151.98	17.33	30 313	6 287 054.20	3 923	19 021	33.1
Lomonosov Moscow State University	1755	2015	86.93	13.98	30 822	5 657 091.20	3 786	19 065	33.1
National Research Nuclear University MEPhI (Moscow Engineering Physics Institute)	1942	2016	425.99	12.02	7 398	1 958 940.10	582	2 799	34.9
National Research Nuclear University MEPhI (Moscow Engineering Physics Institute)	1942	2015	185.26	16.38	8 093	2 025 584.40	489	2 731	34.9
Novosibirsk State University	1959	2016	317.47	8.02	6 413	565 805.90	327	1 721	74.6
Novosibirsk State University	1959	2015	148.16	7.97	6 485	527 715.10	275	1 672	74.6
Moscow Institute of Physics and Technology	1951	2016	113.32	6.35	5 878	1 516 753.40	789	1 922	69.9
Moscow Institute of Physics and Technology	1951	2015	94.77	7.93	5 611	1 748 659.60	655	1 794	69.9
Saint-Petersburg State University	1724	2016	152.34	6	19 395	1 625 152.50	2 251	10 739	33.1
Saint-Petersburg State University	1724	2015	99.62	6.21	19 944	1 050 194.40	2 003	11 121	33.1
National Research University Higher School of Economics	1992	2016	199.87	4.49	19 680	2 489 007.40	679	5 440	20
National Research University Higher School of Economics	1992	2015	154.4	4.22	17 760	2 484 401.40	663	5 392	20
Bauman Moscow State Technical University	1830	2016	206.09	3.63	18 557	2 759 860.70	946	6 914	29.8
Bauman Moscow State Technical University	1830	2015	116.76	0	17 138	3 295 811.10	910	6 881	29.8
Peoples' Friendship University of Russia	1960	2016	281.81	3.45	21 484	323 670.80	2 926	4 786	21.1
Peoples' Friendship University of Russia	1960	2015	116.76	0	17 138	3 295 811.10	910	6 881	21.1
National Research Tomsk State University	1878	2016	251.62	19.65	13 940	1 827 700.00	687	4 318	41.6
National Research Tomsk State University	1878	2015	229.83	20.38	13 952	1 400 801.40	663	4 245	41.6
National Research Tomsk Polytechnic University	1896	2016	191.63	12.34	16 841	1 908 691.90	867	5 234	22.6
National Research Tomsk Polytechnic University	1896	2015	178.48	13.29	18 196	1 859 027.40	888	5 290	22.6
Kazan (Volga region) Federal University	1804	2016	253.14	10.74	29 491	1 107 791.20	1 034	6 054	20.7

Kazan (Volga region) Federal University	1804	2015	194.88	13.48	28 964	978 334.10	989	5 859	20.7
ITMO University (Saint Petersburg National Research University of Information Technologies, Mechanics and Optics)	1900	2016	222.26	20.87	12 139	1 927 920.50	826	2 778	33.2
ITMO University (Saint Petersburg National Research University of Information Technologies, Mechanics and Optics)	1900	2015	87.54	19.79	13 391	1 694 590.00	771	2 777	33.2
Peter the Great St.Petersburg Polytechnic University	1899	2016	157.66	2.71	29 367	1 365 117.40	828	6 352	28
Peter the Great St.Petersburg Polytechnic University	1899	2015	106.13	3.67	24 461	1 554 056.40	711	6 003	28
National University of Science and Technology "MISIS" (Moscow Institute for steels and alloys)	1930	2016	111.1	9.23	8 241	1 261 360.00	461	2 853	28.9
National University of Science and Technology "MISIS" (Moscow Institute for steels and alloys)	1930	2015	84.85	0	9 532	1 499 869.20	483	2 908	28.9
Ural Federal University	1920	2016	198.86	5.42	32 720	1 427 041.80	1 031	6 995	37.2
Ural Federal University	1920	2015	96.74	6.34	34 326	826 807.70	929	6 967	37.2
The Russian Presidential Academy of National Economy and Public Administration (The Presidential Academy, RANEPA)	1977	2016	503.47	1.77	17 412	1 087 050.70	703	3 778	28.8
The Russian Presidential Academy of National Economy and Public Administration (The Presidential Academy, RANEPA)	1977	2015	387.95	3.32	15 400	1 018 265.80	805	3 590	28.8
Southern Federal University	1915	2016	298.37	23.66	26 772	1 300 270.20	1 006	7 163	17.6
Southern Federal University	1915	2015	137.34	24.58	30 365	1 134 804.30	1 086	7 662	17.6
Siberian Federal University	1930	2016	88.96	0	29 819	487 036.70	829	6 130	38.7
Siberian Federal University	1930	2015	84.8	0	31 573	474 030.80	769	6 397	38.7
Belgorod National Research University	1876	2016	167.16	12.92	17 461	957 150.00	1 093	2 749	14.7
Belgorod National Research University	1876	2015	177.24	11.5	19 105	838 158.80	680	2 793	14.7
Lobachevsky State University of Nizhni Novgorod - National Research University	1916	2016	205.26	4.97	18 705	988 316.80	812	3 908	20.4
Lobachevsky State University of Nizhni Novgorod - National Research University	1916	2015	166.75	9.05	18 404	948 648.80	752	3 837	20.4
Samara State University	1942	2016	90.92	6.52	15 106	868 188.00	525	3 334	22.7
Samara State University	1942	2015	83.87	5.48	8 308	797 428.80	299	2 067	22.7
Saint Petersburg Electrotechnical University 'LETI'	1886	2016	93.35	4.36	7 782	565 820.00	334	2 460	28.2
Saint Petersburg Electrotechnical University 'LETI'	1886	2015	83.44	6.32	7 377	653 998.90	298	1 967	28.2
Far Eastern Federal University	1899	2016	131.25	8.38	19 954	983 935.60	516	5 724	23.4
Far Eastern Federal University	1899	2015	113.83	11.53	22 176	646 434.10	593	5 998	23.4
Gubkin Russian State University of Oil and Gas (National Research University)	1930	2016	92.22	2.55	8 539	913 814.80	413	2 179	26.1
Gubkin Russian State University of Oil and Gas (National Research University)	1930	2015	77.66	2.21	8 741	726 390.40	436	2 197	26.1

National Research University of Electronic Technology (MIET)	1965	2016	109.98	5.67	4 259	962 066.60	236	1 682	19.4
National Research University of Electronic Technology (MIET)	1965	2015	58.01	4.74	4 494	848 270.10	235	1 672	19.4
Kazan National Research Technological University (KNRTU)	1890	2016	149.99	2.3	20 219	708 484.10	591	3 877	25.5
Kazan National Research Technological University (KNRTU)	1890	2015	195.1	1.51	19 729	946 220.10	593	3 297	25.5
Voronezh State University	1802	2016	354.83	7.92	16 845	340 082.20	733	3 428	15.3
Voronezh State University	1802	2015	221.08	5.45	18 384	372 729.00	652	3 492	15.3
Financial University under the Government of the Russian Federation	1919	2016	1 110.77	2.14	19 201	265 237.70	598	2 999	27
Financial University under the Government of the Russian Federation	1919	2015	658.03	1.03	20 390	286 710.40	669	3 348	27
Moscow Aviation Institute	1930	2016	54.6	5.38	19 556	1 306 597.20	590	4 352	20.7
Moscow Aviation Institute	1930	2015	5.29	6.87	14 341	865 897.80	459	3 598	20.7
Irkutsk National Research Technical University	1930	2016	176.89	4.54	15 824	230 470.80	444	3 071	27.9
Irkutsk National Research Technical University	1930	2015	111.81	3.39	16 673	328 350.20	473	3 355	27.9
Petrozavodsk State University	1940	2016	100.91	14.37	9 607	258 117.70	347	2 297	14.7
Petrozavodsk State University	1940	2015	79.87	12.48	10 361	308 888.10	144	2 417	14.7
Saint Petersburg Mining University	1773	2016	205.63	20.22	7 627	1 089 350.50	423	2 013	13
Saint Petersburg Mining University	1773	2015	119.8	22.39	10 073	866 832.30	407	2 001	13
Saratov State University named after N.G. Chernyshevsky	1909	2016	227.32	7.64	17 183	277 520.90	536	3 019	17.2
Saratov State University named after N.G. Chernyshevsky	1909	2015	150.69	7.93	17 535	226 149.20	500	3 178	17.2
North-Eastern Federal University (NEFU)	1934	2016	200.78	1.85	13 113	197 221.00	581	3 631	11.6
North-Eastern Federal University (NEFU)	1934	2015	138.45	18.04	14 680	410 755.50	327	3 842	11.6
Moscow Technological University	1947	2016	41.25	2.08	16 221	538 619.10	529	2 542	28.6
Moscow Technological University	1947	2015	439.17	0	18 011	32 416.80	0	163	28.6
Tomsk State University of Control Systems and Radioelectronics (TUSUR University)	1962	2016	92.32	4.61	10 488	566 181.80	212	1 838	21.4
Tomsk State University of Control Systems and Radioelectronics (TUSUR University)	1962	2015	53.38	4.45	10 775	438 232.80	246	1 891	21.4
I.M. Sechenov First Moscow State Medical University	1758	2016	207.78	1.79	15 624	562 555.50	2 644	3 431	49.5
I.M. Sechenov First Moscow State Medical University	1758	2015	133.23	0.78	15 253	622 985.60	721	3 483	49.5
South Ural State University	1943	2016	284.77	3	26 722	373 613.50	563	4 601	10.4
South Ural State University	1943	2015	219.49	1.64	28 682	548 690.60	518	4 643	10.4
Perm State University	1916	2016	143.78	10.01	10 930	351 845.20	235	1 910	17.8
Perm State University	1916	2015	141.38	10.89	10 871	401 225.30	239	1 888	17.8
Novosibirsk State Technical University	1950	2016	118.6	3.75	13 631	261 554.40	413	2 753	31
Novosibirsk State Technical University	1950	2015	98.74	3.05	14 293	229 933.30	385	2 843	31
Moscow State University of Civil Engineering	1921	2016	169.14	0.86	11 502	487 943.60	464	2 528	18.6
Moscow State University of Civil Engineering	1921	2015	147.34	0.44	14 491	503 980.80	482	2 691	18.6
Altai State University	1973	2016	259.24	8.06	10 600	141 767.80	260	1 589	11.4

Altai State University	1973	2015	231.13	7.56	10 866	161 130.10	269	1 804	11.4
Perm National Research Polytechnic University	1953	2016	217.91	6.46	15 921	1 047 352.80	589	2 773	16.4
Perm National Research Polytechnic University	1953	2015	233.59	6.64	18 556	540 427.50	583	2 809	16.4
Moscow Power Engineering Institute (MPEI)	1930	2016	271.63	11.34	12 761	823 887.70	651	3 412	18.7
Moscow Power Engineering Institute (MPEI)	1930	2015	74.51	8.71	12 270	834 789.50	610	3 509	18.7
Dmitry Mendeleev University of Chemical Technology of Russia	1898	2016	142.75	4.04	5 007	521 160.30	360	1 667	26
Dmitry Mendeleev University of Chemical Technology of Russia	1898	2015	164.57	9.84	5 099	415 023.70	275	1 723	26
N.P.Ogarev Mordovia State University	1931	2016	129.21	2.5	15 637	295 951.40	880	3 251	10.7
N.P.Ogarev Mordovia State University	1931	2015	104.51	3.59	16 528	339 342.50	568	3 463	10.7
Plekhanov Russian University of Economics	1903	2016	428.61	3.26	22 881	170 087.10	595	3 250	20.5
Plekhanov Russian University of Economics	1903	2015	275.19	1.98	19 581	171 697.00	470	2 665	20.5
North Caucasian Federal University	1930	2016	487.56	1.96	17 264	148 367.60	563	2 759	14
North Caucasian Federal University	1930	2015	281	1.48	18 276	192 201.80	624	2 976	14
Kazan National Research Technical University named after A.N.Tupolev - KAI (KNRTU-KAI)	1932	2016	259.67	3.12	9 583	451 049.80	453	2 268	15.1
Kazan National Research Technical University named after A.N.Tupolev - KAI (KNRTU-KAI)	1932	2015	137.95	2.86	9 804	485 147.70	462	2 551	15.1
Pirogov Russian National Research Medical University	1906	2016	97.17	1.19	8 480	396 616.10	1 980	3 263	39.1
Pirogov Russian National Research Medical University	1906	2015	64.33	1.16	8 719	326 163.50	397	3 518	39.1