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THE RUSSIAN UNIVERSITY EXCELLENCE INITIATIVE: IS IT REALLY EXCELLENCE THAT IS PROMOTED?

We estimate the effect of the Russian University excellence program (Project 5-100) initiated by the Government in 2013 on research performance of top Russian universities which received, on a competitive basis, substantial financial support within this program. To do so we use an econometric analysis of longitudinal data applying a linear growth model with mixed effects, with different characteristics of research output as dependent variables. We demonstrate that there is a significant positive effect of Project 5-100 which appeared from the very first years of its implementation – that is, the universities receiving financial support demonstrate a substantial, steady increase in publications both measured in total numbers and per capita when compared to universities from the control group. An analysis of the structure of publication output allows us to demonstrate that not only quantitative but also qualitative growth has taken place, although the impact of Project 5-100 on quality is heterogeneous across universities and disciplines. Finally, we examine to what extent the change in the structure of research output may be attributed to changes in research collaboration patterns.

JEL Classification: I23, I28, C22

Keywords**:** research universities, university research performance, scientometrics, research collaboration, Web of Science, university excellence initiatives, Russia

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Introduction

Knowledge produced in universities and research centers is a decisive factor in the development of innovation, competitiveness and the socio-economic progress of state (Adams 2014; Henderson et al. 1998). In this context, many governments strive to increase the scientific and intellectual level of national universities to be at the cutting edge of world development. In recent decades, there have been at least 37 university excellence initiatives across the world, 19 of which were initiated in European countries (Salmi 2015). Improving the position of the group of national universities in the global academic market is one of the main objective of these programs.

Having limited resources, many governments choose to support a very limited number of institutions in their efforts to improve performance and to enter the league of world-class universities. This method of preferential funding has some risks, including the inefficient use of resources and their suboptimal distribution between universities, and pursuing league table positions provided by non-reliable rankers (Lim et al. 2017; Lim 2018) instead of building a high-quality research and educational environment (Salmi 2015). Despite the possible risks, the implementation of excellence programs is an acceptable way for developing countries to increase global competitiveness in creating, applying and spreading new ideas and technologies (Altbach and Salmi 2011).

The aims of excellence programs are often to stimulate participating universities to change the structure of collaboration. To achieve results in a short period, the fastest way to access knowledge and equipment is collaboration with other organizations. Scientific collaborations increase scientific productivity and the quality of research (Abramo et al. 2009; Khor and Yu 2016). Thus, government excellence initiatives have significant influence on the structure of collaboration (Guskov, Kosyakov and Selivanova 2018; Ivanov et al. 2016; Möller et al. 2016). Being a typical product of modern public management, excellence initiatives are usually designed as projects with key performance indicators, sometimes – as in Russian case - in the shape of vaguely defined quasi-numeric goals (become one of the world’s top X universities by the year Y). Thus, they are usually assessed by governments and project offices themselves. Such assessments, however, should be supplemented with independent scholarly evaluation of the intended and unintended consequences, which may be many-sided. Impact assessment is complex for several reasons: the impact of government excellence initiatives occurs over time and affects not only those participating in the programs, the quantity indicators are not equally applicable for all research activities (Durieux and

Gevenois 2010), and since Goodhart's law by which statistical regularity will tend to collapse once pressure is placed upon it for control purposes (Elton 2004).

One of the key components of virtually every university excellence initiative is the promotion of ‘world-class research’, which is often perceived as more important than teaching (Pruvot et al. 2015)and is usually assessed via publications in international scholarly journals. The aim of this paper is to see if there is an impact of the Russian University excellence initiative (Project 5-100) on HEI research output, and also to analyze the structure of this impact: whether this program results in just greater quantitative or also qualitative output. To do so we look at the relative growth of research output in 5-100 universities in comparison to the output of the control group of similar institutions not included in the first round of 5-100 Project, building on and expanding the earlier work (Poldin et al. 2017). In addition, in both groups we analyze the number and share of papers co-authored with scholars from other organizations (including foreign ones) for all publications and for publications in high and low-quality journals.

The Russian case is especially interesting[2]because Russia represents a mature academic system with many disciplines having produced research at the top-level, although not always visible in the WoS or Scopus (for a discussion of the reasons see Moed et al. 2018). During the Soviet period there was a clear divide between research (coordinated by the Russian Academy of Sciences) and teaching institutions (Gokhberg and Kuznetsova 2009). To become world-class universities these institutions should now not only increase their research performance but in many cases also reconsider their mission and structure and reform the governance model to better fit research goals. Such reforms and their quick implementation have a profound impact on the internal structure of universities, faculty contracts and salaries, career concerns of academics and many other aspects of university life (Block and Khvatova 2017). In most cases the ambitious goals of boosting international research performance are considered by faculty as externally imposed by university administration and public authorities, and sometimes are not supported by existing academic norms. Under these conditions, the issue of resulting research performance is especially relevant.

[2] For a critical review of modern Russian state research and innovation policy see (Dezhina 2017)

Excellence Initiatives in different countries

East Asian countries were among the first to launch large-scale public policies aimed at improving both the quality of education and the research competitiveness of national universities. The Korean “21 project” was implemented 1999–2005, and the main aim of the program was to promote a group of existing national universities in the global academic market along with the creation of new universities, focused on industrial development. Shin (2009) shows that during the period of the program, the number of Korean publications in the Web of Science (WoS) increased significantly. In addition, 4 new universities were established. However, as the researchers note, the same publication growth rates are observed in the US and Japan, and the growth in the number of publications in China is even higher than in Korea.

Another example is the "985 project", which was implemented in China. The program functioned in two periods from years 1999–2003 and 2004–2007. The aim of the program was to strengthen the global position of leading Chinese universities. The main criterion of efficiency was the number of publications in international journals. In Zhang et al. (2013), the impact of this program on the research performance of participating universities was assessed by taking into account the size of the universities, research and development funding and per capita income in the regions. They show that, in general, there is an increase in the number of publications in international journals after universities joined this program, but the publication activity of participants is significantly different. A more recent study criticizes Zhang et al.’s methodology but confirms the publication growth, albeit finding a “homogenizing trend within 985 universities” (Zong and Zhang 2017).

For many government university excellence programs, publication output is a key indicator of successful participation.. However, these programs influence not only publications activity of the participating universities but also their interaction with the academic environment. The German Excellence Initiative is an example of this. It was launched in Germany in 2006 to increase the competitiveness and attractiveness of German universities. Möller and colleagues concluded that participation in the program contributed to the interaction of universities with the non-university academic environment. However, changes in the German academic system that have occurred since the beginning of the program are not massive (Möller et al. 2016).

The experience of the first excellence programs shows that creation of world-class universities requires not only targeted financial investments for increasing publication activity, but also the reorganization of higher education systems. The main goal of the "Global University

Project" in Japan was the integration of 37 national universities into the world academic community. The key indicators of the program include indicators of international cooperation: international co-authorship, participation in international research and educational projects, and citations. The program was launched in 2014 and intends to operate for not less than ten years. While this policy has increased the productivity of participating universities, the gap between universities at the national level is also increasing (Yonezawa and Shimmi 2015). In addition, at this stage of the program, it is difficult to assess how the policy of global integration of Japanese universities will lead to qualitative improvements in the system. Zong and Zhang (2017) studying the Chinese project 985, also note that the publication gap between different types of universities is growing as a result of the excellence initiative.

The Russian case

In Russia, the most high-profile program of targeted support of leading universities started in 2013 and is aimed to improve "the competitiveness of Russian universities" (Yudkevich 2013). Research performance was chosen as one of the key indicators of university progress. Namely, each year the universities taking part in this program have to report to the Ministry of Science and Higher Education about the progress in the number of indicators to secure funding for the next year, including both publication and citation counts in WoS and Scopus[3]. Thus, the key feature of this program, which differentiates it from many similar excellence university programs across the world is the short-term character of control over performance and funding. Obviously, such a design creates strong incentives for universities for quick results and pushes them to seek the possibility to be on the positive trend every year.

Turko et al. (2016) reveal the positive effect of Project5-100 on the publication activity of universities. Changes in the total number of publications of participating universities and the share of publications in 10% of the most cited journals before and after joining the program were analyzed. This is one of the first works devoted to the quantitative assessment of publication activity of5-100 universities and it has several drawbacks: it does not take into account the size of the universities, the control group includes only five universities, the obtained data reflects the early stage of Project 5-100, and the indicators used are derived from the Scopus database. This database

[3]List of requirements to reports on realization action plans of the universities selected through competitive process for granting state support to the leading universities. Read more: **https://5top100.ru/en/documents/regulations/74076/**

indexes a significant number of potentially unscrupulous journals, which are used for artificially increasing publication indicators, especially in Russia (Sterligov and Savina 2016).

Poldin et al. (2017) estimate the effect of the program on the publication activity of participating universities taking into account the volume of funding and the number of scientific staff. In the first two years of Project 5-100, universities outperform their own trend and the general trend (taking into account the control group).In addition, participating universities increased the number of publications per capita in high-quality journals.

Agasisti et al. (2018) use data about average entry exam scores, students, R&D expenditure, regional GDP per capita and other factors to estimate the effect of Project 5-100 on university efficiency. They find positive effects both on the productivity and on the efficiency of the participating universities. Participation in the project may also push university administration to prioritize quantity over quality and to create incentives for faculty to publish faster while targeting low quality journals. Guskov et al. (2017) argue that participation in the program forced universities to change their publication strategies in favor of increasing the number of publications. Moreover, some participating universities use unfair strategies (for example, publishing in "predatory" journals) to increase publication output (Guskov, Kosyakov and Selivanova 2018; Moed et al. 2018).

One can easily see an increase in the research activity and performance of the Russian university sector in general. Until recently higher education institutions in the country were mostly focused on teaching while now their missions have expanded to include research as well. Most of the participating universities use collaboration strategies aimed at collaboration with other scientific organizations (Guskov, Kosyakov and Selivanova 2018). Thus, Ivanov et al. (2016) analyzed the contribution of the Russian Academy of Sciences (RAS) to the growth of publication activity of Russian universities and reported growth in the number of publications written jointly by Project 5-100universities and RAS.

The observed publication success of Russian universities is taking place during the implementation of several Russian government initiatives aimed at improving research system. Among them the following should be mentioned: the competitive grant program (started in 2010) giving financial support and promoting scientific innovation, including the involvement of internationally recognized scientists in the creation of research laboratories in Russian universities and research institutions (http://www.p220.ru/en/); the creation in 2011 of the Skolkovo Institute of Science and Technology in partnership with the Massachussets Institute of Technology (https://www.skoltech.ru/en/); the establishment of Russian Science Foundation that since 2013 has provided research grants on a competitive basis (http://xn--m1afn.xn--p1ai/en/).This complex of initiatives has had a cumulative effect on Russian universities and research institutes. To identify the effect of Project 5-100it needs to be seen whether there is growth in the research output of universities that participate in the Project compared to those who do not.

Data

Our sample consists of 14 universities that have participated in Project 5-100 since 2013 (treatment group)[4] and other 13 Russian universities (control group)[5]. The Higher School of Economics was excluded from the treatment group because this university is not managed by the Ministry of Science and Higher Education unlike other universities of the sample. The control group includes universities that at the beginning of the project had comparable key indicators of research intensity to those of the treatment group: the number of publications in highly cited journals. Here we have to admit that bibliometric indicators were on average somewhat lower than those of the 5-100 universities although we included those with a minimal gap from the treatment group; this difference is inevitable because bibliometric indicators were used in selection process of 5-100 participants. We also chose universities with similar disciplinary profiles, and thus excluded medical universities.

We use data about the total number of journal articles and reviews from 2010 to 2016 attributed to university profiles in WoS (Science Citation Index Expanded and Social Sciences Citation Index, document types "article" and "review") and the number of publications in the journals of the highest (Q1) and the lowest (Q4) quartiles according to their Journal Impact Factor (JIF); using quartiles instead of rough JIF values attenuates the problem of varying journal citation levels across different subject areas). We also collected data about the number of scientific staff at each university and the amount of R&D funding from the statistics of the Ministry of Education and

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[5] Baltic Federal University (BFU), North-Eastern Federal University in Yakutsk (NEFU), Peoples Friendship University of Russia (RUDN), Siberian Federal University (SibFU), Tyumen State University (TyUU), South Ural State University (SUSU), Moscow Aviation Institute (MAI), Perm National Research Polytechnic University (PGTU), Saratov State University (SSU), Southern Federal University (SFU), Bauman Moscow State Technical University (MSTU), Voronezh State University (VSU), Ufa State Aviation Technical University (UGATU).

Science of Russia. As the citation windows suitable for most disciplines are more than three years, we cannot directly compare citation counts for recent years (2015–2016). So JIF quartiles provide a viable alternative indicator of quality (see Waltman (2016) for a review of using JIFs for such purposes).

Before the program started, the total number of publications, the number of publications per capita and the amount of funding per capita in the 5-100 universities were approximately twice higher than that of the control group (see Supplementary Table 1). After 2013 the gap between the treatment and control group became wider: in 2013 participating universities have 0.39 publications per capita and 1,327,230 rubles (rub) funding per capita, and the control group has 0.06 and 501,230rub; in 2016 the treatment group has 0.87 publications per capita and 1,884,960 rub funding per capita, the control group has 0.12 publications per capita and 475,550 rub funding per capita. So despite the decrease of funding and the number of scientific staff, the control group has slightly increased the number of publications in 2016. At the same time, during the whole period the control group have more academic staff than 5-100 universities. The dynamics of this parameter exhibit different patterns in different periods in both groups, with increases and decreases in different years. For example, the number of scientific staff declined in the treatment group from 1,640 to 1,588 in 2013 and from 1,616 to 1,442 in 2016.

To describe the difference between universities, we look at the changes in individual university publication counts. In almost all universities, the number of publications increased 2010–2016 and this growth has different dynamics in the observed university groups (see Supplementary Figure 1). The number of publications in many 5-100 universities grew rapidly 2013–2015 and the growth slowed in 2016. In the control group, the pace of growth is different within the group: several universities demonstrated rapid growth after 2013 and some universities have small growth during the period.

Some universities of the 5-100 group demonstrate an increase of publications per capita in the observed period and the growth of these universities intensified in the last three years. Control group universities have a more similar pattern for the absolute value of this indicator (the widest gap between universities within the control group is in 2016 and it is over 0.15) and most universities demonstrate a gradual increase in the number of publication per capita (see Supplementary Figure 2).

Thus, we see that there is growth in the number of publications both in the treatment and control groups. In the next sections, we analyze whether and to what degree 5-100 universities outperform general and their own publications trends.

Quantitative dynamics of publications activity: a model

To estimate the impact of Project 5-100 the following parameters were used:

1) Indicators which measure publication activity of universities overall (without separation by publication types), in different quality segments, and with higher collaboration between academics: the total number of publications, the number of publications per capita (scientific staff); the number of publications in Q1 and Q4 journals and their normalized values per capita; the number of publications with more than 10 authors and its value per person. Descriptive statistics for the two groups of universities are presented in the Supplementary Table 1, 2.

2) Indicators that describe the dynamics of collaboration with other organizations in different quality segments: the average number of author affiliations, the total number of affiliations per author and the number of affiliations per author in Q1 and Q4 quartiles, the share of publications with one author and 1-4 affiliations, and the share of international collaboration. The analysis of affiliation allows us to see the collaboration patterns of universities. In recent years, there has been the growth of academic collaboration (Glänzel and Schubert 2004) and as a consequence an increase in the number of affiliations per author (Hottenrott and Lawson 2017). The reasons for academics having two or more affiliations include access to new resources and infrastructure (Long 1978; Long and McGuinnis 1981), an increase in research visibility, reducing administrative barriers (Hottenrott and Lawson 2017) or receiving personal benefits (Bhattacharjee 2011). Along with that, papers with multiple affiliations have on average more citations (Sanfilippo et al. 2018).

To estimate the effect of Project 5-100 and the variation of the effect by years we use a linear mixed-effects model (LME) with a correlated random trend. This model is a generalized type of linear regression model and it takes into account the variation in the parameters over time and over individuals (Verbeke 1997). Estimated effects may be both fixed and random. The fixed part is the observed relation between variables represented in the regression coefficient and the random part is the unobserved deviation. Both parts can be estimated at two levels: between groups of universities and between individual universities. To take into account individual dynamics between universities we use an LME model with a correlated random trend (Wooldridge 2012). The model is applicable for the presence of individual growth in the sample. As can be seen from the Supplementary Figure 1-2, on average there is an increase in the total number of publications and the number of publications per capita, but there are differences in individual dynamics between universities.

The basic model is:

$$In(publications)_{it} = \alpha_0 + \alpha_i + (\beta_0 + \beta_i) \cdot (year)_t + \lambda_t +$$
$$+ \delta^{2014} \cdot d(year = 2014)_t + \delta^{2015} \cdot d(year = 2015) + \delta^{2016} \cdot d(year = 2016) + \xi_{it}$$

where:

α_i, β_i – random intercept and trend coefficients (not estimated);

α_0, β_0– fixed intercept and trend coefficients;

$(year)_t$– time trend (… -3, -2, -1, 0, 1, 2, 3…);

λ_t – time dummies (for taking into account control group);

δ– average treatment effect, ATE;

d_t– dummy for project years;

d_i – dummy for participants;

ε_{it}– standard errors.

Variable covariates have been added for the response variable of the total number of publications, the covariates are *R&D funding* and the *number of scientific staff,* for the response variable of the number of publications per capita the covariate is *R&D funding per capita.* As response variables, the total number of publications, the number of publications in Q1 journals, the number of publications in Q4 journals, and the number of multi-author publications and their normalized values by number of scientific staff were used.

Papers with more than 10 authors were used as multi-author works. This number was determined by an analysis of the distribution function and the Pearson correlation. The distribution function was constructed for the number of publications by the number of authors. The Pearson correlation was calculated between all publication dynamics and publications with a certain number of authors for 2009–2016 (see Supplementary Figure 5). The distribution functions for the two groups of universities are very similar: smooth and with gradual fading. Articles with more than 10 authors represent ~1% of all publications with a continuous decrease of this percentage with an increase in the number of coauthors. For 5-100 universities, 10% of publications have more than 10 authors and for the control group this value is about 2%. The smoothness of the distribution function does not allow us to find the exact border where publications have different dynamics in contradiction to the Pearson correlation. The values of the correlation between all publication dynamics and publications with a certain number of authors decreases for publications with more than 10 authors.

To investigate the effect of Project 5-100 on collaboration patterns we analyze the dynamics of affiliation by author in the treatment and control groups. The WoS publication records were filtered by the number of affiliations, by the number of authors and by journal quartiles. The affiliations-to-author ratio was calculated taking into account the minimum value of this ratio, which corresponded to the number of single affiliations for any number of authors. For publications with one affiliation the ratio of affiliations/authors cannot be less than 1, for publications with one author the subtracted value is 1/1 for publications with two authors - 1/2 and so on for any number of authors.

Results

Participation in Project 5-100 positively affects the number of publications (see Table 1 for the results of the regression analysis). The greatest effect is observed in 2015, the second year of the project and the value of the effect decreased in 2016. Estimates are calculated in exponential form, in the tables their linear modifications are presented (in this and in the following tables). For instance, the coefficient 1.352 for the variable *Year=2014×participant of 5-100* in the first column means that in this model specification 5-100 universities in 2014 outperform general publications trend by 35.2%. If the value of the coefficient is less than one, the growth of the factor is due to a reduction of the response variable.

We consider 4 specifications of the model: specifications 1-2 are for the full sample and specifications 3-4 are for Project 5-100 universities only. This separation shows the effect on participating universities in comparison with the general publication trend and how these universities outperform their own trend. Table 1 shows that the values of the effect are slightly higher for the full sample. Universities outperform their own publication trends to a lesser degree.

The inclusion of R&D funding in the model (with the amounts from Project 5-100) as an explanatory variable allows us to consider the non-financial effects of participation, such as improved management and intangible incentives. As follows from the estimates in columns 2 and 4, such effects exist. The number of scientific staff positively correlates with the number of publications in the full specifications. In the sample with only 5-100 universities, a significant correlation between these variables was not detected. The insignificance of the correlation may be explained by the reduction of scientific staff in 5-100 universities for several years (see Supplementary Table 1)

Table 1. Results for total number of publications

	(1)	(2)	(3)	(4)
Year=2014×participant of 5-100	1.352*** (0.078)	1.367*** (0.084)	1.273*** (0.082)	1.252*** (0.076)
Year=2015×participant of 5-100	1.578*** (0.141)	1.588*** (0.148)	1.456*** (0.147)	1.441*** (0.143)
Year=2016×participant of 5-100	1.523*** (0.145)	1.512*** (0.145)	1.353*** (0.154)	1.367*** (0.161)
Year (β_0)	1.186*** (0.028)	1.196*** (0.029)	1.196*** (0.030)	1.178*** (0.035)
Scientific staff (thousands)	1.099* (0.058)	1.109* (0.065)	1.011 (0.040)	1.006 (0.033)
Funding of R&D (bln. rubles)		0.932 (0.072)		1.106 (0.102)
Control group	yes	yes	no	no
Time effects	yes	yes	no	no
N	189	189	98	98

Standard errors in parentheses
$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

To understand how Project 5-100 affects the productivity of scientific staff we estimate the effect on publications per capita. The effect is positive and its value varies depending on the model specification. When taking into account the control group, the values of the effect are higher (specifications 1-2), that is, participating universities enhance the general trend by a larger value than their own. This effect grows during the whole period (from 35.4% in 2014 to 69.4% in 2016), but this growth can partly be explained by the reduction of scientific staff in 2016. And as listed in Table 2, funding per capita significantly correlates with publications per capita.

Table 2. Results for number of publications per capita

	(1)	(2)	(3)	(4)
Year=2014×participant of 5-100	1.354*** (0.101)	1.314*** (0.102)	1.330*** (0.116)	1.274*** (0.088)
Year=2015×participant of 5-100	1.557*** (0.172)	1.559*** (0.155)	1.522*** (0.187)	1.560*** (0.149)
Year=2016×participant of 5-100	1.694*** (0.215)	1.689*** (0.198)	1.649*** (0.238)	1.685*** (0.194)
Year (β_0)	1.181*** (0.028)	1.155*** (0.031)	1.156*** (0.030)	1.081*** (0.026)
Funding of R&D per capita (mln. rubles)		1.306* (0.206)		1.681*** (0.138)
Control group	yes	yes	no	no
Time effects	yes	yes	no	no
N	189	189	98	98

Standard errors in parentheses
$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Thus we found that participating in the Project allowed universities to surpass the general publication activity by more than 35% in 2014 and more than 50% in 2016. However, to be able to conclude whether the Project was successful one needs to understand its influence on publications of different quality. So we then look at the relative growth of high-quality (Q1) publications in comparison with Q4 output.

In both groups, growth in the number of publications and the number of publications per capita in Q1 journals is observed, but the growth rate is higher in the 5-100 group (see Supplementary Table 2). In 5-100 universities the absolute number of publications in Q1 journals is much higher than in the control group. In 2014 participating universities increased the number of their publications in Q1 by 74%, and in the following years the rate of growth slowed. In the control group, the total number of publications in Q1 journals increased monotonically in the analyzed period.

The total number of publications in Q4 journals and the number of publications in Q4 per capita increased during all the observed years for both groups. There are also differences in the growth rate of these indicators. For 5-100 universities the greatest increase in the number of publications in Q4 was observed 2014–2015 (27%). For the control group this indicator has the lowest growth rates in 2012 (-7%) and in 2014 (2%), the largest is also in 2014–2015 (18%). In addition, in 5-100 universities the growth rate of publications in Q1 journals is higher than in Q4.

The individual publication dynamics in Q1 within the treatment and control groups are also different (see Supplementary Figure 3). The majority of participating universities (except for LETI and SNRU) demonstrated rapid growth of this indicator after 2012–2013. In the control group, three universities also increased the number of publications in Q1 journals after 2012 and for many universities from this group the growth of this indicator is not observed.

After 2014, the majority of participating universities increased the annual number of publications in Q1 journals per capita (see Supplementary Figure 4). The most prominent growth is observed in 2016 and this can also be explained by the reduction of scientific staff. NSU and MEPhI demonstrate substantial growth in this indicator after 2012, which we attribute to their participation in several high-profile physics collaborations at CERN (see below), each producing hundreds of papers in high-quality journals. Most universities from the control group demonstrate a gradual increase in the number of publications in Q1 journals per capita. This growth is comparable to the general tendency of an increasing number of publications per author (Baethge 2008; Pintér 2013).

The positive, significant effect of the Project on high-quality publications is observed in the first two years (Table 3), although the values of the effect are lower in 2015 (43% in 2014 and 33% in 2015). Results are also provided for 3 specifications which differ in the number of explanatory variables. A significant correlation between the number of publications in Q1 journals and the number of scientific staff was not found, which can be explained by the large variation in the number of scientific staff.

Table 3. Results for total number of publications in Q1 journals

	(1)	(2)	(3)
Year=2014×participant of 5-100	1.433***	1.438***	1.434***
	(0.144)	(0.144)	(0.164)
Year=2015×participant of 5-100	1.328*	1.334*	1.332*
	(0.202)	(0.202)	(0.213)
Year=2016×participant of 5-100	1.119	1.136	1.139
	(0.182)	(0.183)	(0.185)
Year (β_0)	1.346***	1.345***	1.341***
	(0.043)	(0.042)	(0.045)
Scientific staff (thousands)		1.046	1.043
		(0.110)	(0.111)
Funding of R&D (bln. rubles)			1.022
			(0.180)
N	182	182	182

Standard errors in parentheses
$^{*}p < 0.1$, $^{***}p < 0.01$

The effect of Project 5-100 on the number of publications in Q1 journals per capita was detected in 2014 and 2015 (Table 4). The highest values of effect are observed in 2014 (44.6%) Funding per capita positively correlates with the number of publications in Q1 journals per capita.

Table 4. Results for number of publications in Q1 journals per capita

	(1)	(2)
Year=2014×participant of 5-100	1.446***	1.367***
	(0.146)	(0.154)
Year=2015×participant of 5-100	1.322*	1.332*
	(0.220)	(0.197)
Year=2016×participant of 5-100	1.283	1.282
	(0.240)	(0.222)
Year (β_0)	1.339***	1.282***
	(0.042)	(0.040)
Funding of R&D per capita (mln. rubles)		1.688**
		(0.363)
N	182	182

Standard errors in parentheses
$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

The government observes general output without differentiation between quality segments. Thus, to maximize this value, universities may be interested in increasing low-quality output (Guskov, Kosyakov and Selivanova 2018), which is often cheaper, easier, and faster to produce. So we look at the relative dynamics of Q4 output. The Project has a positive significant effect on Q4 journal publications in all three years (Table 5). Participating universities outperform the general publication trend for Q4 journals by more than 23% in 2014 and more than 42% in 2016. In specifications that include the number of scientific staff, the greatest value of the effect is in 2016 (49%).

Table 5. Results for number of publications in Q4 journals

	(1)	(2)	(3)
Year=2014×participant of 5-100	1.239***	1.249***	1.257***
	(0.079)	(0.082)	(0.089)
Year=2015×participant of 5-100	1.456***	1.471***	1.477***
	(0.111)	(0.114)	(0.122)
Year=2016×participant of 5-100	1.425***	1.492***	1.489***
	(0.114)	(0.122)	(0.124)
Year (β_0)	1.120***	1.118***	1.122***
	(0.024)	(0.023)	(0.024)
Scientific staff (thousands)		1.188***	1.195***
		(0.060)	(0.062)
Funding of R&D (bln. rubles)			0.965
			(0.065)
N	189	189	189

Standard errors in parentheses
***p < 0,01

The significant effect of the Project on the number of publications in Q4 journals per capita was also revealed in all years (Table 6), the highest value is in 2016 (more than 50%). For the number of publications in Q1 journals, we observe the opposite results: the effect is highest in 2014 and decreases in 2016 (see Table 3 and Table 4).

Table 6. Results for number of publications in Q4 journals per capita

	(1)	(2)
Year=2014×participant of 5-100	1.204**	1.167*
	(0.100)	(0.110)
Year=2015×participant of 5-100	1.375***	1.363***
	(0.138)	(0.138)
Year=2016×participant of 5-100	1.527***	1.503***
	(0.176)	(0.182)
Year (β_0)	1.121***	1.103***
	(0.024)	(0.025)
Funding of R&D per capita (mln. rubles)		1.226*
		(0.135)
N	189	189

Standard errors in parentheses
*p < 0.1, **p < 0.05, ***p < 0.01

Another way to investigate the quality of publication output is to analyze the publications with many authors. These works assume a special form of collaboration with a minimum contribution per author. Although, on average these works have 35% of citations from citations of all publications of the first wave of Project 5-100,2012–2016. For NSU this indicator is 63%, for MEPI it is 81%. The most mentioned university publications with ten or more co-authors are highly cited and are based on experiments at large high-energy physics installations. During the observed period, the growth of these works is typical for the 5-100 universities which have experience in relevant fields (MEPhI, NSU, MIPT, SpbGPU, TSU)[6].

Table 7 and 8 show that the effect of the Project on these works is large for the total number of these publications and for their number normalized by scientific staff. The value of the effect increases from 2014 to 2016. For example, 5-100 universities outperform the general trend by 272% in 2014 and by 465% in 2016 (the coefficients 2.726 and 4.651 in the first column of Table 7). The number of scientific staff negatively correlates with the number of multi-author publications. Funding per capita positively correlates with multi-author works per capita.

Table 7. Results for publications with more than 10 authors

	(1)	(2)	(3)
Year=2014×participant of 5-100	2.726***	2.718***	2.771***
	(0.487)	(0.483)	(0.534)
Year=2015×participant of 5-100	3.536***	3.486***	3.553***
	(0.929)	(0.912)	(0.954)
Year=2016×participant of 5-100	4.651***	4.360***	4.419***
	(1.328)	(1.245)	(1.262)
Year (β_0)	1.048	1.048	1.053
	(0.049)	(0.047)	(0.063)
Scientific staff (thousands)		0.740*	0.746*
		(0.119)	(0.114)
Funding of R&D (bln. rubles)			0.943
			(0.230)
N	163	163	163

Standard errors in parentheses
$^{*}p < 0.1$, $^{***}p < 0.01$

[6] It should be noted that by preliminary data for 2017-2018 the list of 5-100 Universities participating in such “mega collaborations” became noticeably longer.

Table 8. Results for publications with more than 10 authors per capita

	(1)	(2)
Year=2014×participant of 5-100	2.646***	2.326***
	(0.491)	(0.426)
Year=2015×participant of 5-100	3.515***	3.128***
	(0.936)	(0.763)
Year=2016×participant of 5-100	5.165***	4.364***
	(1.594)	(1.257)
Year (β_0)	1.047	1.019
	(0.051)	(0.057)
Funding of R&D per capita (mln. rubles)		1.690*
		(0.472)
N	163	163

Standard errors in parentheses
$^{*}p < 0.1$, $^{***}p < 0.01$

The regression analysis of the effect of Project 5-100 shows that it has a positive effect on the total number of publications and the number of publications in Q4 journals during these three years of participation. The Project's effect on publications in Q1 journals in 2015 was weaker than in 2014 and was not found in 2016. In addition, we found a large increase in the number of publications with more than 10 authors in 5-100 universities during these three years. The results for publications normalized by the number of scientific staff are the same.

The effect of the Project on collaboration patterns

A common strategy to quickly increase publication output is to increase cooperation with other higher education institutions and research organizations (in Russia and abroad). Does this effect really take place?

Scholars from 5-100 universities publish fewer single-affiliation papers while in the control group this share is relatively stable and even grew in 2016 (see Fig.1). That is, in participating universities the share of publications co-written with other organizations increased after 2012.

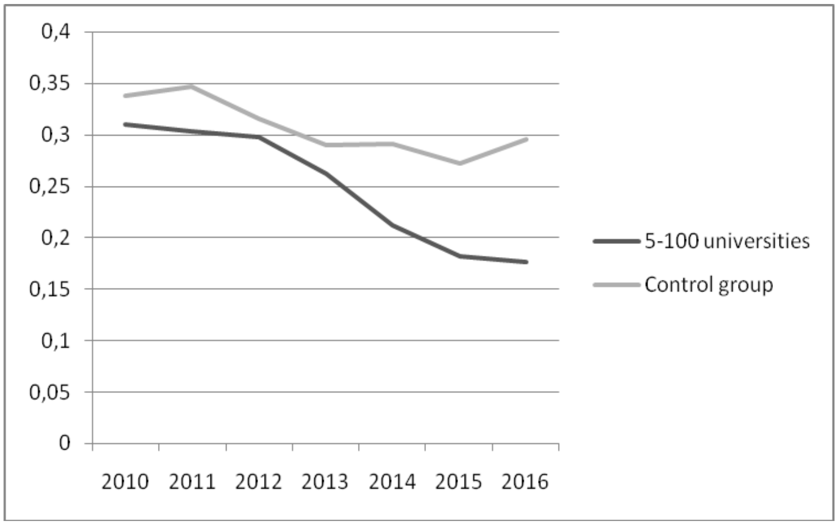

Fig.1. Share of publications with single affiliation by years

Next, we analyzed the changes in average numbers of author affiliations for publications with different numbers of authors. The division by the number of authors allows us to determine two types of collaboration for 5-100 universities. The first is in the increasing number of affiliations of one author after 2013 (Fig.2). This reveals that after joining Project 5-100, universities increase the number of publications partly due to the works of scientists who have multiple affiliations, i.e. work in different organizations outside Project 5-100. The number of affiliations for works with 2–4 authors also increased after 2013. That demonstrates the increase of papers which were prepared in collaboration with other organizations. In the control group a steady increase in the number of affiliations by author is not observed until 2016 when the number of affiliation by author for publications with 1 author increased drastically.

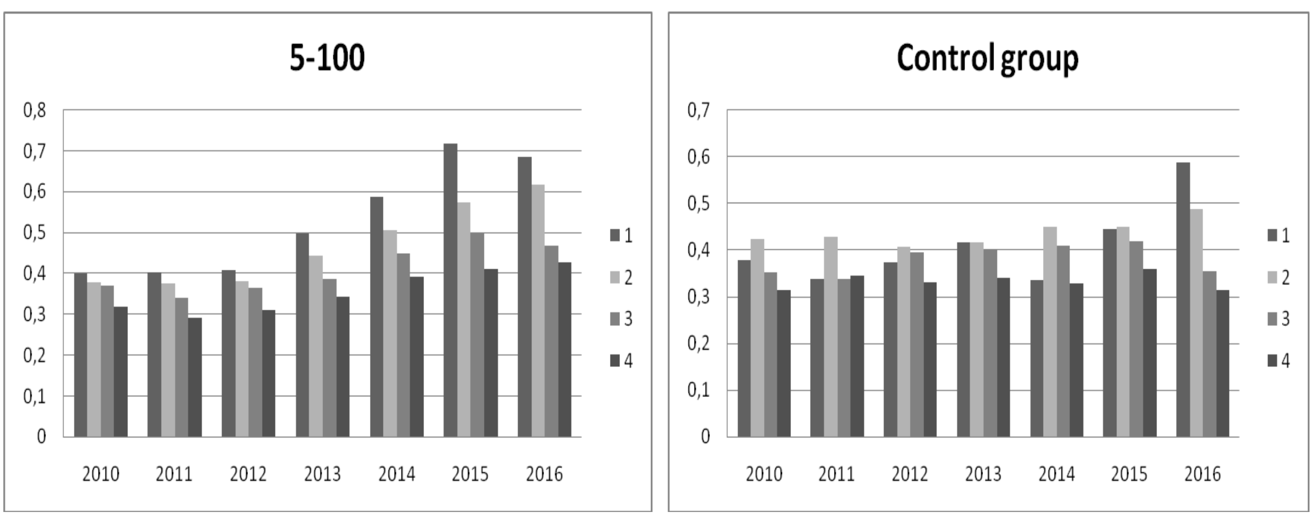

Fig. 2. Number of affiliations by authors for publications with 1–4 authors

We look at the dynamics of multiple affiliations – in general and in particular segments (Q1 and Q4 journals) – to test the hypothesis: increasing cooperation (in a bibliometric sense) is much more viable in the Q1 segment[7], and there is no substantial change in the Q4 segment. Since publication dynamics are different in the Q1 and Q4 segments, we assumed the patterns of collaborations in these segments are different. This hypothesis was partially confirmed. Fig.3 shows the variation of author affiliation in the Q4 output is less than in the Q1output. In 5-100 universities, there is an increase in the number of author affiliations in both quartiles after 2013. After joining the Project, participating universities intensified their collaboration with other organization in Q1 and Q4 output, however to a lesser extent in Q4. Before 2014 academics from the control group have more affiliations than those from 5-100 universities especially in Q1. Since 2012–2013 in 5-100 universities, the growth of the number of author affiliations is observed in the Q1 and Q4 segments. The gap between two groups of universities decreases, and in 2016, the average number of author affiliations of 5-100 universities is about the same as in the control group.

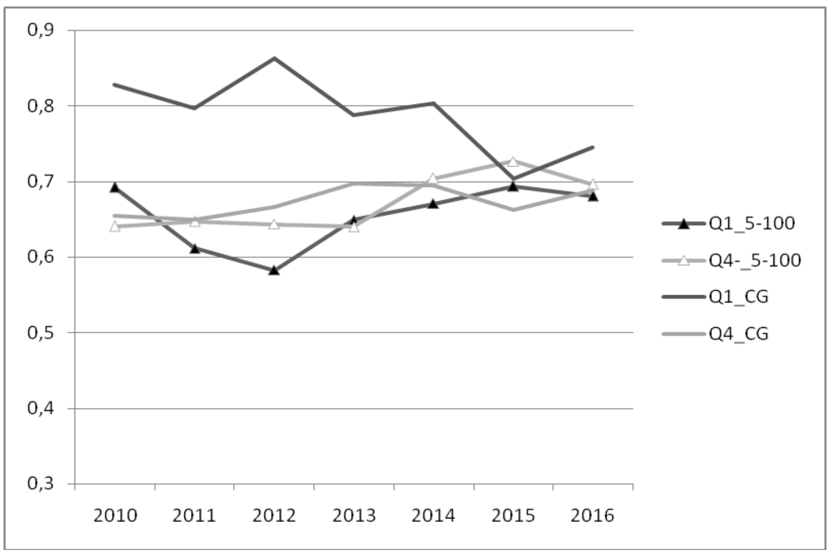

Fig. 3. Dynamics of average number of author affiliations by journal quartiles

For the 5-100 universities there is stable growth in the number of affiliations for publications with 1–2 authors in Q1 journals after 2013 (Fig.4). Moreover, the number of affiliations by one author in Q1 is noticeably higher than that in all types of works and in Q4 journals. Control group universities have both an increase and a decrease of this indicator in the observed period. Scientists

[7] When we consider publication sets large enough, aiming at Q1 journals means more highly cited papers, which is crucial for university rankings implemented in 5-100 design (namely THE and QS subject rankings).

from the control group have fewer affiliations in Q1 journals than scientists from 5-100 universities.

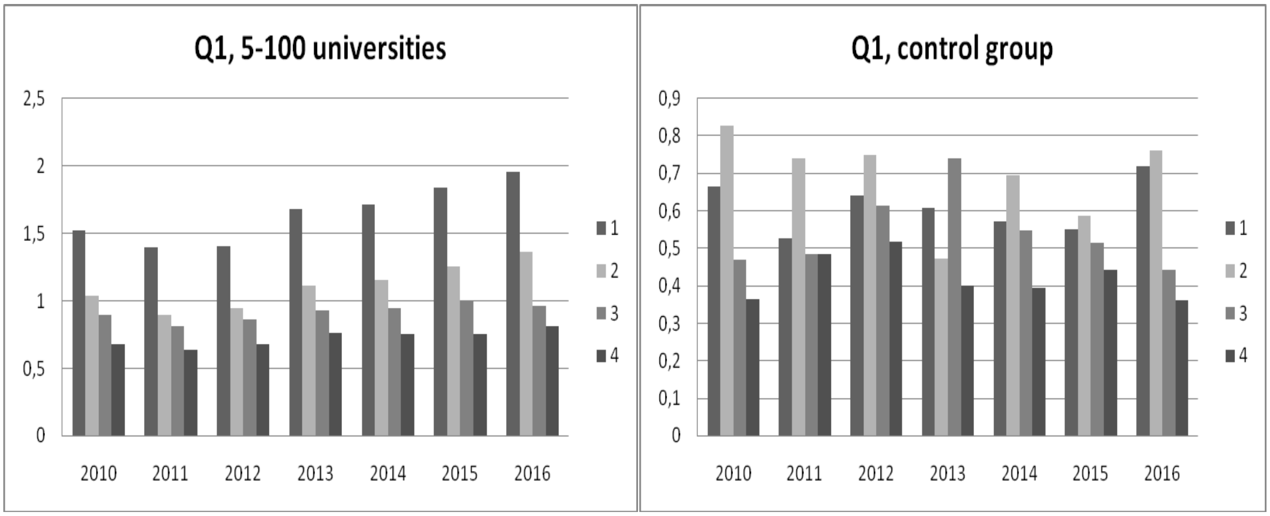

Fig.4. Number of affiliations by authors for publications with 1 - 4 authors in Q1 journals

Fig.5 shows that 5-100 universities demonstrate an increase of author affiliations in publications in Q4 journals. In period of 2013-2015 the number of affiliations of one author has doubles. In 2016 these values decreased.

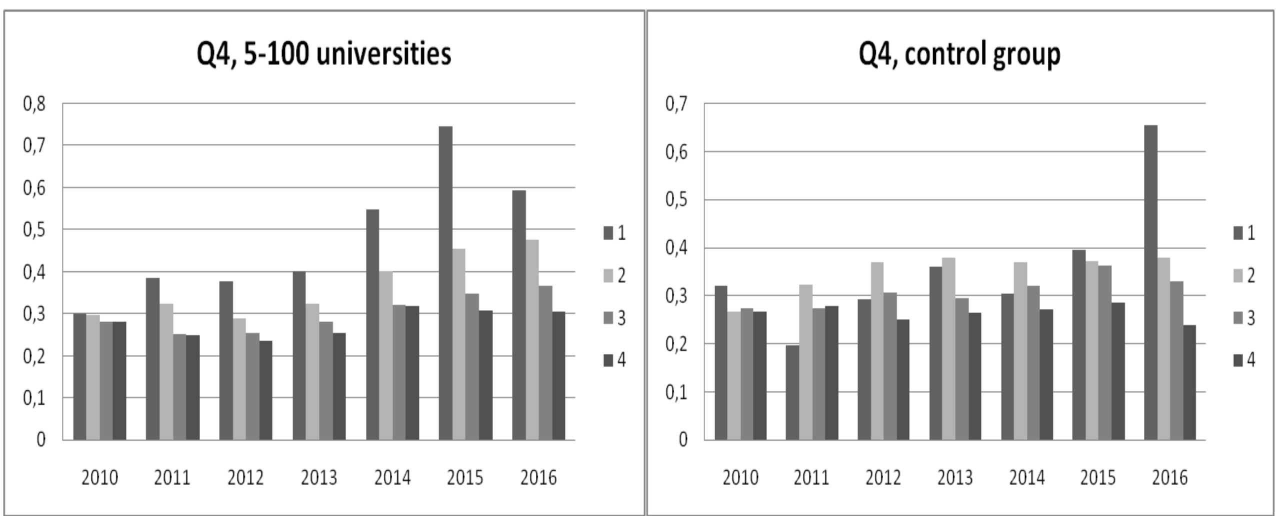

Fig.5. Number of affiliations by authors for publications with 1 - 4 authors in Q4 journals

Publications with several affiliations may appear for 2 reasons. First, they may be the result of joint work of people from different organizations. Second, it may happen when some of the co-authors work in several organizations simultaneously and mention all of them in the paper. After 2013, 5-100 universities intensified both of these. More often scientists from 5-100 universities have double affiliations in Q1 publications. For example, in 2016 one scientist on average had almost two affiliations in Q1 and 0,6 affiliations in Q4 publications.

We also examine the share of these publications in Q1 and Q4. For each year we calculated the percentage of works with one author and 1-4 affiliations from all works with one author in a specific year. As shown in Fig. 6, in Q1 journals in 5-100 universities after 2012 the share of publications in which one author has only one affiliation, dropped significantly. The share of publications with 2 affiliations per author has symmetrical opposite dynamics (that is, more often one author increases the number of affiliations up to 2 affiliations). After 2013 the percentage of publications by single authors with 2 affiliations is higher than the percentage of publications with one affiliation. The percentage of works with 3-4 affiliations has also increased after 2013.

In the control group, the share of publications in Q1 journals with one author and one affiliation dropped in 2013–2015. Publications with 2 affiliations per author increased.

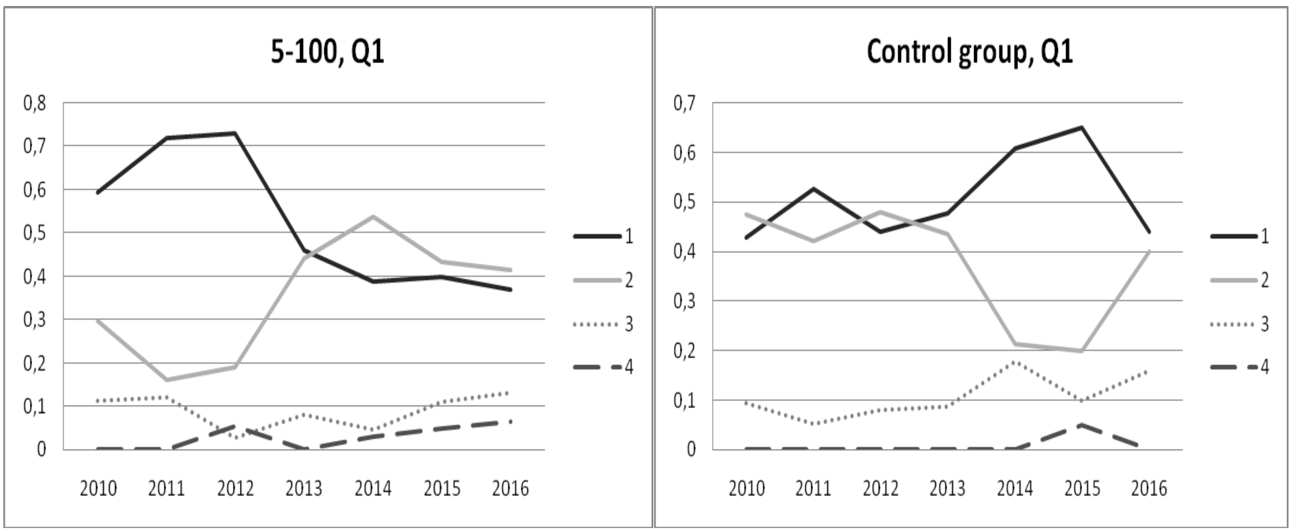

Fig.6. Share of publications with one author and 1-4 affiliations in Q1

For Q4 journals, in 5-100 universities the share of publications with one affiliation and one author decreased 2011–2013 and 2014–2016, although during the whole observed period single-authored publications from 5-100 universities mostly have one affiliation. The growth of the number of affiliations per solo author is observed in 2014 (up to 2 affiliations per author) and in 2015 (up to 3-4 affiliations per author). For the control group in Q4 journals, the share of publications with one affiliation per author decreased 2013–2015 and the share of works with 2 affiliations increased 2013–2014 almost symmetrically (See Fig.7).

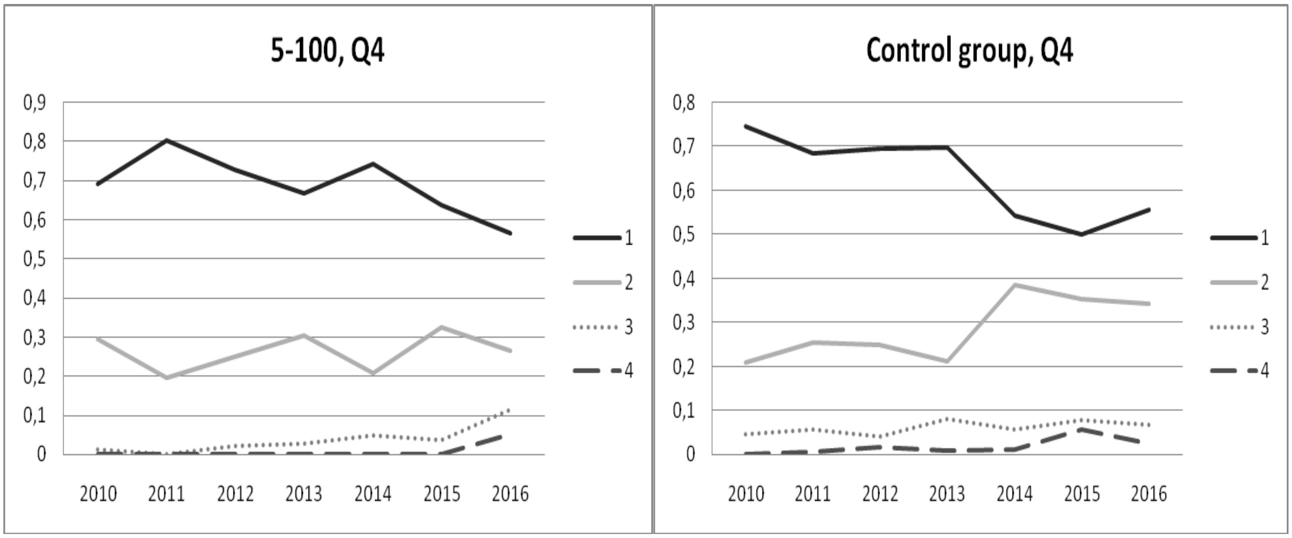

Fig.7. Share of publications with one author and 1-4 affiliations in Q4

Finally, we study the dynamics of papers written in international collaboration (See Fig.8). In 2010, the 5-100 universities and the control group have equal shares of publications co-authored with foreign colleagues. In 5-100 universities, this indicator increased from 33% in 2012 to 44% in 2016. The control group intensified international collaboration 2011–2013, then the share of such publications was stable.

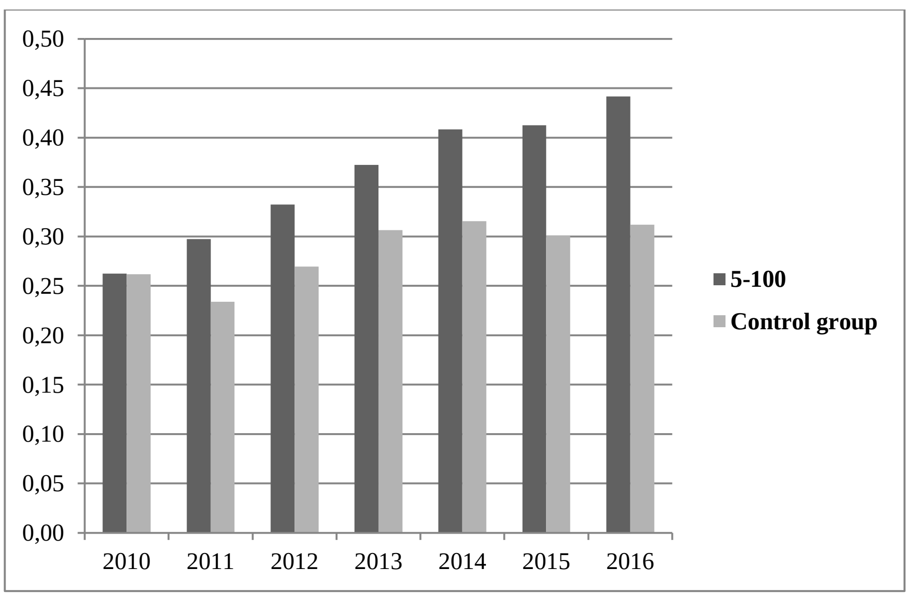

Fig.8 Share of international collaboration

Conclusions

Our analysis shows that Project 5-100 has had a significant effect on participating universities. We demonstrate that this growth is expressed both in quantitative terms and in terms of the structure of the research output.

The value of the effect varies by type of publication and by year. For the total number of publications, publications in Q4 journals, and for multi-author papers the effect increases with each year of participation. In 2014, participating universities outperform the general publication trend by more than 35% and by more than 50% in 2016. The maximum value of the effect is observed for publications with more than 10 authors (more than 460% in 2016). To understand how Project 5-100 affects the productivity of scientific staff we estimate the effect on publications per capita. The effect is positive and its value varies depending on model specification.

We also estimated the relative growth of high-quality (Q1) publications in comparison with low-quality (Q4) output. In 2014, the Project’s effect was higher for Q1 journals (43%) than for Q4 (23%). In 2015, the results were reversed: the Project's effect for Q4 journals is 45% and for Q1 it is 32%. And in 2016 for Q1output, a positive significant effect is not observed.

This positive publication growth is observed when several government excellence programs were implemented at the same time in Russia. These measures could have cumulative effect on publication activity of Russian universities. So the process of creating a knowledge is often complex and resource-intensive, it is difficult to differentiate the effect of one project from others. To measure the effect of Project 5-100, we assessed publication activity of participating universities in comparison with universities from a control group, which are in the same institutional environment.

We also show that collaboration patterns of the universities rapidly changed over the course of the project, having a qualitative impact of the general research output of the university. The analysis of affiliations shows that 5-100 universities greatly increased the share of co-authored publications after 2012. Before 2014, academics from control group universities have more affiliations than those from 5-100 universities especially in Q1 journals. After 2012-2013 in 5-100 universities, an increase in author affiliations is observed both in the Q1 and Q4 segments. The gap between two groups of universities decreases, and in 2016 the average number of author affiliations of 5-100 universities is about the same as in control group.

5-100 universities also increased the number of academics with multiple affiliations. This growth is particularly evident in Q1output. The share of publications in Q1 journals, in which one author has only one affiliation, dropped greatly after 2012 in 5-100 universities. This reveals that after joining Project 5-100, universities increased the number of publications partly due to those scientists who work in different organizations outside the 5-100. In the control group, the increase of the number of affiliations by author is not observed until 2016, when the number of affiliations by author for publications with 1 author increased drastically. In addition, we show that 5-100 universities increased the share of international collaboration from 33% in 2012 to 44% in 2016.

Our findings underline the highly problematic nature of excellence initiatives based on rankings and formal scientometric assessments: on the one hand, there is a marked and rapid increase of publication output, including an increase in the number of papers in highly-cited and highly selective international journals. On the other hand, the scope and speed of this increase means that the majority of research leading to these papers was not prepared using 5-100 funds. Nowadays even the publication of already prepared manuscripts can take several years, especially in top journals in some disciplines (Bjork and Solomon 2013), in addition to at least 1-2 years needed for every project's design and completion. This means that the project's real success at the early stage was mostly in adding university affiliations to papers prepared elsewhere, with the help of authors with multiple affiliations. Such a specific collaboration pattern is primarily aimed at a quick increase of bibliometric KPIs and ranking positions (Bornmann and Bauer 2015) and is becoming more and more widespread, as we see a rapid increase in the share of authors with multiple affiliations in the control group in the most recent year observed. Increased collaboration, which is at least partly driven by the global advent of formalized evaluation regimes (Dahler-Larsen 2015) means that it is becoming more and more difficult to assess individual organizations using standard bibliometric apparatus employed by funders and governments.

Collaboration per se is almost universally accepted not only as a positive and even defining trend of modern academia, but as a proxy for higher citation counts, or 'excellence' (Bornmann 2017). In this sense, the rapid increase of collaboration – both national and international –forced by blunt bibliometric or ranking KPIs can be viewed as an unintended, but highly beneficial consequence.

Thus, the true effect of Project 5-100 on the production and research capacity of participating universities is much more complicated than can be judged by publication counts alone, and should be studied accordingly.

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Supplementary materials

Figure 1. Total number of publications

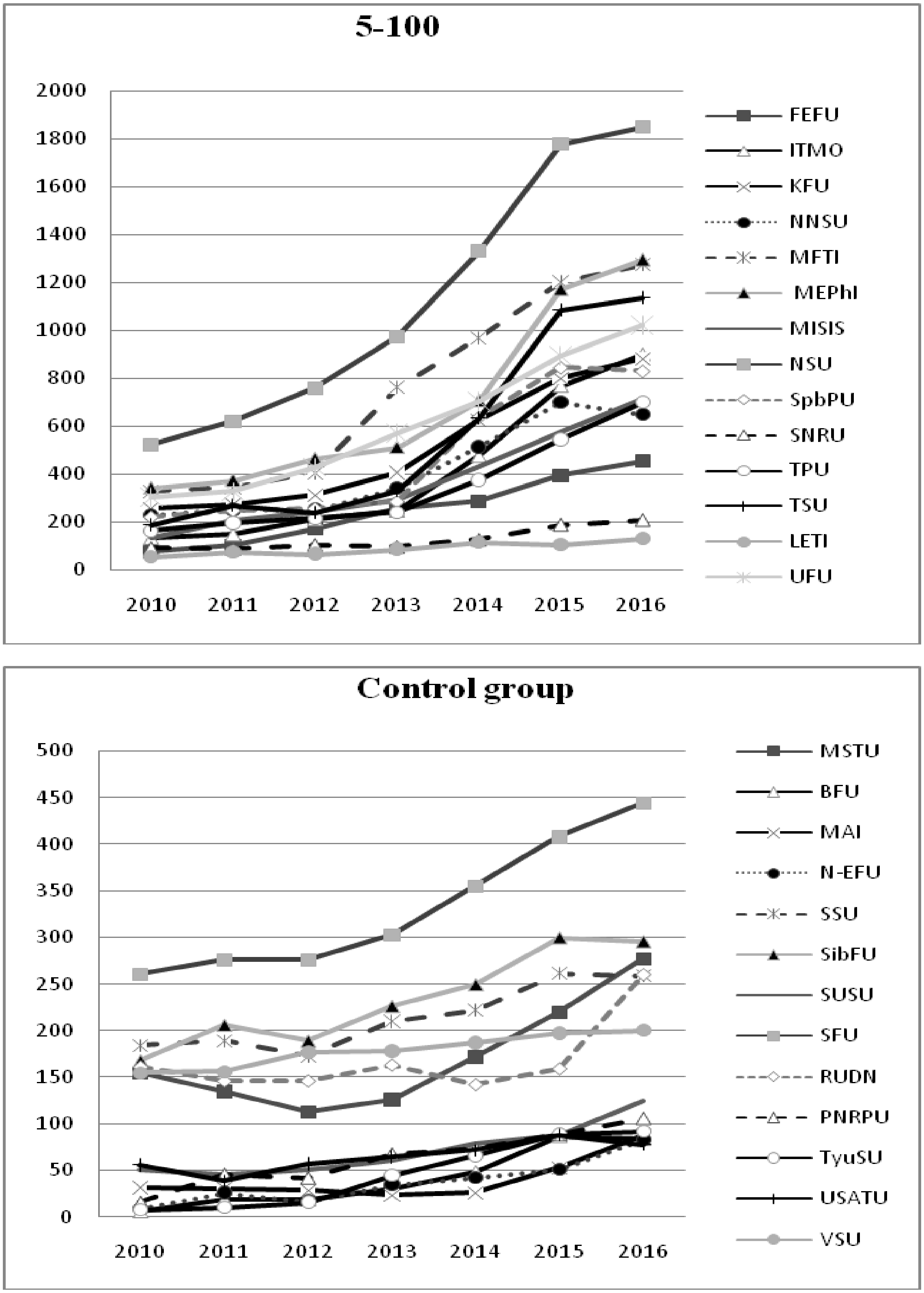


Figure 2. Number of publications per capita

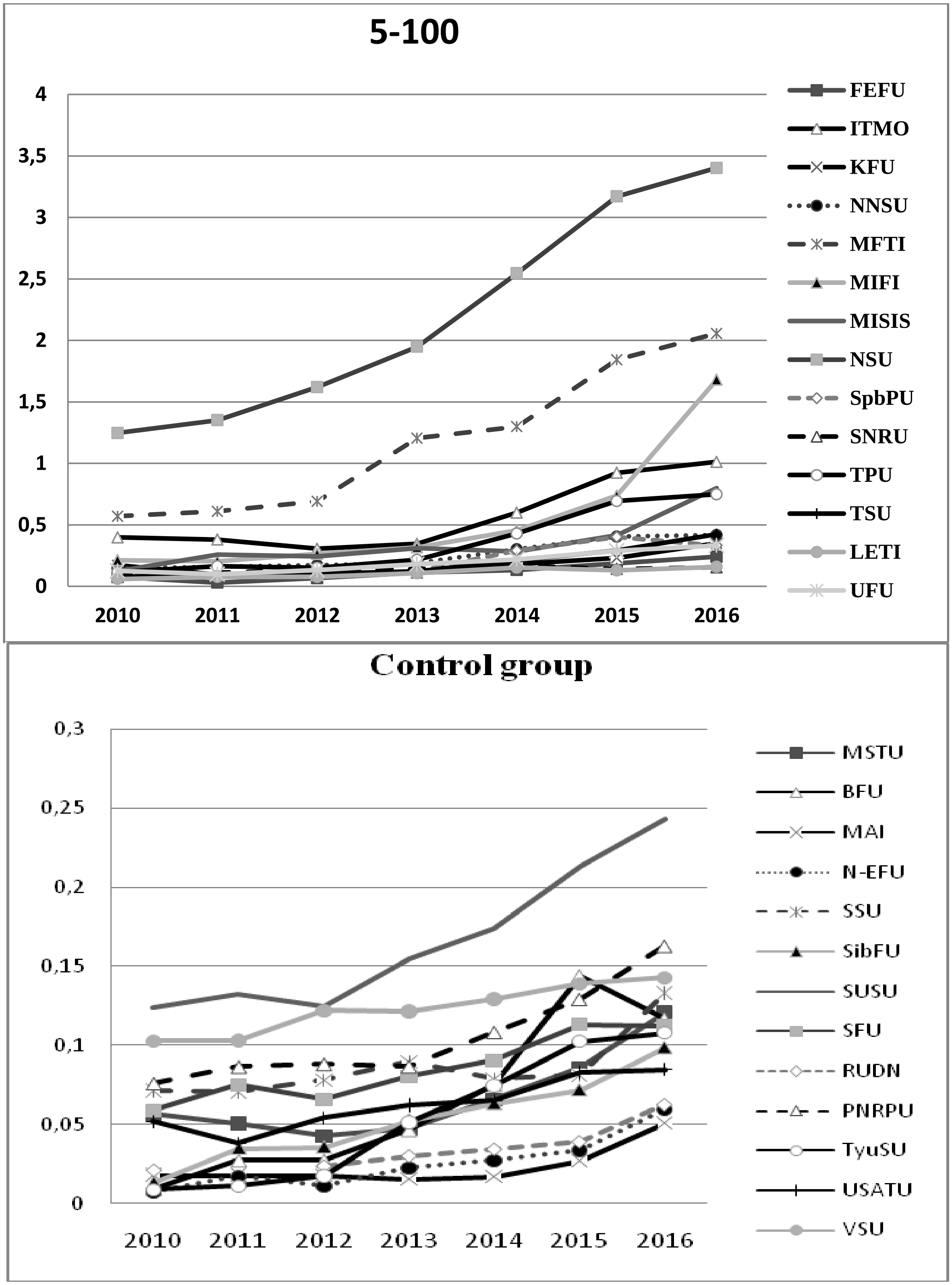


Figure 3. Number of publication in Q1 journals

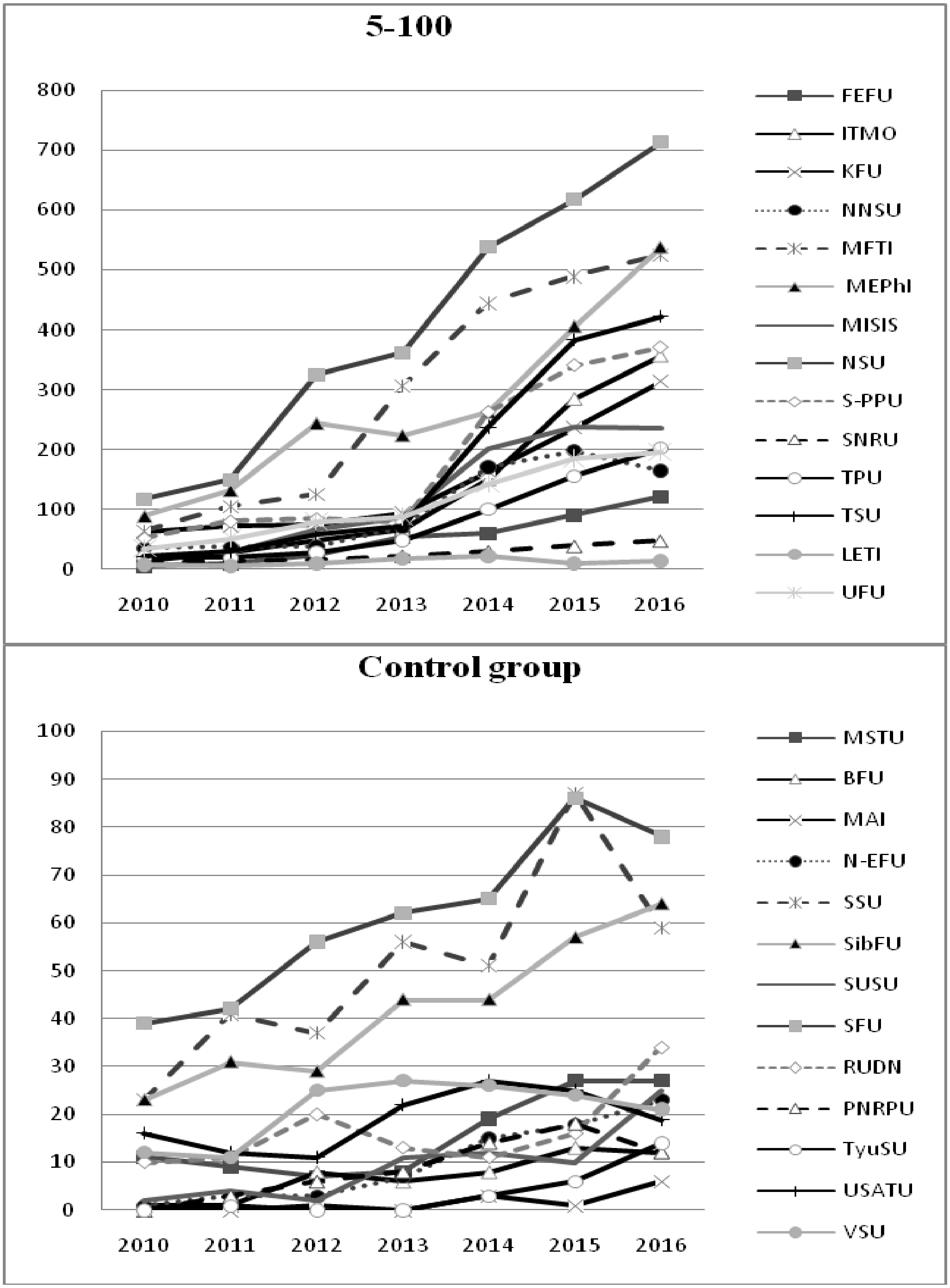


Figure 4. Number of publication in Q1 journals per capita

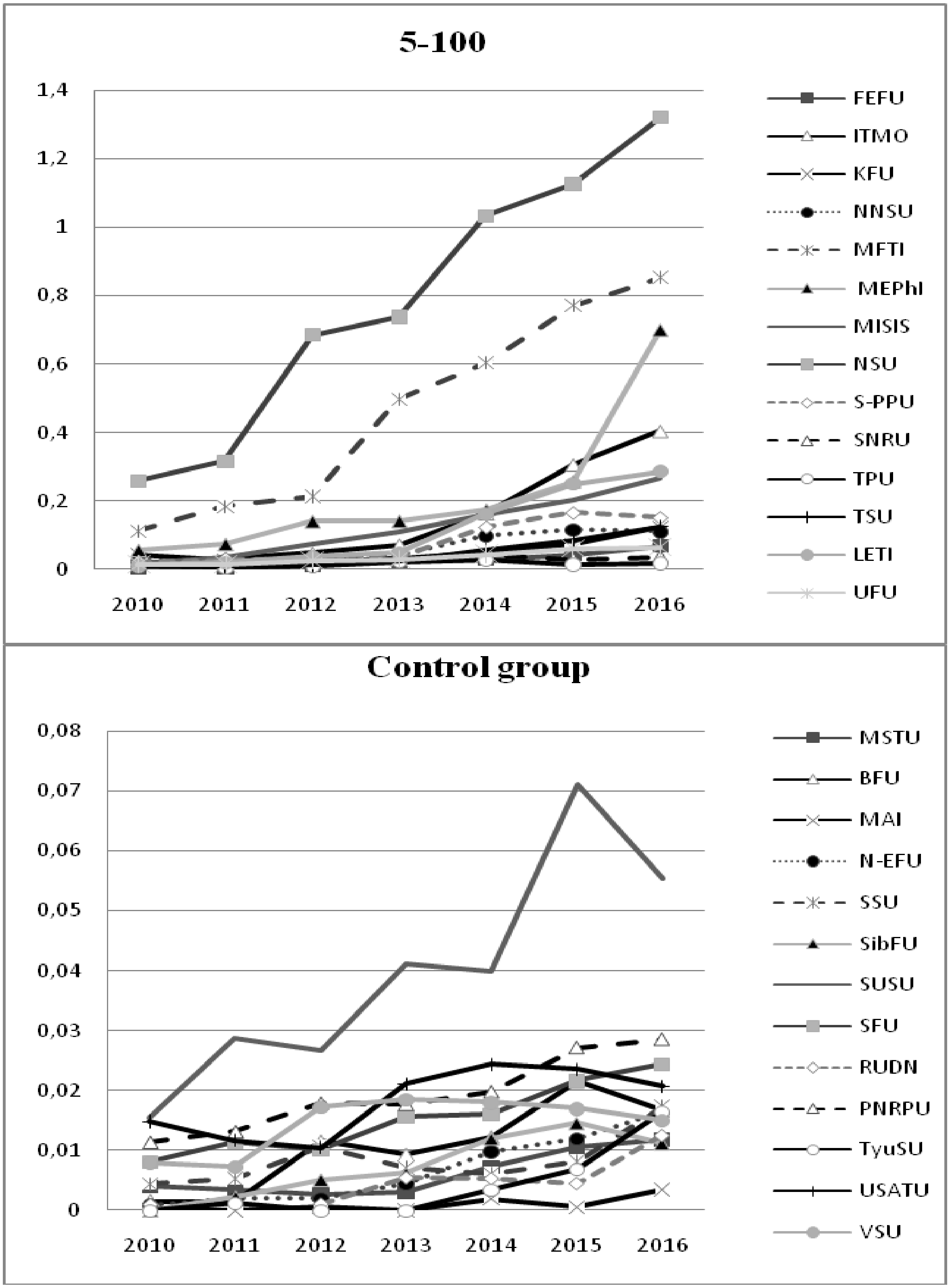
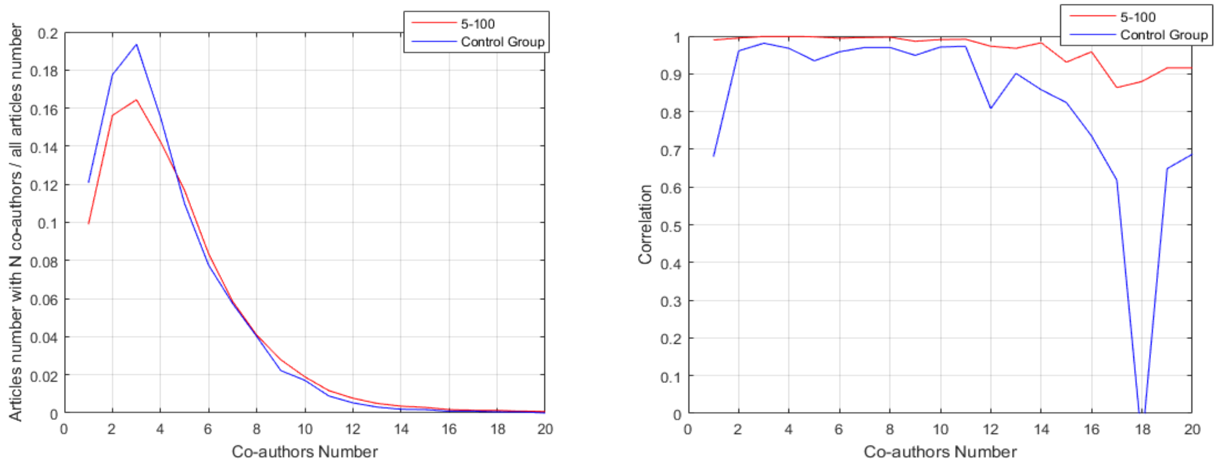


Table 1. Descriptive statistics for two groups of universities: mean value. In brackets are standard deviations

		2010	2011	2012	2013	2014	2015	2016
Number of publications	5-100 universities	217.29	251.29	294.21	385.86	566.50	789.50	860.21
		(127.33)	(142.26)	(175.42)	(246.74)	(320.93)	(437.73)	(452.12)
	Control group	97.00	101.85	100.31	118.00	133.38	160.69	183.92
		(86.10)	(87.14)	(84.51)	(90.09)	(98.61)	(109.96)	(115.08)
Number of scientific staff	5-100 universities	1339	1657	1640	1588	1591	1616	1442
		(630.61)	(985.56)	(949.43)	(925.72)	(882.98)	(827.89)	(776.09)
	Control group	1812	1776	1732	1740	1722	1729	1598
		(853.27)	(788.87)	(768.95)	(822.06)	(789.40)	(766.60)	(679.63)
Number of publications per capita	5-100 universities	0.230	0.250	0.290	0.392	0.521	0.714	0.874
		(0.296)	(0.336)	(0.408)	(0.542)	(0.657)	(0.856)	(0.929)
	Control group	0.048	0.055	0.054	0.066	0.077	0.097	0.115
		(0.039)	(0.038)	(0.039)	(0.040)	(0.043)	(0.052)	(0.051)
R&D funding (thousand rubles)	5-100 universities	471784.17	868861.34	877613.54	1560652.71	2134904.14	2154886.12	2071539.46
		(256127.95)	(509603.71)	(512156.55)	(591883.62)	(748362.81)	(804851.69)	(719676.06)
	Control group	418731.49	585238.77	757792.50	953655.60	913029.69	907259.81	800796.61
		(458555.09)	(637795.19)	(961531.71)	(1368470.91)	(1236670.84)	(1075387.19)	(890738.32)
R&D funding per capita (thousand rubles)	5-100 universities	439.35	720.84	758.54	1327.23	1754.32	1660.92	1884.96
		(272.94)	(465.61)	(551.86)	(789.43)	(1021.32)	(985.59)	(1256.33)
	Control	211.37	294.99	398.76	501.23	487.62	494.77	475.551

	group	(165.27)	(224.36)	(367.88)	(549.28)	(487.13)	(447.55)	(391.69)

Figure 5 a, b. The distribution function and Pearson correlation of all publications and publications with certain number of authors



a b

Table 2. Dynamics of publications in Q1 and Q4 journals: mean values. Standard deviations are in brackets

		2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Number of publications in Q1 journals	5-100 universities	39.64	54.71	87.50	113.93	199.36	262.71	301.57
		(33.54)	(46.39)	(90.54)	(105.64)	(147.29)	(172.20)	(200.38)
	Control group	10.62	13,00	15.77	20.31	22.92	29.85	30.31
		(12.05)	(15.03)	(16.89)	(20.96)	(19.29)	(28.54)	(22.51)
Number of publications in Q1 journals per capita	5-100 universities	0.230	0.250	0.290	0.392	0.521	0.714	0.874
		(0.296)	(0.336)	(0.408)	(0.542)	(0.656)	(0.855)	(0.929)
	Control group	0.047	0.055	0.054	0.066	0.077	0.097	0.115
		(0.039)	(0.038)	(0.039)	(0.039)	(0.042)	(0.052)	(0.051)
Number of	5-100 universities	99.43	115.86	121.28	147.29	182.28	231.92	242.64

		(41.51)	(55.74)	(46.08)	(67.95)	(82.45)	(102.27)	(104.19)
	Control group	53.69	58.46	54.00	63.08	64.46	76.69	83.92
		(42.04)	(46.83)	(48.40)	(48.16)	(48.22)	(58.08)	(58.69)
Number of publications in Q4 journals per capita	5-100 universities	0,098	0,109	0,104	0,131	0,153	0,189	0,227
		(0,101)	(0,126)	(0,100)	(0,133)	(0,155)	(0,180)	(0,202)
	Control group	0,026	0,031	0,028	0,035	0,036	0,044	0,051
		(0,022)	(0,020)	(0,021)	(0,021)	(0,021)	(0,022)	(0,023)