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*Tommaso Agasisti, Ekaterina Abalmasova,*
*Ekaterina Shibanova, Aleksei Egorov*

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*Tommaso Agasisti[1] Ekaterina Abalmasova[2],*
*Ekaterina Shibanova[3], Aleksei Egorov[4]*

# THE CAUSAL IMPACT OF PERFORMANCE-BASED FUNDING ON UNIVERSITY PERFORMANCE: QUASI-EXPERIMENTAL EVIDENCE FROM A POLICY IN RUSSIAN HIGHER EDUCATION

In most countries which experience structural transformation of their higher education system, a crucial goal of policy makers is to tie the amount of university public funding to their performance. This research analyzes the Russian performance-based funding (PBF) reform to provide a quasi-experimental assessment of its effects on Russian universities' performance. Data comes from the Monitoring for HEIs performance and covers the period between 2014/2015 and 2017/2018. To evaluate the causal effect of the PBF policy on university performance, in a first step we define the treatment and the control groups by distinguishing universities on the basis of the trend in their performance-based allocations. In a second step, we estimated the causal effect of the redistribution of public funds across universities as a result of PBF policy. Results indicate that the performance of universities is actually affected by getting extra funding after the reform, although heterogeneity is at play. The short-run effect is related with the impact on average national exam scores, indicating that the policy forced universities to be more selective.

JEL Classification: I22, I23, I28

Keywords: performance-based funding, higher education funding, policy evaluation, difference-in-differences

[1] Politecnico di Milano, School of Management, Milan – Italy

[2] Laboratory for University Development of Institute of Education, National Research University Higher School of Economics, Moscow – Russia

[3] Laboratory for University Development of Institute of Education, National Research University Higher School of Economics, Moscow – Russia

[4] Laboratory for University Development of Institute of Education, National Research University Higher School of Economics, Moscow – Russia

## 1. Introduction

Over the last decades, many countries have been promoted structural transformations of higher education (HE) systems in order to increase the accountability and performance of Higher Education Institutions or HEIs (Parker, 2011). Higher education expansion and marketization, together with lowering amounts of available public funding due to fiscal pressure (Johnstone et al., 1998), forced the national governments to reconsider existing funding principles. Negotiation processes have been replaced with mechanisms fostering a more productive and efficient way of public services provision (van Vught, 1997; Liefner, 2003; Agasisti and Pérez-Esparrells, 2010). Performance-based funding (PBF) became one of the main instruments to align state interests, the amount of public funding of universities, and their performance (Jongbloed & Vossensteyn, 2016; Jongbloed et al., 2018).

The Russian government started a range of new public management reforms in higher education sector in recent years. Since 2012, the Russian government implemented performance evaluation, the transparency of data use and managerialism in order to enhance performance increase and institutional changes (Platonova & Semyonov, 2018). The interesting example for this paper is that new mechanisms of distributing public funding according to the performance of universities have been introduced in 2015.

PBF mechanisms aim at improving various university activities, including retention rates, research performance and quality assurance. Effects of such funding reforms have been studied in a range of academic papers, which focus on university management behavior (Jongbloed and Vossensteyn, 2001), system differentiation (Sorlin, 2007; Abankina et al., 2018), and efficiency and productivity growth (Bolli et al., 2016). However, research on causal assessment of PBF on university performance is rather limited and mainly focuses on the experience of the USA. For example, Hillman et al. (2015) use the difference-in-differences approach and find a small short-run effect on retention rates and associate's degree productivity in local community colleges in the Washington state. Umbricht et al. (2017) use the same methodology and find that PBF did not contribute to increased graduation in Indiana. Kelchen (2018), again using DiD, finds no significant effects of the new policy on the enrollment of underrepresented students in 4-year public colleges in the USA.

The introduction of PBF in Russia is an interesting case, giving an understanding of the short-term effects of shifting funding rules on a range of university performance indicators. Since the new policy has been introduced, the largest part of public funding (at least 60%, which is 35.5% of total funding of public universities) is defined on the basis of the number of publicly funded places and their standard cost, and this makes public universities heavily dependent on the competitive mechanism of resource allocation. In the context of such policy, the scarcity of available resources makes some universities "winning" and the others "losing" under the new scheme (Abankina et al., 2018). Given that the amount of resources allocated through PBF is a substantial part of the overall universities' budget, it can be the case that the policy has a potential to influence actual institutions' incentives and behavior.

This paper provides a quasi-experimental assessment of the effects of the new funding mechanism on performance of Russian universities. More specifically, we focus on the effects of the funding redistribution consequences on university performance in the years immediately after the reform was implemented, by answering the following research question: *did the redistribution of funds due to the PBF reform causally influence the performance of*

*universities in the subsequent years*?

The main institutional challenge for causal assessment of this system-level reform is that it affects all universities alike, which makes selection of a control group difficult. In this paper, we solve this methodological issue by distinguishing universities on the basis of the amount of funding they received as an (exogenous) effect of PBF. After having created a treatment and control group, we employ an innovative semiparametric difference-in-differences approach in order to assess the causal effect of the redistribution of public funds across universities. To the best of our knowledge, this is the first research which assesses the causal impact of a PBF policy on HE institutions in the European context.

The remainder of the paper is organized as follows. The section §2 introduces the reader to the Russian PBF reform and provides details on the new funding mechanism. The section §3 presents a general overview of funding mechanisms in higher education, with a particular focus on the rationale behind PBF policies and the assessment of their effects. The section §4 provides the theoretical framework for analyzing the reaction of universities to the new policy – especially, the expected effects on their performance. The section §5 describes the data and the econometric strategy used in the study. Lastly, the main results and their discussion are presented in sections §6 and §7, respectively.

## 2. Policy background – funding of HE in Russia

The budget of Russian public higher education institutions is composed by two main parts: (i) private funds received as tuition fees and from the commercialization of university R&D, and (ii) public funds distributed from the federal budget. Historically, the main mechanism through which public funds were distributed across universities was based on negotiations between university managers and the Ministry of Education and Science (MoES)[5]. HEIs were financed according to their financial plans (line-item budgeting): the budget of HEIs had to be split into expenditure items and the university receive the money for each item separately. The funds which are unspent during the year could not be used during the next period.

From the 2010s, the Russian government started to actively reform the financing schemes according to which public sector organizations, including universities, are financed. The main idea of these reforms was linking the amount of financial resources available for the organization to the quantity of services that it provides. In technical terms, the reforms realized a transition from a funding system based on budgets to a normative per capita funding mechanism. The consequence for HEIs is that the amount of public funding for providing educational services should be dependent on the number of students for whom these services are provided (on the principle of "money follows the students"). Moreover, this transition from funding by budget to normative per capita funding was introduced in order to tie up money and performance demonstrated by HEIs and to make the mechanism of public funding allocation more transparent for stakeholders. The first standards of HEIs per capita funding were proposed in 2012 by the Decree of the President of Russia (#599, 07/05/2012).

[5] In 2018 the Ministry of Education and Science was reorganized and split into two separate authorities: the Ministry of Education responsible for vocational education and the Ministry of Higher Education and Science accountable for higher education and science.

The current scheme according to which Russian universities receives public funding has various steps. Firstly, MoES defines the total amount of publicly funded places at universities for a particular year, for the whole national public higher education system. This amount is defined on the objective that for each 10,000 of population in the age cohort 17-30 years the federal budget should provide 800 publicly funded places at HEIs. Then, the Ministry collects the propositions of universities on the number of students they can admit to each field of study. In parallel with this process, government agencies are consulted on the distribution of publicly funded places across different regions and fields of study.

After these distributions are defined and university propositions are collected, the Ministry starts the formal procedure and distributes places across universities. This process is based on two well-specified and predefined formulas. The first formula determines the amount of publicly funded places for a particular institution through indicators of its performance. The second formula defines the amount of public funding for each place (standard cost). The complete list of performance indicators used in both formulas is presented in Table 1. In addition to these baseline formulas, the amount of resources that a particular university receives from the federal budget also depends on the location of the university and/or on the study program (all fields of study are divided into three groups).

In practical terms, the Ministry holds a competition for the distribution of the number of publicly funded places and the amount of funding per place. Thus, HEIs compete for both the number of places and the amount of funding per place. After the number of publicly funded places for each university is defined, universities receive the so-called "State Task". According to the Russian Budget Code, a State Task is a document which establishes the "requirements for the composition, quality, content, terms, procedures and results of rendering state services". The State Task is set annually during drawing up the federal budget for the next year and the planning period in accordance with the government decision No. 640.

The public funding that universities receive according to the procedure described above is aimed at covering different types of universities' costs related to the provision of educational services. The cost of providing educational services can be divided into two groups. The first group considers the costs directly associated with the payroll budget of teaching, and administrative and research staff, inventories and other expenses. The second group of costs deals with the general economic needs and includes communication costs, transport, payroll for other (non-core) staff and utility bills. The standard costs are associated with current costs and do not cover capital expenditure. Standard costs vary with fields of study. There are three groups of specialties with the same 'basic' standard cost. Standard costs of each group take into account the basic requirements to facilities and resources of HEIs, learning and teaching support material of specialty and human resources.

Before the implementation of the per capita funding mechanism described above, the difference of the actual costs per student was substantial: universities differed by 4-5 times in terms of the amount of the State Task. Such a cost differentiation was caused by both the area and the type of HEIs and also its status (for example, "leading university" or not). In the new funding system, this heterogeneity is reduced by correction coefficients (adjusting factors) that affect the size of basic standard cost.

There are several other mechanisms through which universities can receive public resources above PBF. Particularly, during the last three years the government has introduced

mechanisms of project funding for higher education, such as the excellence initiative denominated "5-100 project" (Agasisti et al., 2019). In any case, the State Task is the most crucial instrument of HEIs funding, especially because it accounts on average for the 35.5% of the total.

What is crucial to underline from the description above is that universities can have very imprecise forecast about the precise amount that they will receive through the PBF system. Indeed, this amount results not only from the analysis of the single university's performance, but also from the (simultaneous) performance of all the others. Moreover, even the performance of the single university is determined by the aggregation of numerous indicators selected for the evaluation purpose, so that each institution cannot really predict its specific result in advance. Such feature of the system leads the case to be a very interesting one, because we can easily assume that the gain or loss in terms of funding can be regarded as "exogenous", and the effects of the redistribution can be assessed in a causal way if a proper methodology is employed (see our approach in section §5.2).

## 3. Related literature

### *3.1. HE funding mechanisms*

As higher education yields feature of both public and private goods, it relies on investments from three main sources: (i) public financing, (ii) private support and (iii) tuition fees. Despite the fact that a shift from public to private funding is being observed today (Jongbloed et al., 2018), state funding remains the core source income for universities in most countries (OECD 2016), which holds for countries with a non-Anglo-American HE systems in particular. Public funding is a crucial condition for the functioning and performance of HEIs (Elbasir & Siddiqui, 2018), which makes the policies of public funding an important steering mechanism and one of the most widespread subjects of public policy debate (Parker, 2011).

Public fund allocation mechanisms can have a significant impact on both system and institutional level of HE. After or during a decision about the total amount of public spending is set, universities react differently based on the way they receive public resources (Liefner, 2003). The existence of other sources of public funds provision (e.g. targeted grants) additionally shape the way managers and academics behave. Lepori et al. (2012) note that the type of public fund allocation system may have an impact on the incentives of university managerial activities, such as budgeting practices. Frolich et al. (2010) discuss how funding systems influence HEIs and their strategies and core tasks. These systems may affect not only particular universities and their management practices, but the landscape of the whole regional or national higher education system. For example, Horta et al. (2008) show that fund allocation schemes may be related to the institutional diversity of higher education.

Many authors provide approaches to classify funding mechanisms, which vary significantly according to the particular context of each state and its higher education system (Hearn, 2015). To simplify the topic, Salmi and Hauptman (2006) distinguish between the funding of institutions (which may occur in various forms, from vouchers to formulae) and funding of students through grants and scholarships. Jongbloed (2004) presents the following classification of funding systems: there are two main trade-offs, the first one between market-driven mechanisms and state regulation, the second – between input and output orientation. In Lepori et al. (2007) three aggregated types of public funding allocation mechanisms are

highlighted: negotiated allocation based on historical criteria; negotiated allocation based on input or performance indicators; formula-based allocation (a mathematical formula for calculating the allocation for each institution based on a set of indicators). Orr et al., (2007) define four types of funding mechanisms: indicator-based funding, project-based funding (earmarked grants), mission-based funding, discretionary incremental funding.

The decline in the overall amounts of state funding coming into the higher education sector (Armbuster, 2008; Webber, 2018) has brought additional competition for the limited amount of resources via a shift towards a higher degree of accountability and monitoring, and thus, a performance-oriented funding of universities, which is discussed in detail in the next section §3.2.

*3.2. Performance-based funding*

Historically, in most countries, state funding in higher education was based on a low degree of performance orientation and a high degree of regulation by central authorities. Different external forces such as the expansion of the higher education sector and trend towards the marketisation of higher education – together with diminishing amounts of available public funds (Johnstone et al., 1998) – led to a shift in funding paradigm. Governments are now more interested in favoring organizations that service the national interest in a more productive and efficient way (Liefner, 2003; De Witte and López-Torres, 2017; Agasisti and Pérez-Esparrells, 2010; Agasisti and Johnes, 2009), which is stimulated through the alignment of state interests and institutional incentives (Miller, 2016).

In order to increase transparency, accountability and performance in higher education funding, governments started reforms focused on changing fund allocation mechanisms (Jongbloed and Vossensteyn, 2001). Negotiation procedures and other funding modalities started to be replaced by competitive schemes[6], where funding is linked to performance indicators (van Vught, 1997; Williams, 1997). The main idea of PBF is that the current amount of resources received by each university depends on its performance in the previous period. PBF is usually based on a particular formula that relates university performance to the amount of funding (McKeown, 1996). This formula usually contains a wide range of different performance indicators, such as the number of formative credits accumulated by students, the number of degrees awarded, the number of research publications and other indicators that can be controlled by university management (Jongbloed and Vossensteyn, 2001) – thus, policymakers treat universities as multi-product organizations (Cohn et al., 1989). However, the set of specific indicators included in the formula is often a debated choice, involving discussions about the effective measures of educational and research performance not via simple quantitative indications of some generated output, but the value added by a university. In any case, the composition of indicators used varies from one system to another and depends on the political agenda (Jongbloed, 2018).

Several theoretical frameworks for competitive funding mechanisms in higher education exist, the first of which is New Public Management theory (Ferlie et al., 1996). The NPM approach suggests that public organizations should be managed based on the same principles as privately-owned organizations. This attitude towards the management of HEIs

[6] A notable exception is reported by Estermann et al. (2013), as negotiation remains the main way of public funds delivering in Austria, Germany and Spain.

might also be characterized as a "state supervision steering" or "framework steering" (Van Vught, 1989). In other words, government just supports the frames, and universities are considered to be autonomous organizations inside these frames. Another possible conceptual framework for the analysis of PBF is an economic principal-agent model where government as a principle is looking for optimal ways for specifying the contracts with their agents – public universities (Hillman et al., 2015). Finally, resource dependency theory (Tolbert, 1985) suggests that HEIs, just like other organizations, cannot be regarded as fully self-sufficient entities, and cannot produce all the resources they need to sustain their functioning. Thus, they need to interact with the environment and stakeholders to attract the resources they lack. In case of uncertainty of future public inflows through PBF, a university will adopt its internal organizational structure and functioning in order to diversify risks or maximize financing from governmental resources (Slaughter & Leslie, 1997).

The stream of the literature that analyses the characteristics of the PBF mechanisms suffers some important limitations, thus. In particular, it would be necessary to test empirically whether the assumed consequences for the implementation of a PBF actually realized, in other words to evaluate the real effects of PBF mechanisms on universities' performance. Some studies engaged in such objectives, and a critical review of them is provided in the next section §3.3.

### *3.3. Effects of performance-based funding mechanisms*

There are a range of anticipated effects of formula financing, starting with quality assurance (Miller, 2016) to efficiency and productivity growth (Bolli et al., 2016). Some researchers argue that PBF contributes to competition between organizations. With PBF, universities have more incentives to demonstrate better performance in order to obtain more funding in the subsequent years. Aghion et al. (2010) provide empirical evidence that the level of competition in the HE sector is positively correlated with the performance of universities in European countries and the US.

Some researchers also note the negative and unintended sides of this funding mechanism. Jongbloed and Vossensteyn (2001) suppose that the introduction of PBF may lead to risk-avoidance by university management, i.e. managers will try to achieve the easiest performance indicators and ignore difficult ones. Another possible shortcoming is that using formula for public funds allocation may lead to a convergence of all universities to a common level of mediocrity, undermining the university incentive to look for alternative sources of financial resources. Besides, the introduction of PBF leads to positive outcomes only under certain conditions. Liefner (2003) studies different approaches to higher education funding and their influence on university performance and notes that the influence of changes in financing mechanisms depends on the share of public funds in the total amount of financial resources available for the university. Such evidence suggests that the introduction PBF may lead to different effects for different universities.

Few empirical papers assess the effects of formula budgeting on HEIs performance, and all of them explore cases of single states in the USA. Hillman et al. (2015) uses difference-in-differences to trace the effects of the introduction of PBF in Washington state, and found a small short-run effect on retention rates and associate's degree productivity in local community colleges, which, however, managed to produce more short-term certificates after the policy

reform. The latter are rewarded by the policy design but provide a lower return to education for graduates, making the reforms controversial. Kelchen (2018), using the same methodology, finds no significant effect of formula financing on underrepresented student enrollment in 4-year public colleges. Hillman et al. (2014) find no effect of the reform on college completion rate in Pennsylvania state. Umbricht et al. (2017) use difference-in-differences and find no increase in the number of graduates in Indiana due to the introduction of PBF.

Another group of academic contributions assesses the PBF in the logic of system differentiation. Sorlin (2007) suggests that PBF as introduced in many countries promotes vertical differentiation and specialization between universities, but the mechanism ensures horizontal diversity within the system. Abankina et al. (2018) conclude that PBF in Russia contributed to an increase in university stratification on the basis of their disposable financial resources, which in turn significantly affects the quality of education provided.

Despite these shortcomings, PBF schemes are gaining momentum in different countries. In the USA, where the governance of the higher education system is carried out at the state level, 22 states have already adopted or are in the process of adopting of PBF (Nisar, 2015). Most European countries also actively utilize PBF principles (Wang, 2019), and even develop new performance-based funding modalities, such as political agreements based on performance indicators (Jongbloed et al. 2018).

## 4. Theoretical framework

In this paper, the PBF scheme is analyzed within the theoretical framework of a basic principal-agent model (Stiglitz, 2008). This model suggests that the Ministry (regulator) is the principal that aims to motivate regulated universities (considered as agents) to achieve the goals of national higher education system. These goals are determined by the vision of the regulator regarding how universities should act, which practices should they implement and which results they should achieve. However, the Ministry cannot observe all the actions of agents, so it decides to monitor a particular set of performance indicators. Consequently, it is assumed that the level of observed performance is a function of agents' efforts and a random disturbance term (Stiglitz, 2008). PBF can be viewed in this context as a contract issued by that the regulator constructs in order to maximize desirable performance indicators of the agents.

The principal-agent problem has a clear intertemporal nature. When two parties enter into the contract, one party promises to pay to the other party if a particular event occurs. In other words, the regulator promises to pay to the university a particular amount of money in the subsequent period if it achieves the particular level of performance in the current period. Taking into account this intertemporal nature of the model, we can highlight four stages of the implementation of PBF as represented by the Figure 1. At Stage (1), the regulator informs universities about the contractual conditions, specifically the performance indicators that should be targeted and how the achievement of these indicators will be rewarded. In the context of Russian PBF system, this stage suggests that all universities should be informed about the sets of indicators included in the formulae that are used for defining the quantity of publicly funded places available for university and the corresponding standard costs. At Stage (2), agents make their effort in order to maximize the performance indicators that determine the amount of public funds in the next period. At Stage (3), the agents report their performance to the regulator which uses these data in order to calculate amount of public funding to be

distributed to each agent according to the formulae set at (1). Finally, at Stage (4) the regulator rewards the performance of agents by distributing financial resources for the next period.

Insert [Figure 1] around here

The simple theoretical scheme depicted here suggests that the universities have direct economic incentives to act in the way desired by the regulator and to concentrate on maximizing the performance indicators included in the PBF formula. However, in practice a variety of failures and problems arising at each of four highlighted stages may prevent the system from fully achieving its goals. Particularly, at Stage (1) miscommunication may arise between the regulator and universities. The formulas may be too complicated, and universities may misrepresent it or not fully understand the mechanisms. Another problem is that university managers may not be fully aware of the information regarding important principles and rules of PBF, such as, for example, that the formula actually determine the specific allocation of funds to each institution. At Stage (2), different external factors (such as an unfavorable regional context) may prevent universities from maximizing the performance indicators. Particularly, harsh socio-economic conditions of the region or city where university is located may be a problem for attracting talented school graduates with high entrance exam scores – and this will lead to lower performance of the institution, all else equal. At Stage (3), different data collection and reporting problems may arise from a technical viewpoint. Finally, at Stage (4), the size of the financial reward may be too small to be a significant economic incentive, or internal coordination mechanisms can create practical difficulties for universities to react to the results with a specific plan.

The principal-agent conceptual framework similar to the one presented in this section has been already used in the context of analysis of PBF in higher education, e.g. in (Hillman et al., 2014; 2015) where the authors study the effects of performance-based funding in Pennsylvania and Washington respectively.

## 5. Data and Research Design

### *5.1. Data sources*

In this research, we use data from two sources. The first is the Monitoring of HEIs performance which provides university-level data on performance indicators covering the 2014/2015 to 2017/2018 academic years. The second source of information on the amount of public funding comes from the Ministry of Education and Science (MoES) database. Financial data is available only for universities that are governed by the MoES, so implying to restrict our sample to these institutions. Thus, the final sample used in the empirical analysis includes 214 universities under MoES authority in 77 regions (out of the total 85 regions in Russia). Universities governed by MoES cover 68,5% of full-time equivalent (FTE) student number of all public universities.

### *5.2. Research Design*

In order to evaluate the causal effect of PBF policy on university performance, we implement a two-step research strategy. At the first step we define and build treatment and control groups by distinguishing universities on the basis of the trend of financial resources

they received through PBF. The treatment group includes universities that started to receive greater public funding as a result of PBF reform. It is important to clarify that we consider the variation of funding as an exogenous shock, given that universities were not able to anticipate the effects of the reform for their own budget. As a second step, the causal effect of the redistribution of public funds between universities as a result of PBF policy on universities performance is estimated by means of an appropriate econometric technique, namely a semiparametric difference-in-differences method, to compare the performance of treated universities with that of similar counterparts which did not experience such an increase of available funds.

### *5.2.1. Identifying winners and losers*

As a result of the implementation of the new funding scheme, some universities started gaining more public funding, while some others less. If a university had a positive PBF trend during 2015-2018 it is considered a *winner*. If a university obtained less PBF than in the previous periods starting from 2015, it is considered a *loser*. There are also universities with an unstable PBF trend, for which there is no clear tendency towards winning or losing. We label them *"no trend"* universities. The practical differentiation between funding trends is obtained through the use of time series cluster analysis (Vilar and Montero, 2014). The idea of this technique is to estimate the dissimilarity measures of each pair of universities and then apply a k-means clustering algorithm.

There are two main concepts of measuring dissimilarity in time series data: shape-based, according to which n local patterns of two datasets are compared, and structure-based, which takes into account the global structure of trends (Vilar and Montero, 2014; Lin and Li, 2009). Since the clustering objective is to show similar underlying structures (i.e. positive/negative trend or absence of the trend) the structure-based dissimilarity measure was chosen. Following Vilar and Montero (2014), we use Pearson's correlation-based distance between $X_T$ and $Y_T$ which represent time series of PBF given by the equation (1):

$$COR(X_T, Y_T) = \frac{\sum_{t=1}^{T}(X_t - \underline{X_T})(Y_t - \underline{Y_T})}{\sqrt{\sum_{t=1}^{T}(X_t - \underline{X_T})^2}\sqrt{\sum_{t=1}^{T}(Y_t - \underline{Y_T})^2}} \quad (1)$$

where $\underline{X_T}$ and $\underline{Y_T}$ are the average values of the serial realizations of $X_T$ and $Y_T$ respectively, in our case indicating the amount of funding received by the government.

At the second stage we use k-means clustering algorithm (Hennig et al., 2015). This algorithm initiates values that indicate the centers of clusters (random centroids) and assigns other values to the closest centroids, using Euclidean distances between them. At the second iteration the centroid's new value is the mean of all data points in a cluster. These iterations continue until the centroids stop moving (in other words, the algorithm converges). The k-means clustering algorithm requires knowing the precise number of clusters. To validate the number of clusters proposed by purposes of study, the three groups of universities with positive, negative and neither positive nor negative trends, we use the Elbow method.

### *5.2.2. Estimating the causal effect of the policy*

To establish causality between the increase in the amount of PBF and university performance in the subsequent periods, we employ the difference-in-differences (DID) estimator. This approach is widely used to evaluate the effect of the policy intervention by comparing the variation in an outcome variable over time between the treatment and the control group (Pedraja-Chaparro 2016; Zong and Zhang, 2019). Considering the obtainment of more resources from the government as a policy intervention (treatment), we calculate the effect of this increase on the set of performance indicators (outcome variables). These indicators are those used in the PBF formula (and listed in Table 1): (i) average national entrance exam score (for both publicly funded places and places funded by tuition fees), (ii) the number of publications in journals indexed by Web of Science and Scopus per 100 units of academic staff, (iii) R&D income from extra-budgetary sources, (iv) total R&D income and (v) total income per unit of academic staff respectively, (vi) the share of foreign students and (vii) the ratio of the average monthly salary of the university's academic staff to the regional average monthly salary. As the Figure 2 shows, the trends of one of the performance indicators – WoS publications per academic staff capita – were parallel before the introduction of the reform, but diverged after. The same holds for other performance indicators of interest (Figure 3). We consider the winning universities to be the treatment group as they experienced an increase in public funding. The universities without a particular trend are the control group, as fluctuations in their public funding trends are close to zero. The group of losing universities cannot be considered as a control group, because they experienced a decrease of public funding which may be considered as a negative treatment (or, related to other unobservable features that can have affected the performance, too). For this reason, the empirical analysis that follows includes only the winning universities (treated) and the universities with unstable/no trends (controls).

Insert [Figure 2] around here

The conventional parametric DID estimator strongly depends on the assumption of a parallel trend, which implies that in the absence of the treatment, the outcome variables would have followed the same trend for the treatment and control groups. However, in our quasi-experimental design the selection for the treatment is non-random and is determined by the performance-based multi-factor formula. Hence, it is possible that performance in the pre-treatment period could be a source of an additional variation in the outcome variables and, as a result, causes a bias in the effect estimates. To obtain an unbiased estimate of the treatment effect, the semiparametric DID estimator developed by Abadie (2005) is used. This method is to applies weightings to changes in the outcome variable between the baseline and the follow-up periods based on their propensity scores which are approximated semi-parametrically by the use of the series logit estimator (Hirano et al., 2003) and then compares these weighted changes across the treatment and the control groups. This approach also helps to avoid the estimation errors which are due to functional misspecification related with the use of a nonparametric estimator.

We assume that the increase of PBF does not affect every university in the same way and on the same scale (the effect depending, for example, by specific observable and unobservable features of the universities). The semiparametric DID estimator allows the

treatment effect to vary among universities with changes in covariate values, so controlling for potential nonlinearities of the effect. In our particular specification of the empirical model, we take into account the fact that the treatment effect might vary with the share of PBF (indicating the degree of dependence on the government). In so doing, our empirical estimations control for the influence of PBF share (over the total budget) on subsequent performance indicators.

*5.3. Description of variables*

Following Abadie's (2005) method, we consider the change in the performance indicators employed in formula between 2014 and 2017 as outcome variable. The full list of the specific performance indicators is presented in Table 1, along with the methodology for their calculation. Different studies treat some of these variables e.g. USE scores and share of international students differently, as either inputs or outputs. However, since the government includes all indicators from Table 1 into the formula as outcome variables and takes into account values of these indicators in allocating public funding, we adhere to its logic and consider them as output variables.

Universities in the sample are clearly different in terms of performance. Some of them show higher values of performance indicators as well as higher growth rates of these indicators. This results in unbalanced chances for universities with different absolute values of performance indicators exploited in PBF formula, as well as for other implicit quality characteristics of universities to be treated (i.e. to get extra public funding). We overcome the potential bias of the estimations by controlling for such individual characteristics of universities which might be associated with the variations of the outcomes. Specifically, besides performance indicators in pre-treatment year (2014) – which captures some unobserved heterogeneity affecting universities' resources before the policy – we also control for the number of FTE students and the total income of a university. These two variables represent specific dimensions of the universities' activities (size and overall available resources) which might be potentially correlated with the level of performance and its dynamics over time. Controlling for these factors allows avoiding to wrongly attribute some changes in performance to the effect of the policy.

Assumptions about heterogeneity of the policy effect go even further. We hypothesize that universities with different characteristics may be affected differently. Specifically, universities with different shares of PBF in total income (i.e. a different level of dependence on the government) may experience different treatment intensity. We also assume that universities which are actively involved into governmental programs[7] and consequently obtain extra special-purpose funding from the government, may be affected differently than other universities which do not participate in such programs. Thus, in the empirical analysis we control for the status of a university. *Leading* status means that university is either Federal university, National Research university or a university that participate in 5-100 Project. In the other case, the status is labelled and regarded as *regional* university.

Insert [Table 1] around here

[7] Federal Universities (10 universities), National Research Universities standing for advanced research (29 universities), Project 5-100 (2012) – Russian excellence initiative (21 universities the vast majority of which are from among Federal and National Research Universities).

## 6. Results from the empirical analysis

*6.1. Identifying winners and losers – descriptive, preliminary evidence*

Descriptive statistics of the outcome variables and covariates employed in the semiparametric difference-in-differences estimation are presented in the Table 2, which provides a comparison between the mean values of the treatment and control groups. The last column reports the difference between these means, along with t-tests for unequal variances.

The share of universities identified as *winners* accounts for 47% of the entire sample. Descriptively, it is possible to observe how the winning universities consistently report higher absolute values of performance indicators (on average) compared to the control group. Specifically, the winning universities accumulate better enrollees, generate more Web of Science and Scopus publications and obtain larger funding flows mostly from research activities than their counterparts (almost twice as much considering total R&D income and total income and more than double considering the extra-budgetary R&D income compared to the control group). The average number of FTE students was approximately the same in 2014, but after the intervention the winning universities started to increase their student body with higher growth rates. The only performance indicator equal for all universities is the average monthly salary ratio, due to the implementation of the Presidential Decree #599 which implies the average monthly salary ratio to account for 200 percent of the average regional salary by 2018. In this perspective, the salary ratio can be hardly considered a real performance indicator, and must be interpreted much more like a measure of available inputs.

Despite the fact that the winners demonstrate higher values for the performance indicators employed in the formula, the changes in performance between 2014 and 2017 generally do not differ between the treatment and control universities. This evidence points at considering the differences in the absolute performance like a structural difference before the implementation of the policy, which in turn is not clearly associated with radical change in performance. The only exception are the changes in (i) the number of WoS and Scopus publications per faculty staff capita and (ii) total income per faculty staff capita. For these two indicators, it seems that the policy can have exerted some kind of effect in changing the performance trajectory for the "treated" (winning) universities.

There is also a crucial distinction between the treatment and control groups when considering the educational programs. The winning universities have higher shares of education programs majoring in engineering, technical sciences, mathematics and natural sciences, while the control universities (no trend universities) have more agricultural and pedagogical programs. This distinction takes place because of standard cost differences between fields of study. Engineering and technical educational programs are associated with a more sophisticated material and technical base and require complex laboratory equipment unlike pedagogical programs.

Insert [Table 2] around here

*6.2. Trends in outcome variables*

The Figure 3 graphically reports the performance indicators used in the formula and compares the treatment and the control group averages over time. 7 out of 9 indicators show parallel trends before treatment (dotted lines). Exceptions to these parallel trends are the (i) R&D income from extra-budgetary sources per capita of academic staff and (ii) the total R&D income per capita of academic staff. The extra-budgetary R&D income trend for the treatment group is negative throughout the whole period, while the trend of the same indicator for the control group is slightly positive and fluctuating. The total R&D income of the treatment group decreased in 2015 compared to 2014, but after that trend direction changed and in 2017 the value of indicator was at the level of 2014. The descriptive analysis seems indicating the absence of any clear effect of the PBF policy, but a rigorous evaluation of such effect is reported in the next paragraph, where a proper econometric approach is implemented as indicated in the section §5.2.

Insert [Figure 3] around here

*6.3. The impact of the policy on university performance*

The Table 3 reports the estimates for the effect of being a "winner" after the introduction of the formula on performance indicators of universities under MoES authority. We run different models to check the sensitivity of the results to alternative specifications. All models control for the absolute values of performance indicators in 2014. Models (1) and (2) are estimated using the whole sample while models (3) and (4) are estimated based on a subsample of regional universities (Moscow and Saint-Petersburg universities are excluded). Models (1) and (3) report the estimates of the average treatment effect on the treated (ATT). Models (2) and (4) shows how the average treatment effect varies with share of PBF in the total funding of a university, the status of a university (leading = 1 or regional = 0) and the location of a university (Moscow or Saint-Petersburg = 1, otherwise = 0). In addition, Models (3) and (4) compare the average treatment effect between leading and regional universities.

Starting with the simplest model (1), extra funds resulting from the PBF introduction have positive effect on 6 out of 9 performance indicators: average USE scores (both publicly and privately funded), number of WoS and Scopus publications per faculty staff, share of foreign students and total income per faculty staff. Specifically, the policy's effect appears to result in increased average USE scores by 0.92 points for publicly funded places and by 1.63 points for places funded by tuition fees in 2017. Universities start paying more attention to the abilities of their enrollees with the aim of attracting more public funds through the formula. When taking heterogeneity into account, the effect of extra funding on average USE scores decreases with increase in share of PBF in the total income of a university – see the model (2). Universities located in Moscow and Saint-Petersburg experience a higher effect of extra funding on average USE scores in comparison to universities in other regions. Leading status of a university also brings a few more points in performance compared to regional universities. However, this effect is observed only for the average USE scores funded by tuition fees. The effect is no more statistically significant in models (3) and (4), which are estimated on a subsample of non-leading universities.

Getting extra funds also leads to an increase in the share of foreign students by almost 1% and number of WoS and Scopus publications by 16 publications per academic staff. There

is an explanation for the potential channel of the effect on the share of foreign students. Indeed, it might be the case that once a university gets extra funds it started to invest more in its reputation, for example developing academic mobility programs, establishing contacts with foreign universities and professors and attracting international students. For the impact of the policy on the number of publications there are three main possible explanations. The first is that some papers would have been on track before the policy was implemented – so attributing this effect to the policy would be misleading. The second is that in order to significantly increase number of publications within a year, universities start publishing more in lower quality journals, which guarantee faster acceptance (again, the effect would not be in line with the reform's purpose). Therefore, the third potential explanation is that universities were able to leverage resources towards higher research productivity, for example with incentives for tenured staff or with employing international productive scholars.

Therefore, another major finding is that when looking beyond the baseline results from model (1), and proceeding to more sophisticated specification models (2), (3) and (4) it can be observed that the policy effect is statistically significant only for leading universities and for those located in Moscow and St Petersburg regions. Indeed, the effect of the policy on the subsample of regional universities is not statistically significant. Such heterogeneity corroborates the idea that the policy can be effective only in the presence of specific characteristics of the treated universities, something that is associated with specific policy implications (discussed in the final section §7).

Insert [Table 3] around here

## 7. Discussion and concluding remarks

The results show that the introduction of PBF has a positive and statistically significant effect on almost all performance indicators that are included in the funding formula. However, controlling for the status of a university and its location shows that these characteristics are somehow responsible for this effect, meaning that the policy could have had a significant effect only in a heterogenous way, concentrated on leading universities and those located in Moscow and St Petersburg areas. The main short-run effect of the policy that is statistically significant after controlling for HEIs characteristics is on the average national exam scores. From a policy perspective, this result must be interpreted as the PBF policy gives clear incentives to universities to be more selective and enrolling high-ability students. Moreover, only universities with the certain features (leading status and location in the two main features) were able to implement these actions that led to an improvement of performance (i.e. selectivity).

Overall, the reform design stimulated a competitive environment and additional incentives for universities to improve their performance indicators, exactly because the amount of public funding was tied to performance indicators (see the theoretical discussion in section §4). However, the mechanism behind this effect may lead to negative side effects as well. Particularly, the redistribution of public funding across universities may have led to a further polarization of higher education system in terms of performance level, a consequence that can be not so desired by policy makers. Universities with higher performance obtain more governmental resources and thus more opportunities to convert them into still higher outputs.

Low-performing universities, on the contrary, receive less resources and may have no chance to invest in their development and improve performance in the future.

It is also interesting to discuss the lack of effect of the policy on performance for some universities. There are several possible explanations for the fact that non-leading universities fail to successfully convert extra funding into performance improvement. Firstly, in addition to the formula, universities in Russia have other governmental requirements to satisfy. For example, in 2012 the Presidential Decree #599 has been issued and it implied that ratio of the university academic staff average monthly salary of to the regional average monthly salary have to account for 200 percent by 2018. Another governmental Decree #234 established student-faculty ratio to be 12:1. Overall, such multidimensional regulations and constraints make university management difficult in terms of maximizing performance and/or to respond to the specific incentive designs.

Another central finding is that the treatment effect on performance (i.e. exam scores) decreases with an increase of the share of PBF in university budgets. A likely explanation is that the share of non-public funding (i.e. the ability of a university to attract external funding) can be considered as a proxy for the quality of university management. On average, the share of non-public funding in leading Russian universities is 2 or 3 times higher than the average across all public universities. Additional public money given to universities with high-quality management (universities with a high share of resources from non-public sources) may lead to a greater increase in output because of the more efficient use of these resources.

This study has some limitations, that pave the way for future research. First, the organizational changes to react to the introduction of PBF, require time (Manning, 2012). This is especially true when considering the potential effects on research productivity growth. Our analysis is limited to short-run effects, as the reform was implemented only in 2015. New analyses during the next years will be necessary to assess the PBF effects in the medium-long run. Second, we do not consider private universities and HEIs not under the MoES authority, and thus our results cannot be generalized for the entire Russian higher education system. Lastly, another intrinsic limitation of the study occurs due to the complex design of the reform – more specifically, its gradual implementation. We consider the treatment (additional funding) to occur only after the universities in our sample started to be financed according to the new scheme completely, so can be that some pre-existing differences affect the results in the meantime the reform is implemented completely. This attribution challenge, however, has successfully faced in our empirical analysis by demonstrating that the assumption of pre-reform parallel trends between the comparison and the treatment group actually holds.

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Figure 1. A graphical representation of the theoretical framework - main stages of contract implementation between the regulator (Ministry) and the regulated universities

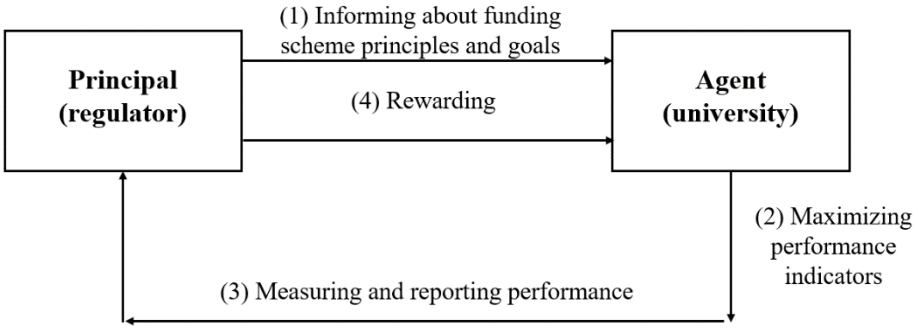
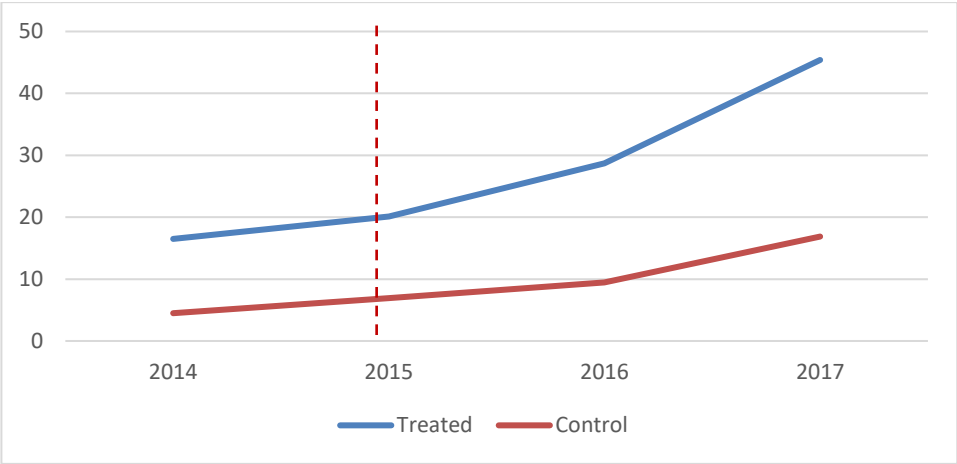



Figure 2. Trend of the number of publications in journals indexed by Web of Science per 100 units of academic staff for treated and untreated universities before and after treatment




Note. Authors' elaborations on data provided by the Monitor of Higher Education Performance, Ministry of Education

Figure 3. Trends of performance indicators (used in the formula) for the treatment and control universities before and after treatment

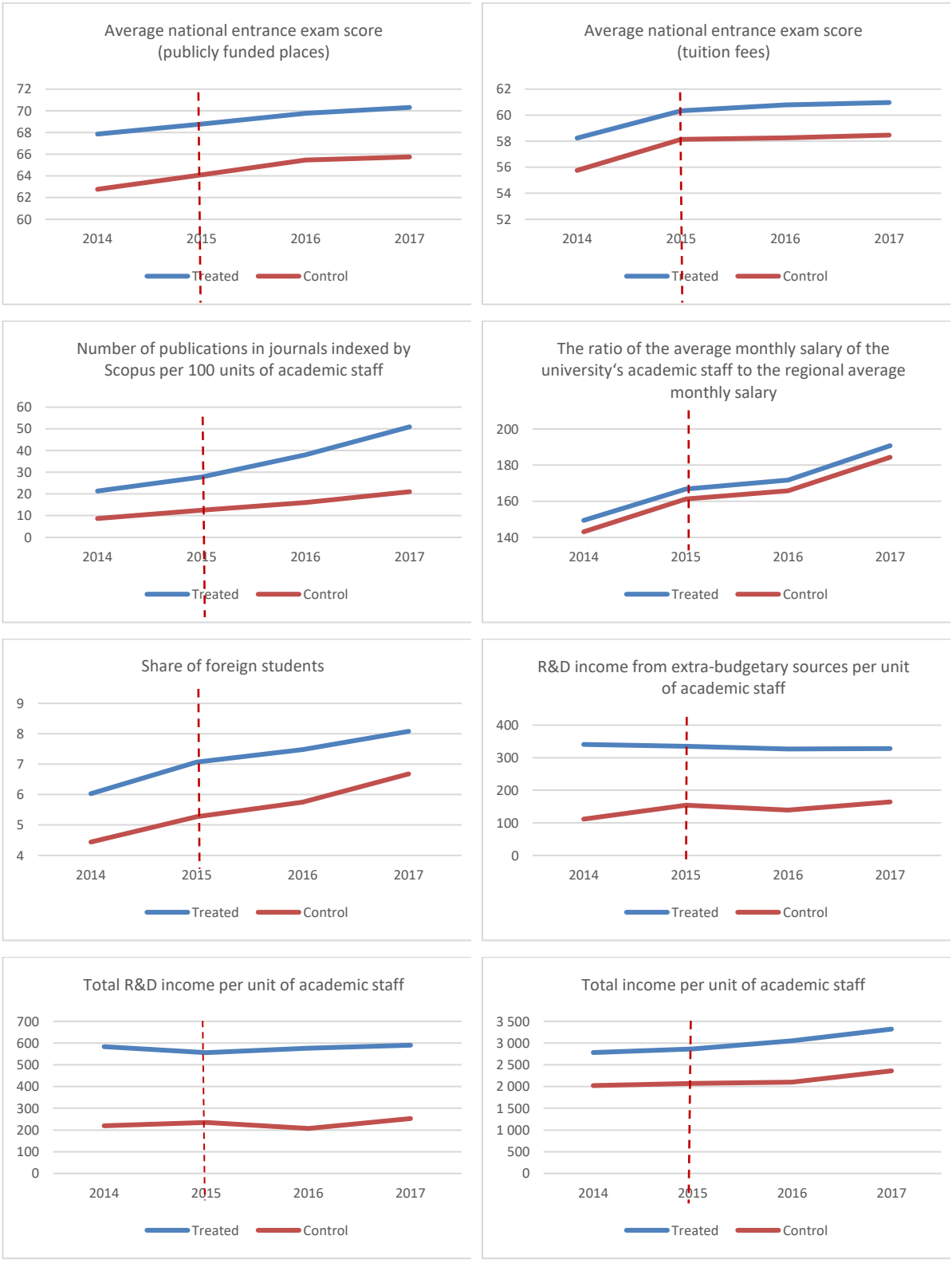


Table 1. Performance indicators employed in formula-based funding in Russian HE and the methodology for their calculation

| Performance indicators | Employment of the indicators in the formula defining: | | Methodology of calculating |
|---|---|---|---|
| | the number of places | standard cost per place | |
| Average national entrance exam score (publicly funded places) | + (Separately over the whole university and over particular specialties) | + (Separately for publicly funded places and places funded by tuition fees) | The ratio of the sum of the products of the number of full-time students enrolled on a state funding basis and their individual average national entrance exam scores to the total number of full-time state funded enrollees<br>Note: 1) except targeted admission 2) national entrance exam score of students with special right to be enrolled without entrance examinations (for example, winners of Olympiads) equals 100 (highest score) |
| Average national entrance exam score (tuition fees) | + (Separately over the whole university and over particular specialties) | + (Separately for publicly funded places and places funded by tuition fees) | The ratio of the sum of the products of the number of full-time students enrolled on a tuition fee basis and their individual average national entrance exam scores to the total number of full-rime privately funded enrollees<br>Note: except targeted admission |
| Number of publications in journals indexed by Web of Science per 100 units of academic staff | + | + | The ratio of the number of publications of the university published in the reporting year in journals indexed by Web of Science to the total number of faculty staff multiplied by 100 |
| Number of publications in journals indexed by Scopus per 100 units of academic staff | – | + | The ratio of the number of publications of the university published in the reporting year in journals indexed by Scopus to the total number of faculty staff multiplied by 100 |
| Total R&D income per 1 unit of academic staff | + | – | The ratio of the total amount of funds received from research and development activities in reporting year to the total number of faculty staff |
| R&D income from extra-budgetary sources per 1 unit of academic staff | – | + | The ratio of the amount of extra-budgetary funds received from research and development activities in reporting year to the total number of faculty staff |
| Share of foreign students | + | – | The ratio of the number of foreign students in full-time equivalent to the total number of students in full-time equivalent |
| Total income per 1 unit of academic staff | + | – | The ratio of the total amount of university funds in reporting year to the total number of faculty staff |
| The ratio of the average monthly salary of the university ‘s academic staff to the regional average monthly salary | + | – | The ratio of the university wage fund of faculty staff to the average number of faculty staff divided by 12 and by average salary in the regional economy.<br>Note: except civil contracts (independent contractor agreement) |

Table 2. Characteristics of the universities under MoES authority, treatment vs control group

| VARIABLES | Entire sample | Treated | Non-treated | Diff, |
|---|---|---|---|---|
| Share of treated | 0.47 | | | |
| | [0.5] | | | |
| Outcome variables: | | | | |
| *Change between 2017 and 2014 in:* | | | | |
| Average USE scores (publicly funded places) | 2.73 | 2.45 | 2.98 | -0.53 |
| | [3.43] | [3.25] | [3.59] | (0.57) |
| Average USE scores (tuition fees) | 2.72 | 2.73 | 2.71 | 0.02 |
| | [4.43] | [4.22] | [4.64] | (0.74) |
| WoS publications per academic staff | 20.18 | 28.91 | 12.38 | 16.53*** |
| | [34.06] | [46.59] | [11.98] | (5.86) |
| Scopus publications per academic staff | 20.48 | 29.57 | 12.35 | 17.22*** |
| | [33.97] | [45.89] | [13.35] | (5.81) |
| Share of foreign students | 2.15 | 2.06 | 2.24 | -0.18 |
| | [3.47] | [3.68] | [3.3] | (0.59) |
| Extra-budgetary R&D incomes per academic staff | 22.07 | -12.36 | 52.83 | -65.19* |
| | [240.23] | [303.47] | [160.59] | (41.45) |
| Total R&D incomes per academic staff | 20.32 | 6.24 | 32.9 | -26.66 |
| | [313.53] | [385.11] | [233.86] | (54.25) |
| Total incomes per academic staff | 433.67 | 540 | 338.68 | 201.32* |
| | [605.64] | [721] | [464.64] | (103.14) |
| Salary ratio | 41.28 | 41.32 | 41.25 | 0.07 |
| | [24.85] | [29.16] | [20.45] | (4.27) |
| Covariates: | | | | |
| *Share of education programs with major in:* | | | | |
| Mathematics and natural sciences | 0.07 | 0.09 | 0.05 | 0.04** |
| | [0.11] | [0.14] | [0.06] | (0.02) |
| Engineering and technical sciences | 0.42 | 0.48 | 0.37 | 0.11** |
| | [0.33] | [0.31] | [0.34] | (0.06) |
| Medicine | 0.01 | 0.01 | 0.02 | -0.01 |
| | [0.05] | [0.04] | [0.06] | (0.01) |
| Agricultural sciences | 0.01 | 0.01 | 0.02 | -0.01 |
| | [0.04] | [0.01] | [0.06] | (0.01) |
| Social sciences and Humanities | 0.3 | 0.34 | 0.27 | 0.07** |
| | [0.2] | [0.21] | [0.19] | (0.03) |
| Pedagogical sciences | 0.16 | 0.05 | 0.26 | -0.21*** |
| | [0.28] | [0.12] | [0.34] | (.04) |
| Art and cultural sciences | 0.02 | 0.02 | 0.01 | 0.01 |
| | [0.04] | [0.05] | [0.04] | (0.01) |
| *Performance indicators in absolute values in 2014:* | | | | |
| Number of students in full-time equivalent | 6,500.69 | 7,304.30 | 5,782.80 | 1,521.50** |
| | [3,915.22] | [4,229.64] | [3,484.97] | (654.94) |
| Total income | 1,756,425.08 | 2,314,888.78 | 1,257,530.84 | 1,057,357.94*** |
| | [1,881,677.11] | [2,158,837.46] | [1,433,567.05] | (311,387.9) |
| Average USE scores (publicly funded places) | 65.17 | 67.86 | 62.77 | 5.09*** |
| | [6.95] | [7.69] | [5.18] | (1.11) |
| Average USE scores (tuition fees) | 56.93 | 58.24 | 55.76 | 2.48*** |
| | [5.34] | [5.72] | [4.73] | (0.89) |
| WoS publications per academic staff | 10.15 | 16.49 | 4.49 | 12*** |
| | [20.24] | [27.96] | [3.8] | (3.44) |

| | | | | |
|---|---|---|---|---|
| Scopus publications per academic staff | 14.66 | 21.35 | 8.69 | 12.66*** |
| | [20.97] | [28.23] | [7.13] | (3.55) |
| Share of foreign students | 5.19 | 6.03 | 4.44 | 1.59* |
| | [4.81] | [4.94] | [4.59] | (0.80) |
| Extra-budgetary R&D incomes per academic staff | 219.65 | 340.78 | 111.45 | 229.33*** |
| | [300.06] | [382.88] | [125.15] | (48.96) |
| Total R&D incomes per academic staff | 391.67 | 584.14 | 219.72 | 364.42*** |
| | [538.84] | [678.59] | [281.1] | (89.03) |
| Total incomes per academic staff | 2,381.15 | 2,782.71 | 2,022.42 | 760.29*** |
| | [1,121.27] | [1,321.8] | [748.92] | (183.18) |
| Salary ratio | 146.07 | 149.41 | 143.09 | 6.32 |
| | [30.09] | [37.69] | [20.95] | (5.20) |
| *Additional indicators and dummies* | | | | |
| PBF share | 0.36 | 0.32 | 0.39 | -0.07*** |
| | [0.09] | [0.09] | [0.09] | (0.01) |
| Leading status of university | 0.16 | 0.27 | 0.07 | 0.2*** |
| | [0.37] | [0.45] | [0.25] | (0.06) |
| Moscow or Saint-Petersburg | 0.23 | 0.42 | 0.07 | 0.35*** |
| | [0.42] | [0.5] | [0.25] | (0.07) |
| Number of universities | 142 | 67 | 75 | 142 |

Note: Standard deviations are in brackets and standard errors are in parentheses and significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table 3. The causal impact of the policy: the effect of being a "winner" on performance indicators of universities under MoES authority

| Outcome variable | | (1) | (2) | (3) | (4) |
|---|---|---|---|---|---|
| Average USE scores (publicly funded places) | ATT | 0.923* | 4.534* | -0.0621 | 4.724* |
| | | (0.536) | (2.373) | (0.634) | (2.828) |
| | PBF share | | -16.12** | | -16.63** |
| | | | (6.369) | | (7.484) |
| | Leading status | | 1.406 | | |
| | | | (1.157) | | |
| | Moscow or Saint-Petersburg | | 3.028*** | | 2.639** |
| | | | (0.913) | | (1.136) |
| Average USE scores (tuition fees) | ATT | 1.632** | 4.637 | 0.304 | 4.337 |
| | | (0.705) | (3.059) | (0.880) | (3.691) |
| | PBF share | | -15.22* | | -14.18 |
| | | | (8.982) | | (10.83) |
| | Leading status | | 3.112** | | |
| | | | (1.460) | | |
| | Moscow or Saint-Petersburg | | 2.680* | | 2.379 |
| | | | (1.409) | | (1.804) |
| Share of foreign students | ATT | 0.983* | 1.399 | 0.521 | 1.258 |
| | | (0.516) | (2.365) | (0.613) | (2.919) |
| | PBF share | | -1.692 | | -0.0534 |
| | | | (6.534) | | (7.982) |
| | Leading status | | 1.777* | | |
| | | | (1.076) | | |
| | Moscow or Saint-Petersburg | | -0.817 | | -1.957 |
| | | | (1.028) | | (1.270) |
| WoS publications per academic staff | ATT | 15.54** | 20.05 | -1.776 | -6.021 |
| | | (7.110) | (24.11) | (5.855) | (24.86) |
| | PBF share | | -97.73 | | -10.43 |
| | | | (63.14) | | (63.62) |
| | Leading status | | 51.90*** | | |
| | | | (14.90) | | |
| | Moscow or Saint-Petersburg | | 32.05*** | | 21.38* |
| | | | (11.24) | | (12.60) |
| Scopus publications per academic staff | ATT | 16.98** | 17.25 | -0.253 | -13.38 |
| | | (6.737) | (23.30) | (5.037) | (23.95) |
| | PBF share | | -82.6 | | 18.68 |
| | | | (64.81) | | (65.86) |
| | Leading status | | 53.64*** | | |
| | | | (14.83) | | |
| | Moscow or Saint-Petersburg | | 29.27** | | 18.14 |
| | | | (12.00) | | (12.53) |
| Salary ratio | ATT | 10.81 | -0.847 | 3.604 | 0.448 |
| | | (6.633) | (35.71) | (7.230) | (40.32) |
| | PBF share | | -29.18 | | -20.08 |
| | | | (98.08) | | (113.6) |
| | Leading status | | 18.3 | | |
| | | | (16.08) | | |
| | Moscow or Saint-Petersburg | | 38.89*** | | 27.51 |
| | | | (13.82) | | (19.05) |
| Extra-budgetary R&D income per academic staff | ATT | -43.31 | -127.9 | -89.06** | -113.4 |
| | | (39.57) | (162.9) | (40.06) | (164.5) |
| | PBF share | | 192.7 | | 352.1 |
| | | | (431.3) | | (438.3) |
| | Leading status | | 209.7* | | |

| | | | | | |
|---|---|---|---|---|---|
| | | | (108.2) | | |
| | Moscow or Saint-Petersburg | | -82.59 | | -265.5*** |
| | | | (83.62) | | (86.02) |
| Total R&D income per academic staff | ATT | -26.34 | -151.4 | -81.77 | -135.1 |
| | | (53.02) | (194.9) | (56.50) | (206.0) |
| | PBF share | | 176.4 | | 317.5 |
| | | | (508.8) | | (537.4) |
| | Leading status | | 214.3 | | |
| | | | (138.8) | | |
| | Moscow or Saint-Petersburg | | 23.82 | | -154.1 |
| | | | (111.5) | | (123.1) |
| Total income per academic staff | ATT | 275.2** | 38.28 | 224.0* | 236.4 |
| | | (120.1) | (607.4) | (124.2) | (612.2) |
| | PBF share | | 6.16 | | -136.6 |
| | | | (1 652.0) | | (1 734.0) |
| | Leading status | | 74.6 | | |
| | | | (335.5) | | |
| | Moscow or Saint-Petersburg | | 514.2* | | 95.12 |
| | | | (282.2) | | (319.2) |
| Number of universities | | 142 | 142 | 119 | 119 |

Note: All effects are estimated using a logit specification to estimate the propensity score.
Standard errors in parentheses and significance levels are denoted as follows: *** p<0.01, ** p<0.05,* p<0.1

**Ekaterina Abalmasova**

Laboratory for University Development of Institute of Education, National Research University Higher School of Economics, Moscow – Russia, eabalmasova@hse.ru