An university efficiency evaluation with using its reputational component

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Abstract

We estimate efficiency scores for Russian universities based on data set of input and output criteria by using Data Envelopment Analysis. In addition, we use a reputation index as another indicator of a university's productivity. To construct it, 4000 contexts are analyzed and 13 reputation criteria are found. The threshold procedure is used to aggregate them into a reputation indicator. Factors which lead a university to be efficient are studied.

Keywords: Universities; Efficiency; Reputation; DEA; threshold procedure.

Introduction

Universities have an influence on a great number of modern society aspects such as quality of labour, human capital, etc. For universities management it is important to evaluate their efficiency because it is impossible to define the goals of a university and how to achieve them without understanding its weak and powerful features.

We apply Data Envelopment Analysis (DEA) in order to estimate efficiency of Russian universities. In addition we construct a separate ranking of universities based on their reputation. To do this we introduce 13 key reputation indices and use the threshold procedure to construct the reputation ranking.

A survey

Two methods are used for universities' efficiency evaluation — Data Envelopment Analysis and Stochastic Frontier Analysis (SFA). The former uses non-parametrical linear programming approach while the latter is associated with application of econometric techniques to efficiency evaluation problem.

However, DEA is used more frequently than SFA. Examples of articles which choose DEA as a main tool for evaluation are Athanassopoulos (2006), Johnes (2006), Beasley (1995) and Katharaki (2010). The following input/output indicators are mostly specified.

- General academic/nonacademic expenditure;
- Research income;
- Full time equivalent undergraduate/graduate/postgraduate;
- Entrants quality;
- Full time equivalent academic/nonacademic staff;
- Numbers of successful leavers.

In McMillan et al. (1997), Stevens (2005) and Glass et al. (1995) the SFA is used. The latter paper estimates cost efficiency, scale and scope economy of universities. Stevens (2005) estimates cost efficiency as well but uses different types of a cost function. Finally, McMillan et al. (2006) compare DEA and SFA efficiency scores. The authors conclude that there is no consistency between efficiency estimates obtained from different methods.

In Vasilyev (1997) and Granichina (2008) the problem of Russian universities' efficiency evaluation is studied. These authors, however, do not use mathematical models for efficiency evaluation. They offer some simple criteria of universities' activity such as the number of students and professors, expenditures, etc. Final efficiency score is a linear convolution of those criteria, however, an importance of those criteria is not evaluated. Thus, these articles provide only methodological recommendations about the selection of the criteria but empirical results are not presented.

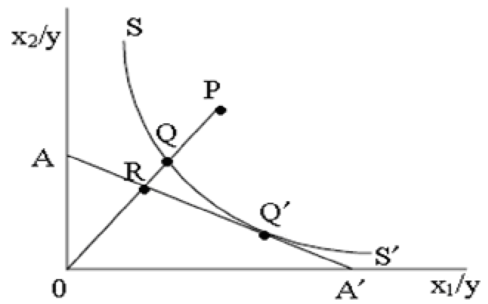
DEA methodology

We assess how effectively university's resources are placed. The assessment is relative with respect to other universities in a sample. The efficiency score is evaluated via efficiency frontier construction. Such frontier is a set of 100% efficient universities.

To construct efficiency frontier, we employ DEA (see Coelli, 2005 for details). Our sample consists of 29 universities.

The following example briefly presents how efficiency scores are found for universities based on the DEA (Figure 1). Let x_1 denote fixed assets (a number of computers) and x_2 — a labour (the number of professors). In this case efficiency frontier is a curve SS' which shows every possible combination of two recourses required for producing certain output amount. All universities which belong to that curve namely S, Q, Q', S', will be determined as technically efficient ones. Note that technical efficiency is a measure characterized by university's ability to minimize recourse's amount for achieving desirable output.

Figure 1. *Efficiency frontier*



We define efficiency of university P in the following way. It consumes higher amount of resourse than, for example, university Q. But university P can proportionally reduce the amount of computers and professors on quantity QP in order to become technically efficient. Now we are able to calculate technical efficiency by the following formula

$$TE_p = 1 - \frac{QP}{OP} = \frac{OQ}{OP}. \tag{1}$$

Assume now that the analyzed sample consists of I universities and they are characterized by N input and M output parameters (we provide the list of all parameters in the model below). The optimization problem is formulated as follows

$$\max_{u,v} \frac{< u, q_i >}{< v, x_i >}, \tag{2}$$

subject to

$$\begin{cases} \frac{< u, q_i >}{< v, x_i >} \leq 1, \forall i = 1,2, \dots, I; \\ u, v \geq 0, \end{cases} \tag{3}$$

where q_i is $M \times 1$ vector of output parameters for *i*-th university, x_i is $N \times 1$ vector of input parameters, u and v are weight vectors of appropriate dimension. The notation $< u, q_i >$ denotes a scalar product of vectors u and q_i. The result of solving the optimization problem (2)-(3) is the number $h_i = \max_{u,v} \frac{<u,q_i>}{<v,x_i>}$. The h_i represents the productivity (or, in other words, efficiency) measure of *i*-th university in a sample.

Using duality of linear programming problems and substitution $< v, x_i > = 1$ we can pass to the widely-spread form of DEA model

$$\min_{\lambda,\theta} \theta_i \tag{4}$$

subject to

$$\begin{cases} -q_i + Q\lambda \geq 0; \\ \theta x_i - X\lambda \geq 0; \\ \lambda \geq 0, \end{cases} \tag{5}$$

where X is $N \times I$ matrix of all input parameters, Q is $M \times I$ matrix of all output parameters, q_i is $M \times 1$ vector of output parameters for *i*-th university, x_i is $N \times 1$ vector of input parameters for *i*-th university, λ is $I \times 1$ vector of constants. The value of θ_i in (4) is the efficiency score for *i*-th university. Note that the linear programming problem (4)-(5) must be solved *I* times, once for each university in the sample.

The model (4) represents so-called DEA Constant Return to Scale (CRS) model, because there are no restrictions on vector λ. One can add one additional condition to (6)

$$\sum_{i=1}^{I} \lambda_i = 1. \tag{7}$$

Thereby, the model (4)-(5) together with (7) forms so-called DEA Variable Return to Scale (VRS) model.

One can also calculate scale economy of *i*-th university via efficiency scores obtained from VRS and CRS DEA models. Namely,

$$SE_i = \frac{\theta_{CRS}}{\theta_{VRS}}, \tag{8}$$

where SE_i is a scale economy for *i*-th university, θ_{CRS} and θ_{VRS} are CRS and VRS efficiency scores for *i*-th university respectively.

DEA data

The model uses the following input parameters as proxy variables for main productive factors (i.e., labour and fixed assets)

- I_1 — the ratio of budget funds to the number of students who do not pay a tuition fee (budget students);
- I_2 — the percentage of employees who have a degree of Doctor or Candidate of Science;
- I_3 — the quality of university entrants (a mean value of Universal State Exam (USE), which is mandatory for admission to any university).

As output parameters we use

- Q_1 — the ratio of non-budget income to the number of students paid for higher education;
- Q_2 — the score of scientific and publishing activity (NRU HSE provides the scheme of calculation this indicator at: http://www.hse.ru/org/hse/sc/interg).

Descriptive statistics for input and output parameters used for efficiency evaluation is given in Table 1.

Table 1. *Data descriptive statistics (2008, number of observations is 29)*

	I_1	I_2	I_3	Q_1	Q_2
Mean value	94,92	63,43	61,47	90,84	4,90
Variance	1038,10	36,18	25,85	931,04	14,78
St. deviation	32,21	6,01	5,08	30,51	3,84
Median	84,84	62,94	61,1	83,54	3,46
Min	53,71	55,76	54,2	43,19	1,47
Max	175,65	75,92	76,7	170,07	18,25
Sum	2752,80	1839,48	1782,8	2634,59	142,18

Correlation between input-output parameters of the model has not been observed.

Note that we use the mean value of USE as input parameter. This model shows quite consistent from experts' point of view results. Efficiency scores are distributed from 30% to 100%. We considered the quality of university entrants as output parameters, but under that assumption efficiency is distributed from 80% to 100% which is obviously not the case of Russian educational system.

Reputation index methodology

In order to calculate aggregated reputation index we use threshold procedure. This process consists of the following steps (Aleskerov et al., 2011). Let m be the number of *alternatives* (i.e., universities) and n be the number of *criteria* by which we evaluate the reputation. Note that the row information about university's reputation is represented by the frequency of university mentionings in each of 13 criteria. After that this frequency is converted into a grade which is an integer number a_{ij}, $1 \le a_{ij} \le \gamma$, where i is the number of university, j is the number of the criterion.

For each university u_i from the set of all alternatives one can define the vector $V_i = (I_1(u_i), \ldots, I_k(u_i))$, where $I_S(u_i)$ is the number of criteria which were evaluated in s scores. Now we can compare two universities u_i and u_l by the following rule: $u_i \succ u_l$ if $V_i(1) < V_l(1)$. If these entries are equal then we compare the next components of vectors V_i and V_l and so forth.

We choose 4 grade system of evaluation and it can be checked that having 13 criteria and 4 grades for each criterion all possible universities are ranked from 1 to 560, because 560 is the maximal number of ranks under this parameters. Namely, the number of ranks for n criteria and k grades is given by the formula:

$$N = \sum_{i=0}^{k-1} C_k^i \cdot C_{n-1}^{k-1-i}, \tag{9}$$

where C_k^i is the binomial coefficient and N is the final number of ranks.

Reputation data

The reputation index evaluation is based on the algorithms of automatic retrieval and analysis of data from the texts from mass-media sources. We use OntosMiner software to accomplish these algorithms. We investigate about 4000 contexts in which universities are mentioned. Based on the contexts analysis, we define the main types of events associated with university's activity. The 13 final criteria (categories or components) of reputation are presented in Table 2.

Table 2. *Summary on reputation data*

Reputation criterion	Tags	Scheme of mapping to 4 level system of grading			
		1	2	3	4
Educational process	School Olympiad, training courses, master's programs, received the status of University, a contest of projects, cooperation with the University	0-190	190-300	300-600	>600
Sport, culture and social activity	The competition, assistance to children's homes, people with disabilities and etc., creative competitions, festivals, exhibition, etc., social projects (AIDS, etc.)	0-40	40-215	215-400	>400
State structures	People associated with the University participates in politics, a joint project with the administration, implementation of the national project	0-40	40-120	120-340	>340
Employment	Day of career, a job fair, a company often takes on employment of graduates of the University, other information about the placement of graduates of the University	0-20	20-80	80-100	>100
Business structures	An employee or student of the University founded a company, owns the company, etc., holds a large position in the company, an employee or student of the University cooperates with the enterprises	0-5	5-31	31-65	>65
Science and innovation	The conference, Congress (participation and organization), grants, publication of a book, conduct studies, with the entire scientific activity, the creation of the scientific center	0-150	150-350	350-600	>600
Religion	The construction of the temple, the training of specialists in theology, conference on theology, etc, cooperation with the diocese	0-10	10-33	33-50	>50
Financial activity	The cost of education, the company gave money to the University, provided a grant, organized a scholarship, sources of financing of the University or its specific programs	0-5	5-70	70-180	>180

University's infrastructure	Dormitory, a stadium, a swimming pool, sports complex, building, temple, computers and equipment, and all other things related to the infrastructure	0-80	80-200	200-500	>500
Reputation	Comment of an expert, a statement, an employee or student of the University - the author of the article in the magazine, popular or scientific-popular, praise the University or its representative, awards, best student, best economist, etc	0-80	80-220	220-450	>450
Students	The student language club, friendship of the people among the students, the students' association, other information, related to the independent activity of students	0-10	10-100	100-250	>250
Alumni	The history of specific people-graduates of the University	0-30	30-70	70-150	>150
Scandals	Detained by police, any scandals associated with the University and its representatives take bribes	>530	450-530	300-450	0-300

The mentioning of a university in one of the first 12 categories is considered as an indicator of increasing its reputational score. The thirteenth category is scandals. They decrease the relevant university's final reputational score.

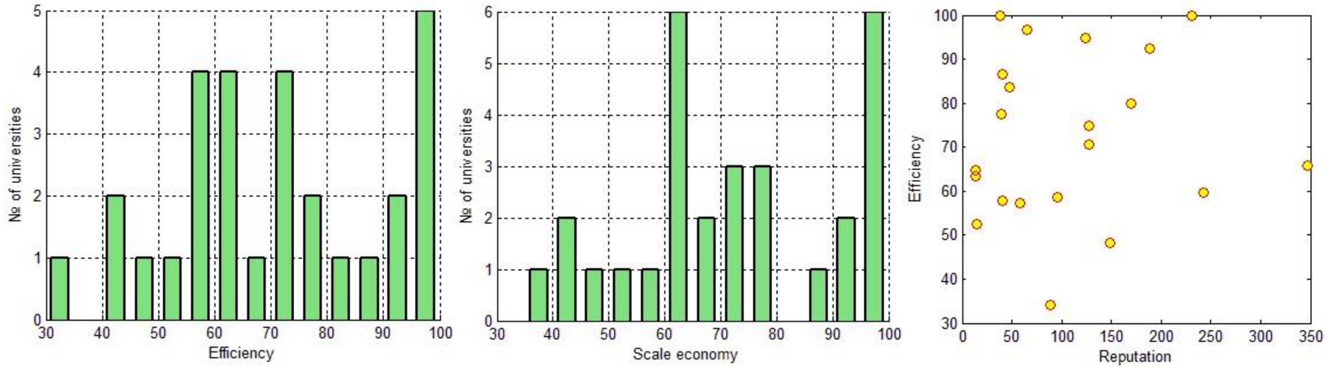
As though efficiency score is calculated for each university in the sample of 29 ones, mentionings of universities are found only for 22 of them.

Results

We calculated efficiency score for each university in the sample, using both CRS and VRS specifications of DEA. Besides we define peers (i.e., optimal values of input and output parameters) for inefficient universities. Also a reputation index was calculated for each university in the sample.

Figure 2 provides scatter plot and distribution of efficiency and scale economy. Note that below we present efficiency estimates which were calculated by DEA CRS model.

Figure 2. *Summary of results for CRS specification*



The VRS efficiency score is in average higher than CRS one. That is a good indicator of results' consistency because the least θ_i defined by the problem (4), i.e., CRS efficiency score, is always less than or equal to the least θ_i defined by the problem (4) together with the restriction (7), i.e., VRS efficiency score. It is true, because feasible set of the latter problem (4)-(7) is contained within feasible set of the former problem (4).

Conclusions

The results are obtained for the small sample of universities but nevertheless they are interesting for expert analysis. For example, there is a significant correlation between publication activity factor and a mean USE value. On the contrary, there is a weak correlation between a percentage of scientific degrees and publication activity. Therefore universities which have high quality entrances also have active professors.

The proposed approach to efficiency evaluation is a transparent procedure. The aggregate estimate for each university can be unrolled in a set of components which are specific for each university in the sample.

We plan to proceed with the large sets of universities (divided by geographical location, historical and strategic type, the economic model of behavior) and reveal the factors which lead a university to be efficient.

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