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# EVALUATION OF HIGHER EDUCATION INSTITUTIONS USING DATA ENVELOPMENT ANALYSIS

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**Abstract**
*We focus on performance assessment of higher education institutions in their core areas, i.e. education and research and development. There exist various approaches to the evaluation of higher education institutions performance which are used for the allocation of subsidies from public sources, for the assessment of higher education institutions by official accreditation authorities or for their ranking provided by independent agencies. For these purposes different indicators and methods of their aggregation are used. In our paper we apply an alternative approach. We use publicly available performance indicators and aggregate them using relative efficiency scores calculated by Data Envelopment Analysis models. This approach is illustrated on the case of business and management faculties in Slovakia.*

***Key words:*** *higher education institution, performance in education, performance in research and development, aggregation of performance indicators, Data Envelopment Analysis (DEA).*

## 1. Introduction

The core business of higher education institutions (HEIs) consists in education and research and development (R&D). Efficient performance is important for HEIs due to budgeting and accreditation purposes. The assessment methodology of HEIs' performance varies, depending on the evaluating authority (Ministry of Education, accreditation body, independent ranking institutions).

Benchmarking is one way of evaluation of the performanceand comparison the institutions among themselves. Benchmarking is interestingnot only for HEIs themselves, but it may bring important information to the public, e.g. attract more potential studentstosuccessfulHEIs.

The process of assessment consists of severalsteps. The evaluator must chooseproper indicators and appropriate methodology for their normalization, weighting, and aggregation. Moreover, the benchmarking results should be clearly and relativelyeasilyinterpreted.

Numerous rankings of HEIs are regularly published at international and national levels. In Slovakia, the most popular is the ranking annually provided by Academic Rating and Ranking Agency (ARRA). This ranking includes all faculties of Slovak public HEIs divided to categories by their study and research fields, but also some private HEIs that agree to provide ARRA with the necessary data on their performance. The ARRA ranking is widely accepted and discussed by the academics as well as by the public. Its advantage consists in elaborate system ofuniversal indicatorscovering the main outputs of HEIs and a simple wayof their aggregationinto final benchmarking score that allows a clear interpretation of the results. But this approach allows a full substitution of individual indicators within specified performance areas, and does not consider the specific mission of individual HEIs, for more details see (Barta et al., 2013).

In this paper we focus on setting the weights for selected indicators so that the specificities of individual HEIs might be taken into account. We apply the DEA methodology on the set of indicators proposed by ARRA in order to design an alternative tool for setting the weights and calculating the scores for ranking. The advantage of DEA consists in the fact that instead of uniform weights for all HEIs it allows us to find the best individual weights for each HEI, and thus emphasize its strong points. However, since all the considered indicators are relevant, we prefer DEA models that admit the weights to range only within specified constraints.

We shall illustrate the designed approach on the assessment of Slovak faculties specialized in business and management sciences.

## 2. Data and Methodology

In order to evaluate the HEIs performance, we use the indicators introduced by ARRA. However, we apply alternative methodsfor computing performance scoresfor individual criteria, which covered the ARRA indicators. We also change the way of aggregation of these partial scores into final score for comparing and ranking considered HEIs.

Table 1introducesthecriteriaused by ARRA to evaluate the HEIs performance in their two core areas, education and R&D.

Table 1. Assessment criteria

| Area | Criteria | Indicators |
|---|---|---|
| Education | Teachers and students | SV1–SV4 |
| | Attractiveness of study | SV6–SV10 |
| R&D activities | Publishing activities | VV1–VV2a |
| | PhD studies | VV4a–VV6 |
| | Research grants | VV7–VV9 |

Source:http://www.arra.sk/ranking-2013

Assessment criteria are aggregated from the partial indicators characterized in Table 2.According to ARRA, assessment for each criterion is calculated in points as an average of values assigned for the corresponding indicators. The number of HEI's points in particular indicator is calculated so that the HEI with the highest value of the indicator is assigned 100 points and the others are assigned the numbers of points proportionally to the top value. The total HEI's score is then calculated as an average of points assigned for individual criteria. This assessment focuses on the intensity of performance in individual indicators, not on the absolute value of performance, i.e. the size of the HEI is taken into account. Also, it is based on relative scale using the performance of the best HEI in the given group and respective year as the benchmark.

In order to rank the HEIs we need to express their performance in unique numbers. In contrast with ARRA, we use DEA to compute the scores for individual criteria and aggregate them to final scores.

To calculate partial scores for individual criteria, we apply the Slacks-Based Measure model (SBM) which reflects nonzero slacks in inputs and outputs when they are present. Since the criteria reflect the intensity of the performance, we may suppose input values equal to 1 for all HEIs. Hence, we use an output-oriented SBM model with constant returns to scale (SBM-O-C).

Table 2. List of indicators

| Indicator | Description |
|---|---|
| sv1 | Total number of full-time and part-time students per teacher (in year 2012)[1] |
| sv2 | Total number of full-time and part-time students per professor andcollege lecturer(in 2012)[2] |
| sv3 | Percentageof professors, college lecturers and teachers with PhD on the total number of teachers (in 2012) |
| sv4 | Percentage of professors and college lecturers on the total number of teachers(in 2012) |
| sv6 | Ratio of the actual number of applications received to the planned number of admitted students (in 2012) |
| sv7 | Ratio of the number of registered students to the number of admitted students (in 2012) |
| sv8 | Percentage of foreign students on the total number of full-time students (in 2012) |
| sv9 | Percentage of full-time students outgoing within Erazmus or SAIA programs on the total number of full-time students (in academicyear 2010/11) |
| sv10 | Percentage of unemployedgraduates on the total number of graduates (average for years 2010-12) |
| vv1 | Number of publications registered in WoK[3] per employee[4] (in years 2003-2012) |
| vv2 | Number of citations of publications in WoK[3] per employee[4] (in years 2003-2012) |
| vv2a | Average number of citations per publication registered in WoK[3] (in years 2003-2012) |
| vv4a | Percentage on the average number of PhD graduates in 2010-12 to the average number of all 1st -year PhD students in 2007-09 |
| vv4b | Number of publications in WoK[3]per PhD student (in years 2010-12) |
| vv4c | Number of citations in WoK[3]per PhD student(in years 2010-12) |
| vv5 | Ratio of the average number of full-time PhD graduates to the number of professors and college lecturers in years 2010-12 |
| vv6 | Percentage of full-time PhD students on the Bachelor and Master full-time students (in 2012) |
| vv7 | Amount of research grants obtained from Slovak grant agencies per employee[4] in € (in 2012) |
| vv9 | Amount of research grants obtained from foreign sources per employee[4] in € (in 2012) |

Source: http://www.arra.sk/ranking-2013

[1] In our methodology we use the number of teachers per 100 students instead of sv1
[2] In our methodology we use the number of professors and college lecturers per 100 students instead of sv2
[3] Web of Knowledge
[4] Academic staff

The final score for HEI will be calculated based on the partial scores for individual criteria using output-oriented Assurance Region model (AR-O-C) under the constant returns to scale (CRTS). We again suppose a normalized unit input, and the partial scores for individual criteria as outputs for all HEIs. In the contrast to SBM, AR model allows us to defined weight restrictions for considered criteria.

The following figure displays the methodology for assessment of HEIs. It indicates the DEA model used for computing partial scores for all criteria as well as the final score, the notification ofindividual partial scores and the weights of respective criteria fortheir aggregation to final score.

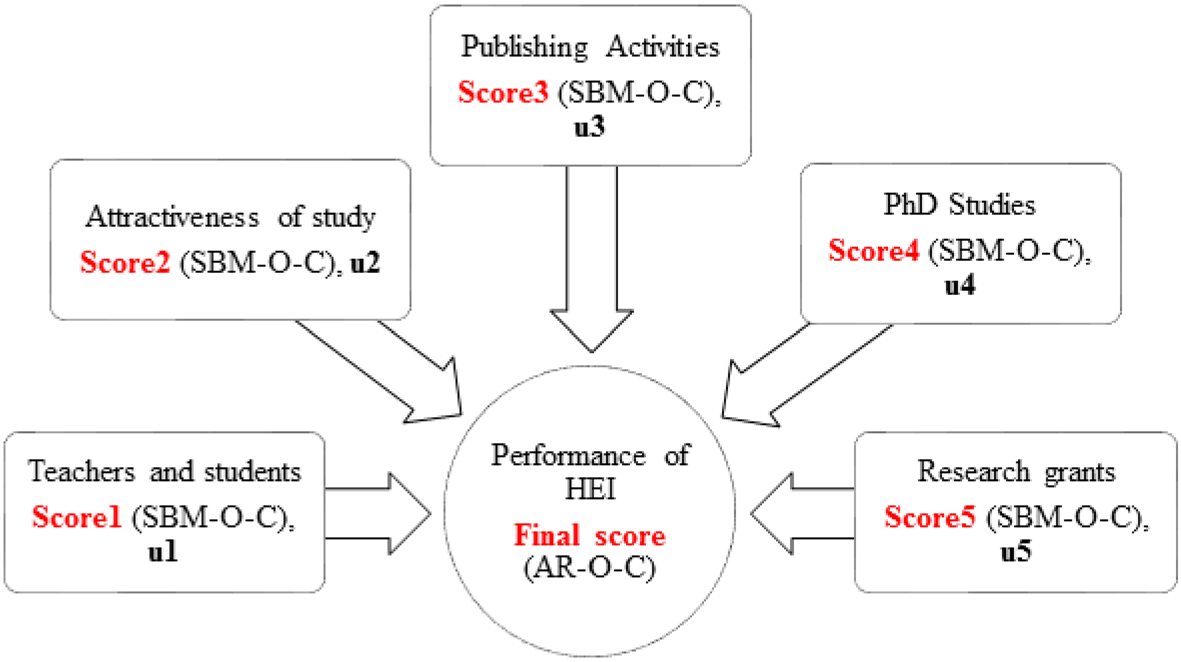


Figure 1. Scheme of calculating and aggregating final score
Source: authors

The AR model allows us to set the weights constraintsto limit the region of weights for individual outputs, for details see (Cooper et al., 2007). Thus we can distinguish the importance of considered criteria with the relative magnitude of their weights. Moreover, this model is able to differentiate the HEIs efficiency if their number is relatively low to the total number of considered inputs and outputs.

In order to apply AR model we need to restrict the ratios of the weights (u1, …, u5) of considered outputs with appropriate lower and upper bounds.

We consider two alternatives for setting the weight restrictions (AR model 1-2). First, we supposed that all considered criteria (our outputs) are of the same importance. Second, following the criteria for the allocation of subsidies for public HEIs, we define the importance of individual criteria (outputs) by the following ratio of their weights

$$u1:u2:u3:u4:u5=3:3:3:1:2.$$

When setting the weight restriction we supposed that the weights for individual partial scores may differ from the weight of Score1 by +- 10%. Hence, the lower and upper bounds of AR intervals for the two alternatives are set as follows:

Table 3.Output weights constraints for calculating final score

| | AR model 1 | | AR model 2 | |
|---|---|---|---|---|
| Ratio | Low. bound | Up. Bound | Low. bound | Up. Bound |
| u2/u1 | 0.90 | 1.10 | 0.90 | 1.10 |
| u3/u1 | 0.90 | 1.10 | 0.90 | 1.10 |
| u4/u1 | 0.30 | 0.36 | 0.90 | 1.10 |
| u5/u1 | 0.60 | 0.74 | 0.90 | 1.10 |

Source: authors

For each HEI, the models give scores in the range <0, 1>, where the value 1 indicates the efficient HEIs. The ranking of HEIs is then determined by the descending order of their scores.

We use the software DEA Solver to do the analysis.

## 3. Application

We apply the approach designed in previous section to the assessment of selected business faculties in Slovakia, which were included in ARRA evaluation.

### 3.1. Slovak Business Faculties

The group of 14 business faculties in Slovakia is introduced in the table below.

Table 4. Observed Slovak faculties

| ID | Faculty | Shortened na |
|---|---|---|
| 1 | Faculty of Economics of the Technical University of Košice | EF TUKE |
| 2 | Faculty of Economics and Management, the Slovak University of Agriculture Nitra | FEM SPU |
| 3 | Faculty of National Economy, EU in Bratislava | NHF EU |
| 4 | Faculty of Economics, Matej Bel University, Banská Bystrica | EF UMB |
| 5 | Faculty of Economic Informatics, EU in Bratislava | FHI EU |
| 6 | Faculty of Commerce, EU in Bratislava | OF EU |
| 7 | Faculty of Business Economy, Košice (EU) | PHF EU |
| 8 | Faculty of Business Management, EU in Bratislava | FPM EU |
| 9 | Faculty of Management, of Comenius University in Bratislava | FM UK |
| 10 | Faculty of Operation and Economics of Transport and Communications, ŽU | FPEDAS ŽU |
| 11 | Faculty of Economics and Business of Pan-European University | FEP PEVŠ |
| 12 | Faculty of Management, University of Prešov | FM PU |
| 13 | VŠMP International School of Management, Prešov | VSMPISMP |
| 14 | Faculty of Economics, SelyeJános University in Komárno | EF UJS |

Source: authors

The IDs of the faculties correspond to the ARRA ranking for the year 2013. We will further refer to individual faculties with their shortened names. Two of evaluated schools are private (FEP PEVŠ and VSMPISMP), all the others are public.

Next fourfigures showsome characteristics of the observed faculties, first two educational and last two R&D characteristics.

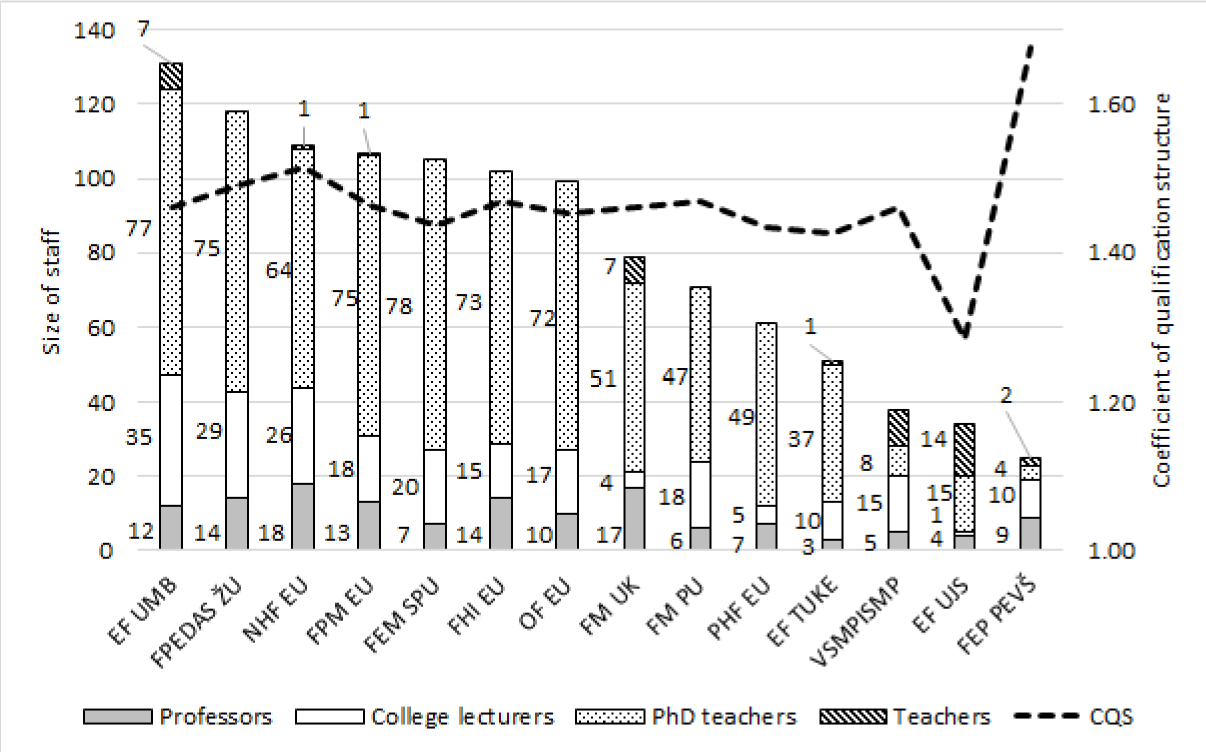


Figure 2. Structure of the academic staff

Source: authors

Figure 2 displays the qualification structure of academic staff (stacked columns) as well as the coefficient of the qualification structure (CQS, dashed line) as a composite indicator of the qualification level of the staff. The CQS is calculated as a converted number of teachers, i.e. the number of teachers multiplied by a value depending on their qualification (professors – 2, college lecturers – 1.66, teachers with PhD – 1.33, others - 1) divided by the number of all teachers at the HEI (for details see Hužvár andRigová, 2010).

The schools are sorted by the total size of academic staff in descending order. The size varies from 131 to 25 teachers.

Figure 3 displays the number of students structured by the form of study. Doctoral (PhD) students are indicated separately from bachelor and master students. The schools are sorted by the total size of students of the faculty in descending order.

Figure 4and Figure 5show the main R&D activities in relation to CQS.

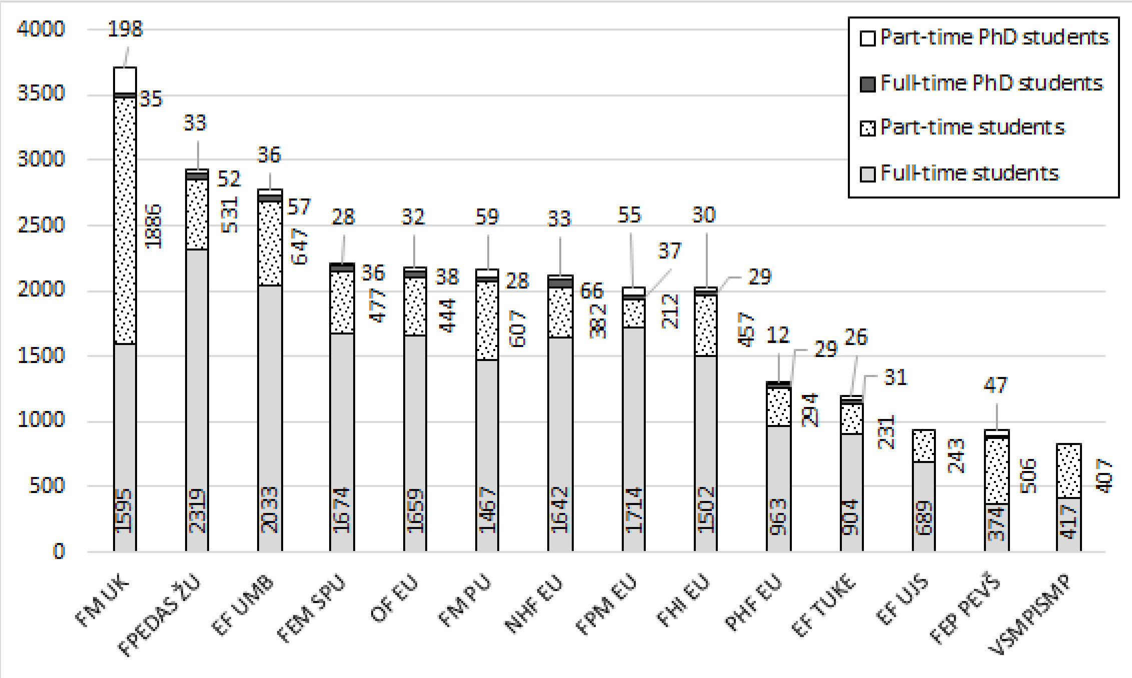


Figure 3. Structure of students at selected faculties
Source: authors

Figure 4 depicts the number of the publications and citations registered in WoK per employee (in years 2003-2012) sorted by the CQS in descending order. Figure 5 compares the amount of research grants obtained from domestic and foreign grant agencies per employee in € in 2012 sorted by the total grant amount.

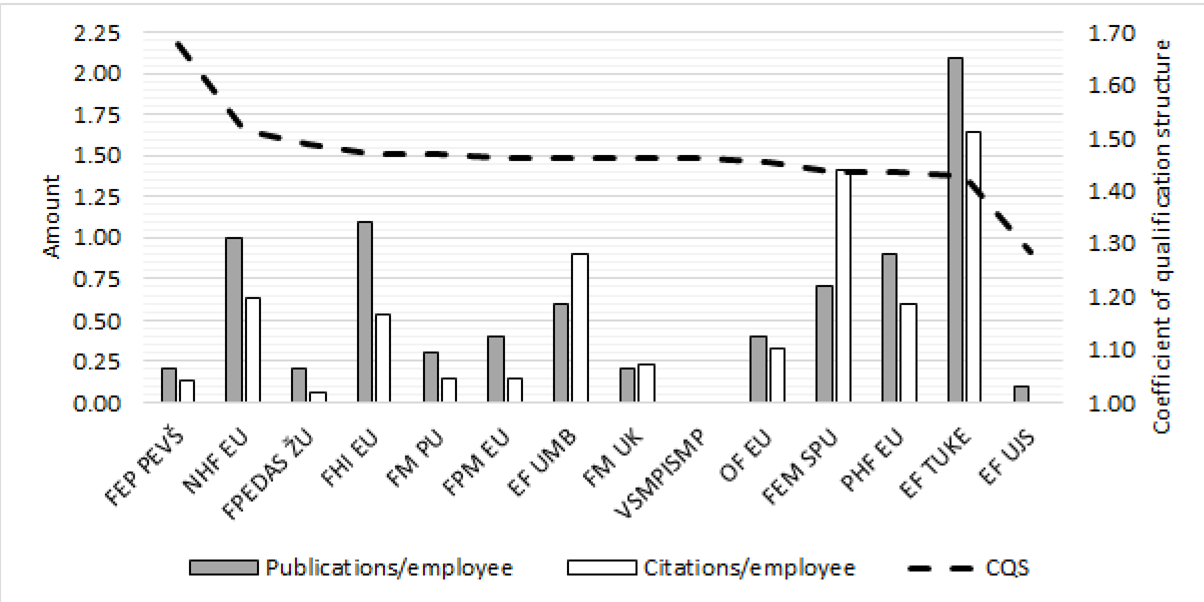


Figure 4.Publishing activities
Source: authors

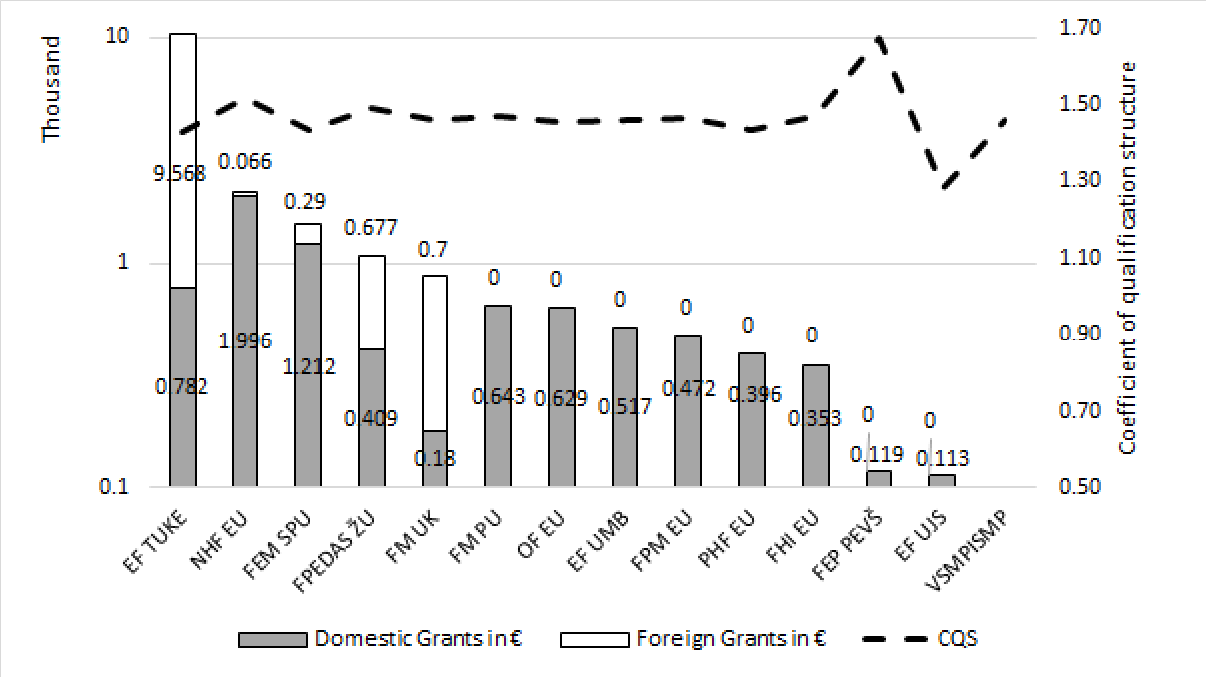


Figure 5.Volume of research grants
Source: authors

### 3.2. Results and discussion

In this section we will discuss the results of the analysis and compare them with the results of ARRA evaluation.

Table 5 shows the results of the assessment on the firs level. We compute the partial scores for criteria given in Table 1by using SBM-O-C model as it is indicated in Figure 1.

Table 5.Partial efficiency scores for selected criteria

| | Score1 | Score2 | Score3 | Score4 | Score5 |
|---|---|---|---|---|---|
| EF TUKE | 1 | 1 | 1 | 1 | 1 |
| FEM SPU | 0.706 | 0.526 | 1 | 0.653 | 0.089 |
| NHF EU | 1 | 0.785 | 0.504 | 1 | 1 |
| EF UMB | 0.872 | 0.600 | 0.666 | 0.426 | 0.013 |
| FHI EU | 1 | 1 | 0.432 | 0.359 | 0.013 |
| OF EU | 0.716 | 1 | 0.269 | 1 | 0.013 |
| PHF EU | 0.594 | 1 | 0.484 | 0.942 | 0.013 |
| FPM EU | 1 | 0.903 | 0.154 | 0.243 | 0.013 |
| FM UK | 0.448 | 1 | 0.181 | 0.125 | 0.111 |
| FPEDAS ŽU | 0.909 | 0.493 | 0.074 | 1 | 0.125 |
| FEP PEVŠ | 1 | 0.282 | 0.131 | 0.063 | 0.013 |
| FM PU | 1 | 0.221 | 0.154 | 0.175 | 0.013 |
| VSMPISMP | 1 | 0.056 | 0.053 | 0.058 | 0.013 |
| EF UJS | 0.362 | 0.067 | 0.055 | 0.058 | 0.013 |

| | Score1 | Score2 | Score3 | Score4 | Score5 |
|---|---|---|---|---|---|
| Average | 0.829 | 0.638 | 0.368 | 0.507 | 0.175 |
| Standard Deviation | 0.225 | 0.367 | 0.328 | 0.406 | 0.352 |
| Median | 0.955 | 0.693 | 0.225 | 0.393 | 0.013 |

Source: authors

We can observe that the number of efficient HEIs and efficiency scores are much higher in education criteria. In R&D, differences between efficient and inefficient HEIs are much higher. The biggest differences can be found in research grants. All inefficient HEIs reach the score not greater than 0.125.

Figure 6 displays the efficiency scores calculated by defined AR models, sorted by AR model 1 scores. Note that the scores in AR model 2 are higher for the HEIs (NHF EU, OF EU, PHF EU, FPEDAS ŽU) which show better performance in PhD studies and Research grants criteria (partial scores 4 and 5).

If we change lower and upper bounds of weight constraints specified in Table 3 so that the weights for individual partial scores may differ from the weight of Score1 by± 25% (instead of ± 10%),we observe only minor changes of final scoresin AR models.Pearson correlation coefficient for final scores is 0.997 in both AR models.

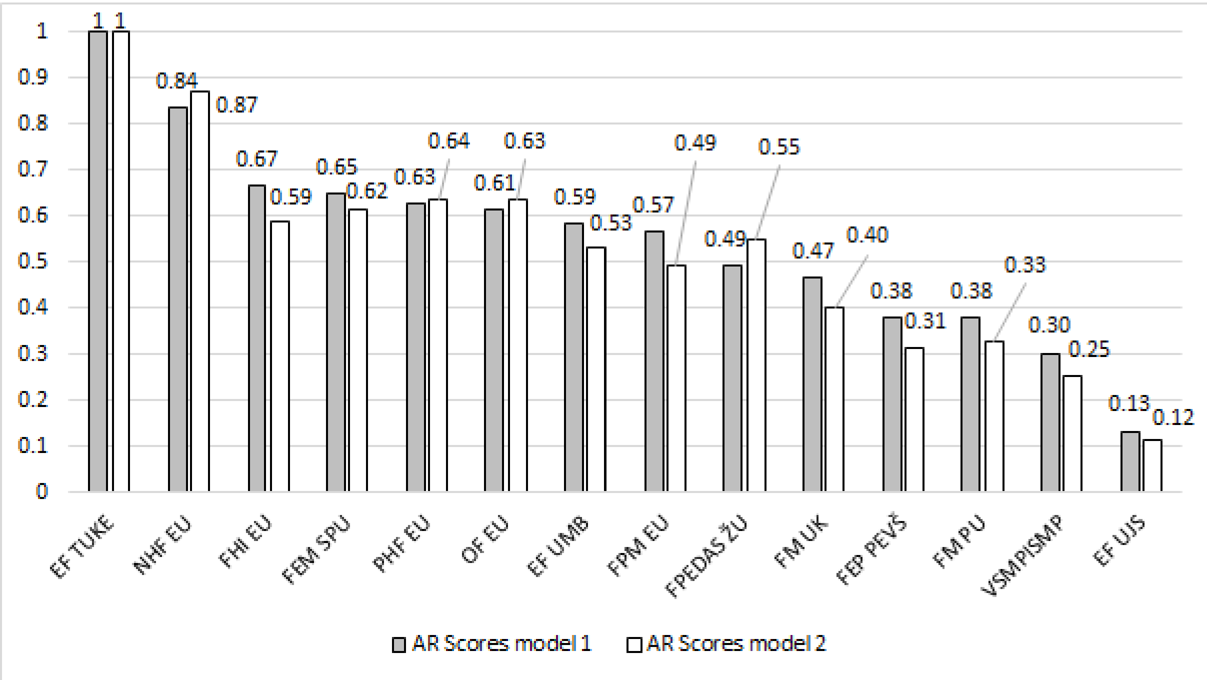


Figure 6. Comparison of AR models scores

Source: authors

Finally, we compare the rankings obtained by AR models with the ARRA ranking in Table 6. EF TUKE is a leader in all three rankings. Also, the last four HEIs keep their positions in all rankings. Generally, the HEIs which exhibit efficient performance in some partial criteria tend to improve their positions in AR rankings (NHF EU, FHI EU, OF EU, PHF EU, FPEDAS ŽU). On the other hand, EF UMB has worsened its position compared to ARRA ranking although it reaches above-average performance in 14 of 20 indicators listed in Table 2. However, it has no strength in any partial score(criteria).

Table 6. Comparison of alternative rankings

| HEIs | ARRA | AR model 1 | AR model 2 |
|---|---|---|---|
| EF TUKE | 1 | 1 | 1 |
| FEM SPU | 2 | 4 | 5 |
| NHF EU | 3 | 2 | 2 |
| EF UMB | 4 | 7 | 8 |
| FHI EU | 5 | 3 | 6 |
| OF EU | 6 | 6 | 4 |
| PHF EU | 7 | 5 | 3 |
| FPM EU | 8 | 8 | 9 |
| FM UK | 9 | 10 | 10 |
| FPEDAS ŽU | 10 | 9 | 7 |
| FEP PEVŠ | 11 | 11 | 12 |
| FM PU | 12 | 12 | 11 |
| VSMPISMP | 13 | 13 | 13 |
| EF UJS | 14 | 14 | 14 |

Source: authors

## 4. Conclusion

We designed methodology for the evaluation and comparison of HEIs performance based on their efficiency scores. We focused on setting alternative weights for the considered indicators in the process of their aggregation to the efficiency scores. Our approach is based on DEA techniques that we used in two steps. First, we applied SBM model to calculate partial efficiency score for each of main areas of HEIs activities in education and R&D. Second, we applied AR model to aggregate the partial scores to final efficiency score for all HEIs.

We applied thedesigned methodology on Slovak business HEIs. In order to calculate the partial scores for five performance areas we considered the output indicators introduced by ARRA and inputs equal to 1. For the aggregation of the partial scores to final efficiency score we used two AR models with different settings of output weight constraints. In the first model constraints were set with respect to the rules of allocation of subsidies from the state budget to public HEIs for their education and R&D performance. In the second model we assumed the same importance for all five performance areas. However, in each of the models we allowed the weight constraints to range within the specified bounds.

Compared to ARRA ranking, the designed methodology favors the HEIs which surpass their competitors in some of the indicators or performance areas. On the other hand, AR models allow us to restrict the differences between the weights so that all performance area remain significant for the efficiency score. However, the designed approach of HEIs assessment may be more convenient if we desire to take into account the specificities of the compared HEIs.

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