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EFFICIENCY OF INSTITUTIONS PROVIDING SPORTS ACTIVITIES: A CASE STUDY*

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Abstract. Sport as a public benefit activity is of social and economic importance and contributes to the objectives of national economies and the European Union. An economic view of sports involves assessing the costs and benefits associated with sporting activities, and sports can be categorised according to their public benefit character. Despite the specificities of sport, the analysis of the efficiency of institutions providing sporting activities is as relevant as in other public sector sectors. This paper aims to evaluate the success of individual sports in a selected public sector organisation using DEA analysis with a focus on technical efficiency. The paper covers 2016-2019, where sports are considered separate units with their own management. Analysing the efficiency of institutions providing sports activities using DEA analysis is not common, as the availability of relevant data limits quantitative analyses. Although sport is a public good, assessing the efficiency of these institutions is critical to optimising their activities. This specific analysis is essential, as it is for other public sector organisations, as it helps to identify areas for improvement and more efficient use of available resources. In this context, the contribution of the scientific article is also that it highlights the importance of evaluating the efficiency of sport at a higher level, which is becoming an important area within the general economics and economics of sport. The search for optimal ways to use resources in sports poses a challenge, especially when it comes to individual sports under the umbrella of relevant organisations. The performance of these sports will be evaluated in detail using technical efficiency, which will allow a more accurate assessment of individual sports' contribution to the organisation's overall efficiency. Given the specificities of the sporting environment and the decentralised management of individual sports, this analysis will contribute to gaining a better insight into how to optimise the conditions for achieving outstanding sporting results in the environment of the public sector organisation analy

Keywords: effectiveness of sports activities; individual sports; performance evaluation; optimisation of sports processes; DEA analysis; military sports programs

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1. Introduction and review of literature

Sport is legislatively defined as a public benefit activity in numerous countries, encompassing social and economic dimensions that play a crucial role in achieving the socio-economic goals outlined by national economies and the European Union. Simultaneously, it generates positive externalities, leading to substantial economic and social advantages (Novotný et al., 2011; Onwumechili, 2018, Potts & Thomas, 2018; Leeds, 2022; Zhou, Ke & Waqas, 2023). From an economic perspective, understanding the costs and benefits associated with sports activities becomes pertinent. Thus, assessing the efficiency of implementing such activities is of significance. Depending on the primary bearer of costs related to a specific type of sport, it can be categorised as a pure public good, a mixed public good, or a private good (Dittrichová, 2010; Andreff, & Szymanski, 2006, Hronec et al., 2021).

There is a separate strand of literature devoted to the various facets of sports institutions' efficiency (e.g., Kahane & Shmanske, 2012; Lee, 2019; Kahane, 2022; Mardosaite, & Jasinskas, 2021; Griban et al., 2022; Bogatyrev et al., 2022; Zhang et al., 2023; Abrahamyan, 2023; Feng, 2023; Lefebvre et al., 2023).

Analysing the efficiency of institutions covering sports activities using DEA analysis is rare (Lozano et al., 2002; Meza et al., 2015; Alyaseri, 2023; Ortíz et al., 2023; Miragaia, Ferreira, & Vieira, 2023).

The data availability necessary for these analyses also limits deeper quantitative analyses. Despite the specific nature of sport as a public good, examining the effectiveness of institutions covering sporting activities is as relevant as for other public sector organisations.

It was also the intention of the paper to show that the evaluation of the efficiency of sport and sporting activities at the top level is a legitimate area of analysis within general economics and the economics of sport. Therefore, on this basis, we consider the treatment of the above topic to be beneficial.

The paper's main objective is to evaluate the success of the individual sports activities covered by the Military Sports Centre Dukla Banská Bystrica (hereinafter referred to as MSC) in the form of a small case study. The success of the sports was evaluated by means of data envelopment analysis (DEA) and identified with their efficiency. In this paper, we analysed the so-called technical efficiency. Simplistically, it can be described as the capacity of the MSC to produce a certain volume of outputs (number of medal placements, number of 4-20 placements, athletes' limit fulfilment) for a given set of inputs (total number of athletes, number of active athletes, resources for training).

The sports supported by the MSC were seen as separate decision-making units (as each sport type has its own decentralised management) with some kind of "production" means necessary to achieve sporting success. Four years from 2016 to 2019 were considered, using aggregated (summary) data for 25 sports covering the entire four-year period.

2. Determination of input data and their characteristics

Just as education has effects at the macroeconomic level, its positive effects can also be expected to be felt in the local government environment. Since few authors have addressed the educational attainment of elected officials at the local level and the context of local government economic indicators (Mihályi, 2019), we have to rely on the research conducted at the economy level as a whole.

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The evaluation of the success (effectiveness) of the sports covered by the MSC was based on three input variables:

- Total number of athletes in a given year,
- the number of active athletes in a given year,
- the total financial resources allocated to the training of athletes in a given year (€)
- and several variables on the output side:
- number of 1st to 3rd place finishes in a given year,
- number of placements in 4th to 10th place in a given year,
- number of placements in 11th to 20th place in a given year,
- number of placements in 21st to 50th place in a given year,
- the total number of placement requirements (thresholds) met,
- total number of placements not meeting the requirements (thresholds)

In this form, it was not possible to consider input and output variables because there were data for 25 sports and the entire menu had 3 inputs and 6 outputs, which would make the DEA have no discriminatory power. Another problem was that from the point of view of the funding of the MSC and the internal evaluation of its sports results, rankings above 20th place have no justification. In addition, there were very often zero rankings for some places in the rankings. Another characteristic of the output variables available was that unmet thresholds actually represent an undesirable outcome to be avoided. The DEA solver at our disposal did not allow the selection of a DEA model with undesirable outputs. Finally, not all inputs and outputs were equally relevant to the evaluation of sports or did not carry enough relevant information: specifically, the total number of athletes in a given year, which includes not only active athletes (a separate variable) but also athletes who the MSC registered without submitting performances.

Therefore, four different choices of inputs and outputs were considered in solving the input-output situation, as shown in Table 1. Models 1 to 4 each have 2 inputs and 3 outputs and differ in one input and one output at each time.

Table 1. Selected inputs and outputs for models 1 to 4

	Limits fulfilled	Net limits fulfilled
Athletes together	Model 1 Inputs: *sport_together, funds* Number of athletes Allocated funds (€) Outputs: *place1_3, place4_20, limits_fulfilled* Number of 1st to 3rd places Number of 4th to 20th places Number of fulfilled limits	Model 2 Inputs: *sport_together, funds* Number of athletes Allocated funds (€) Outputs: *place1_3, place4_20, limits_fulfilledNETTO* Number of 1st to 3rd places Number of 4th to 20th places Number of fulfilled minus unfulfilled limits
Active athletes	Model 3 Inputs: *sport_together, funds* Number of active athletes Allocated funds (€) Outputs: *place1_3, place4_20, limits_fulfilled* Number of 1st to 3rd places Number of 4th to 20th places Number of fulfilled limits	Model 4 Inputs: *sport_together, funds* Number of active athletes Allocated funds (€) Outputs: *place1_3, place4_20, limits_fulfilledNETTO* Number of 1st to 3rd places Number of 4th to 20th places Number of fulfilled minus unfulfilled limits

Source: own elaboration

Models 1 and 2 consider the total number of athletes (sport_total), while models 3 and 4 consider active athletes (sport_active). Models 1 and 3 use the number of fulfilled requirements (limits_fulfilled) and models 2 and 4 in turn rely on the newly introduced variable "number of fulfilled minus unfulfilled requirements" (limits_fulfilled_NETTO). This variable is created by reducing the number of requirements met by the number of requirements not met, thereby accounting for the undesirable status of the number of requirements not met variable and allowing the resulting net variable to be used as a more comprehensive desired output. On the input side, the four placement count variables are considered in a modified form: the number of placements in 1st to 3rd place and the number of placements in 4th to 20th place. In the short term, active athletes are primarily important (Models 3 and 4). Still, inactive athletes should also be considered for longer-term sustainability, and the number of all athletes should be calculated (Models 1 and 2). But obviously, the results with respect to models 3 and 4 are more interesting.

Models 1 to 4 view individual sports as units that have athletes and financial resources and use these to achieve performance. The analysis uses data for the years 2016 to 2019. Because using data for only one year can be highly biased and affected by multiple one-off factors (e.g. if there were no European or World Championships in a given sport), a 4-year period corresponding to the Olympic cycle was used. The data for all 4 years were summed so that e.g. the variable sport_total finally represents the total number of athletes recorded in total over the 4-year period. The same athlete could have been counted once up to four times.

The economic and personnel indicators necessary for the elaboration of the paper on the evaluation of the efficiency of the sports peak training (number of athletes, training costs, athletes' fulfilled limits and points placements) were obtained from the annual reports, from the information system of the MSC and from the invoice records - the use of funds. As the MSC does not have the necessary data in a suitable structure, the data had to be mechanically retrieved from a large number of electronic and written documents and subsequently processed into the required form. Therefore, the acquisition and processing of the data required for the analysis was time-consuming.

Table 2. Statistical indicators of input and output variables

Indicator	Maximum	Minimum	Average	Standard deviation
sport_together (number)	188	4	42,960	44,413
sport_active (number)	114	4	29,480	29,147
funds (€)	494901	8923	120122	147343
place1_3 (number)	19	0	3,880	4,710
place4_20 (number)	54	0	14,480	18,296
limits_fulfilled (number)	114	4	29,160	29,143
limits_fulfilledNETTO (number)	41	0	14,040	11,975

Source: own elaboration

Table 2 shows the statistics of the input and output variables in each of the 4 models. There is obvious variability across sports. Some sports had only one athlete each year (these were always active athletes). Consequently, the minimum value of 4 for sport_total occurred 8 times (these are the sports of boxing, cyclocross, track cycling, kickboxing, bodybuilding, archery, triathlon, and aquatics). In contrast, the sport with the most athlete support was athletics with 188 registered athletes over 4 years and 114 active. The high variability can be seen not only in the minimum and maximum values, but also in the standard deviations, which, except for the variable limits_fulfilledNETTO, are approximately the same or substantially larger than the mean values. At the same time, the existence of null values for the variables place1_3, place4_20 and limits_splneneNETTO (17, 16 and 7 sports, respectively) can be seen. The occurrence of null values will be treated by selecting an appropriate DEA model, but it is also important that the newly defined variable is always non-negative, as this would probably pose a more serious problem. This means that each sport has always met more limits in total over the 4-year period than it has not.

Table 3. Correlations between the input and output variables considered

	sport_together	sport_active	funds	place1_3	place4_20	limits_ fulfilled	limity_ fulfilled NETTO
sport_together	1,000	0,968	0,801	0,514	0,668	0,967	0,871
sport_active	0,968	1,000	0,834	0,666	0,756	0,999	0,895
funds	0,801	0,834	1,000	0,663	0,641	0,839	0,655
place1_3	0,514	0,666	0,663	1,000	0,740	0,337	0,220
place4_20	0,668	0,756	0,641	0,740	1,000	0,706	0,528
limits_fulfilled	0,967	0,999	0,839	0,673	0,762	1,000	0,886
limits_fulfilledNETTO	0,871	0,895	0,655	0,489	0,648	0,886	1,000

Source: own elaboration

The correlation matrix in Table 3 shows that there is a high correspondence between the number of athletes and active athletes (correlation coefficient of 0.968) and similarity with the resources spent (correlation coefficients of 0.801 and 0.834). Interestingly, the number of athletes and active athletes are highly correlated with the number of limits met (correlation coefficients of 0.967 and 0.999, respectively). After accounting for unmet limits, the correlation of this variable with the other variables decreased.

3. Choice of model and justification of methods

Since models with different inputs and outputs can produce differentiated results, we decided to develop 4 models for evaluating efficiency and then compare the results. Obviously, each model has its limitations resulting from the parameters set and the model inputs and outputs used. Using the models, we tried to identify efficient and inefficient sports and the differences in the range of efficiency between them. In the database for each of the 4 models, there were zeros for the output variables that precluded the use of basic DEA models. Both because of this limitation and for a more reliable measure of efficiency, a slacks-based measure (SBM) model was used, which accounts for the non-proportional slips of inputs and outputs, while also allowing for a convenient solution to the situation of how to measure even with negative or zero values (Tone, 2001; Cooper, Seiford, & Tone, 2007). In the evaluation situation under consideration, the proportionality of inputs or outputs cannot be automatically assumed. There are better-funded sports (in € per athlete or active athlete), such as in this case aquatics, downhill skiing, biathlon, water slalom, while the counterparts in financial support are wrestling, gymnastics, luge, and weightlifting. This is related to economies of scale and some sports' material and technical needs. It cannot be assumed that an increase in the number of (active) athletes should be matched by an equal increase in financial resources. Similar considerations appear on the output side, where the numbers of placements and the numbers of limits met (net) are shown. The correlation analysis in Table 3 shows that the output variables are not even as strongly correlated as the chosen inputs. Placements in 1st to 3rd place and placements in 4th to 20th place are also influenced by the quality of athletes other than those from the MSC, and many random factors, not just the quality of training, affect sporting performance. Proportionality cannot be expected here, either. The observed disproportionality of the inputs and outputs of the individual sports precludes the constancy of returns to scale, and as a result, variable returns to scale were used. For the same percentage increase in the number of athletes and resources, the same increase in placements and number of limits cannot be expected at all.

The nature of the sports activity implies a higher influenceability of the inputs involved (number of athletes, resources allocated), while placements and limit fulfilments are beyond the control of MSC DUKLA. Thus, the appropriate orientation is input. On the other hand, in this case, the role of inputs in achieving outputs is significantly differentiated. In the same way, the output variables for the evaluation are necessarily of different importance. To take into account the different importance of inputs and outputs, a non-oriented model was

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preferred, allowing full incorporation of the different weights of inputs and outputs into the measurement. For inputs, weights of 0.40 (sport_total/sport_active) and 0.60 (prostr) were used for each model. For outputs, the weights were 0.50 (place1_3), 0.10 (place4_20) and 0.40 (limits_fulfilled/limits_fulfilled_NETTO).

Thus, the calculations included in the electronic appendix were obtained using a weighted non-oriented SBM model. For models 2 and 4, the transformed variable (limits_fulfilled_NETTO) was used. The transformation and aggregation of the 4-year data were explained and justified in the previous chapter.

4. Results and discussion

The results are presented in Tables 4 to 9. The computed efficiency scores for the 25 sports evaluated in turn and the reference sets for Models 1 and 2 are included in Table 4 and for Models 3 and 4 are presented in Table 5. The reference sets are presented only for the inefficient sports along with the lambda coefficients, which sum to one for variable returns to scale. The basic statistics of the summed scores for each model are presented in Table 5.

Table 4. Efficiency scores and reference sets for models 1 and 2

Nr.	Sport	Model 1		Model 2	
		Score	Reference sports	Score	Reference sports
1	Athletics	1		1	
2	Biathlon	0,4947	Water motor racing 0,042 Water slalom. 0,016 Weightlifting. 0,943	0,4536	Weightlifting 1
3	Bobsleigh	0,3861	Kickboxing 1	0,423	Box 1
4	Box	0,9355	Kickboxing 1	1	
5	Road cycling	0,0853	Water motor racing 0,228 Weightlifting 0,772	0,0907	Water motor racing 0,091 Weightlifting 0,909
6	Cyclocross	0,7091	Kickbox 1	0,7463	Box 1
7	Track cycling	1		1	
8	Judo	0,1844	Kickbox 0,246 Weightlifting 0,754	0,1921	Kickboxing 0,125 Weightlifting 0,875
9	Gymnastics	1		1	
10	Karate	1		1	
11	Kickboxing	1		1	
12	Bodybuilding	0,336	Kickbox 1	0,4679	Box 0,333 Kickbox 0,667
13	Archery	0,6331	Track cycling 0,286 Kickboxing 0,714	0,8322	Box 0,25 Track cyc. 0,279 Kickbox 0,441 Water mot. 0,029
14	Modern pentathlon	0,5884	Track cycling 0,286 Kickboxing 0,714	1	
15	Motorcycle sport	0,6495	Kickbox 1	0,6892	Box 1
16	Swimming	0,4709	Kickboxing 0,204 Weightlifting 0,796	0,496	Kickboxing 0,204 Weightlifting 0,796
17	Speed canoeing	0,4065	Water motor racing 0,123 Weightlifting 0,877	0,2703	Kickbox 0,241 Weightlifting 0,759
18	Tobogganing	0,5377	Track cycling 0,632 Weightlifting 0,368	1	
19	Sport shooting	1		0,5265	Gymnastics 0,201 Kickboxing 0,293 Weightlifting 0,506
20	Triathlon	0,7005	Kickboxing 1	0,7367	Box 1
21	Water motor racing	1		1	
22	Water slalom	1		1	
23	Weightlifting	1		1	
24	Wrestling	1		1	
25	Downhill skiing	0,1429	Water motor racing 0,298 Weightlifting 0,702	0,1243	Kickboxing 0,594 Weightlifting 0,406

Source: own elaboration

Table 5. Efficiency scores and reference sets for models 3 and 4

Nr.	Šport	Model 3		Model 4	
		Score	Reference sports	Score	Reference sports
1	Athletics	1		1	
2	Biathlon	0,6102	Water motor racing 0,042 Water slalom 0,016 Weightlifting 0,943	0,5706	Water motor racing 0,042 Water slalom 0,016 Weightlifting 0,943
3	Bobsleigh	0,7551	Kickbox 1	0,7858	Box 1
4	Box	0,9463	Kickbox 1	1	
5	Road cycling	0,1121	Aquatics 0,228 Weightlifting 0,772	0,999	Road cycling 1
6	Cyclocross	0,7576	Kickbox 1	0,7886	Box 1
7	Track cycling	1		1	
8	Judo	0,158	Track cycling 0,246 Weightlifting 0,754	0,2136	Swimming 0,058 Bobsleigh 0,435 Weightlifting 0,507
9	Gymnastics	0,5544	Track cycling 0,173 Kickboxing 0,427 Wrestling 0,4	1	
10	Karate	1		1	
11	Kickboxing	1		1	
12	Bodybuilding	0,4334	Kickbox 1	0,5179	Kickboxing 0,667 Modern pentathlon 0,333
13	Archery	0,6589	Track cycling 0,5 Kickbox 0,5	0,6838	Modern pentathlon 1
14	Modern pentathlon	0,7144	Track cycling 0,5 Kickbox 0,5	1	
15	Motorcycle sport	0,7746	Kickbox 1	0,8077	Box 1
16	Swimming	1		1	
17	Speed canoeing	0,5704	Water motor racing 0,123 Weightlifting 0,877	0,3982	Modern pentathlon 0,26 Weightlifting 0,74
18	Tobogganing	0,3241	Track cycling 0,632 Weightlifting 0,368	1	
19	Sport shooting	0,5358	Water motorcycling 0,404 Weightlifting 0,596	0,5279	Kickboxing 0,438 Weightlifting 0,562
20	Triathlon	0,7504	Kickbox 1	0,7806	Box 1
21	Water motor racing	1		1	
22	Water slalom	1		1	
23	Weightlifting	1		1	
24	Wrestling	1		1	
25	Downhill skiing	0,1071	Swimming 0,708 Weightlifting 0,292	0,0908	Track cycling 0,593 Swimming 0,068 Weightlifting 0,339

Source: own elaboration

On the one hand, there are no critical differences between the models in terms of overall average scores, but on the other hand, models 1 and 2 (using sport_together) give efficiency scores on average lower overall than models 3 and 4 (using sport_active). Thus, the use of active athletes on the input side puts the individual sports in a more favourable light overall, as can be seen not only in the averages but also in the value of the worst (smallest) score. Considering unmet thresholds as a (negative) desirable outcome in Models 2 and 4 leads to an increase in the overall efficiency level, most noticeably in Model 4 when combined with sport_active. According to the standard deviations, the least variability is for model 4 and the most variable results are for model 2, although there is no dramatic difference. Each model identified a different number of effective sports, ranging from 9 (model 3) to 13 (model 4).

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For each model, inefficient sports found were biathlon, bobsledding, road cycling, cyclocross, judo, bodybuilding, archery, motorcycle sport, speed canoeing, triathlon, and downhill skiing (11 sports in total). In some cases the differences in scores for the different models were not significant, e.g. for cyclocross the scores for the different models were between 0.7091 and 0.7886, while for speed canoeing, for example, the scores were 0.2703 (model 1) and around 0.4 (models 1 and 4) and 0.5704 (model 3), respectively. Some sports were effective for at least one of the models (6 sports). The sports of boxing, modern pentathlon and luge became efficient for models 2 and 4, i.e., considering the unmet thresholds. Swimming was effective when using active athletes, i.e., for models 3 and 4, and sport shooting only for model 1. Gymnastics was effective for three models, with only model 3 having a relatively low effectiveness of 0.5544. Thus, for gymnastics, there is some margin in the total number of athletes combined with the limits met. The remaining sports, athletics, track cycling, karate, kickboxing, aquatics, water slalom, weightlifting and wrestling, are still found efficient regardless of the choice of model (8 sports).

Models 1 and 3 are similar in terms of patterns. The most common pattern for inefficient sports for Model 1 is kickboxing (6 times with a weight of 1,000 and 4 times in proportion). In addition, track cycling, aquatic motoring, and weightlifting occur a few times in some proportion. Water slalom occurs only once. For model 3, again the most frequent pattern is kickboxing (6 times with a weight of 1,000 and 3 times with a lower weight) then track cycling, aquatic motoring, weightlifting and once also water slalom appear in common combination (also with kickboxing). The patterns of models 1 and 3 are almost identical for each sport (with modification of weights). There are more substantial differences between models 2 and 4. For model 2, boxing dominates as a pattern (4 times with a weight of 1,000 and 2 times with a weight lower), then kickboxing (7 times in the co-participation). Other patterns are weightlifting, aquatics, gymnastics, and track cycling. For pattern 4, boxing is also the most common pattern (4 times with a weight of 1,000) but concurrent with weightlifting (4 times in a sub-pattern). Other patterns are aquatics, water slalom, swimming, luge, modern pentathlon and road cycling. The clear conclusion is that, with respect to overall athletes, the "most exemplary" sport is kickboxing (patterns 1 and 2), while for active athletes it is boxing (patterns 3 and 4).

Table 6 below gives the correlation coefficients. The table provides information on the effectiveness of these models within the implemented sports and enables a comparison of their performance based on various indicators. Model 4 stands out for its high mean efficiency and low standard deviation, which could indicate its better ability to predict the efficiency results of individual sports.

Table 6. Efficiency score statistics for models 1 to 4

Indicator	Model 1	Model 2	Model 3	Model 4
Average	0,6904	0,722	0,7105	0,8066
Maximum	1	1	1	1
Minimum	0,0853	0,0907	0,1071	0,0908
Standard deviation	0,3139	0,3226	0,300	0,2729
Number of effective sports	10	12	9	13
Number of inefficient sports	15	13	16	12

Source: own elaboration

All four models are relatively efficient on average, with values ranging between 0.6904 and 0.8066. This value provides an overall view of how well these models predict the efficiency results of individual sports. Regarding the maximum efficiency score value, all four models achieve the highest possible score of 1 for some sports, indicating that some of the sports analysed within these models were absolutely efficient. The minimum values of the efficiency score indicate the possible significant inefficiency of some sports within the developed models. The results suggest that there are substantial differences between individual sports in this indicator. The measured minimum efficiency scores ranged from 0.0853 to 0.1071. The standard deviation made it possible to measure the variability of the efficiency score within individual models. Model 4 has the lowest standard deviation, indicating

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that its predictions were more consistent compared to the other models. The number of sports that were considered efficient within the developed models differed between individual models, with Model 4 predicting efficiency in the largest number of sports - 13. The number of sports that did not achieve efficiency within the investigated models also varies strongly between the developed models. Model 2 had the lowest number of ineffective sports - 12. Table 7 provides information on the correlations between the models. The correlations can provide insight into the extent to which these models are similar or different in their predictions. The results are shown in the following table.

Table 7. Correlations between efficiency scores for models 1 to 4

Indicator	Model 1	Model 2	Model 3	Model 4
Model 1	1.0000	0.8624	0.7897	0.6133
Model 2	0.8624	1.0000	0.7322	0.7524
Model 3	0.7897	0.7322	1.0000	0.6630
Model 4	0.6133	0.7524	0.6630	1.0000

Source: own elaboration

The correlation coefficients in Table 7 indicate that there is generally not much difference in the sports rankings by the different models (correlation coefficient values between 0.7322 and 0.8624 indicate a direct strong linear fit). A slightly larger difference occurs between the scores of models 1 and 4 (correlation 0.6133) and the scores of models 3 and 4 (correlation 0.6630). In the former case, a marked difference of 0.914 occurs for road cycling (scores of 0.085 in model 1 and 0.999 in model 4), while for the sports of swimming, sport shooting, luge and modern pentathlon the difference is between 0.400 and 0.529. In the latter case, road cycling is the most different with a difference of 0.887 (score of 0.112 in model 3 and score of 0.999 in model 4), followed by luge with a difference of 0.675 and gymnastics with a difference of 0.446. In all these cases, the Model 4 score is higher (1 or nearly 1). These are essentially the same sports viewed differently by these models. In practice, this means that these sports look different in terms of efficiency when evaluated over the total number of athletes and the number of limits met (Model 1) and over the number of active athletes and the number of limits after accounting for unmet limits (Model 4). Differences also emerge when different values for the number of active athletes are used for the number of limits (Models 3 and 4). This is consistent with the differences in mean scores in Table 6 (but which apply to all sports).

Table 8. Percentage slips for models 1 and 2

Sport	Model 1						Model 2					
	Score	Slips (%)					Score	Slips (%)				
		sport_together	funds	place1_3	place4_20	limits_fulfilled		sport_together	funds	place1_3	place4_20	limits_fulfilledNETTO
Athletics	1	0	0	0	0	0	1	0	0	0	0	0
Biathlon	0.495	12.13	75.66	0	5.64	0	0.454	9.09	76.08	0	10.2	26.92
Bobsleigh	0.386	80	48.97	48.97	48.97	0	0.423	80	42.84	42.84	42.84	0
Box	0.936	0	10.74	10.74	10.74	0	1	0	0	0	0	0
Road cycling	0.085	35.36	52.05	931.58	747.37	0	0.091	24.71	48.15	972.73	887.27	0
Cyclocross	0.709	0	48.48	48.48	48.48	0	0.746	0	42.28	42.28	42.28	0
Track cycling	1	0	0	0	0	0	1	0	0	0	0	0
Judo	0.184	32.76	29.9	364.04	918.42	0	0.192	22.81	19.78	406.25	1081.25	0
Gymnastics	1	0	0	0	0	0	1	0	0	0	0	0
Karate	1	0	0	0	0	0	1	0	0	0	0	0
Kickboxing	1	0	0	0	0	0	1	0	0	0	0	0
Bodybuilding	0.336	0	26.65	300	300	0	0.468	0	23.71	166.67	166.67	0
Archery	0.633	0	38.53	42.87	0	0	0.832	0	27.97	0	0	0
Modern pentathlon	0.588	33.33	25.36	42.87	0	0	1	0	0	0	0	0

Motorcycle sport	0.65	20	45.08	45.08	45.08	0	0.689	20	38.47	38.47	38.47	0
Swimming	0.471	18.04	10.95	139.35	0	33.48	0.496	18.04	10.95	139.35	0	10.34
Speed canoeing	0.407	31.98	50.32	77.19	16.43	0	0.27	40.54	58.73	55.25	0	129.97
Tobogganing	0.538	35.65	10.73	10.73	474.74	0	1	0	0	0	0	0
Sport shooting	1	0	0	0	0	0	0.526	0	47.1	68.42	20.53	0
Triathlon	0.701	0	49.91	49.91	49.91	0	0.737	0	43.88	43.88	43.88	0
Water motor racing	1	0	0	0	0	0	1	0	0	0	0	0
Water slalom	1	0	0	0	0	0	1	0	0	0	0	0
Weightlifting	1	0	0	0	0	0	1	0	0	0	0	0
Wrestling	1	0	0	0	0	0	1	0	0	0	0	0
Downhill skiing	0.143	32.01	74.91	152.63	1192.98	0	0.124	58.36	86.59	71.09	631.26	0

Source: own elaboration

Table 9. Percentage slips for models 3 and 4

Sport	Model 1						Model 2					
	Score	Slips (%)					Score	Slips (%)				
		sport_together	funds	place1_3	place4_20	limits_fulfilled		sport_together	funds	place1_3	place4_20	limits_fulfilledNETTO
Athletics	1	0	0	0	0	0	1	0	0	0	0	0
Biathlon	0.61	0	75.66	0	5.64	0	0.571	0	75.66	0	5.64	21.21
Bobsleigh	0.755	0	48.98	48.98	48.98	0	0.786	0	42.83	42.83	42.83	0
Box	0.946	0	10.74	10.74	10.74	0	1	0	0	0	0	0
Road cycling	0.112	0	52.05	931.58	747.37	0	0.999	0	0.02	0.13	0.14	0
Cyclocross	0.758	0	48.48	48.48	48.48	0	0.789	0	42.28	42.28	42.28	0
Track cycling	1	0	0	0	0	0	1	0	0	0	0	0
Judo	0.158	0	29.45	314.91	1004.39	0	0.214	0	30.26	190.58	701.48	0
Gymnastics	0.554	0	0	0	241.11	0	1	0	0	0	0	0
Karate	1	0	0	0	0	0	1	0	0	0	0	0
Kickboxing	1	0	0	0	0	0	1	0	0	0	0	0
Bodybuilding	0.433	0	26.65	300	300	0	0.518	0.01	15.85	233.29	233.29	0
Archery	0.659	0	35.27	0	75.02	0	0.684	0	17.64	0	0	100
Modern pentathlon	0.714	0	21.4	0	75.02	0	1	0	0	0	0	0
Motorcycle sport	0.775	0	45.08	45.08	45.08	0	0.808	0	38.47	38.47	38.47	0
Swimming	1	0	0	0	0	0	1	0	0	0	0	0
Speed canoeing	0.57	0	50.32	77.19	16.43	0	0.398	14.48	59.22	44.33	0	131.45
Tobogganing	0.324	21.88	10.73	10.73	474.74	0	1	0	0	0	0	0
Sport shooting	0.536	0	24.96	144.74	45.31	0	0.528	5.1	43.38	98.44	32.07	0
Triathlon	0.75	0	49.91	49.91	49.91	0	0.781	0	43.88	43.88	43.88	0
Water motor racing	1	0	0	0	0	0	1	0	0	0	0	0
Water slalom	1	0	0	0	0	0	1	0	0	0	0	0
Weightlifting	1	0	0	0	0	0	1	0	0	0	0	0
Wrestling	1	0	0	0	0	0	1	0	0	0	0	0
Downhill skiing	0.107	0	72.14	51.04	1440.28	0	0.091	41.91	86.4	0	884.18	0

Source: own elaboration

Tables 8 and 9 give the percentage lags by which the original inputs and outputs need to be adjusted to make the respective sports efficient relative to the others. The problem with the recommendations derived from Tables 8 and 9 is that they are sometimes more difficult to achieve and often clearly unrealistic. This can be illustrated by the example of a selected sport, where the applicability of all these calculations can be shown.

Conclusions

All models rate downhill skiing as a weak sport covered by MSC DUKLA. It scores best in Model 1, where the active number of athletes is used, regardless of the number of unmet limits. In this case, the score is 0.1429. This value takes into account excesses in inputs and deficiencies in outputs. Downhill skiing should be compared with aquatics and weightlifting, which represent theoretically achievable patterns with unequal weights (aquatics 0.298 and weightlifting 0.702). Interpretation of the recommendations and slips is complicated because data aggregated over 4 years were used. Over this period, downhill skiing had 44 met thresholds, which are not required to be adjusted to achieve a technically efficient optimum with a score of 1.000. Slips and necessary adjustments are identified in other directions. To achieve technically efficient performance, downhill skiing would need to have only 50.32 persons on the athlete register for the years 2016 to 2019 instead of 74 persons (i.e. 32.01% less) and €99,923 (i.e. 74.91% less) instead of the cumulative total of €398,245 allocated for these 4 years (i.e. 74.91% less). On the output side, it would be necessary to increase the number of placements in the first 3 places from 4 to 10.11 (i.e. increase placements by 152.63%) and the number of placements in the next 17 places from 3 to 38.79 (i.e. up by 1,192.98%). The values of the percentage slippages given in parentheses can be found in Table 8. These recommendations are clearly not realistic, but the valuable information is that we should look to aquatic sports and weightlifting for inspiration in managing downhill skiing. For other models, somewhat different recommendations and even patterns emerge. These sports are significantly different from downhill skiing, and their adequacy needs to be understood in managerial terms.

The performed research allows us to claim that data envelopment analysis (DEA) can be successfully used to estimate the efficiency of sports institution performance in selected areas.

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