PERFORMANCE TEAM EVALUATION IN 2008 BEIJING OLYMPIC GAMES

João Carlos Correia Baptista Soares de Mello (UFF)
jcsmello@pesquisador.cnpq.br
Lidia Angulo Meza (UFF)
lidia_a_meza@yahoo.com
Fábio Gomes Lacerda (UFF)
fagolac@gmail.com
Luiz Biondi Neto (UERJ)
luizbiondi@terra.com.br

In recent years, a lot of work has been done dealing with alternative performance rankings for the Olympic Games. Almost all of these works use Data Envelopment Analysis (DEA). Generally speaking, those works can be divided into two categorries: Pure rankings with unitary input models and relative rankings with classical DEA models; both output oriented. In this paper we introduce an approach taking into account the number of athletes as a proxy to the country investment in sports. This number is an input for a DEA model, and the other input is the population of the country. We have three outputs, the number of gold, silver and bronze medals earn by each country. Contrary to the usual approach in the literature, our model is not output oriented. It is a non-radial DEA model oriented to the input "number of athletes". The Decision Making Units (DMU) are all the countries participating in the Beijing Olympic Games, including those which did not earned any medal. We use a BCC model and we compare the target of each DMU with the number of athletes that earned, at least, a single medal.

Palavras-chaves: DEA, Sport Evaluation, Olympic Games

1. Introduction

Performance evaluation has been widely studied in sport for the last 25 years (NEVILL *et al.*, 2008). In the case of the Olympic Games the rank of the nations is traditionally carried out with the so-called Lexicographic Multicriteria Method (LINS *et al.*, 2003). In this very paper the drawbacks of the Lexicographic Method are pointed out and a new ranking is suggested.

There are already some other approaches using Data Envelopment Analysis (CHARNES *et al.*, 1978). The very first one was proposed by Lozano et al (2002). They used population and GNP as inputs and the medals as outputs. In a similar approach, Lins et al (2003) built a new model taking in account one more constraint: the total amount of medals is a constant. This resulted in the development of a new model, the so-called Zero Sum Gains DEA model (ZSG-DEA). Churilov and Flitman (2006) used DEA to establish a ranking, the inputs of which were some social economics variables (population, GDP, DEL index and IECS index). The outputs were some linear combination of the number of medals earned by each country. Li et al (2008) use GDP per capita and population as inputs and impose different weight restrictions for each DMU, according to a previous country categorization.

Wu et al (2009) have used the concept of Nash equilibrium in a BCC-DEA Cross Evaluation for the Olympic Ranking They came across the same problem described in Soares de Mello et al (2002), the existence of negative efficiencies in the BCC-DEA model. They solved the problem with the same approach used by Soares de Mello et al (2008) and Angulo-Meza et al (2004).

All the works mentioned hereabove take into account the results in the Olympics and the socio economical conditions of each country. Models using DEA and nothing but medals won by each country were presented by Soares de Mello et al (2008; 2009) and Soares de Mello et al (SOARES DE MELLO, GOMES *et al.*, 2008).

Despite their important differences, the papers cited hereabove have some common points. The first one is that those papers evaluate only countries that have earned medals. In other words the units evaluated by DEA (Decision Making Units - DMU) are the countries that have one at least one medal. The second in common in all those papers is that the DMU´s objective is to maximize some combination of the number of medals earned.

In this paper we are interested in studying if the number of competitors of each country is a reasonable one when compared to all the other countries. Moreover, we will evaluate all participating countries in the Beijing´s Olympic Games including those ones that have earned no medal. This is possible because of a mathematical property of the DEA model with variable returns to scale, the so-called BCC DEA model (BANKER *et al.*, 1984). In such a model, it is possible for a DMU to be efficient with all its outputs nil valued. Our model will have three outputs as a majority of the models concerning Olympic evaluation, number of gold, silver and bronze medals. The model will have two inputs: the population and the number of competitors for each country. As we intend to evaluate the dimension of each country´s team we will orient the DEA model to only input. This leads to the study of non radial DEA models. Such model will be summarized in section 2. Section 3 presents the DEA model used in our study. The results are present in section 4 and Section 5 has some final comments of this study.

2. Data Envelopment Analysis models with non discritionary variables

The classical BCC input orient model (BANKER *et al.*, 1984) in the envelopment formulation is presented in (1).

$$\begin{aligned} & Min\ h_0 \\ & subject\ to \\ & h_0 x_{i0} - \sum_{k=1}^{n} x_{ik}\lambda_k \geq 0,\ \forall i \\ & -y_{j0} + \sum_{k=1}^{n} y_{jk}\lambda_k \geq 0,\ \forall j \\ & \sum_{k=1}^{n} \lambda_k = 1 \\ & \lambda_k \geq 0,\ \forall k \end{aligned} \qquad (1)$$

Where h_0 is the efficiency of the DMU *0*, the DMU under evaluation; x_{ik} is the input *i* of DMU *k*; y_{jk} is the output *j* of DMU *k*; λ_k is the share of DMU *k* for the DMU *0* target. According to the model when an inefficient DMU achieves efficiency, all its inputs are proportionally reduced. If we want to achieve efficiency changing the value of a single input, we shall use model (2). This model was introduced by Banker e Morey (1986) and can be seen as a particular case of MORO model (LINS *et al.*, 2004; QUARIGUASI FROTA NETO e ANGULO-MEZA, 2007), when all but one factor are not allowed to be changed.

$$\begin{aligned} & Min\ h_0 \\ & subject\ to \\ & h_0 x_{v0} - \sum_{k=1}^{n} x_{vk}\lambda_k \geq 0, \\ & x_{i0} - \sum_{k=1}^{n} x_{ik}\lambda_k \geq 0,\ \forall i \neq v \\ & -y_{j0} + \sum_{k=1}^{n} y_{jk}\lambda_k \geq 0,\ \forall j \\ & \sum_{k=1}^{n} \lambda_k = 1 \\ & \lambda_k \geq 0,\ \forall k \end{aligned} \qquad (2)$$

In model (2) x_{vk} is the variable allowed to be changed.

3. Modelling

As mentioned earlier the main goal of our study is to evaluate the performance of the Olympic teams in Beijing 2008 Games, taking into account the number of athletes for each and every country. We use as outputs the number of gold, silver and bronze medals won by each country. The controlled input is the number of athletes in each team, which is a proxy for the country investment in sports. As an uncontrolled input we use population of each country. We have restraint the weight of each medal as in Soares de Mello et al (2008; 2009) and Soares de Mello et al (2008), i.e. the weight of the gold medal is not lower than the weight of the silver medal, which is not lower than the weight of the bronze medal. Moreover, the difference of weights between the gold and the silver medals is not lower that the difference of weights between the silver and bronze medals. Model (3) is the linear programme for a given country.

$$
\begin{aligned}
& Min\ h_0 \\
& st \\
& x_{POP0} - \sum_{j=1}^{n} \lambda_j x_{POPj} \geq 0 \\
& h_0 x_{ATHL0} - \sum_{j=1}^{n} \lambda_j x_{ATHLj} \geq 0 \\
& y_G \leq \sum_{j=1}^{n} \lambda_j y_{Gj} - \gamma_1 - \gamma_3 \\
& y_S \leq \sum_{j=1}^{n} \lambda_j y_{Sj} + \gamma_1 - \gamma_2 + 2\gamma_3 \\
& y_B \leq \sum_{j=1}^{n} \lambda_j y_{Bj} + \gamma_2 - \gamma_3 \\
& \sum_{j=1}^{n} \lambda_j = 1 \\
& \lambda_j \geq 0, \forall j
\end{aligned}
\qquad (3)
$$

In model (3), h_o is the efficiency of the observed country; λ_j is the share of country j for the observed country o; x_{POP0} is the population of the observed country; x_{ATH0} is the number of athletes of each country; y_G, y_S e y_B are the number of gold, silver and bronze medals of the observed country; y_{Gj}, y_{Sj} and y_{Bj} are the number of gold, silver and bronze medals of country j. Variables γ_1, γ_2 and γ_3 are the dual variables corresponding to the weight restrictions in the primal problem (multipliers formulation).

4. Results

Table 1 summarizes the results for some countries using model (3). In this table the “ideal” number of Athletes is the non radial target for each country, it is obtained by multiplying the efficiency by the number of athletes. The Number of Medal Winners represents how many athletes did a country need to win all its medals. For instance, if a country wins eight medals with only one athlete it would have number of medal winners equal to one. On the other hand if a country wins a medal in a collective sport, for instance, soccer, it would lead at least eleven athletes to win that medal.

Country	Number of Athletes	Medals	Number of medal winners	"Ideal" number of Athletes	DEA Efficiency
Australia	439	46	85	439	1,000000
Belize	1	0	0	1	1,000000
Burundi	1	0	0	1	1,000000
Central African Republic	1	0	2	1	1,000000

China	564	100	159	564	1,000000
Dominica	1	0	0	1	1,000000
Gabon	1	0	0	1	1,000000
Jamaica	56	11	13	56	1,000000
Kenya	52	14	14	52	1,000000
Nauru	1	0	0	1	1,000000
Niger	1	0	0	1	1,000000
Russia	411	72	134	411	1,000000
Togo	2	1	1	2	1,000000
United Kingdom	297	47	59	297	1,000000
United States	629	110	272	629	1,000000
Belarus	123	19	28	114	0,922794
Bahrain	11	1	1	10	0,886249
Sudan	8	1	1	4	0,474044
Netherlands	230	16	63	83	0,361910
Rumania	95	8	19	35	0,361662
Denmark	85	7	18	30	0,358455
Trinidad and Tobago	28	2	4	28	0,350909
Bangladesh	3	0	0	1	0,333333
Iceland	19	1	14	6	0,305579
Brazil	265	15	74	58	0,218692
New Zealand	195	9	14	42	0,215002
India	48	3	3	8	0,173611
Poland	230	10	20	39	0,168983
Mexico	67	3	4	10	0,154229
Chile	23	1	1	23	0,149759
Argentina	137	6	53	19	0,140811
Nigeria	82	4	24	12	0,140244
Serbia	88	3	15	9	0,106003

Table 1 – Results for model (3)

5. Final Comments

In Table 1, we notice that all but seven countries has the "Ideal number of athletes" larger than the "Number of athletes". This is a very desirable situation, it means that even in the ideal case, the country will have some athletes that will not win any medal at all, preserving the "De Coubertin" Olympic spirit. For some countries this does not happen. This is the case of Brazil, Nigeria, Serbia, Argentina and Iceland. If those countries succeed to reduce their number of athletes, they will not be able to win the same number of medals. For those countries the investments policy in sports is probably not the best one.

Future studies may explore this conclusion and try to identify which are the most profitable sport investments for each country.

References

ANGULO-MEZA, L., SOARES DE MELLO, J. C. C. B., GOMES, E. G. & BIONDI NETO, L. *Eficiências negativas em modelos DEA-BCC: como surgem e como evitá-las*. VII Simpósio de Pesquisa Operacional e Logística da Marinha - SPOLM. Niterói, 2004. p.

BANKER, R. D., CHARNES, A. & COOPER, W. W. *Some models for estimating technical scale inefficiencies in data envelopment analysis*. Management Science Vol. 30, n. 9, p. 1078-1092, 1984.

BANKER, R. D. & MOREY, R. C. *Efficiency Analysis for Exogenously Fixed Inputs and Outputs*. Operations Research. Vol. 34, n. 4, p. 513-521, 1986.

CHARNES, A., COOPER, W. W. & RHODES, E. *Measuring the efficiency of decision-making units*. European Journal of Operational Research. Vol. 2, n. 6, p. 429-444, 1978.

CHURILOV, L. & FLITMAN, A. *Towards fair ranking of olympics achievements: The case of Sydney 2000*. Computers and Operations Research. Vol. 33, n. 7, p. 2057-2082, 2006.

LI, Y., LIANG, L., CHEN, Y. & MORITA, H. *Models for measuring and benchmarking olympics achievements*. Omega. Vol. 36, n. 6, p. 933-940, 2008.

LINS, M. P. E., ANGULO-MEZA, L. & DA SILVA, A. C. M. *A multi-objective approach to determine alternative targets in data envelopment analysis*. Journal of the Operational Research Society. Vol. 55, n. 10, p. 1090-1101, 2004.

LINS, M. P. E., GOMES, E. G., SOARES DE MELLO, J. C. C. B. & SOARES DE MELLO, A. J. R. *Olympic ranking based on a zero sum gains DEA model*. European Journal of Operational Research. Vol. 148, n. 2, p. 312-322, 2003.

LOZANO, S., VILLA, G., GUERRERO, F. & CORTÉS, P. *Measuring the performance of nations at the Summer Olympics using data envelopment analysis*. Journal of the Operational Research Society. Vol. 53, n. 5, p. 501-511, 2002.

NEVILL, A., ATKINSON, G. & HUGHES, M. *Twenty-five years of sport performance research in the Journal of Sports Sciences*. Journal of Sports Sciences. Vol. 26, n. 4, p. 413-426, 2008.

QUARIGUASI FROTA NETO, J. & ANGULO-MEZA, L. *Alternative targets for data envelopment analysis through multi-objective linear programming: Rio de Janeiro Odontological Public Health System Case Study*. Journal of the Operational Research Society. Vol. 58, n., p. 865–873, 2007.

SOARES DE MELLO, J. C. C. B., ANGULO-MEZA, L. & BRANCO DA SILVA, B. P. *Some rankings for the Athens Olympic Games using DEA models with a constant input*. Investigação Operacional. Vol. 8, n. 1, p. 77-89, 2008.

SOARES DE MELLO, J. C. C. B., ANGULO-MEZA, L. & BRANCO DA SILVA, B. P. *A ranking for the Olympic Games with unitary input DEA models*. IMA Journal Management Mathematics Vol. Forthcomming, n., p., 2009.

SOARES DE MELLO, J. C. C. B., ANGULO-MEZA, L., GOMES, E. G. & BIONDI NETO, L. *Alguns paradoxos em modelos DEA-BCC: eficiências negativas e inexistência de retornos de escala*. XXVIII ENEGEP. Rio de Janeiro: ABEPRO, 2008. p.

SOARES DE MELLO, J. C. C. B., GOMES, E. G., ANGULO-MEZA, L. & BIONDI NETO, L. *Cross Evaluation using Weight Restrictions in Unitary Input DEA Models: Theoretical Aspects and Application to Olympic Games Ranking*. WSEAS Transactions on Systems. Vol. 7, n. 1, p. 31-39, 2008.

SOARES DE MELLO, J. C. C. B., LINS, M. P. E. & GOMES, E. G. *Construction of a smoothed DEA frontier*. Pesquisa Operacional. Vol. 28, n. 2, p. 183-201, 2002.

WU, J., LIANG, L. & CHEN, Y. *DEA game cross-efficiency approach to Olympic rankings*. Omega. Vol. 37, n. 4, p. 909-918, 2009.