

A FDH Study of the Vancouver 2010 Winter Olympic Games

JULIANA DA CÂMARA TORRES BENICIO

Coordenação de Extensão

La Salle-RJ

Rua Gastão Gonçalves, 79 – Santa Rosa, 24240-030 Niterói, RJ, Brazil

juliana.benicio@lasalle.org.br

NÍSSIA CARVALHO ROSA BERGIANTE

Departamento de Engenharia de Produção

Universidade Federal Fluminense

Rua Passo da Pátria, 156 – São Domingos, 24210-240 Niterói, RJ, Brazil

nissiabergiante@id.uff.br

JOÃO CARLOS CORREIA BAPTISTA SOARES DE MELLO

Departamento de Engenharia de Produção

Universidade Federal Fluminense

Rua Passo da Pátria, 156 – São Domingos, 24210-240 Niterói, RJ, Brazil

jcsmello@pesquisador.cnpq.br

Abstract:- Many authors have been used different mathematical models to study the results of the Olympic Games. Some of these studies try to find new ways to establish alternative performance rankings while others evaluate the efficiency of the countries participating to the competition. Some use economics variables as inputs, others, included social aspects but in general, all of them chose the output orientation. In this work we are interested in studying the results of the Winter Olympic Games, held in Vancouver, Canada in 2010. We choose FDH (Free Disposal Hull) model but we decided to use input orientation. We brought into account the number of athletes of each country as input. As outputs, we use the number of gold, silver and bronze medals. The unit of analysis will be all the countries that took part in the games, even though they had not won any medals.

Key words: - Winter Olympic Games, FDH model studies, BCC model.

1 Introduction

Since the beginning of the idea of the Olympic Games, it has attracted the attention of many people. Not only because the athletes and those entire thing that related the Games with heroes. Neither only because the Olympic Games are related to the idea of national unity ([28],[4],[21], [47], [21]), but also because, in the Modern era, under the market economic condition, its impact in the cities that host the Games has been considerate [16] in addition to the benefit to their tourism industry ([16]; [11]; [52]). The Olympic games is also a benchmark to the academic research to analyze the impact of some world normative rules, as studied by [43]. Besides, it has been considerate as an important field to study in the academic researches.

Although the Ancient Games had started in 776 AC, in Olympia, Greece and the Modern Games took place in 1896 in Athens [44], the winter version of the dispute, held in Chamonix, France, only happened in 1924. Since then until 1994, the Summer Olympic Games and Winter Olympic Games were held in the same year, every four year. From 1994 and forth, the winter and summer Games have been held in different years (two years apart). Due to their characteristics, [22] showed that are significantly differences between these two Olympics Games.

In the literature, many authors have been interested in study these games. As an example, we can pointed out some social studies ([7]; [14]; [24]; [2]), environmental and health studies ([17]; [1];

[46]; [42]) and studies related to mathematics and economics in sport ([19]; [6]; [25]; [26]) not to mention all the others.

Some differences between the Summer and the Winter Olympic Games are also discussed. [22] say that the ability to participate in both Games is not the same to all countries and even if all the countries took part in the two Games, they will not have an equal ability to win medals. This study argues, as expected, that countries with heavy winter will have better results in the Winter Games than in the Summer Games. [3] Found home advantages in some modalities in the Winter Games related to familiarity with local conditions which could prejudice away athletes. In the same work presented before, [22] will argue that it has become easier to win any medal as the number of available medals in the Olympic Games has increased. From this idea it is possible to infer that it is harder to win a medal in the Summer Games than in the Winter Olympics games since the number of medals available in the Summer Games is higher than in the Winter Games.

As said by [20], due to the obtainment of the medals and all their positive impact as economy growth and a superior international prestige, many countries have been invested more and more to achieve a better position in the medals ranking in the Olympic Games. It was not different in the Winter Olympic Games.

Although there are not an official ranking to evaluate the countries results in the Olympic Games, as discussed by [37] the International Olympic Committee (IOC) presents the results in a table that suggest to the grant majority of people, include the media, that it is, in fact, a ranking. This table counted only the gold medal as criteria to order the countries. However, there are a lot of studies already published about alternative ranking in the Olympic Games. One of these understands that the ranking should suggest the efficiency of a country in turning their available resources on medals. That is, a rich country with a large population should be able to win more medals than a small and poor country. As [31] highlight, in a competitive economy resource allocation should be done efficiently, so that, the investment in sport is date sustainable over time. [40] Analyze the use of 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.

Initially, many of them have used Data Envelopment Analysis (DEA), proposed by [10] as a mathematical model to establish new models of assortment. [27] discussed the importance to consider the economic aspect of the country to

evaluate its results in the competition. So, this study proposed population and GNP as inputs and the medals as outputs. [26] Continued the study of [27] but included a new constraint considering that the total amount of medals is a constant. In a similar approach to choosing the inputs, [12] also used some social economics variables, not only GDP and population but also DEL index and IECS index. [25] used almost the same input as [27] but the authors decided to use GDP per capita and not only GDP as an input. In all these cases, data and knowledge applied would make a huge difference in assessing the robustness of a modeling system as discussed by [30]. Others studies in this field has been published as [48]; [53]; [25]; [51]; [49]; [54].

Nowadays, the search for new models, based on the reformulation of the classical DEA model, is reaching alternatives ways for the interpretation of data. For example, [49] discuss, by means of integer-valued DEA model, the performance of each country at 2008 Beijing Summer Olympic Games. Another example is the studies of [18] and [38] that uses DEA model with weight restrictions to ponder the importance of the medals; this methodology was first introduced by [34].

In that way, the Free Disposal Hull (FDH) provides additional analytical tool that enriches this theoretical framework. That method was developed by [13], and analyses the efficiency not including the convexity restriction of the production set. In that way, this model allows increasing and decreasing returns in any region of the production set.

As outlined by [32], the FDH is the most used non-convex DEA model, and that relies in the fact that in most of cases is desirable to measure de efficiency of an inefficient DMU "with targets that actually correspond to observed units rather than targets resulting from convex combinations of units".

In our case, we are interested in using FDH model to study the results of the Vancouver 2010 Olympic Games. Our main purpose is to establish some realistic target, in terms of the size of their delegations, to all the countries that took part in these Games and evaluate which results could be called benchmarks. This will help us to study countries that have established peculiar political sports decisions.

To do so, we take into consideration the proposal of [36] that used as an input, the number of athletes of each country as a way to evaluate their results in the competition. Our main objective is to analyze the delegation size in a view of the results got by the countries studied.

In this paper we will use the mathematical model FDH ([13]). The choice for the FDH model is justified since this model shows integer value for the targets in opposition to regular DEA models that establish their targets as a combination of different DMU. Besides, in spite of being considered an antique technique, the FDH model is still used by many authors as ([45]; [33]; [29]; [9]).

The model will have one input, the number of competitors for each country and three outputs, number of gold, silver and bronze medals considering a restraint in the weight of each medals. By gathering information about how many athletes these countries took to the game and related these numbers to the results of the Game (i.e., the number of medals won by these countries), we intend to evaluate whether there are some relationship between these variables. Since we want to understand the adequacy of the size of the delegation of athletes in comparison to the number of medals won by the countries, we are going to orient the FDH model to input.

The subsequent section pointed out some aspects of the Winter Olympic Game. The section 3 summarizes the FDH model and in the Section 4 we described the model used in this study. After that, we will present the results and a briefly analysis of them. Following that analysis we summarize our conclusions and some future research directions.

2 The Winter Olympic Games

As said before, the Winter Olympic Games tradition began in 1924 in Chamonix, France where 258 athletes from 16 countries attended to the Games. Since then it has been happened every four year. An exception occurred in 1940 and 1944 when the Winter Games was cancelled because the World War II.

Until 1992, both Games (summer and winter) were held in the same year. In 1986 was decided to intercalate the Games, so from 1992 on they have been staggered two years apart. So, the Winter Olympics Games in Albertville - 1992 was followed by the Winter Olympic Games in Lillehammer, in 1994.

According to International Olympic Museum (2007) in the first version of the Winter Olympic Games, from 16 countries that took part in it, the majority were from Europe and North America. Comparing to the last competition, held in Vancouver, Canada in 2010, 82 nations, as diverse as Hong Kong, Brazil, India and Ethiopia, attended to the Games. In terms of number of athletes, in Chamonix, France, 1924, 258 participants come

together while in Vancouver, Canada, 2010, almost 2600 athletes participated in the events.

In Chamonix, 1924, six sports were programmed as bobsleigh, curling, ice hockey, figure and speed skating, skiing and the military patrol race. Nowadays, the Winter Olympic Games had fifteen sports disciplined programmed. They were: alpine skiing, biathlon, bobsleigh, cross-country, curling, figure skating, freestyle skiing, ice hockey, luge, Nordic combined, short track, skeleton, ski jumping, snowboard and speed skating.

In relation to the number of medals distributed in these Games, in the Vancouver, 2010 Games, a total of 258 medals (including gold, silver and bronze) were disputed. Since many competitions were composed by teams, an amount of 615 medals was awarded.

3 FDH Model

We started this section showing in (1) the FDH model proposed by [13]. The model take into account each unity evaluate as Decision Making Unit, known as DMU.

In this model, the term h_0 is called the efficiency of the DMU_0 (evaluated DMU). We consider a set of n production units ($k=1,2,3...n$) using an input vector (1):

$$x_i = (x_{1k}, \dots, x_{ik}) \in R_+^i \quad (1)$$

That vector (1) produces an output vector (2):

$$y_j = (y_{1k}, \dots, y_{jk}) \in R_+^j \quad (2)$$

All the λ_k represents the improvement (increasing or reducing) that DMU_k has to do to reach the efficiency of the DMU_0 , established as a target. The input correspondence satisfying free disposability of inputs and outputs can be defined as h_{fdh} (3) [13]:

$$h_{FDH} = \left\{ \frac{x}{\sum_{k=1}^n \lambda_k \cdot y_1 \geq y, \sum_{k=1}^n \lambda_k \cdot x_1 \leq x, \sum_{k=1}^n \lambda_k = 1} \right\} \quad (3)$$

$$\lambda_k \in (0,1), k = 1, \dots, n$$

[32] Highlight that the non-convex nature of efficiency is expressed in the binary constrains associated to λ_k values. Without these restriction

the model would match up with the BCC model proposed by [5] where we technologic set correspond to the variable returns of scale.

4 Modeling

To describe the model that will be used to building the new ranking to the Vancouver 2010, Olympic Games we use the information mentioned before: our input will be the number of athletes carried by each country to the Olympic Games (as we have already explained in the introduction, we are interested in the adequacy of the delegation size to the number of medals won by the countries) and as outputs we used the number of gold, silver and bronze medals won by each country. In this variable we included weights restrictions also proposed by [35], [37] and [38] in which was considerate that the weight of the gold medal is bigger or equal to the weight of the silver medal and this one has weight bigger or equal to the weight of the bronze medal.

In addition, the difference weights between of the gold and the silver medals is not lower that the difference of weights between the silver and bronze medals. The DMU's will be all the countries that took part in the Winter Olympic Games held in Vancouver in 2010, including all that had not won any medals. In (4) we present the linear program used.

Min h_0

$$\begin{aligned}
 h_0 \cdot x_{nath} - \sum_{k=1}^n x_{nath} \cdot \lambda_k &\geq 0 \\
 y_g &< \sum_{k=1}^n y_{gk} \cdot \lambda_k - \gamma_1 - \gamma_3 \\
 y_s &< \sum_{k=1}^n y_{sk} \cdot \lambda_k + \gamma_1 - \gamma_2 + 2\gamma_a \\
 y_b &< \sum_{k=1}^n y_{bk} \cdot \lambda_k + \gamma_2 - \gamma_3 \\
 \sum_{k=1}^n \lambda_k &= 1, \lambda_k \in \{0,1\}_k, \forall k
 \end{aligned}
 \tag{4}$$

In the model (4) presented here, the term h_0 is called the efficiency of the DMU observed, i.e., the efficiency of the country analyzed. The variable x_{nath} is the number of athletes of the country analyzed and the variables y_g, y_s, y_b are the number of gold, silver and bronze medals, used as the outputs of DMU analyzed. All λ_k the represents the improvement (increasing or reducing) that DMU k has to do to reach the efficiency of the DMU₀, established as a target. Variables $\gamma_1, \gamma_2, \gamma_3$ are the

dual variables corresponding to the weight restrictions in the primal problem.

5 Results

Technical efficiency was calculated by nonparametric production frontier, Free Disposal Hull (FDH), using model (2). Our objective was estimate the ideal number of athletes that a country would need to take to the Games in order to win the same number of medals that it had already won. The results may be observed as follows.

In the first column of the table 1 shows the results of the FDH efficiency. As could be expected, the FDH model, increases the probability for having observations with efficiency score equal to one. As we can see Canada, Germany, USA, Norway, South Korea, China, Austria, Netherlands and Croatia were considered efficient. Moreover, we note that some countries, as Albania, Cayman Island and Chinese Taipei, called efficient, have not won any medals. These results are possible due to FDH model that denominate efficient any DMU that has unitary input. So, these countries are mathematically efficient although they are not really efficient at all.

The best relation between the numbers of medals and the numbers of athletes was acquired by South Korea. In addition, Canada was efficient by default because their number of gold medals was bigger than the others countries, in this case, Canada would always be efficient despite the number of athletes that it had brought to the competition.

Table1: Results for model (4)

Country	FDH Efficiency	Athletes	Total Number of Medals	Ideal Number of Athletes
Canada	1	220	26	220
Germany	1	166	30	166
United States	1	224	37	224
Norway	1	107	23	107
South Korea	1	46	14	46
China	1	96	11	96

Austria	1	88	16	88
Netherlands	1	34	8	34
Croatia	1	19	3	19
Albania	1	1	0	1
Algeria	1	1	0	1
Cayman Islands	1	1	0	1
Chinese Taipei	1	1	0	1
Colombia	1	1	0	1
Costa Rica	1	1	0	1
Ethiopia	1	1	0	1
Ghana	1	1	0	1
Hong Kong	1	1	0	1
Jamaica	1	1	0	1
Kenya	1	1	0	1
Mexico	1	1	0	1
Morocco	1	1	0	1
Pakistan	1	1	0	1
Portugal	1	1	0	1
Senegal	1	1	0	1
Sweden	0,8	120	11	96
Australia	0,6938	49	3	35
Poland	0,68	50	6	34
Great Britain	0,6538	52	1	34
Switzerland	0,6294	170	9	107
Azerbaijan	0,5	2	0	1
Bermuda	0,5	2	0	1

Cyprus	0,5	2	0	1
North Korea	0,5	2	0	1
Kyrgyzstan	0,5	2	0	1
Mongolia	0,5	2	0	1
Montenegro	0,5	2	0	1
Nepal	0,5	2	0	1
San Marino	0,5	2	0	1
South Africa	0,5	2	0	1
Tajikistan	0,5	2	0	1
Belarus	0,4857	70	3	34
Russia	0,4444	198	15	88
Slovakia	0,4047	84	3	35
Slovenia	0,3653	52	3	20
France	0,3511	131	11	46
Japan	0,3469	98	5	35
India	0,3333	3	0	1
Lebanon	0,3333	3	0	1
Peru	0,3333	3	0	1
Uzbekistan	0,3333	3	0	1
Israel	0,3333	3	0	1
Czech Republic	0,3238	105	6	35
Finland	0,3063	111	5	34
Italy	0,2956	115	5	34
Monaco	0,25	4	0	1
Iceland	0,25	4	0	1
Macedonia	0,25	4	0	1

Chile	0,25	4	0	1
Armenia	0,25	4	0	1
Bosnia& Herzegovina	0,2	5	0	1
Brazil	0,2	5	0	1
Turkey	0,166667	6	0	1
Lithuania	0,166667	6	0	1
Ireland	0,166667	6	0	1
Andorra	0,166667	6	0	1
Argentina	0,142857	7	0	1
Grécia	0,142857	7	0	1
Iran	0,142857	7	0	1
Moldova	0,1428	7	0	1
Liechtenstein	0,1111	9	0	1
Belgium	0,1	10	0	1
Georgia	0,0833	12	0	1
Serbia	0,0769	13	0	1
New Zeland	0,0588	17	0	1
Denmark	0,0555	18	0	1
Bulgaria	0,0526	19	0	1
Spain	0,0526	19	0	1
Hungary	0,05	20	0	1
Estonia	0,0333	30	1	1
Romania	0,0303	33	0	1
Kazakhstan	0,0256	39	1	1
Ukraine	0,0192	52	0	1
Latvia	0,0144	69	2	1

Other aspect to be taking into account is the Ideal Number of Athletes, as shown in the Table 1. These targets numbers were calculated by multiplying the efficiency of each country by the number of its athletes. In all the cases where countries are not efficient, the results indicated that the ideal number of athletes must be smaller than the actual number. The smallest efficiency represents a greater reduction in the number of athletes. For example, Latvia took to the Game 69 athletes, but to be considered efficient should have taken just 2. It is important to point out that this is not a desirable situation, because in the ideal case, to preserve the Olympic Spirit of compete is more important than win, some athletes will not won any medal but a country would cogitate to take them to the Games, despite the probability to win medals.

Another important point for consideration is the target reached by the DMUs. In the FDH model the λ_k is binary, other words, the countries are going to present just one benchmark, as showed in Table 2.

Even South Korea had presented de best relation between the numbers of medals and the numbers of athletes, Netherlands was the country which was more often benchmark. That happens because of the weight restrictions and the different scale presented by the countries.

Table 2: Benchmarks

Country	Benchmarks
Canada	Canada
Germany	Germany
United States	United States
Norway	Norway
South Korea	South Korea
Switzerland	Norway
China	China
Sweden	China
Austria	Austria
Netherlands	Netherlands
Russia	Austria

France	South Korea
Australia	Netherlands
CzechRepublic	Netherlands
Poland	Netherlands
Italy	Netherlands
Belarus	Netherlands
Slovakia	Netherlands
GreatBritain	Netherlands
Japan	Netherlands
Croatia	Croatia
Slovenia	Croatia
Latvia	Albania
Finland	Netherlands
Kazakhstan	Albania
Estonia	Albania
Albania	Albania

Senegal	Azerbaijan	Bermuda
Cyprus	North Korea	Kyrgyzstan
Mongolia	Montenegro	Nepal
San Marino	South Africa	Tajikistan
India	Lebanon	Peru
Uzbekistan	Israel	Monaco
Iceland	Macedonia	Chile
Armenia	Ukraine	Romania
Bosnia& Herzegovina	Brazil	Turkey
Lithuania	Ireland	Andorra
Argentina	Grécia	Iran
Moldova	Liechtenstein	Belgium
Georgia	Serbia	New Zealand
Denmark	Bulgaria	Spain
Hungary		

For all the countries that have not won any medal, as shown in table 3, the Benchmark was Albania (including itself). This happened because there are multiple solutions in the LP solution of efficient DMU in FHC. In fact, all country that took only one athlete and did not win any medal (or even a linear combination of these countries) could be an alternative benchmark for the countries that did not won medal and took more than one athlete.

Table 3: Countries that have not won any medal

Albania	Algeria	Cayman Islands
Chinese Taipei	Colombia	Costa Rica
Ethiopia	Ghana	Hong Kong
Jamaica	Kenya	Mexico
Morocco	Pakistan	Portugal

6 Final Considerations

This paper has proposed, using the non-parametric techniques, a FDH study to the results of Vancouver 2010 Olympic Games. Overall, the paper has demonstrated that it is feasible to use this technique to examine the productive performance of countries in the Olympic Games, input oriented. In particular, the application has shown that FDH can provide useful information regarding the efficiency patterns.

We have obtained some interesting results such as the Ideal Number of Athletes, that shows that the countries that presented efficiency smaller than one, would be efficient with that numbers of athletes. In other words, with smaller numbers of athletes took to the competition than the actual number. This is an interesting aspect since if these countries were able to reduce their number of athletes they might not win the same number of medals. Besides, we have to take in consideration all the questions related to the Olympic spirit and national unity, which involves

sending as athletes as possible to the competition believing that the participation is even more important than win any medals.

Despite the difference between the results found in the benchmark, this discussion seems aligned with [39] which analyzed the efficiency of the countries in the Winter Olympic Game of Vancouver using DEA model. Anyway, both concluded that some countries have not the best investment policy in sports.

Besides, as showed in [41], some countries were called efficient only by their higher number of the gold medal, and others were efficient even so they have not won any medal. These authors also find that some countries would be seeing efficient only whether the ideal number of their athletes was smaller than the actual number.

As we can see in comparison to the Summer Games, we found similar results, taking into account that the models were different.

As a future work suggestion, one can compare these results with the DEA model results [39], in addition, compare with an output orientation. Moreover, future studies may explore the economic aspect of these conclusions and develop a model of investment policy in sports for each country.

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