A DEA STUDY OF THE VANCOUVER 2010 WINTER OLYMPIC GAMES

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ABSTRACT

Many authors have been used Data Envelopment Analysis (DEA) as mathematical model 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 BCC DEA 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.

KEYWORDS: Winter Olympic Games, DEA model studies, BCC model. **DEA - Análise Envoltória de Dados.**

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 (Maguire and Poulton (1999); Bairner (2001); Houlihan (1997); Wong (2002); Hillvoorde, Elling and Stokvis (2010)), but also because, in the Modern era, under the market economic condition, its impact in the cities that host the Games has been considerate (Glynn, 2008) in addition to the benefit to their tourism industry (Glynn, 2008; Chen, 2009; Xiaoduo and Jianxin, 2008). 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 (Wallechinsky, 2004), 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, Johnson and Ali (2004) 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 (Bernstein (2000); Farrell (1989); Levine (1974); Ball (1972)), environmental and health studies (Hadjichristodoulou et al (2006); Allen et al.(2006); Weiler, Layton, Hunt (1998); Streets et al (2007)) and studies related to mathematics and economics in sport (Heazlewood (2006); Bernard and Lusse (2004); Li, Liang, Chen and Morita (2008); Lins, Gomes, Soares de Mello et al (2003)) not to mention all the others.

Some differences between these two games are also discussed. Johnson and Ali (2004) 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. Balmer, Nevill and Williams (2001) 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, Johnson and Ali (2004) 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 Hillvoorde, Elling and Stokvis (2010), 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 Soares de Mello, Angulo-Meza and Silva (2008) 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. Many of them have used Data Envelopment Analysis (DEA), proposed by Charnes et al (1978) as a mathematical model to establish new models of assortment. Lozano et al (2002) 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.

Lins et al (2003) continued the study of Lozano et al (2002) but included a new constraint considering that the total amount of medals is a constant. In a similar approach to choosing the inputs, Churilov and Flitman (2006) also used some social economics variables, not only GDP and population but also DEL index and IECS index. Li et al (2008) used almost the same input as Lozano et al (2003) but the authors decided to use GDP per capita and not only GDP as an input. Others studies in this field has been published as Wu et al (2009a); Yang et al., 2009; Li et al., 2008; Wu et al., 2008; Wu et al., 2009b; Zhang et al., 2009.

In our case, we are interested in using DEA model to study the results of the Vancouver 2010 Olympic Games. Our main purpose is to establish some realistic target 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 Soares de Mello et al (2009) that used as an input, the number of athletes of each country as a way to evaluate their results in the competition.

In this paper we will use the mathematical model BCC DEA (Banker et al, 1984). 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 importance of the number of athletes took by the countries, we are going to orient the DEA model to input.

The subsequent section pointed out some aspects of the Winter Olympic Game. The section 3 summarizes the DEA 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. Dea Model

We started this section showing in (1) the DEA BCC model proposed by Banker et al (1984). The model take into account each unity evaluate as Decision Making Unit, known as DMU.

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

In this model, the term h_0 is called the efficiency of the DMU 0, i.e.. the DMU that is been evaluated. The variable x_{ik} is the input i of the DMU k and the variable y_{jk} is the output j of DMU k. 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. As this model is oriented to input, to achieve efficiency, a DMU has to reduce its input, proportionally.

4. Modelling

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 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 Soares de Mello, Angulo-Meza and Branco da Silva (2008;2009) and Soares de Mello et al (2008) 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 (2) we present the linear programme used.

$$
\begin{aligned}
& Min\ h_0 \\
& subject\ to \\
& h_0 x_{NATHL0} - \sum_{k=1}^{n} x_{NATHLk} \lambda_k \geq 0 \\
& y_G \leq \sum_{k=1}^{n} y_{Gk} \lambda_k - \gamma_1 - \gamma_3 \\
& y_S \leq \sum_{k=1}^{n} y_{Sk} \lambda_k + \gamma_1 - \gamma_2 + 2\gamma_3 \\
& y_B \leq \sum_{k=1}^{n} y_{Bk} \lambda_k + \gamma_2 - \gamma_3 \\
& \sum_{k=1}^{n} \lambda_k = 1 \\
& \lambda_k \geq 0, \forall k
\end{aligned}
\qquad (2)
$$

In the model (2) 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_{NATHL0} is the number of athletes of the country analyzed and the variables y_G, y_S and y_B are the number of gold, silver and bronze medals, used as the outputs of DMU analyzed. The variable x_{NATHLk} is the number of athletes of the country k and the variables y_{Gk}, y_{Sk} and y_{Bk} are the number of gold, silver and bronze medals, used as the outputs of DMU k. 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. Variables γ_1, γ_2 and γ_3 are the dual variables corresponding to the weight restrictions in the primal problem.

5. Results

In this section we summarized the results obtained using model (2). Our objective was calculate the ideal number of athletes that a country need to take to the Games in order to win the same number of medals that it had already won. These targets numbers were calculated by multiplying the efficiency of each country by the number of its athletes.

Other information was the Number of Medal Winner. These numbers represents the how many athletes indeed won medals. In ice hockey, for example, the team was formed by eighteen players (in media). So, if one country won this game, in fact, it had won eighteen medals because each of its athletes won a medal.

Table 1 showed all the results. The results in the column Ideal Number of Athletes were rounded.

COUNTRY	DEA EFFICIENCY	ATHLETES	TOTAL NUMBER OF MEDALS	NUMBER OF MEDAL WINNERS	IDEAL NUMBER OF ATHLETES
Canada	1	220	26	87	220
Germany	1	166	30	52	166
United States	1	224	37	88	224
Norway	1	107	23	38	107
South Korea	1	46	14	17	46
Albania	1	1	0	0	1
Algeria	1	1	0	0	1
Cayman Islands	1	1	0	0	1
Chinese Taipei	1	1	0	0	1
Colombia	1	1	0	0	1
Costa Rica	1	1	0	0	1
Ethiopia	1	1	0	0	1
Ghana	1	1	0	0	1
Hong Kong	1	1	0	0	1
Jamaica	1	1	0	0	1
Kenya	1	1	0	0	1
Mexico	1	1	0	0	1
Morocco	1	1	0	0	1
Pakistan	1	1	0	0	1
Portugal	1	1	0	0	1
Senegal	1	1	0	0	1
Netherlands	0,911765	34	8	11	31
Austria	0,676768	88	16	26	60
Croatia	0,56015	19	3	3	11
Azerbaijan	0,5	2	0	0	1
Bermuda	0,5	2	0	0	1
Cyprus	0,5	2	0	0	1
North Korea	0,5	2	0	0	1
Kyrgyzstan	0,5	2	0	0	1
Mongolia	0,5	2	0	0	1
Montenegro	0,5	2	0	0	1
Nepal	0,5	2	0	0	1
San Marino	0,5	2	0	0	1
South Africa	0,5	2	0	0	1
Tajikistan	0,5	2	0	0	1
Poland	0,405714	50	6	9	20
China	0,401042	96	11	19	39
India	0,333333	3	0	0	1
Israel	0,333333	3	0	0	1
Lebanon	0,333333	3	0	0	1
Peru	0,333333	3	0	0	1

COUNTRY	DEA EFFICIENCY	ATHLETES	TOTAL NUMBER OF MEDALS	NUMBER OF MEDAL WINNERS	IDEAL NUMBER OF ATHLETES
Uzbekistan	0,333333	3	0	0	1
Australia	0,326531	49	3	3	16
Sweden	0,320833	120	11	17	39
France	0,277535	131	11	14	36
Switzerland	0,270588	170	9	12	46
Russia	0,266554	198	15	23	53
Armenia	0,25	4	0	0	1
Chile	0,25	4	0	0	1
Macedonia	0,25	4	0	0	1
Iceland	0,25	4	0	0	1
Monaco	0,25	4	0	0	1
Slovenia	0,20467	52	3	3	11
Bosnia & Herzegovina	0,2	5	0	0	1
Brazil	0,2	5	0	0	1
Czech Republic	0,193197	105	6	9	20
Japan	0,174198	98	5	8	17
Andorra	0,166667	6	0	0	1
Ireland	0,166667	6	0	0	1
Lithuania	0,166667	6	0	0	1
Turkey	0,166667	6	0	0	1
Great Britain	0,163461	52	1	1	8
Finland	0,153797	111	5	47	17
Belarus	0,152041	70	3	3	11
Italy	0,148447	115	5	5	17
Argentina	0,142857	7	0	0	1
Greece	0,142857	7	0	0	1
Iran	0,142857	7	0	0	1
Moldova	0,142857	7	0	0	1
Estonia	0,140476	30	1	1	4
Slovakia	0,126701	84	3	3	11
Liechtenstein	0,111111	9	0	0	1
Kazakhstan	0,108059	39	1	1	4
Latvia	0,10766	69	2	5	7
Belgium	0,1	10	0	0	1
Georgia	0,083333	12	0	0	1
Serbia	0,076923	13	0	0	1
New Zealand	0,058824	17	0	0	1
Denmark	0,055556	18	0	0	1
Bulgaria	0,052632	19	0	0	1
Spain	0,052632	19	0	0	1

COUNTRY	DEA EFFICIENCY	ATHLETES	TOTAL NUMBER OF MEDALS	NUMBER OF MEDAL WINNERS	IDEAL NUMBER OF ATHLETES
Hungary	0,05	20	0	0	1
Romania	0,030303	33	0	0	1
Ukraine	0,019231	52	0	0	1

Tabela 1 – Results for model (2)

In the table (1) we note that some countries, as Cayman Island and Chinese Taipei, called efficient have not won any medals. These results are possible due to DEA model that denominate efficient any DMU that has unitary input. So, these countries are mathematically efficient although they are not really efficient at all. All the countries classified in this situation are listed in table 2. Moreover, Canada was seeing efficient since 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.

COUNTRY	DEA EFFICIENCY	ATHLETES	TOTAL NUMBER OF MEDALS	NUMBER OF MEDAL WINNERS	IDEAL NUMBER OF ATHLETES
Albania	1	1	0	0	1
Algeria	1	1	0	0	1
Cayman Islands	1	1	0	0	1
Chinese Taipei	1	1	0	0	1
Colombia	1	1	0	0	1
Costa Rica	1	1	0	0	1
Ethiopia	1	1	0	0	1
Ghana	1	1	0	0	1
Hong Kong	1	1	0	0	1
Jamaica	1	1	0	0	1
Kenya	1	1	0	0	1
Mexico	1	1	0	0	1
Morocco	1	1	0	0	1
Pakistan	1	1	0	0	1
Portugal	1	1	0	0	1
Senegal	1	1	0	0	1

Tabela 2 – Countries called efficient due to their unitary inputs.

Other aspect to be taking into account is the Ideal Number of 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. 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. For these countries we evaluate the benchmarks and showed the relevant results in table 3.

COUNTRY	BENCHMARKS					
	Canada	Germany	United States	Norway	South Korea	Albania
Canada	1	0	0	0	0	0
Germany	0	1	0	0	0	0
United States	0	0	1	0	0	0
Norway	0	0	0	1	0	0
South Korea	0	0	0	0	1	0
Switzerland	0	0	0	0	1	0
China	0	0	0	0	0,83333331	0,166667
Sweden	0	0	0	0	0,83333331	0,166667
Austria	0	0	0	0,222222	0,77777778	0
Netherlands	0	0	0	0	0,66666661	0,333333
Russia	0	0	0	0,111111	0,88888889	0
France	0	0	0	0	0,78571424	0,214286
Australia	0	0	0	0	0,33333322	0,666667
Czech Republic	0	0	0	0	0,42857138	0,571429
Poland	0	0	0	0	0,42857131	0,571429
Italy	0	0	0	0	0,35714272	0,642857
Belarus	0	0	0	0	0,21428555	0,785714
Slovakia	0	0	0	0	0,21428555	0,785714
Great Britain	0	0	0	0	0,16666653	0,833333
Japan	0	0	0	0	0,35714279	0,642857
Croatia	0	0	0	0	0,21428562	0,785714
Slovenia	0	0	0	0	0,21428562	0,785714
Latvia	0	0	0	0	0,1428571	0,857143
Finland	0	0	0	0	0,35714279	0,642857
Kazakhstan	0	0	0	0	0,07142852	0,928571
Estonia	0	0	0	0	0,07142852	0,928571
Albania	0	0	0	0	0	1

Tabela 3 - Benchmarks

For all the countries that have not won any medal, the Benchmark was Albania (including itself). This happened because there are multiple solutions in the LP solution of efficient DMU in DEA. 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 a benchmark.

6. Final Considerations

We have proposed, in this paper, a DEA study to the results of Vancouver 2010 Olympic Games. We have obtained some interesting results such as the Ideal Number of Athletes smaller than the actual number of athletes took to the competition by some countries. 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.

In table (1) we notice an interesting result. To Finland the Ideal Number of Athletes is smaller than the Number of Medal Winners. This situation indicates that probably the investments policy in sports of this country is based in team-based sports which is not a good option to win medals.

This discussion seems aligned with Soares de Mello et al (2009) which analyzed the results of a Summer Olympic Game. Despite the difference between the models, both concluded that some countries have not the best investment policy in sports.

As a future work suggestion, one can use integer variables as proposed by Lozano et al (2002). Another option is to use the FDH model. 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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