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OLYMPIC MEDALS: SUCCESS PREDICTIONS FOR RÍO-2016

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ABSTRACT

Medals are the maximum exponent of successful sporting events. One of the most relevant of these sporting events is the Olympic Games, which gathers major athletes and teams from across the world every four years. Predicting the distribution of the medals at these Games is nothing new. As a matter of fact, this practice gained considerable popularity just before the latest edition of the London-2012 Games. After the games were over, this study took a look at the results and the predictions made at the time to determine which of these predictions had been the most accurate. This information was then used to carry out an estimation exercise to predict the medal distribution for the upcoming edition of the Games in Rio-2016. To guarantee a greater predictive success, several predictions were carried out in ranges for the main Olympic delegations. The final estimation provides a ranking of medals per country. This classification is consistent with former rankings, especially those of leading countries.

***Key words*:** Olympic Medals; Olympic success; Predictions; Rio-2016.

INTRODUCTION

The Olympic Games are the ultimate sports showcase. These Games follow a long tradition dating back to ancient Greece, which Pierre de Coubertin portrayed in the first edition of the modern Olympic Games in Athens in 1896[1]. The Olympic Charter defines the values of Olympism as "a philosophy of life which exalts and combines the qualities of body, will and spirit as a balanced whole. Blending sport with culture and education, Olympism seeks to create a way of life based on the joy of effort, the educational value of setting a good example and the respect for fundamental universal ethical principles" (IOC, 2014:14). Baron de Coubertin probably never imagined that the movement created in the late 19th century was going to turn into an entirely economic event. The legacy of the Olympic Games, the maximum paradigm of mega-sporting events, is far beyond a mere sport event for the territories hosting them (Hiller, 2000). Sporting success or failure of participating delegations has been analysed and evaluated increasingly from an economic standpoint (Humphreys *et al.*, 2011). As Kasimati (2003) points out, a great number of countries considers that this event serves as a showcase for publicity beyond their borders, as well as an engine to spur economic development.

[1] The games took place in Athens from 6 to 15 April 1896 in commemoration of the birth of the Olympic Games in Greece.

Even though the London Games were not the first games to see this, 2012 witnessed the proliferation of predictions and approximations of sporting results for each of the delegations. Once the games were held, the objective for this study was two-fold: (a) to check on the accuracy of past predictions; and (b) to use what was learned from these methods to improve predictions. Following Wicker *et al*. (2012), improved predictions are useful to the participating countries' sport authorities who, in light of this information, may better establish goals, allocate resources, define sport policies or plan activities. All sports can benefit from knowing more about the current situation, as well as knowing more about the expected medium-term situation.

PURPOSE OF RESEARCH

The hypothesis for this research relies on the likelihood of determining Olympic success through more accurate predictions. After checking the extent to which the predictions are fulfilled, new methods were applied in an attempt to improve previous ones. Once this premise is proven, a prediction is made for the Olympic medals for Brazil's Rio de Janeiro-2016 Games. The methods which improve prediction will be submitted jointly but only for those countries where the likelihood of success is greater, namely the ones that will obtain more medals (Forrest *et al*., 2010).

This article is organised as follows. The second section reviews the predictions made of Olympic medals to date with special attention to the predictions made on the occasion of the London-2012 Games. The third section weighs up two key aspects of the prediction process dealing with the variables and the methods applied for several predictions. The fourth section proposes the predictions for the Rio-2016 Games and the final section concludes with the main results of the study.

REVIEW OF OLYMPIC MEDAL PREDICTIONS

Predicting the number of medals obtained by athletes participating in the Olympic Games is nothing new. Indeed, stakes were one of the main attractions of the classic games in competitions like racing or cockfighting, in which the importance of the bet usually overshadows that of actually winning the game. However, as from the 1950s, the importance of the sport component of these games has given way to the ever-increasing importance of economic, sociological and political components which has, in turn, begun to capture the interest of academics and researchers alike. Sporting success is quantified according to the variable "medals won", as well as the type of medal won.

Within the Academia, one of the pioneers in this kind of prediction is Professor Daniel Johnson of the University of Colorado, who made predictions on four Olympic Games using an assorted set of data for his predictions (including economic variables)[2]. Likewise, Andrew Bernard of Dartmouth College has also been making his own predictions since the year 2000[3]. Andreff *et*

[2] A summary of this may be found in:
https://faculty1.coloradocollege.edu/~djohnson/olympics.html

[3] More information in: http://mba.tuck.dartmouth.edu/pages/faculty/andrew.bernard/

al. (2008), Maennig and Wellebrock (2008) and Shibli and Bingham (2008) joined Bernard (2008) and Johnson and Ali (2008) in making predictions for the Beijing Games. Although London-2012 represented the milestone for the moment, the exponential growth of this type of work, this numerical growth came along with the use of more complex techniques and an increased number of variables in the design models. Williams technically implemented Bernard's usual predictions (Williams, 2012). Likewise, the predictions of Johnson and Alonso-Arenas (2012) also became available. Authors, such as Andreff (2010), Forrest *et al*. (2010), Kuper and Sterken (2012) and Nevill *et al*. (2012), all conducted their own predictions in much the same way.

In the private sector, consultants and financial institutions carried out similar studies. The investment bank, *Goldman Sachs*, conducted one of the most wide-spread studies to predict the number of medals for each country at the Games. This financial institution based its predictions on an economic indicator called "Growth Environment Score"[4], which described each country according to the function of its state of development (Goldman Sachs, 2012). *PricewaterhouseCoopers* (2012) made its own projections by using the services of the company, Infostrada Sports, and crossing macro-economic data. In Spain, the consultancy firm, Conento (2012), also developed a statistical model to predict medals for the major countries participating in the London Games. Similarly, the Australian Olympic Committee estimated a rank of medals for the Olympics in 2012 based on the results of the World Championships, World Cups and other major international events[5]. Additionally, the media have not only echoed the projections, but they have also attempted to use them to make their own predictions. The most relevant examples of this are "medal tracker"[6] of *USA Today* and "virtual forecaster" of Australia's *Herald Sun*[7]. The latter still predicts who will step up on the Olympic podium according to sporting criteria given by experts of the brands used by athletes at each of the international sport meets. Finally, *Financial Times*, elaborated the so-called "consensus estimate"[8], a compendium of a vast number of predictions.

METHODOLOGY

The previous section reviewed the prediction models for the Olympic medals based on calculations and predictions using economic data over recent years. These models use *data mining* techniques to obtain correlations or patterns for cases like those used for this research, in which data is abundant. The starting point within this data-set should purely be sport information, namely the athletic performance of each of the delegations. However, nearly all of the variables used are economic (Flatau & Emrich, 2013). The reason for not using other

[4] This self-elaborated indicator gathers a series of political, economic and social conditions that affect the productivity and growth of these countries.
[5] http://corporate.olympics.com.au/09715C2F-5056-B031-6A82E667D964D795
[6] http://usatoday30.usatoday.com/sports/olympics/medal-tracker.htm
[7] http://www.heraldsun.com.au/sport/london-olympics/medal-table
[8] http://blogs.ft.com/ftdata/2012/07/26/olympic-medal-table-predictions-london-2012/

variables (technical or sport) is the great heterogeneity among the different sports[9] and the fact that this type of information is required for all the countries. Andreff and Andreff (2010) point out that, when predicting, one should bear in mind a number of issues that will affect the final results. Among them are:

- The state/condition of host country (in the current or previous editions);
- The differences between team and individual sports;
- The influence of sport stars; and
- The country's political regime (dictatorship vs. democracy)

Economic variables help explain and predict success in the Olympics, that is, the number of medals won by the athletes in each of the Olympic events. A totally other matter is the extent to which these variables may affect the number of medals that are actually won. Following Bernard and Busse (2004), it may be said that achieving Olympic medals closely correlates with the population and the wealth of a country. The population indicator is evident (although there could be an alternative to the absolute population figure). However, this is not the case when quantifying the second indicator. The first question that arises here is whether wealth should be a relative or absolute term. The relative term, per capita, is the most common.

Recent studies have extended the range of economic variables employed. Complementary to the country's income (measured in terms of GDP), the aforementioned study by Bernard and Busse (2004), had already incorporated the income level of the population. This same variable was once again present in studies conducted on the occasion of the London-2012 games, for example by the consultancy firm, *PricewaterhouseCoopers* (2012). Since then, additional economic conditions like macroeconomic stability, macroeconomic conditions, human capital, technology and the microeconomic environment (concerning businesses) have also been observed. Finally, Vagenas and Vlachokyriakou (2012) also incorporated aspects like the degree of urbanisation, inflation, unemployment and health expenditure for each of the countries.

As for the prediction methods, Andreff and Andreff (2010) suggest the work of Bernard and Busse (2004) to be "the best economic model developed for estimating and predicting Olympic performance". These authors used a Tobin (1958) model in which the two main independent variables are those identified above: population and gross domestic product. The same model was used by Bian (2005), Forrest *et al*. (2010) and Nevill *et al*. (2012). The other benchmark for Olympic predictions, Johnson and Ali, used a Probit model (Johnson & Ali, 2008). Other authors, like Andreff (2010), used a logit model, while Shibli and Bingham (2008) and PricewaterhouseCoopers (2012) used a linear regression. The regression with panel data has been used as a prediction method by Kuper and Sterken (2012) and Goldman Sachs (2012), while Conento (2012) developed a mathematical model obtained through a Poisson

[9] This aspect has an important impact in terms of individual sports as opposed to team sports. In the first case, the medal is for the athlete, while in the second case, the medal is for the team and this affects the final medal count.

regression[10]. Neural networks have also been employed to predict medals. Such is the case of Condon *et al.* (1999) for the 1996 games. Even though this method was never used for the Games again, it has been used for other mega-events. Hematinezhad *et al*. (2011), for example, used it for the Asian Games[11].

RESULTS

Before estimating the medals for the Rio-2016 Games, the study first examined the results of London-2012 to determine which of the predictions had been the most successful. Seven predictions were found to be accurate given that their correlation with the actual medals was above 97% (Table 1).

Table 1. **CORRELATIONS BETWEEN MEDAL PREDICTIONS AND LONDON-2012 RESULTS**

Prediction made by:	**Correlation**	**Number**
Financial Times (UK)	0.9865966	85
Williams (2012)	0.9825133	85
PricewaterhouseCoopers (PWC)	0.9822014	77
Goldman Sachs	0.9818714	48
Herald Sun (Australia)	0.9775409	71
USA Today	0.9773890	71
Johnson (2012)	0.9719374	61

The *pairwise* method was used to optimise the calculation of each coefficient, thus the number is different for each case. The correlations are very high; therefore, all the predictions could be considered fairly accurate. Moreover, the first 2 predictions were good for 85 countries. The first 2 methods are the ones that correlated best with the actual results. This justifies why the researchers chose to focus on them. Of interest is the fact that the *Financial Times* (the most effective) used a combination of various prediction methods for its forecasts.

Table 2 shows the economic variables employed. These variables are conditioned by their availability in *The World FactBook*, which the CIA issues and makes available online periodically[12]. The literature broadly considers the first 2, GDP and population, to be the main factors (Bernard & Busse, 2004; Andreff *et al*., 2008). Data concerning the medals of each country are added to this.

[10] The *USA Today* prediction method is the only one that uses a classification algorithm based on prior recent sports results.
(http://usatoday30.usatoday.com/sports/olympics/medal-tracker.htm)
[11] Celik and Gius (2014) indicate that neuronal networks have been extensively employed in the analysis of sports success in the Olympics, even though predicting was never the purpose.
[12] https://www.cia.gov/library/publications/resources/the-world-factbook/

Five prediction methods were considered: Linear regression model; Poisson regression model; Random Forest (RF); Support Vector Machines (SVM); and Relevance Vector Machine (RVM). The first 2, Linear and Poisson, have already been used in the literature: Shibli and Bingham (2008) and PricewaterhouseCoopers (2012) for the former and Conento (2012) for the latter. The other 3 forecasting methods have not been applied to estimate Olympic medals yet. However, they are being used in other sport fields increasingly. For example, Hothorn and Müller (2010), Schumaker *et al*. (2010) and Demers (2015) use them to carry out their estimations.

Table 2. **VARIABLES**

Variables	Unit of measurement
Gross domestic product	$ billions
Population	No. of people
Life expectancy	years
Health expenditure	% of GDP
Employment rate	%
Youth employment rate	%
Gross fixed investment	%
Public debt	% of GDP
Inflation rate	%
Value of stock on the stock market	US$
Direct foreign investment entered	US$
Checking account balance	US$
Exports	$ billions
Imports	$ billions
Gold and currency reserves	US$
Electricity consumption	Billions of kWh
Petrol consumption	Barrels/day
Natural Gas consumption	Cubic meters
Telephones	Landlines in use
Internet users	Number
Railways	km
Roads	km
Airports	Number

The Random Forest is a nonlinear regression method using a large number (500) of regression trees obtained through random permutation. Each tree is constructed by choosing the partition (corresponding to an explanatory variable) at each step which minimises the mean squared error (MSE). This is then applied to a different bootstrap sample obtained from the original data leaving out a third of the cases. This allows one to measure the error rate and avoid overfitting, a problem common to other procedures. The Support Vector Machines (SVM) (Vapnik & Vapnik, 1998) is a non-probabilistic regression model supervised by neural networks. Finally, the Relevance Vector Machine is a Bayesian regression model with neural networks and the same functional form as the SVM, which usually renders better results. The best prediction method was selected as follows. First, a prediction was made for the last games

held, which in this case would be for London-2012. In so doing, use was made of variables, such as sport medals for the previous two games, Beijing and Athens. The regression and prediction methods with the greatest explanatory power were verified and contrasted the results with the actual results obtained in London. After this, these methods were applied to predict the medals for each country at the Rio-2016 Games.

Table 3. **CORRELATION BETWEEN PREDICTIONS AND LONDON-2012 MEDAL RESULTS**

Prediction method	Correlation with medal results 2012
Linear regression model	0.9899380
Relevance Vector Machine	0.9879273
Poisson regression model	0.9852042
Support Vector Machines	0.9081173
Random Forest	0.8919492

Table 3 displays the correlations between the number of actual medals in London-2012 and the various predictions in descending order. The top 3 models (Linear, Relevance Vector Machine and Poisson) had a higher correlation with the target variable for the best predictions (*Financial Times* 0.983; PWC 0.980, Williams 0.979). The degree of adjustment of the first 2 may be observed in Figure 1 and Figure 2. This, therefore, justifies the use of the 3 methods to estimate Rio-2016. Table 4 summarises the predictions.

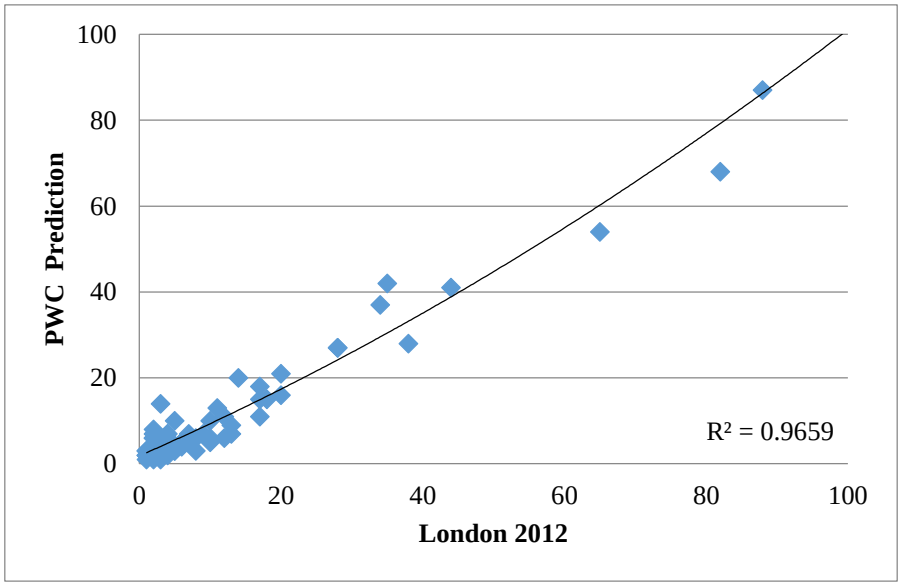

Figure 1. **ADJUSTMENT OF *FINANCIAL TIMES* PREDICTION FOR LONDON-2012**

Table 4. **PREDICTIONS FOR MEDALS IN RIO-2016**

Country	No. predicted medals Linear	Poisson	RVM	Country	No. predicted medals Linear	Poisson	RVM
United States	101	106	104	Switzerland	6	4	6
China	81	80	88	Ukraine	21	20	6
Russia	87	88	81	Bulgaria	2	2	5
Great Britain	69	60	65	Colombia	9	8	5
Germany	46	47	44	Slovakia	3	4	5
Japan	43	42	37	Slovenia	3	4	5
Australia	30	31	36	Greece	1	1	5
France	31	29	33	Kenya	9	9	5
South Korea	29	31	27	Lithuania	5	6	5
Italy	28	28	25	South Africa	9	10	5
Canada	20	19	17	Trinidad & Tobago	6	5	5
Netherlands	23	23	17	Tunis	5	5	5
Spain	19	20	16	Uzbekistan	6	5	5
Brazil	17	17	13	Venezuela	2	2	5
Mexico	10	11	11	Armenia	3	3	4
Iran	14	14	10	Estonia	2	2	4
Jamaica	12	12	10	Ethiopia	8	8	4
Finland	2	2	9	Georgia	4	4	4
Poland	11	11	9	Latonia	2	2	4
India	7	8	8	Moldova	1	2	4
Morocco	3	2	8	Mongolia	4	4	4
New Zealand	16	15	8	Algeria	3	1	3
Portugal	2	2	8	Ireland	3	4	3
Argentina	0	2	7	Norway	4	5	3
Denmark	9	9	7	Turkey	3	2	3
Egypt	7	6	7	Azerbaijan	5	7	2
Kazakhstan	10	12	7	Bahamas	2	1	2
Czech Republic	9	10	7	Thailand	2	2	2
Dominican Rep.	2	2	7	Chinese Taipei	2	2	1
Singapore	5	3	7	Tajikistan	-1	0	1
Sweden	7	7	7	Belgium	3	2	0
Croatia	8	7	6	Belarus	5	5	0
Cuba	9	11	6	Indonesia	-1	0	0
Hungary	16	17	6	Malaysia	4	3	0

RVM= Relevance Vector Machine

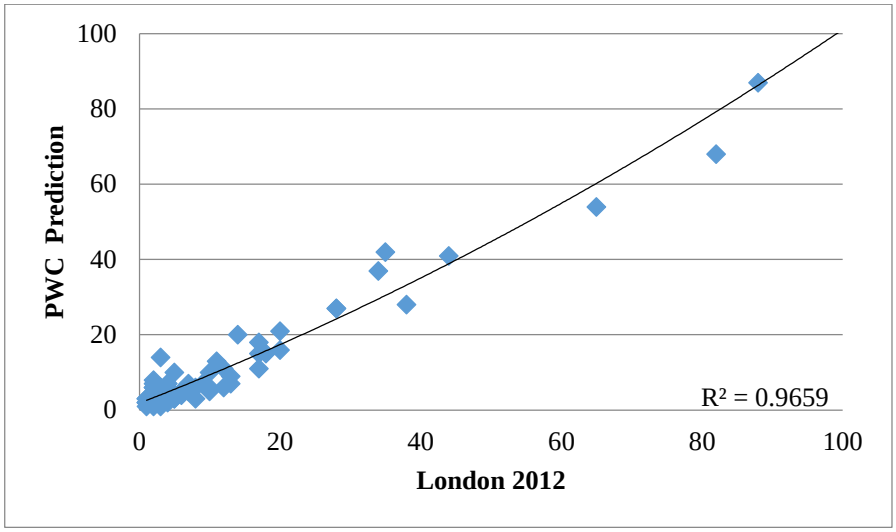

Figure 2. **ADJUSTMENT OF PRICEWATERHOUSECOOPERS PREDICTION FOR LONDON-2012**

CONCLUSIONS

Predicting Olympic Games medals is nothing new. However, the predictions for the latest edition of the 2012 London Olympics witnessed a considerable increase in the methods and variables used for this purpose. This paper provides innovative methodological elements and new statistical techniques to predict sport results better than previous methods have.

Error! Reference source not found shows a summary of the predictions. Following Forrest *et al*. (2010), it combines the three methods at intervals and focuses only on countries with over 10 medals. The width of the window does not indicate a confidence interval; it does not intend to measure the accuracy of the estimate, but rather show the differences between the three proposed models. The authors believe it was more reasonable to apply each of the methods separately. Thus it is up to the reader to judge the adequacy and reliability of each of the methods based on the criteria set (correlation of prediction with actual results in the past for each method) rather than building a single prediction by combining the final results of the different methods[13].

The summary in Table 5 combines the three prediction methods. Presenting a range of possible medals improves the chances of predicting successfully. Countries with a small number of medals are excluded from the prediction because their expected results vary more than the actual results. In this case, the threshold was set at 10 medals; that is, this is a tenth of the medals won by the team winning the most medals. Finally, it is important to stress that medal

[13] A combined prediction does not necessarily improve the degree of adjustment of each of the methods one by one.

ranking is traditionally very stable, especially in terms of the leading countries, although this is less so in terms of positions. The current predictions confirm this.

Table 5. **PREDICTED MEDALS AT RIO 2016: SUMMARY OF MAIN COUNTRIES**

Country	No. of predicted medals[14]
United States	101-106
Russia	81-88
China	80-88
Great Britain	60-69
Germany	44-47
Japan	37-42
Australia	30-36
France	29-33
South Korea	27-31
Italy	25-28
Netherlands	17-23
Canada	17-20
Spain	16-20
Brazil	13-17
Iran	10-14
Jamaica	10-12
Mexico	10-11
Poland	9-11
New Zealand	8-16
Kazakhstan	7-12
Czech Republic	7-10
Hungary	6-16
Cuba	6-11
Ukraine	6-21
South Africa	5-10

In conclusion, participating countries are the first to benefit from improved Olympic sporting result predictions. These predictions provide information, in advance, that may help plan medium- and long-term national sport policies. Sport with a greater chance of success will also

[14] This only includes countries expected to win more than 10 medals

benefit because local authorities will presumably focus greater attention on them. Furthermore, improved predictions may also affect the sport industry as a whole given that greater economic resources may be assigned and administered much more efficiently.

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