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INVESTIGATING THE EFFICIENCIES OF WORLD CUP TEAMS VIA DEA APPROACH

Abstract:

It is crucial to analyze football teams since football has increasingly become a significant industry within the economy. Data Envelopment Analysis (DEA) has been applied to many branches and especially to football. This paper investigates the technical efficiency levels of national teams participating in World Cup 2014 to shed light on the sport performance. Input oriented CCR/BCC model and super efficiency analyses have been used to investigate the football efficiencies. In this study, passes completed, attempts on target and possession are used as input while the only output is goal scored. The results have illustrated that World Cup winner Germany is found as efficient on both CCR and BCC model. On the other hand, only four teams are technically efficient within 32 teams while nine teams have demonstrated pure efficiency. Colombia is the most efficient team for both CCR and BCC super efficiency model. In this regard, we may conclude that efficiency would be a viable instrument in analyzing the football teams.

Keywords:

DEA, World Cup, Football Efficiency.

JEL Classification: C60, C61, L83

1. Introduction

Football is one of the most exciting sport branch for the people. The football has increasingly become a substantial industry within the world economy.

Data Envelopment Analysis (DEA) is a non-parametric efficiency technique based on measuring relative efficiency of decision making units (DMUs) that have multiple inputs and outputs. The concept of data envelopment analysis (DEA) was first introduced by Charnes et al. (1978) (Kao and Liu, 2014: 90). DEA provides analysts with target values that could convert inefficient DMUs into efficient DMUs (Iribarren et al., 2014: 527).

Measuring performance of DMUs is significant due to some reasons (Sport England, 2001: 3):

- If you couldn't measure outcomes, you couldn't reveal the situation properly.
- If you couldn't determine achievement, you couldn't reward it.
- If you couldn't reward success, you're likely rewarding failure.
- If you couldn't determine deficiency, you couldn't improve it.

Academic interest in the professional team sports dates back as far as the mid-1950s. The efficiency of football associations have already been analyzed in the literature.

Barros and Barrio (2008) examines the technical efficiency of the English football Premier League. Villa and Lozano (2016) introduces a novel approach called network DEA to evaluate the scoring efficiency of football teams in a match at La Liga. Bosca et al, (2009) investigates technical efficiency of Italian and Spanish football for three seasons.

Kern (2012) introduced two-stage data envelopment analysis to measure the efficiency of English Premier League football teams. Sanchez (2007) applied three-stage-DEA model to Spanish La Liga separating the teams' economic behavior into three elements. Tiedemann et al, (2011) employ Metafrontier DEA approach to measure players' efficiency scores depending on their playing positions. Barros and Leach (2006) applies DEA method to investigate the performance of English Premier League football clubs taking into consideration sport and financial variables.

The goal of this paper is to investigate the efficiency values of national teams participating in 2014 World Cup. In this regard, CCR, BCC versions and super efficiency model of DEA technique have been applied to national teams so as to find out the efficiency score levels. The main contribution of this study to literature is that there have been no study applied to World Cup teams.

The rest of the study is organized as follows; section two briefly mentions information about World Cup and section three presents the DEA model. Section four illustrates empirical results; finally, section five provides the concluding remarks.

2. Information about World Cup

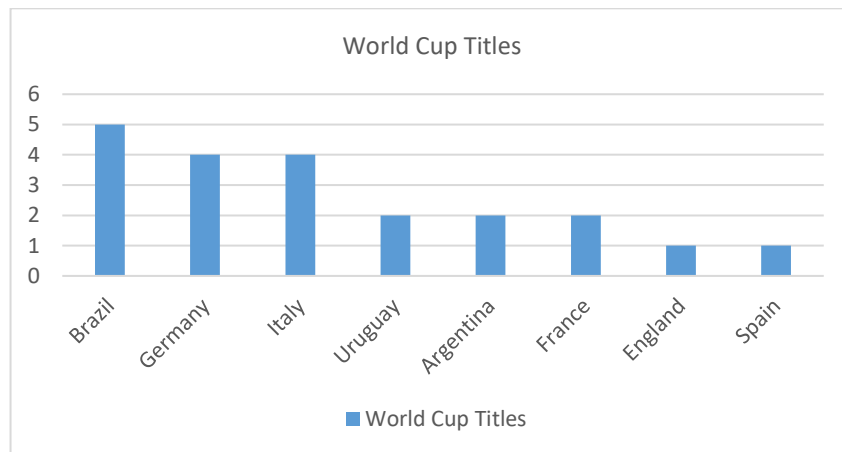
From the first World Cup in 1930 at which sixteen nations participated, and for which there was no real qualifying stage, World Cup has enlarged to include thirty-two teams in its quadrennial final, based upon worldwide qualifying phases in which every national team in the world can participate (Tomlinson and Young, 2006: 2).

Uruguay was the first nation to win a World Cup winning the inaugural tournament in 1930 which they also hosted. World Cup tournament was not held between 1938 and 1950 due to World War II. They won their second World Cup in 1950 following World War II. Uruguay beat Brazil 2-1 in the final at the Estádio do Maracanã in Rio de Janeiro which had the highest ever attendance to a football match with a crowd of 173,850 people.

Brazil is the most successful nation in world football having won the World Cup 5 times. They have also won the Confederations cup on 4 occasions. Brazil stands alone as the only nation to have played in every World Cup. Brazil is the only country to have won the World Cup on four different continents (1958 in Europe, 1962 in South America, 1970 and 1994 in North America and 2002 in Asia). Italy is the most successful European soccer nation having won the World Cup on four occasions and also reached two finals they were unsuccessful in (Wheelwright, 2014: 7).

World Cup titles won by countries from 1930 to 2018 are illustrated in Figure 1.

Figure 1: World Cup Titles within 1930-2018.



Source: <https://www.totalsportek.com/football/fifa-world-cup-winners> (Access Date: 17.07.2018).

3. Methodology

Charnes et al. (1978) introduced non parametric efficiency measurement method dubbed as DEA. Their formulation assumed constant returns to scale. Their formulation enabled multiple input and outputs. Banker et al. (1984) extended the model assuming variable returns to scale (Ruggiero, 2011: 1).

Efficiency via DEA model can be measured either utilizing input orientation or output orientation. The input orientation tries to minimize input level keeping output level constant. The output orientation tries to obtain maximum output level holding input level constant (Ruggiero, 2011: 2).

3.1. CCR Model

CCR model assumed that production technology indicating constant returns to scale (CRS) (Paradi et al, 2018: 6). CCR model might be evaluated as the reduction of the multiple-output/multiple-input situation for each DMU to that of a single virtual output and virtual input (Cooper et al, 2011: 7).

The mathematical programming approach is used to achieve the values for the input "weights" (v_i) $\{i = 1, \dots, m\}$ and the output "weights" (u_r) $\{r = 1, \dots, s\}$ as variables. The model structure is given as the following (Cooper et al., 2006: 23):

$$\text{Max}_{u,v} \theta = \frac{u_1 y_{10} + u_2 y_{20} + \dots + u_s y_{s0}}{v_1 x_{10} + v_2 x_{20} + \dots + v_m x_{m0}} \quad (1)$$

$$\text{subject to } \frac{u_1 y_{1j} + u_2 y_{2j} + \dots + u_s y_{sj}}{v_1 x_{1j} + \dots + v_m x_{mj}} \leq 1 \quad (j=1, 2, \dots, n) \quad (2)$$

$$u_1, u_2, \dots, u_m \geq 0 \quad (3)$$

$$v_1, v_2, \dots, v_m \geq 0 \quad (4)$$

The constraints correspond to the ratio of "virtual output" vs. "virtual input" can't exceed "1" for each DMU. The objective is to attain the weights (v_i) and (u_r) which maximize the ratio of, the DMU being analyzed.

3.2. BCC Model

Banker et al. (1984) suggested a radial DEA model where the production technology displays variable returns to scale (VRS). The input-oriented version of the BCC model is presented the following (Cooper et al., 2006: 91) :

$$\text{Min} \quad \theta_b \quad (5)$$

$$\text{Subject to } \theta_b x_0 - x_\lambda \geq 0 \quad (6)$$

$$Y_\lambda \geq y_0 \quad (7)$$

$$e_\lambda = 1 \quad (8)$$

$$\lambda \geq 0 \quad (9)$$

where θ_b is a scalar, e a row vector with all elements unity and λ corresponds to a column vector with all elements non-negative. Considering the condition $\lambda_j > 0$, for all j , this stipulates a convexity constraint on permissible ways in which the observations for the DMUs can be merged.

3.3. Scale Efficiency

CCR model provides the technical efficiency (TE) and BCC model can provide the pure technical efficiency score (PTE). Scale efficiency (SE) which projects the potential productivity that can be achieved by acquiring an optimum size of a DMU can be measured depending on technical efficiency and pure technical efficiency scores (Toma et al. 2015: 706):

$$\text{Scale efficiency} = \frac{\text{Technical efficiency}}{\text{Pure technical efficiency}} \quad (10)$$

By comparing the efficiency scores calculated from both CCR and BCC models, the effects stemming from unsuitable scale can be detected. The detected sources of inefficiency can make possible to project proper alternatives to thrive the performance of a DMU (Cook and Zhu, 2017: 120).

3.4. Super efficiency DEA model

The conventional CCR model has inefficient distinction when DMUs are on the frontier of production which generally lead to hardship in additional assessment and comparison between DMUs. In order to overcome the deficiency of CCR model and appraise DMUs efficiencies thoroughly, Andersen and Petersen (1993), introduced super efficiency model which can separate efficiency among DMUs (Yang et al, 2015: 15).

Super efficiency model can be formulated as follows (Zhu, 2014: 206):

$$\text{Min} \theta^{super} \quad (11)$$

$$\text{s. t. } \sum_{j=1}^n x_{ij} \lambda_j \leq \theta^{super} X_{io} \quad i = 1, 2, \dots, m \quad (12)$$

$$\sum_{j=1}^n y_{rj} \lambda_j \geq y_{ro} \quad r = 1, 2, \dots, s \quad (13)$$

$$\lambda_j \geq 0 \quad j \neq 0 \quad (14)$$

If we add the following condition, we can get the variable returns to scale (VRS) model (Tone, 2017: 29):

$$\sum_{j=1}^n \lambda_j = 1 \quad (15)$$

4. Empirical Results

In the empirical studies, TE, PTE and SE values and super efficiency scores are measured and evaluated for national teams participating in 2014 World Cup. Selecting the appropriate inputs and outputs has a critical role in DEA process. In this respect, the appropriate inputs and outputs are determined taking into considerations available studies. In this study, passes completed, attempts on target, possession were the selected inputs. Scored goals are selected as output. The data used in the DEA

applications is provided from FIFA web site.¹ Firstly descriptive statistics are illustrated in Table 1.

Table 1. Descriptive Statistics.

Decision Variables		Average	Maximum	Minimum	Standart Deviation
Inputs	Attempts on Target	31.5	72	12	17.32
	Possession	49.7	59.1	35.5	5.22
	Passes Completed	1582	4157	604	763
Outputs	Goals Scored	5.34	18	1	4.03

In the first part of the empirical study, both CCR and BCC Models have been implemented for the teams then SE scores have been measured for the selected DMUs. The efficiency results regarding 2014 World Cup are illustrated in Table 2.

Table 2. Efficiency Results for Teams Participating in World Cup.

DMUs	TE Scores		PTE Scores		Scale Efficiency
	CCR	Super Efficiency	BCC	Super Efficiency	
Germany	1.000	1.056	1.000	1.000	1.000
Netherlands	1.000	1.020	1.000	1.054	1.000
Colombia	1.000	1.417	1.000	1.573	1.000
Brazil	0.728	0.728	0.869	0.869	0.837
France	0.680	0.680	0.813	0.813	0.836
Argentina	0.500	0.500	0.800	0.800	0.625
Algeria	1.000	1.008	1.000	1.110	1.000
Switzerland	0.561	0.561	0.846	0.846	0.663
Croatia	0.824	0.824	1.000	1.001	0.824
Chile	0.993	0.993	1.000	1.053	0.993
Belgium	0.441	0.441	0.792	0.792	0.556
Mexico	0.714	0.714	0.833	0.833	0.857
USA	0.583	0.583	0.871	0.871	0.670
Costa Rica	0.873	0.873	1.000	1.009	0.873
Bosnia Herzegovina	0.421	0.421	0.720	0.720	0.584
Ivory Coast	0.422	0.422	0.710	0.710	0.594
Ghana	0.526	0.526	0.796	0.796	0.661
Spain	0.547	0.547	0.708	0.708	0.772
Portugal	0.451	0.451	0.775	0.775	0.582
Uruguay	0.436	0.436	0.832	0.832	0.524
Ecuador	0.526	0.526	0.955	0.955	0.551
South Korea	0.394	0.394	0.732	0.732	0.538
Australia	0.674	0.674	1.000	1.057	0.674
Greece	0.316	0.316	0.782	0.782	0.404
Nigeria	0.296	0.296	0.768	0.768	0.386
Italia	0.393	0.393	0.813	0.812	0.484

¹ FIFA official web site www.fifa.com (Access Date: 20.06.2018).

DMUs	TE Scores		PTE Scores		Scale Efficiency
	CCR	Super Efficiency	BCC	Super Efficiency	
Russia	0.274	0.274	0.707	0.707	0.387
England	0.331	0.331	0.704	0.704	0.470
Japan	0.226	0.226	0.654	0.653	0.345
Iran	0.262	0.262	1.000	1.429	0.262
Honduras	0.185	0.185	0.751	0.751	0.246
Cameroon	0.185	0.185	0.807	0.807	0.229
Average	0.555		0.844		0.638

As shown in Table I, CCR analyses have revealed that 4 teams are efficient. The teams have the mean technical efficiency as 55.50. According to BCC Model, 9 teams have pure technical efficiencies and the mean PTE level is 0.84. Table I also gives information about scale efficiency. Four teams are found scale efficient. Besides, 28 teams have found scale inefficient, which means that these teams are not operation under optimal scale. Table 3 summarizes improvement ratios of the teams for DEA models.

Table 3. Improvement Ratios for World Cup Teams.

Decision Variables		CCR Model	BCC Model
Inputs	Attempts on Target	-0.453	-0.217
	Possession	-0.527	-0.160
	Passes Completed	-0.495	-0.197
Outputs	Goals Scored	0	0

Inputs for CCR Model have to be decreased within 41.31%-49.56% range and inputs for BCC Model should be diminished by 16.09%-21.76%. However, on the basis of outputs, both CCR and BCC Model would not recommend an output decrease.

Secondly, World Cup teams have separated into two equal groups depending on their FIFA ranking. Then two equal group are analyzed separately. Table 4 and 5 reveal technical efficiency and pure technical efficiency and scale efficiency for the first and last 16 teams respectively.

Table 4. Efficiency Results for First 16 Teams.

DMUs	TE Scores		PTE Scores		Scale Efficiency
	CCR	Super Efficiency	BCC	Super Efficiency	
Germany	1.000	1.056	1.000	1.000	1.000
Netherlands	1.000	1.020	1.000	1.054	1.000
Colombia	1.000	1.498	1.000	1.585	1.000
Brazil	0.727	0.727	0.899	0.899	0.809
France	0.679	0.679	0.856	0.856	0.794
Argentina	0.499	0.499	0.879	0.879	0.568
Switzerland	0.560	0.560	0.959	0.959	0.590
Croatia	0.826	0.826	1.000	1.287	0.826

DMUs	TE Scores		PTE Scores		Scale Efficiency
	CCR	Super Efficiency	BCC	Super Efficiency	
Chile	1.000	1.000	1.000	1.211	1.000
Belgium	0.440	0.440	0.910	0.910	0.484
Mexico	0.719	0.719	1.000	1.020	0.719
Spain	0.550	0.550	0.884	0.884	0.630
Portugal	0.452	0.452	0.983	0.983	0.474
Uruguay	0.436	0.436	1.000	1.048	0.436
Italy	0.395	0.395	1.000	1.308	0.395
England	0.333	0.333	1.000	1.019	0.333
Average	0.663		0.957		0.691

As illustrated in the Table III, CCR model results show that 4 teams are found technical efficient. 12 teams are found inefficient. The average technical efficiency for the teams is 0.663. Chile is also efficient when teams are separated into two groups. According to super efficiency results, Colombia is found the most efficient team among first 16 teams. BCC model results show that 9 teams are found pure technical efficient and the mean PTE level corresponds to 0.957. 4 teams have shown scale efficiency and operate under optimal scale while 12 teams have shown scale inefficiency.

Table 5. Efficiency Results for Last 16 Teams

DMUs	TE Scores		PTE Scores		Scale Efficiency
	CCR	Super Efficiency	BCC	Super Efficiency	
Algeria	1.000	1.716	1.000	1.000	1.000
USA	0.654	0.654	0.871	0.871	0.751
Costa Rica	0.873	0.873	1.000	1.009	0.873
Bosnia Herzegovina	0.483	0.483	0.720	0.720	0.671
Cote de Ivory	0.561	0.561	0.739	0.739	0.759
Ghana	0.640	0.640	0.843	0.843	0.759
Ecuador	0.640	0.640	1.000	1.002	0.640
South Korea	0.444	0.444	0.732	0.732	0.606
Australia	0.673	0.673	1.000	1.078	0.673
Greece	0.397	0.397	0.783	0.783	0.507
Nigeria	0.369	0.369	0.768	0.768	0.480
Russia	0.289	0.289	0.707	0.707	0.410
Japan	0.267	0.267	0.654	0.654	0.409
Iran	0.282	0.282	1.000	1.429	0.282
Honduras	0.184	0.184	0.860	0.860	0.246
Cameroon	0.194	0.194	0.807	0.807	0.240
Average	0.497		0.835		0.582

As illustrated in the Table 5, CCR model results illustrates that only Algeria is found technical efficient. 15 teams are found inefficient. The average technical efficiency for the teams is 0.497. BCC model results show that 5 teams are found pure technical efficient

and the mean PTE level corresponds to 0.835. The results also reveal that the most efficient team in BCC Super efficiency model is Iran.

5. Conclusions

This study comprises the efficiency analysis of World Cup teams by DEA method which is a widely used mathematical programming technique. The empirical study has revealed significant efficiency results for World Cup teams.

Some general results have emerged. Our empirical results are consistent with Espitia-Escuer and Garcia-Cebrian (2004) and Zambom-Ferraresi (2017) as an instance, efficient teams don't necessarily finish the tournament at the top level. This result is consistent with Espitia-Escuer and Garcia-Cebrian (2004), Zambom-Ferraresi (2017) et al. In a similar vein, some teams accomplishing on the field performed relatively low efficient scores. This result is consistent with Guzman and Morrow (2007), Pyatunin et al, (2016).

The efficiency results reveal that World Cup winner Germany is efficient on both models. TE scores among the inefficient teams range from 0.185 for Cameroon to 0.992 for Chile. This finding reveals that Cameroon and Chile can potentially decrease their actual input grades by 81.5% and 0.01% respectively while leaving their output grades constant. We observe that average TE score is 0.55.

Thus, it is obvious from the results that the same level of outputs in teams could be produced with 45 percent less inputs. On the other hand, only four teams are found technically efficient out of 32 teams while nine teams are found pure efficient. The scores of PTE are found higher than the scores of TE. These results are in line with related DEA literature.

Besides, four more teams are found efficient in BCC model when teams are divided into equal groups. In further, Germany, Netherland, Colombia and Algeria are found scale efficient. This result illustrates that these teams have determined optimal size of operation. Out of these 32 teams, 3 teams have PTE score smaller than SE score. This result points out that the inefficiency in resource utilization in these 3 teams namely France, Mexico and Spain is mainly due to managerial inefficiency in comparison to scale inefficiency.

In this regard, we may conclude that DEA approach can provide significant results in analyzing the efficiency level of football teams.

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