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Araştırma Makalesi

Evaluation of Physical Activity, Dietary Habits, and Income as Determinants of Health in European Continental Countries: A Data Envelopment Analysis Approach

Avrupa Kıtası Ülkelerinde Sağlığın Belirleyicileri Olarak Fiziksel Aktivite, Beslenme Alışkanlıkları ve Gelirin Değerlendirilmesi: Veri Zarflama Analizi Yaklaşımı

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ÖZ

Amaç: Bu çalışmanın amacı, veri zarflama analizi kullanılarak Avrupa kıtasındaki ülkelerde fiziksel aktivite, beslenme alışkanlıkları ve gelir göstergelerinin etkinliğini araştırmaktır. **Gereç ve Yöntem:** Çalışmada, 32 Avrupa kıtası ülkesinden 29'unun verileri analiz edildi. Girdi değişkenleri arasında fiziksel aktivite, yürüme, beslenme alışkanlıkları ve kişi başına düşen gayrisafi milli gelir yer alırken, çıktı değişkenleri ise psikolojik semptomlar ve obeziteydi. Bu değişkenler arasındaki korelasyonu belirlemek için Spearman analizi yapıldı. Aykırı ülkeleri belirlemek için Mahalanobis mesafe değerleri hesaplandı. Son olarak, R Studio paketi kullanılarak Veri Zarflama Analizi yapıldı. **Sonuçlar:** Charnes Cooper Rhodes (CCR) modeline göre ülkelerin ortalama etkinliği 0.90, Banker Charnes Cooper (BCC) modeline göre ise 0.91 olarak bulunmuştur. Etkinlik puanlarına göre, CCR modelinde yedi ülke, BCC modelinde ise dokuz ülke etkin olarak belirlenmiştir. Etkin ülkeler arasında Sırbistan ve Romanya, süper etkinlik analizinde 1.37 ile en yüksek etkinlik puanlarına sahip olmuştur. **Tartışma:** Bu çalışma sonuçları, altı ülkenin girdi değişkenlerini artırmaları durumunda daha yüksek çıktılar elde edebileceğini, oysa 14 ülkenin girdilerini artırmaları durumunda daha düşük çıktılar elde edebileceğini göstermektedir.

Anahtar Kelimeler: Sağlık; Etkinlik; Depresyon; Obezite; Alışkanlıklar

ABSTRACT

Purpose: The study aimed to evaluate the effectiveness of physical activity, dietary habits, and income indicators in European Continental countries using the data envelopment analysis method. **Material and Methods:** The study analysed data from 29 of 32 European continental countries. Input variables included physical activity, walking, dietary habits, and gross national income per capita, while output variables included depressive symptoms and obesity. Spearman analysis was performed to determine the correlation between these variables. Mahalanobis distance values were calculated to identify outlier countries. Finally, Data Envelopment Analysis was performed using the R Studio package. **Results:** According to the Charnes Cooper Rhodes (CCR) model, the average efficiency of the countries was found to be 0.90, while it was 0.91 according to the Banker Charnes Cooper (BCC) model. Based on the efficiency scores, seven countries were identified as efficient in the CCR model, and nine in the BCC model. Among the efficient countries, Serbia and Romania had the highest efficiency scores of 1.37 in the super-efficiency analysis. **Discussion:** The study results indicate that if six countries increased their input variables, they could achieve higher outputs, whereas 14 countries might achieve lower outputs if they were to increase their inputs.

Keywords: Health; Efficiency; Depression; Obesity; Habits

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An inactive world is detrimental to health, economics, and sustainability. The World Health Organization emphasizes that physical activity needs to be increased for improvements in health, economics, and sustainability (Bull, Al-Ansari, Biddle et al., 2020). Physical activity plays a crucial role in reducing symptoms of depression, as demonstrated by studies highlighting its significant effects and antidepressant benefits (Singh, Olds, Curtis et al., 2023; Sari, Bayram, Oskay et al., 2023). Furthermore, the link between physical activity and obesity has been the subject of recent research. These studies have revealed the role of physical activity in regulating food intake, promoting appetite regulation and overall calorie consumption, maintaining a healthy energy balance, and reducing the risk of obesity (Oppert, Ciangura, & Bellicha, 2023; Pfisterer, Rousch, Wohlfarth et al., 2022).

Changes in dietary habits and lifestyles, including increased fast-food consumption and symptoms of depression, have contributed to the rise in obesity in society. Obesity increases both direct and indirect healthcare costs (Tapias, Oyamada-Otani, Correa-Vasques et al., 2021; Milligan, Duemling, Radovanovic et al., 2023). Recent investigations have explored the relationship between dietary habits and symptoms of depression, revealing a robust link between the two (Conti, Perdixi, Bernini et al., 2024; Zielinska, Tuszczki, Michonska et al., 2022). Studies have found an inverse relationship between income and obesity, indicating that as income levels decrease, individuals' access to healthy food and healthcare services diminishes, thereby increasing the risk of obesity (Rauf, 2023; Boutari & Mantzoros, 2022). Likewise, a considerable amount of literature has established a negative correlation between gross national income and depression, suggesting that higher income levels provide individuals with better social prestige, psychosocial support, and working conditions, which can be protective against depression (Li, Ning, Wang et al., 2022; Zare, Meyerson, Nwankwo-Adania et at., 2022). Previous studies have linked physical activity, dietary habits, and income with obesity and depression symptoms, emphasizing the importance of addressing these factors (Singh, Olds, Curtis et al., 2023; Tapias, Oyamada-Otani, Correa-Vasques et al., 2021; Boutari & Mantzoros, 2022).

Data Envelopment Analysis (DEA) is a widely used approach in performance measurement that allows for analysis using multiple input and output variables. It quantifies decision-making units' efficiency and effectiveness levels through linear programming (Peykani, Saen, Seyed-Esmaeili et al., 2021). It quantifies decision-making units' efficiency and effectiveness levels through linear programming. DEA enables simultaneous intervention and evaluation of multiple inputs and outputs, making it suitable for complex areas (Tsaples & Papathanasiou, 2020). Both input-oriented and output-oriented analyses can be conducted using the Charnes-Cooper-Rhodes (CCR) model, which assumes constant returns to scale, and the Banker-Charnes-Cooper (BCC) model, which accommodates variable returns to scale (Charnes, Cooper, Lewin et al., 1997; Charnes, Cooper & Rhodes, 1978). The CCR model calculates total efficiency scores under the assumption of constant returns to scale (Adna, Mohd-Yusoff, Syafiqah et al., 2022) while the BCC model differentiates between technical and scale efficiency under varying returns to scale (Lee, 2023). In this study, we employed the DEA method to examine the effects of physical activity, dietary habits, and income on obesity and symptoms of depression, as it is one of the most widely used methods in performance measurement.

MATERIAL AND METHODS

The objective of the current study was to assess the efficiency of indicators related to physical activity, dietary habits, and gross national income (GNI) per capita in European Continental countries using the data envelopment analysis (DEA) method. The main focus of the study was to determine the efficiency levels among the countries based on these indicators. Additionally, the study aimed to identify inefficient countries that could serve as examples for improving their efficiency in these areas.

Data sources

The study focused on 32 European Continental countries, utilizing the most recent available data. However, data for 2020, 2021, and 2022 were incomplete. Therefore, the study included data from the most recent period, specifically 2019. As a result, only 29 of the 32 continental European countries were included in the analysis, as data for some countries were unavailable. The data used in the study were sourced from the World Bank and Eurostat databases.

Ethical approval

Ethics committee approval and consent forms were not required for this study since the data used were obtained from publicly available sources, namely Eurostat and the World Bank. Moreover, the study did not involve any clinical processes or directly include participants, either living or deceased.

Statistical Analysis

In the current study, the performance of European Continental countries in 2019 was measured using the input-oriented CCR and BCC models of DEA. Out of the 32 European Continental countries, data from 29 countries were analyzed. The input variables comprised physical activity, walking, dietary habits, and GNI per capita, while the output variables included depressive symptoms and obesity. The inverses of the output variables were included in the analysis to establish a direct relationship between the input and output variables. The research data were analyzed using R Studio package programs, and the results were then transferred to Microsoft Excel for further interpretation, accompanied by tables and figures. Spearman correlation analysis was conducted as a preliminary analysis to assess the relationship between the variables. The results indicated a significant correlation among the variables, justifying their inclusion in the subsequent analysis. After the variables were determined, the "Mahalanobis Distance" values and chi-square values of the countries were calculated to identify the countries with outliers. The compatibility of Mahalanobis distances with the chi-square distribution was investigated, and the countries whose Mahalanobis Distance value was greater than the chi-square value were excluded from the analysis. Consequently, 27 countries were analyzed using the input-oriented CCR and BCC models of DEA. When performing DEA analysis, it is important to consider the decision-making units. DEA, is a non-parametric method that depends on the total number of decision-making units for the reliability of its results. There are three basic approaches for determining the number of decision-making units: first, having a number of decision-making units greater than twice the number of input and output variables used in the study (Vassiloglou & Giokas, 1990); second, having a number of decision-making units greater than the sum of the number of input and output variables (Sherman, 1982); and third, the most widely used approach, which suggests that the number of decision-making units should be three times the sum of the number of input and output variables (Bowlin, 1998; Friedman & Sinuany-Stern, 1998). In this study, all three approaches were considered. Additionally, the study utilized four input and two output variables with 27 decision-making units.

RESULTS

The data for this study were obtained from Eurostat and the World Bank, and the most recent available data for 2019 were utilized. The selected input variables were physical activity, dietary habits, and GNI per capita. These variables were hypothesized to impact depression symptoms and obesity, which were the chosen output variables. It should be noted that different results may arise when considering different variables influencing depression symptoms and obesity, potentially leading to variations in countries' outcomes.

Table 1. Spearman Correlation Test Results of Variables

	Depression	Dietary Habit	GNI Per Capita	Obesity	Physical Activity	Walking
Depression	1	0.44	0.48	0.15	0.16	-0.26
Dietary Habit		1	0.44	-0.08	0.26	-0.49
GNI Per Capita			1	-0.28	0.01	-0.40
Obesity				1	0.42	-0.02
Physical Activity					1	0.03
Walking						1

GNI: Gross national income

A preliminary analysis of the variables was conducted using Spearman correlation coefficients, as shown in Table 1. The study revealed correlation values ranging from 0.03 to 0.49 between the input and output variables, with no strong relationships found between the inputs and outputs. Since the correlation levels were not particularly strong for the inputs, it was not necessary to make any changes between inputs and outputs, therefore, all variables were included in the analysis. Furthermore, all Spearman correlation coefficient values between the variables were lower than 0.49, indicating a fair correlation (Chan, 2003).

Table 2. CCR and BCC Input Oriented Efficiency Values of Countries

Country	CCR	BCC	Country	CCR	BCC
Belgium	0,84	0,85	**Hungary**	0,90	0,91
Bulgaria	1	1	**Malta**	0,90	0,91

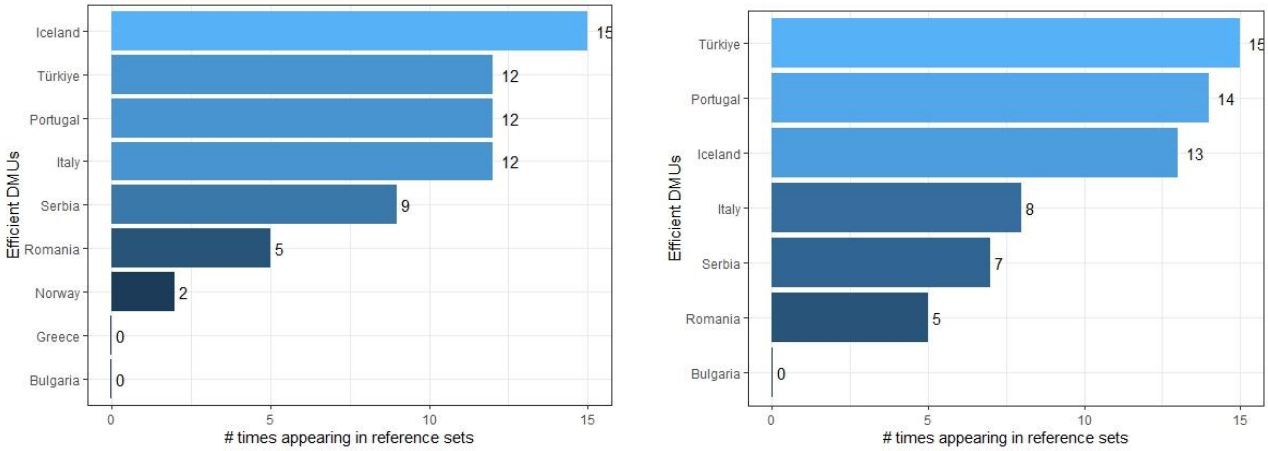
Table 2. CCR and BCC Input Oriented Efficiency Values of Countries Continue

Czechia	0,86	0,91	**Austria**	0,86	0,87
Denmark	0,78	0,78	**Poland**	0,90	0,91
Germany	0,80	0,80	**Portugal**	1	1
Estonia	0,89	0,89	**Romania**	1	1
Greece	0,97	1	**Slovenia**	0,89	0,89
Spain	0,86	0,86	**Slovakia**	0,91	0,94
France	0,83	0,84	**Sweden**	0,81	0,83
Croatia	0,87	0,90	**Iceland**	1	1
Italy	1	1	**Norway**	0,96	1
Latvia	0,93	0,93	**Serbia**	1	1
Lithuania	0,90	0,90	**Türkiye**	1	1
Luxembourg	0,69	0,71	**Average(Mean)**	0,90	0,91

CCR: Charnes Cooper Rhodes, BCC: Banker Charnes Cooper

Table 2 provides the CCR and BCC efficiency scores for the input data of 27 Continental European countries in 2019. According to the CCR model, the average efficiency was found to be 0.90, while it was 0.91 according to the BCC model. In the CCR model, 7 countries were identified as efficient, whereas the BCC model identified 9 countries as efficient. Luxembourg had the lowest efficiency, with efficiency ratios of 0.69 in the CCR model and 0.71 in the BCC model. Among the inefficient countries, Greece had the highest efficiency, with a rate of 0.97 in the CCR model, while Slovakia had a rate of 0.94 in the BCC model. Based on the CCR model, 2 countries had efficiency scores between 0.61 and 0.79, 10 countries between 0.80 and 0.89, and 8 countries between 0.90 and 0.99. According to the BCC model, it was also found that 2 countries were between 0.61-0.79, 8 countries between 0.80 and 0.89, and 8 countries between 0.90 and 0.99. The efficiency scores and ranges of the countries are shown in Figure 1.

Figure 1. Reference Frequencies of Countries Identified as Efficient By CCR Model and Reference Frequencies of Countries Identified As Efficient By BCC Model



Scale efficiency refers to the effectiveness of producing at an appropriate scale and is determined by dividing total efficiency by technical efficiency, i.e., dividing the efficiency values obtained from the CCR model by those from the BCC model. Scale efficiency aims to achieve production at the most appropriate scale. If outputs increase more than inputs when a certain amount of inputs is added, it indicates increasing returns to scale; if outputs increase less, it indicates decreasing returns to scale; and if outputs increase at the same rate, it indicates constant returns to scale (Banker & Thrall, 1992). The results of the returns-to-scale analysis are presented in Table 3. A value equal to 1 signifies constant returns to scale, a value greater than 1 indicates decreasing returns to scale, and a value less than 1 suggests increasing returns to scale. Among the 27 European Continental countries, 6 had increasing returns to scale, 14 had decreasing returns to sclae, and 7 had constant returns to scale.

Table 3. Returns-to-Scale Values of Countries and Mahalanobis Distance and Chi-square Values for Countries

Country	Scale Efficiency	Returns to Scale	Country	Scale Efficiency	Returns to Scale
Belgium	1,03	Decreasing	Hungary	1,01	Decreasing
Bulgaria	1	Constant	Malta	0,99	Increasing
Czechia	1,03	Decreasing	Austria	1	Decreasing
Denmark	0,99	Increasing	Poland	1,01	Decreasing
Germany	0,95	Increasing	Portugal	1	Constant
Estonia	0,99	Increasing	Romania	1	Constant
Greece	1,03	Decreasing	Slovenia	0,98	Increasing
Spain	1,01	Decreasing	Slovakia	1,03	Decreasing
France	1,03	Decreasing	Sweden	1,02	Decreasing
Croatia	0,97	Increasing	Iceland	1	Constant
Italy	1	Constant	Norway	1,09	Decreasing
Latvia	1,01	Decreasing	Serbia	1	Constant
Lithuania	1,01	Decreasing	Türkiye	1	Constant
Luxembourg	1,02	Decreasing			
Country	**Mahalanobis**	**Chi-square**	**Country**	**Mahalanobis**	**Chi-square**
Belgium	2,44	0,78	Hungary	3,88	0,56
Bulgaria	5,88	0,31	Malta	8,80	0,11
Czechia	3,57	0,61	Austria	5,19	0,39
Denmark	4,89	0,42	Poland	1,61	0,89
Germany	2,13	0,83	Portugal	5,24	0,38
Estonia	5,99	0,30	Romania	7,35	0,19
Greece	4,25	0,51	Slovenia	1,76	0,88
Spain	1,35	0,92	Slovakia	4,05	0,54
France	8,13	0,14	Sweden	7,02	0,21
Croatia	4,62	0,46	Iceland	6,93	0,22
Italy	3,31	0,65	Norway	6,03	0,30
Latvia	4,36	0,49	Serbia	5,35	0,37
Lithuania	1,95	0,85	Türkiye	8,34	0,13
Netherlands*	**15,16**	**0,01**	Luxembourg	7,61	0,17
Cyprus*	**20,69**	**0,01**			

The Mahalanobis Distance values and chi-square values of the 29 European Continental countries were calculated, and compatibility with the chi-square distribution was examined. Based on this analysis, the countries whose Mahalanobis Distance values exceeded the chi-square value, namely the Netherlands and Cyprus, were excluded from the study, resulting in the analysis of 27 countries (Table 3).

Table 4. Super Efficiency Values of Efficient Countries

Country	CCR
Italy	1,01
Bulgari	1,04
Portugal	1,06
Austria	1,11
Norway	1,21
Türkiye	1,24
Iceland	1,30
Serbia	1,37
Romania	1,37

CCR: Charnes Cooper Rhodes

The results of the super-efficiency analysis, employing the input-oriented CCR model for the European Continental countries, are presented in Table 4. Since the model is input-oriented, the distance from 1 represents increasing returns to scale. Additionally, super-efficiency values indicate how much countries can increase their inputs. For instance, even if Portugal increases its input amount by 6.5% with an efficiency value of 1.06, it will still remain on the efficient frontier. Therefore, the countries with the highest efficiency values were Romania and Serbia, with efficiency scores of 1.37. These countries can remain on the efficient frontier even if their inputs increase by 37.6%. Iceland and Turkey, with the highest reference values, followed Serbia and Romania as the most efficient countries.

DISCUSSION

The main objective of the current study was to compare the efficiency scores of health systems in European continent countries, utilizing data from Eurostat and the World Bank for 2019, through the application of Data Envelopment Analysis. Healthcare systems are complex entities influenced by political decisions and health processes. The study yields several important implications. Despite Luxembourg's input values being above average compared to those of other countries, the study found that Luxembourg had a significantly lower efficiency score, indicating inefficiency in utilizing its input resources. While there is no research specifically investigating the combination of input variables, output variables, and the analyzed methods used in this study, a few studies have explored the health systems of countries using different variables.

Mirmirani and Lipmann published a paper examining the data of G12 countries between 1991 and 1995. They reported that Japan and Spain consistently had the highest efficiency levels in both models and all years, while the USA exhibited the lowest efficiency (Mirmirani & Lippmann, 2004). Similarly, Asandului et al. analyzed the health systems of European countries and found that developed countries were more efficient, with Romania and Bulgaria (as developing countries) also demonstrating efficiency (Asandului, Roman & Fatulescu, 2014). Another study conducted by Retzlaff-Roberts et al. investigated the effects of infant mortality and life expectancy on overall health outcomes using the DEA method and the OECD database. The study revealed that countries with good health outcomes, such as Japan, Sweden, Norway, and Canada, as well as those with modest health outcomes, like Mexico and Turkey, both had advantages in achieving scale efficiency (Retzlaff-Roberts, Chang & Rubin, 2004).

The current study has several limitations. Firstly, the data for 2019 was used as the most recent available data; however, future studies could incorporate more up-to-date data. Secondly, although data envelopment analysis was applied in an input-oriented manner, an output-oriented analysis was not conducted in this study. Lastly, this study analyzed only four input variables (physical activity, walking, dietary habits, and GNI per capita) and two output variables (depressive symptoms and obesity). Future studies could explore different combinations of input and output variables. These findings highlight the complexity of healthcare systems and the need for further research to improve efficiency and outcomes. Addressing the mentioned limitations will contribute to a more comprehensive understanding of health system performance.

The current study evaluated the efficiency of healthcare systems in 29 European Continental countries based on input variables such as physical activity, dietary habits, walking, and GNI per capita, as well as output variables including depression and obesity. By utilizing the available data, the study assessed the efficiency of the health systems in these countries for the year 2019. The study revealed that a significant majority of the 27 European Continental countries examined fail to achieve optimal efficiency in their health systems. According to the CCR model, approximately 74% of the countries are inefficient, while the BCC model indicates an inefficiency rate of around 67%. Furthermore, upon examining the returns to scale, it was observed that six countries could increase their outputs more by increasing their input variables, while 14 countries need to decrease their outputs despite increasing their inputs. In terms of super efficiency scores, which measure the efficiency of the efficient countries relative to each other, Serbia and Romania are the most efficient countries among the active countries. Although Serbia and Romania's input variables are below the averages, their superior efficiency is attributed to their better utilization of existing input resources compared to other countries.

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