Regional performance evaluation of healthcare services in Türkiye with cross-efficiency approach

Çapraz etkinlik yaklaşımı ile Türkiye'deki bölgesel sağlık hizmetleri performansının değerlendirilmesi

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ABSTRACT

Objective: Monitoring and comparing regional service performance is inevitable to use resources effectively and allocate resources without creating interregional inequalities. With the Health Transformation Program, there has been an increase in the amount and quality of the service provided throughout the country. In addition, there has been a decrease in the inequalities between regions due to its implementation. In order to ensure continuity in health service delivery, health service activities in provinces and regions should be followed regularly, and their performance should be evaluated.

Methods: The study calculated Data Envelopment Analysis efficiencies and Cross-efficiency for 26 subregions in the NUTS-II classification in Turkey. The number of hospital beds and primary care units were the inputs of the research; the number of primary, secondary and tertiary care visits and the number of inpatients are also the output of the study. Subregions are reordered and grouped according to their cross-efficiency. Decision-making units with unusual production structures were investigated by calculating Maverick Index scores.

ÖZET

Amaç: Kaynakların etkin kullanılması ve kaynak tahsisinin bölgeler arası eşitsizlikler yaratmaksızın yapılabilmesi için bölgesel hizmet performansının izlenmesi ve karşılaştırılması kaçınılmazdır. Sağlıkta Dönüşüm Programı ile ülke genlinde sunulan hizmetin miktar ve kalitesinde artışlar olmuştur. Ayrıca hizmet sunumundan kaynaklı bölgeler arası eşitsizliklerde de azalmalar olmuştur. Sağlık hizmetlerinde sürekliliğin sağlanması için illerde ve bölgelerdeki sağlık hizmetlerinin düzenli bir şekilde takip edilmesi ve performanslarının değerlendirilmesi gerekmektedir.

Yöntem: Çalışmada Türkiye'deki IBBS-II sınıflamasında yer alan 26 alt bölgenin Veri Zarflama Analizi etkinlikleri ile Çapraz Etkinlikleri hesaplanmıştır. Hastane yatağı ve birinci basamak sağlık hizmet birimi sayıları araştırmanın girdilerini; birinci, ikinci ve üçüncü basamak sağlık tesislerindeki hasta muayene sayıları ile yatan hasta sayıları da çalışmanın çıktılarını oluşturmaktadır. Alt bölgeler çapraz etkinliklerine göre yeniden sıralanmış ve gruplandırılmıştır. Tüm alt bölgeler için Maverick İndeks puanları hesaplanarak sıra dışı üretim yapılarına sahip olan alt bölgeler belirlenmiştir.

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Results: Regarding DEA efficiency, the average efficiency score of the ten subregions classified as efficient is 0.97 (sd. 0.0395). The average cross-efficiency score obtained from the benevolent method is 0.89 (sd. 0.058), while the average score achieved through the aggressive method is 0.86 (sd. 0.574). Maverick index scores had a balanced distribution. The average maverick index score for aggressive and benevolent are 0.13 (std. 0.0474), and 0.0871 (std. 0.0420), respectively. Although only the Malatya subregion was classified as efficient in the traditional DEA method, it had low scores in the cross-efficiency evaluation and was classified as a maverick decision unit with an MI score of 0.21.

Conclusion: The cross-efficiency method yields more valuable results because it employs more realistic weights for peer evaluation. These outcomes are simpler for decision-makers to comprehend and assess. The regions of Kocaeli, Adana, Aydın, Hatay, Şanlıurfa, and Tekirdağ exhibit notable performance in the cross-efficiency examination, as they have attained the most significant efficiency scores. The regions of Kastamonu, Erzurum, Van, and Ağrı exhibit poor levels of efficiency, thereby requiring the implementation of precautionary measures.

Key Words: Cross-efficiency, data envelopment analysis, health policy, performance management

Bulgular: Veri zarflama analizi etkinlikleri bakımından on alt bölge etkin olarak gruplandırılmış olup bölgelerin ortalama etkinlik skoru 0,97'dir (sd. 0,0395). Benevolent yaklaşıma göre hesaplanan çapraz etkinlik ortalama skoru 0,89 (sd. 0,058) iken aggresive yaklaşıma göre hesaplanan ortalama skor ise 0,86'dır (sd. 0,0574). Maverick indeks skorları dengeli olarak dağılmıştır. Ortalama agressive maverick indeks skoru 0,13 (std. 0.0474) ve ortalama benevolent Maverick indeks skoru ise 0,0871'dir (std. 0.0420). Sadece Malatya alt bölgesi, geleneksel veri zarflama analizi yönteminde etkin olarak sınıflandırılmasına rağmen çapraz etkinlik değerlendirmesinde düşük skorlar almış ve 0,21 indeks skoru ile maverick karar birimi olarak sınıflandırılmıştır.

Sonuç: Çapraz etkinlik yöntemi daha gerçekçi ağırlıklar kullanarak akran-değerlendirmesi yaptığı için daha kullanışlı sonuçlar ortaya koymaktadır. Söz konusu sonuçların karar alıcılar tarafından anlaşılması ve değerlendirilmesi daha kolaydır. Çapraz etkinlik değerlendirmesinde Kocaeli, Adana, Aydın, Hatay, Şanlıurfa ve Tekirdağ alt bölgeleri en yüksek etkinlik skorlu bölgeler olarak öne çıkmaktadır. Kastamonu, Erzurum, Van ve Ağrı alt bölgeleri de düşük etkinlik skorlu bölgeler olup önlem alınması gerekmektedir.

Anahtar Kelimeler: Çapraz etkinlik, veri zarflama analizi, sağlık politikası, performans yönetimi

INTRODUCTION

National health systems strive to ensure health services and establish sustainable health systems. However, healthcare expenditures are on the rise in nearly all nations due to shifting populations, changing disease patterns, and technological advancements. These changes significantly impact countries with fiscal deficits and constrained economic resources for healthcare (1). Several health systems worldwide have implemented significant changes to the administration and provision of care to cope with disparities in health services and healthcare accessibility (2). Despite all of these advancements, resource allocation and management challenges persist. According to the World Health Report (3), it has been estimated that a substantial amount of health spending, ranging from 20% to 40%, is lost due to inefficiencies in health systems. Inefficient utilization of health services wastes resources and harms macroeconomic balances. Scientific productivity measurement is the first step to rational resource utilization (4).

In parallel with global advancements in healthcare systems, the Health Transformation Program in Turkey, initiated in 2003, has undertaken comprehensive reforms in governance, organizational structure, financial mechanisms, resource allocation, and healthcare provision to achieve universal health coverage (5). The primary objective of the Health Transformation Program (HTP) is to establish a health system characterized by effectiveness, efficiency, and equity, ensuring that resources are utilized in the most optimal manner possible (6). Turkey has made significant progress in the process of HTP. Moreover, it is still possible to enhance the general health situation if further progress is made in the area of equity in access to health services, particularly in the geographical dimension (7).

Despite all this improvement potential, some measures should be taken regarding the sustainability of health services. For example, based on data from the Health Statistics Yearbook (8), the health spending per capita (purchasing power parity basis) in Turkey for 2021 amounted to $1,668. Additionally, the proportion of total health expenditure relative to the country's Gross Domestic Product (GDP) was recorded at 4.9%. This rate is significantly lower than the average of other OECD nations (9.7%). It is necessary to increase the share of health expenditures in GDP, to comprehend the efficiency of resource use, and to take measures for productivity.

Performance evaluation of subregions can inform policy-makers about resource usage, allocation, and efficiency. Data envelopment analysis and its extension cross-efficiency approach can be used to achieve this aim.

This article evaluates the performance of 26 NUTS-II subregions in Turkey using the cross-efficiency approach. The study is one of the first studies in healthcare in which the method was applied comprehensively.

Literature review

Data envelopment analysis (DEA) is widely utilized in the field of healthcare services. There are several studies on topics such as nursing centers (9,10), dialysis units (11), hospital efficiency (12,13), and health system comparisons (14,15), case management efficiency (16,17). However, there are few studies on cross-efficiency studies on healthcare services.

In the healthcare area: Abolghasem et al. (18) investigated the performance of 120 countries' health systems and assessed their efficiency relative to their peers using cross-efficiency and cluster analysis. Floku et al. (19) examined the use of post-DEA cross-evaluation and cluster analysis in Greek National Health Service (NHS) hospitals. The researchers found that cross-efficiency assessment enables decision-makers to effectively identify and solve issues that may have been neglected during the first stage of DEA analysis. Adejoh et al. (20), conducted a study to evaluate the efficiency and ranking of primary healthcare services in a metropolitan area in Nigeria with a cross-efficiency approach. Mirmozaffari and Alinezhad (2017), studied heart hospital performance ranking using the cross-efficiency and two-stage DEA method. Wang (21), evaluates the performance of community health service with cross-efficiency approach. Costantino et al. (22), discuss applying a fuzzy cross-efficiency technique to evaluate the performance of healthcare systems in the presence of uncertainty. Yaya et al. (23), used game cross-efficiency approach to assess the efficiency of China's healthcare services. They discovered that the technique improves the conventional DEA. Zare et al.(24), suggested using a game cross-efficiency model to assess performance and productivity in Iranian healthcare centers.

Only two studies have employed the cross-efficiency technique in the field of healthcare services in Türkiye: Torun (25), conducted an assessment of cross-efficiency in Obstetrics and Gynecology Hospitals. Similarly, Kaçak and Yıldırım (26), studied cross-efficincy of research and training hospitals.

Data Envelopment Analysis

DEA is a widely employed method for assessing efficiency. It enables the identification of efficient units using a non-parametric, mathematical linear programming method (19). The main advantage of DEA is to allow the usage of multiple inputs and outputs. Another advantage is that Decision Making Units are compared to their actual performance, instead of an unrealistic theoretical benchmark. Other benefits of the method are: DEA can predict the improvement needed to improve efficiency scores for inefficient DMUs. DEA provides more information on 'peer' organizations. Policymakers can increase allocation efficiency by distributing more resources to DMUs that perform better. On the other hand, DEA's disadvantage is ignoring random error and being sensitive to outliers. Besides, DEA scores measure relative efficiency within the sample, not absolute efficiency (14,27-30).

The DEA method evaluates the efficiency of each DMU by calculating the ratio between the weighted sum of the outputs and the weighted sum of the inputs (31). This model was first proposed by Charnes et al. (32), and formulated as follows:

$$Max \quad E_{dd} = \frac{\sum_{r=1}^{s} u_{rd} y_{rd}}{\sum_{i=1}^{m} v_{id} x_{id}}$$

$$s.t. \quad E_{dd} = \frac{\sum_{r=1}^{s} u_{rd} y_{rj}}{\sum_{i=1}^{m} v_{id} x_{ij}} \leq 1, j = 1,2,\ldots,n. \qquad (1)$$

$$u_{rd} \geq 0, r = 1,\ldots,s.$$

$$u_{id} \geq 0, i = 1,\ldots,m.$$

where vid and urd represent input and output weights for DMUd, respectively.

Cross-Efficiency

Cross-efficiency was introduced by Sexton et al. (33) and further developed by Doyle and Green (34). The cross-efficiency evaluation method is widely utilized for ranking the performance of DMUs due to its ability to effectively eliminate unrealistic weight schemes and distinguish between good and poor performers. This method achieves these advantages without requiring weight restrictions from experts in the application area (35). The utilization of cross-efficiency assessment proves to be a valuable method for ranking DMUs and validating post-DEA outcomes (35,36).

Cross-efficiency is based on employing DEA in peer evaluations rather than self-evaluations. In other words, the purpose of evaluating cross-efficiency is to compare a DMU's self-evaluated DEA efficiency score with the cross-evaluated (equivalent) efficiency scores assigned to it by its peers (25).

Using the weights chosen by DMUd in formula (1), the cross-efficiency of j DMU is calculated as follows (37):

$$E_{dj} = \frac{\sum_{r=1}^{s} u^{*}_{rd} y_{rj}}{\sum_{i=1}^{m} v^{*}_{id} x_{ij}}, d, j = 1,2,\ldots,n$$

The notation (*) represents the optimal values in model (4.1). For each DMUj (where j = 1, 2, ..., n), the average of all Edj (where d = 1, 2, ..., n) referred to as the cross-efficiency score for DMUj.

$$E_j = \frac{1}{n} \sum_{d=1}^{n} E_{dj}$$

Cross-efficiency may be helpful to overcome the maverick DMU problem, assess the similarity of peer groups, sub-classify efficiency DMU calculated by simple DEA, and identify the good all-round performer (29).

Cross-efficiency (or cross-evaluation) analysis offers an additional understanding of the most efficient performers in a given sample. Cross-efficiency is derived from the concept of peer evaluation. In this context, the efficiency scores are recalculated for each DMU by evaluating each unit using the weights of all DMUs instead of relying on its own weights. The mean cross-efficiency score can be interpreted as the average peer assessment (29,38).

Aggressive and Benevolent Cross-Efficiency

Depending on the selection of input/output weights, Sexton et al. proposed two benevolent and aggressive scenarios for conducting cross-efficiency evaluation for DMU k. The initial objective for both scenarios is the maximum simple efficiency score for DMU k. The secondary objective of average peer evaluation is maximized in the benevolent scenario and minimized in the aggressive scenario (25).

$$\begin{aligned}
&\min \textstyle\sum_{r=1}^{s}\left(u_{rk} \sum_{j\neq k} y_{rj}\right) \\
&\text{s.t.} \\
&\textstyle\sum_{i=1}^{m}\left(v_{ik} \sum_{j\neq k} x_{ij}\right) = 1 \\
&\textstyle\sum_{r=1}^{s} u_{rk} y_{rj} - \sum_{i=1}^{m} v_{ik} x_{ij} \leq 1 && j = 1,\dots,n\ (j \neq k) \qquad (5)\\
&\textstyle\sum_{r=1}^{s} u_{rk} y_{rk} - E_{kk} \sum_{i=1}^{m} v_{ik} x_{ik} = 0 \\
&v_{ik} \geq 0 && i = 1,\dots,m \\
&u_{rk} \geq 0 && r = 1,\dots,s
\end{aligned}$$

Aggressive cross-efficiency method can be formulated as follows:

$$\begin{aligned}
&\max \textstyle\sum_{r=1}^{s}\left(u_{rk} \sum_{j\neq k} y_{rj}\right) \\
&\text{s.t.} \\
&\textstyle\sum_{i=1}^{m}\left(v_{ik} \sum_{j\neq k} x_{ij}\right) = 1 \\
&\textstyle\sum_{r=1}^{s} u_{rk} y_{rj} - \sum_{i=1}^{m} v_{ik} x_{ij} \leq 1 && j = 1,\dots,n\ (j \neq k) \qquad (4)\\
&\textstyle\sum_{r=1}^{s} u_{rk} y_{rk} - E_{kk} \sum_{i=1}^{m} v_{ik} x_{ik} = 0 \\
&v_{ik} \geq 0 && i = 1,\dots,m \\
&u_{rk} \geq 0 && r = 1,\dots,s
\end{aligned}$$

Similarly, Doyle and Green proposed the following benevolent scenario model to minimize the cross-efficiency of all ($j \neq k$) DMUs:

Maverick Index:

Mavericks are the units that use “an unusual production technology” when compared to the production technologies of the other DMU units (39). Maverick DMUs generally exhibit distinct optimal input-output weights compared to other normal DMUs, resulting in lower cross-efficiency scores (40).

$$M_k = \frac{E_{kk} - e_k}{e_k}$$

$$e_k = \frac{1}{n-1}\sum_{s\neq k} E_{sk}$$

In the Maverick Index (MI) formulation, Ekk is the simple efficiency or self-evaluation of the generic DMUk, whereas ek is the average peer evaluation of that unit. Consequently, the greater the MI, the more divergent the DMU. Therefore, a unit has no exact maverick threshold (39). The MI (false positive index) assesses the degree to which a unit shifts from peer evaluation to self-evaluation (29). Mavericks are DMUs with a MI in excess of 0.20. A DMU with a self-efficiency of 1 but a high MI is a false positive (41).

In conclusion, mavericks might be evaluated as efficient when using their own weights, but they have significantly lower efficiency scores when using the weights other DMUs choose (42).

MATERIAL and METHOD

The data used in the study were acquired from the Health Statistics Yearbook for the year 2021(8). The data were gathered at the province level and subsequently analyzed by aggregating them into 26 subregions based on the NUTS-II classification. Input Oriented Constant Return to Scale (CRS) DEA model and Cross-efficiency approach were used to analyze subregions’ health data. Under the CRS model, cross-efficiency scores range from 0 to 100%, while under the VRS model, it is possible to have negative cross-efficiency scores because of the non-linear relationship between variables and scale effects. This situation may lead to problems with interpreting cross-efficiency scores (29). Therefore, the CRS model was employed in the evaluation of DEA.

The model’s inputs consist of the number of hospital beds and family medicine units, while the outputs include the number of primary care visits, secondary and tertiary care visits (hospital care), and inpatients. Beds, the number of outpatients, and the number of inpatients are frequently used variables in healthcare studies (43–46) In addition, PHC unit numbers are used to evaluate the performance of family medicine (20,47).

The R Statistical Software’s deaR Package was utilized to perform cross-efficiency analysis.

RESULTS

Descriptive statistics for inputs and outputs are presented in Table 1.

In 2021, There were 254,497 hospital beds and 26,928 Primary Health Care Units throughout the country, the number of outpatient visits in primary care was 245,525,320, the number of outpatient visits in secondary and tertiary hospitals was 430,126,870, the number of inpatients was 11,785,492. There were 9,118 outpatients per primary health care unit, 965 outpatients per secondary and tertiary healthcare institution, and the number of inpatients per bed was 46.

Table 1. Descriptive statistics for input and output variables

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Beds	26	2,220	46,960	9,788	8,460
Primary Health Care Units	26	246	4,969	1,036	883
Primary Health Care Facilities Visits	26	2,340,134	33,518,072	9,443,282	6,238,362
Secondary and Tertiary Health Care Visits	26	3,526,909	86,226,136	16,543,341	15,594,169
İnpatients	26	75,224	2,045,691	313,826	423,464

Cross-efficiency matrixes created based on the aggressive and benevolent models are presented in Tables 2 and 3. The matrixes include peer evaluation, average cross-efficiency scores, and rankings. In addition to cross-efficiency tables, heat maps of cross-efficiencies are presented in Figures 1 and 2. Values in the cross-efficiency matrix are shown in the heat map visually. Table 4 presents the combined display of CCR efficiency, average cross-efficiency scores, and MI.

The average efficiency scores are CCR efficiency 0.9696 (std. 0.0395), Aggressive Cross-efficiency 0.8576 (std. 0.0574), and Benevolent Cross-efficiency 0.8937 (std. 0.0580). According to the table, the average cross-efficiency ranges for aggressive and benevolent models are 0.738-0.960 and 0.755-0.988, respectively. The value of the benevolent strategy is greater than that of the aggressive strategy (Table 4).

Upon examination of the maverick index values, it becomes apparent that a balanced distribution is evident. The range for the aggressive category ranges from a minimum value of 0.04 to a maximum value of 0.21. On the other hand, the range for the benevolent category extends from a minimum value of 0.01 to a maximum value of 0.20. Malatya, with an aggressive maverick index score of 0.21, can be classified as a false positive DMU due to its distinct production structure compared to other entities. When examination of the benevolent maverick index values, it is seen that there is an absence of a maverick DMU (Table 4).

The findings of the DEA CRS model indicated that ten subregions were efficient and 16 were inefficient. The cross-efficiency ranges of CRS-efficient DMUs, such as Ankara (0.836-0.913) and Malatya (0.825-0.899), exhibit noteworthy levels of both aggressiveness and benevolence. The Maverick indexes for these subregions are 0.196 and 0.216, respectively. Malatya has already been identified as the maverick DMU, while the Ankara subregion is placed on the threshold of the maverick classification with a value of 0.196.

Table 2. Aggressive Cross-efficiency Matrix

Subregion	Adana	Ağrı	Ankara	Antalya	Aydın	Balıkesir	Bursa	Erzurum	Gaziantep	Hatay	İstanbul	İzmir	Kastamonu	Kayseri	Kırıkkale	Kocaeli	Konya	Malatya	Manisa	Mardin	Samsun	Şanlıurfa	Tekirdağ	Trabzon	Van	Zonguldak	Aggressive Eff	Rank
Adana	1.0000	0.7457	0.5195	0.6939	1.0000	0.9730	0.7974	0.5244	0.8542	0.8957	0.5339	0.7682	0.7373	0.6824	0.9117	0.8866	0.6132	0.5749	0.8561	0.7988	0.7110	0.8055	0.7926	0.7106	0.5643	0.7117	0.9442	2
Ağrı	0.7289	0.9431	0.7034	0.7112	0.7563	0.7749	0.7245	0.4966	0.7755	0.8090	0.8115	0.8327	0.6547	0.6067	0.6981	0.9107	0.5789	0.5658	0.6609	1.0000	0.6616	0.9135	0.7116	0.6685	0.8146	0.7163	0.7853	23
Ankara	0.8703	0.7333	1.0000	0.9237	0.8658	0.8786	0.8937	0.7904	0.8289	0.8561	0.9885	0.9701	0.8167	0.8689	0.7822	0.9879	0.8758	0.8769	0.8562	0.8113	0.9421	0.8763	0.9627	0.9097	0.8124	0.9073	0.8361	17
Antalya	0.9820	0.7614	0.9896	0.9847	0.9687	0.8532	0.9633	0.8871	0.9709	0.9601	0.9570	0.9508	0.7478	0.9705	0.7926	1.0000	0.9415	0.9983	0.8546	0.8519	0.9697	0.9674	1.0000	1.0000	0.8602	0.9334	0.8709	12
Aydın	0.9949	0.7892	0.5070	0.6837	1.0000	0.9741	0.7903	0.5062	0.8617	0.9048	0.5300	0.7666	0.7298	0.6655	0.9141	0.8926	0.5947	0.5564	0.8438	0.8394	0.6938	0.8247	0.7775	0.6967	0.5746	0.7032	0.9400	3
Balıkesir	0.9848	0.9406	0.6564	0.7746	1.0000	0.9915	0.8497	0.5613	0.9175	0.9608	0.7196	0.8832	0.7782	0.7156	0.9169	1.0000	0.6570	0.6260	0.8560	1.0000	0.7594	0.9547	0.8367	0.7640	0.7474	0.7894	0.8777	10
Bursa	1.0000	0.7793	0.9635	0.9819	0.9876	0.8469	0.9677	0.8788	1.0000	0.9822	0.9367	0.9394	0.7270	0.9699	0.7946	1.0000	0.9300	0.9931	0.8454	0.8719	0.9552	0.9907	0.9910	1.0000	0.8694	0.9265	0.8849	9
Erzurum	1.0000	0.6647	0.9312	0.9519	0.9738	0.8601	0.9443	0.8998	0.9271	0.9196	0.8608	0.8985	0.7485	0.9765	0.8015	0.9436	0.9488	1.0000	0.8811	0.7478	0.9719	0.8782	1.0000	0.9878	0.7559	0.9036	0.7378	26
Gaziantep	0.9941	0.8880	0.6918	0.8193	1.0000	0.8537	0.8707	0.6567	1.0000	0.9912	0.7178	0.8256	0.6536	0.7921	0.8193	0.9451	0.7180	0.7473	0.7807	0.9654	0.7706	1.0000	0.8385	0.8308	0.7915	0.7896	0.9031	7
Hatay	1.0000	0.8499	0.7866	0.8784	1.0000	0.8647	0.9090	0.7249	1.0000	0.9912	0.8033	0.8771	0.6923	0.8508	0.8205	0.9757	0.7875	0.8228	0.8124	0.9342	0.8366	1.0000	0.8957	0.8891	0.8257	0.8432	0.9151	4
İstanbul	0.8775	0.7506	1.0000	0.9278	0.8745	0.8878	0.8998	0.7857	0.8395	0.8674	0.9957	0.9791	0.8218	0.8686	0.7907	1.0000	0.8730	0.8729	0.8601	0.8294	0.9420	0.8911	0.9650	0.9117	0.8250	0.9123	0.8353	18
İzmir	0.8967	0.7373	1.0000	0.9341	0.8904	0.9008	0.9093	0.8015	0.8442	0.8721	0.9853	0.9792	0.8318	0.8843	0.8038	1.0000	0.8885	0.8878	0.8786	0.8158	0.9566	0.8838	0.9795	0.9235	0.8118	0.9184	0.8930	8
Kastamonu	1.0000	0.7152	0.8985	0.9175	0.9838	0.9776	0.9339	0.7894	0.8804	0.9121	0.8733	0.9561	0.8599	0.9000	0.8862	1.0000	0.8810	0.8663	0.9505	0.7905	0.9596	0.8678	1.0000	0.9277	0.7426	0.9097	0.7432	25
Kayseri	1.0000	0.6647	0.9312	0.9519	0.9738	0.8601	0.9443	0.8998	0.9271	0.9196	0.8608	0.8985	0.7485	0.9765	0.8015	0.9436	0.9488	1.0000	0.8811	0.7478	0.9719	0.8782	1.0000	0.9878	0.7559	0.9036	0.8427	16
Kırıkkale	0.9846	0.9415	0.6477	0.7691	1.0000	0.9909	0.8461	0.5562	0.9162	0.9597	0.7106	0.8778	0.7750	0.7109	0.9171	0.9963	0.6515	0.6201	0.8538	1.0000	0.7540	0.9522	0.8319	0.7590	0.7418	0.7844	0.8107	21
Kocaeli	0.9848	0.9406	0.6564	0.7746	1.0000	0.9915	0.8497	0.5613	0.9175	0.9608	0.7196	0.8832	0.7782	0.7156	0.9169	1.0000	0.6570	0.6260	0.8560	1.0000	0.7594	0.9547	0.8367	0.7640	0.7474	0.7894	0.9601	1
Konya	0.9520	0.7059	1.0000	0.9702	0.9344	0.8477	0.9422	0.8961	0.9149	0.9119	0.9474	0.9386	0.7611	0.9647	0.7792	0.9719	0.9509	1.0000	0.8601	0.7912	0.9788	0.9065	1.0000	0.9878	0.8137	0.9237	0.8083	22
Malatya	0.8911	0.5664	0.8567	0.8788	0.8616	0.6648	0.8520	0.8888	0.8761	0.8349	0.7633	0.7554	0.5669	0.9310	0.6418	0.8002	0.8960	1.0000	0.7189	0.6480	0.8698	0.8068	0.8864	0.9302	0.6992	0.8005	0.8248	20
Manisa	1.0000	0.6858	0.8883	0.9104	0.9799	0.9712	0.9277	0.7976	0.8673	0.8982	0.8509	0.9401	0.8556	0.9041	0.8812	0.9813	0.8867	0.8721	0.9533	0.7595	0.9619	0.8430	1.0000	0.9264	0.7166	0.9017	0.8340	19
Mardin	0.7289	0.9431	0.7034	0.7112	0.7563	0.7749	0.7245	0.4966	0.7755	0.8090	0.8115	0.8327	0.6547	0.6067	0.6981	0.9107	0.5789	0.5658	0.6609	1.0000	0.6616	0.9135	0.7116	0.6685	0.8146	0.7163	0.8605	14
Samsun	0.9520	0.7059	1.0000	0.9702	0.9344	0.8477	0.9422	0.8961	0.9149	0.9119	0.9474	0.9386	0.7611	0.9647	0.7792	0.9719	0.9509	1.0000	0.8601	0.7912	0.9788	0.9065	1.0000	0.9878	0.8137	0.9237	0.8654	13
Şanlıurfa	0.8875	0.8662	0.7164	0.8046	0.8948	0.6972	0.8213	0.6640	0.9746	0.9382	0.7451	0.7710	0.5404	0.7729	0.6811	0.8770	0.7042	0.7671	0.6598	0.9498	0.7263	1.0000	0.7791	0.8128	0.8336	0.7516	0.9138	5
Tekirdağ	1.0000	0.6858	0.8883	0.9104	0.9799	0.9712	0.9277	0.7976	0.8673	0.8982	0.8509	0.9401	0.8556	0.9041	0.8812	0.9813	0.8867	0.8721	0.9533	0.7595	0.9619	0.8430	1.0000	0.9264	0.7166	0.9017	0.9097	6
Trabzon	1.0000	0.7389	0.9631	0.9768	0.9828	0.8566	0.9630	0.8904	0.9731	0.9604	0.9206	0.9327	0.7421	0.9758	0.8000	0.9857	0.9421	1.0000	0.8627	0.8283	0.9676	0.9515	1.0000	1.0000	0.8327	0.9245	0.8765	11
Van	0.8746	0.9219	0.8389	0.8537	0.8900	0.8475	0.8590	0.6556	0.9113	0.9262	0.9088	0.9235	0.7200	0.7712	0.7759	1.0000	0.7348	0.7459	0.7671	1.0000	0.8050	1.0000	0.8550	0.8282	0.8864	0.8374	0.7776	24
Zonguldak	0.9643	0.7529	1.0000	0.9790	0.9517	0.8611	0.9546	0.8788	0.9446	0.9411	0.9678	0.9583	0.7654	0.9593	0.7929	1.0000	0.9384	0.9858	0.8603	0.8411	0.9726	0.9490	1.0000	0.9899	0.8512	0.9336	0.8483	15

Table 3. Benevolent Cross-efficiency Matrix

Subregion	Adana	Ağrı	Ankara	Antalya	Aydın	Balıkesir	Bursa	Erzurum	Gaziantep	Hatay	İstanbul	İzmir	Kastamonu	Kayseri	Kırıkkale	Kocaeli	Konya	Malatya	Manisa	Mardin	Samsun	Şanlıurfa	Tekirdağ	Trabzon	Van	Zonguldak	Benevolent Eff	Rank
Adana	1.0000	0.7793	0.9635	0.9819	0.9876	0.8469	0.9677	0.8788	1.0000	0.9822	0.9367	0.9394	0.7270	0.9699	0.7946	1.0000	0.9300	0.9931	0.8454	0.8719	0.9552	0.9907	0.9910	1.0000	0.8694	0.9265	0.9596	2
Ağrı	0.7289	0.9431	0.7034	0.7112	0.7563	0.7749	0.7245	0.4966	0.7755	0.8090	0.8115	0.8327	0.6547	0.6067	0.6981	0.9107	0.5789	0.5658	0.6609	1.0000	0.6616	0.9135	0.7116	0.6685	0.8146	0.7163	0.7864	25
Ankara	0.9643	0.7529	1.0000	0.9790	0.9517	0.8611	0.9546	0.8788	0.9446	0.9411	0.9678	0.9583	0.7654	0.9593	0.7929	1.0000	0.9384	0.9858	0.8603	0.8411	0.9726	0.9490	1.0000	0.9899	0.8512	0.9336	0.9129	13
Antalya	0.9820	0.7614	0.9896	0.9847	0.9687	0.8532	0.9633	0.8871	0.9709	0.9601	0.9570	0.9508	0.7478	0.9705	0.7926	1.0000	0.9415	0.9983	0.8546	0.8519	0.9697	0.9674	1.0000	1.0000	0.8602	0.9334	0.9258	10
Aydın	1.0000	0.8529	0.8237	0.8972	1.0000	0.8908	0.9222	0.7374	0.9904	0.9895	0.8437	0.9100	0.7284	0.8622	0.8361	1.0000	0.8064	0.8343	0.8365	0.9373	0.8625	1.0000	0.9193	0.9028	0.8391	0.8667	0.9525	4
Balıkesir	0.9848	0.9406	0.6564	0.7746	1.0000	0.9915	0.8497	0.5613	0.9175	0.9608	0.7196	0.8832	0.7782	0.7156	0.9169	1.0000	0.6570	0.6260	0.8560	1.0000	0.7594	0.9547	0.8367	0.7640	0.7474	0.7894	0.8740	18
Bursa	1.0000	0.7793	0.9635	0.9819	0.9876	0.8469	0.9677	0.8788	1.0000	0.9822	0.9367	0.9394	0.7270	0.9699	0.7946	1.0000	0.9300	0.9931	0.8454	0.8719	0.9552	0.9907	0.9910	1.0000	0.8694	0.9265	0.9230	11
Erzurum	1.0000	0.6647	0.9312	0.9519	0.9738	0.8601	0.9443	0.8998	0.9271	0.9196	0.8608	0.8985	0.7485	0.9765	0.8015	0.9436	0.9488	1.0000	0.8811	0.7478	0.9719	0.8782	1.0000	0.9878	0.7559	0.9036	0.8015	24
Gaziantep	0.9965	0.7812	0.9665	0.9826	0.9845	0.8431	0.9669	0.8792	1.0000	0.9816	0.9405	0.9398	0.7247	0.9694	0.7911	1.0000	0.9299	0.9940	0.8418	0.8741	0.9544	0.9926	0.9898	1.0000	0.8731	0.9266	0.9338	7
Hatay	1.0000	0.8499	0.7866	0.8784	1.0000	0.8647	0.9090	0.7249	1.0000	0.9912	0.8033	0.8771	0.6923	0.8508	0.8205	0.9757	0.7875	0.8228	0.8124	0.9342	0.8366	1.0000	0.8957	0.8891	0.8257	0.8432	0.9378	6
İstanbul	0.8775	0.7506	1.0000	0.9278	0.8745	0.8878	0.8998	0.7857	0.8395	0.8674	0.9957	0.9791	0.8218	0.8686	0.7907	1.0000	0.8730	0.8729	0.8601	0.8294	0.9420	0.8911	0.9650	0.9117	0.8250	0.9123	0.9036	14
İzmir	0.8967	0.7373	1.0000	0.9341	0.8904	0.9008	0.9093	0.8015	0.8442	0.8721	0.9853	0.9792	0.8318	0.8843	0.8038	1.0000	0.8885	0.8878	0.8786	0.8158	0.9566	0.8838	0.9795	0.9235	0.8118	0.9184	0.9300	9
Kastamonu	1.0000	0.7152	0.8985	0.9175	0.9838	0.9776	0.9339	0.7894	0.8804	0.9121	0.8733	0.9561	0.8599	0.9000	0.8862	1.0000	0.8810	0.8663	0.9505	0.7905	0.9596	0.8678	1.0000	0.9277	0.7426	0.9097	0.7547	26
Kayseri	1.0000	0.6647	0.9312	0.9519	0.9738	0.8601	0.9443	0.8998	0.9271	0.9196	0.8608	0.8985	0.7485	0.9765	0.8015	0.9436	0.9488	1.0000	0.8811	0.7478	0.9719	0.8782	1.0000	0.9878	0.7559	0.9036	0.8984	16
Kırıkkale	0.9846	0.9415	0.6477	0.7691	1.0000	0.9909	0.8461	0.5562	0.9162	0.9597	0.7106	0.8778	0.7750	0.7109	0.9171	0.9963	0.6515	0.6201	0.8538	1.0000	0.7540	0.9522	0.8319	0.7590	0.7418	0.7844	0.8069	23
Kocaeli	0.9820	0.7614	0.9896	0.9847	0.9687	0.8532	0.9633	0.8871	0.9709	0.9601	0.9570	0.9508	0.7478	0.9705	0.7926	1.0000	0.9415	0.9983	0.8546	0.8519	0.9697	0.9674	1.0000	1.0000	0.8602	0.9334	0.9882	1
Konya	0.9520	0.7059	1.0000	0.9702	0.9344	0.8477	0.9422	0.8961	0.9149	0.9119	0.9474	0.9386	0.7611	0.9647	0.7792	0.9719	0.9509	1.0000	0.8601	0.7912	0.9788	0.9065	1.0000	0.9878	0.8137	0.9237	0.8678	20
Malatya	0.9804	0.7569	0.9903	0.9842	0.9667	0.8515	0.9622	0.8889	0.9681	0.9572	0.9559	0.9492	0.7472	0.9712	0.7908	0.9974	0.9429	1.0000	0.8542	0.8472	0.9704	0.9635	1.0000	1.0000	0.8571	0.9326	0.8990	15
Manisa	1.0000	0.6858	0.8883	0.9104	0.9799	0.9712	0.9277	0.7976	0.8673	0.8982	0.8509	0.9401	0.8556	0.9041	0.8812	0.9813	0.8867	0.8721	0.9533	0.7595	0.9619	0.8430	1.0000	0.9264	0.7166	0.9017	0.8476	21
Mardin	0.8746	0.9219	0.8389	0.8537	0.8900	0.8475	0.8590	0.6556	0.9113	0.9262	0.9088	0.9235	0.7200	0.7712	0.7759	1.0000	0.7348	0.7459	0.7671	1.0000	0.8050	1.0000	0.8550	0.8282	0.8864	0.8374	0.8688	19
Samsun	0.9520	0.7059	1.0000	0.9702	0.9344	0.8477	0.9422	0.8961	0.9149	0.9119	0.9474	0.9386	0.7611	0.9647	0.7792	0.9719	0.9509	1.0000	0.8601	0.7912	0.9788	0.9065	1.0000	0.9878	0.8137	0.9237	0.9154	12
Şanlıurfa	0.9893	0.7974	0.9485	0.9701	0.9803	0.8409	0.9580	0.8549	1.0000	0.9825	0.9334	0.9355	0.7183	0.9501	0.7893	1.0000	0.9079	0.9684	0.8316	0.8900	0.9362	1.0000	0.9745	0.9838	0.8776	0.9167	0.9454	5
Tekirdağ	0.9820	0.7614	0.9896	0.9847	0.9687	0.8532	0.9633	0.8871	0.9709	0.9601	0.9570	0.9508	0.7478	0.9705	0.7926	1.0000	0.9415	0.9983	0.8546	0.8519	0.9697	0.9674	1.0000	1.0000	0.8602	0.9334	0.9537	3
Trabzon	0.9820	0.7614	0.9896	0.9847	0.9687	0.8532	0.9633	0.8871	0.9709	0.9601	0.9570	0.9508	0.7478	0.9705	0.7926	1.0000	0.9415	0.9983	0.8546	0.8519	0.9697	0.9674	1.0000	1.0000	0.8602	0.9334	0.9325	8
Van	0.8746	0.9219	0.8389	0.8537	0.8900	0.8475	0.8590	0.6556	0.9113	0.9262	0.9088	0.9235	0.7200	0.7712	0.7759	1.0000	0.7348	0.7459	0.7671	1.0000	0.8050	1.0000	0.8550	0.8282	0.8864	0.8374	0.8256	22
Zonguldak	0.9643	0.7529	1.0000	0.9790	0.9517	0.8611	0.9546	0.8788	0.9446	0.9411	0.9678	0.9583	0.7654	0.9593	0.7929	1.0000	0.9384	0.9858	0.8603	0.8411	0.9726	0.9490	1.0000	0.9899	0.8512	0.9336	0.8924	17

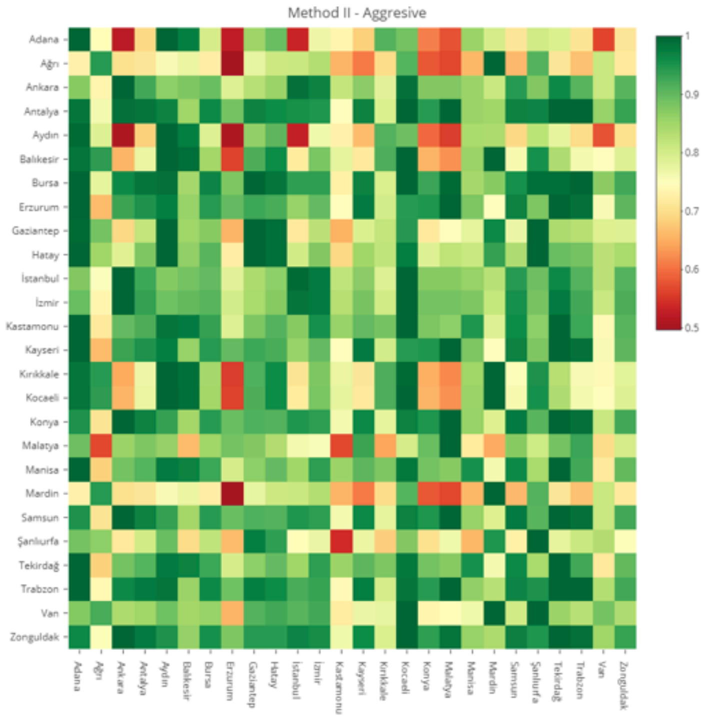

Figure 1. Aggressive Cross-efficiency Heat Map

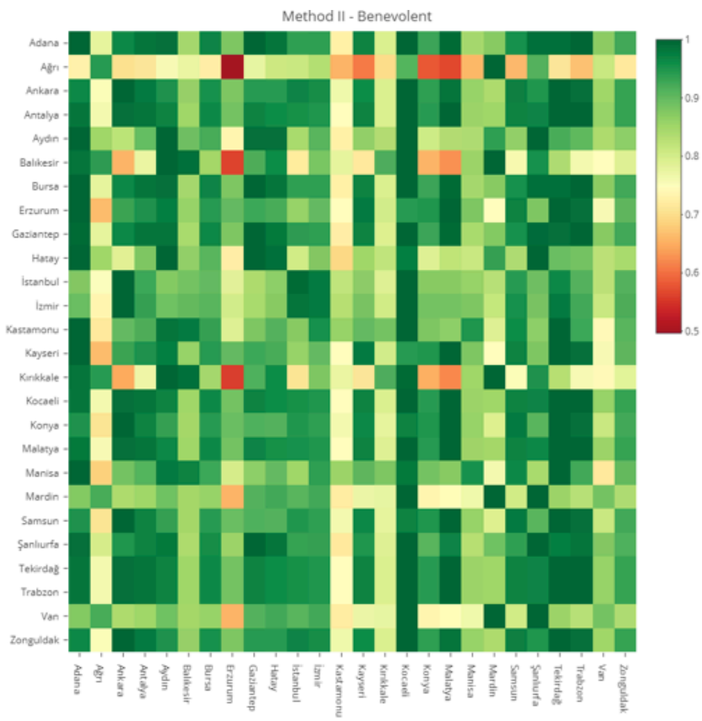

Figure 2. Benevolent Cross-efficiency Heat Map

Table 4. CCR efficiency, Aggressive and Benevolent Cross-efficiency, Maverick Index

	CCR Efficiency & Rankings		Aggressive Cross-efficiency & Rankings		Maverick Index (Aggressive)	Benevolent Cross-efficiency & Rankings		Maverick Index (Benevolent)
Subregion	*Efficiency*	*Ranking*	*Efficiency*	*Ranking*	*Maverick*	*Efficiency*	*Ranking*	*Maverick*
Adana	1.0000	1	0.9442	2	0.0591	0.9596	2	0.0421
Ağrı	0.9431	21	0.7853	23	0.2010	0.7864	25	0.1992
Ankara	1.0000	1	0.8361	17	0.1961	0.9129	13	0.0954
Antalya	0.9847	14	0.8709	12	0.1307	0.9258	10	0.0637
Aydın	1.0000	1	0.9400	3	0.0638	0.9525	4	0.0498
Balıkesir	0.9915	12	0.8777	10	0.1298	0.8740	18	0.1344
Bursa	0.9677	18	0.8849	9	0.0935	0.9230	11	0.0484
Erzurum	0.8998	24	0.7378	26	0.2197	0.8015	24	0.1226
Gaziantep	1.0000	1	0.9031	7	0.1073	0.9338	7	0.0709
Hatay	0.9912	13	0.9151	4	0.0831	0.9378	6	0.0569
İstanbul	0.9957	11	0.8353	18	0.1920	0.9036	14	0.1019
İzmir	0.9792	15	0.8930	8	0.0966	0.9300	9	0.0529
Kastamonu	0.8599	26	0.7432	25	0.1570	0.7547	26	0.1394
Kayseri	0.9765	17	0.8427	16	0.1588	0.8984	16	0.0868
Kırıkkale	0.9171	23	0.8107	21	0.1312	0.8069	23	0.1365
Kocaeli	1.0000	1	0.9601	1	0.0416	0.9882	1	0.0120
Konya	0.9509	20	0.8083	22	0.1765	0.8678	20	0.0958
Malatya	1.0000	1	0.8248	20	0.2125	0.8990	15	0.1124
Manisa	0.9533	19	0.8340	19	0.1430	0.8476	21	0.1247
Mardin	1.0000	1	0.8605	14	0.1621	0.8688	19	0.1510
Samsun	0.9788	16	0.8654	13	0.1311	0.9154	12	0.0692
Şanlıurfa	1.0000	1	0.9138	5	0.0944	0.9454	5	0.0578
Tekirdağ	1.0000	1	0.9097	6	0.0993	0.9537	3	0.0486
Trabzon	1.0000	1	0.8765	11	0.1409	0.9325	8	0.0724
Van	0.8864	25	0.7776	24	0.1399	0.8256	22	0.0737
Zonguldak	0.9336	22	0.8483	15	0.1005	0.8924	17	0.0462
Mean	0.9696		0.8576		0.1331	0.8937		0.0871
Min	0.8599		0.7378		0.0416	0.7547		0.0120
Max	1.0000		0.9601		0.2197	0.9882		0.1992
Std. Dev.	0.0395		0.0574		0.0474	0.0580		0.0420

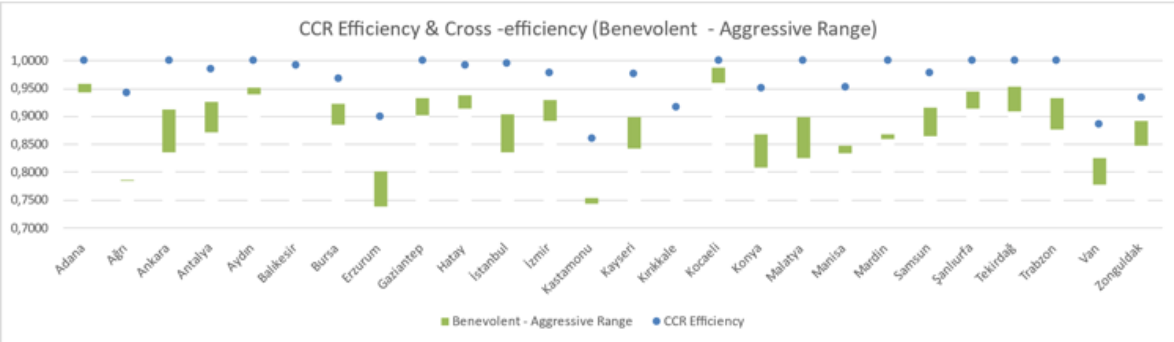

Figure 3. CRS Efficiency and Cross-Efficiencies (Benevolent -Aggressive) Range

The subregions were categorized into four quartiles based on the aggressive and benevolent cross-efficiency scores. The subregions exhibiting the most notable performance (i.e., fourth quartile) in both approaches are Kocaeli, Aydın, Hatay, and Şanlıurfa, respectively. Tekirdağ is included in the fourth quartile only for the benevolent cross-efficiency approach. The subregions of Malatya and Mardin exhibit CRS efficiency; nonetheless, it is important to highlight that they rank in the first quartile, indicating a relatively lower performance in cross-efficiency evaluation. The rankings of these subregions were 20 for Malatya (Aggravate Cross-efficiency) and 19 for Mardin (Benevolent Cross-efficiency).

DISCUSSION

Monitoring and comparing regional service performance is an essential practice to optimize resource use and allocate resources to avoid the creation of interregional inequities (18). Implementing the health transformation initiative in Turkey has resulted in notable improvements in qualitative and quantitative aspects of healthcare service delivery. Nevertheless, global issues, such as economic crises and pandemics, significantly influence the provision of health services and threaten their long-term financial viability. Hence, it is essential to closely observe health policy outcomes at both provincial and regional levels. Cross-efficiency method produces more realistic weights for DMU's (31,34,48–50). Using this method in comparing the units under consideration facilitates the identification of more accurate benchmarks through the implementation of peer appraisal.

Within the scope of the study, 26 subregions were examined regarding both efficiency scores and rankings by DEA and cross-efficiency methods. In the score investigation, Kocaeli, Adana, Aydın, Hatay, Şanlıurfa, and Tekirdağ subregions stand out as the most effective units, respectively. On the contrary, Erzurum, Kastamonu, Van, and Ağrı subregions emerge as the worst subregions with scores below 0.80, respectively, and it would be beneficial to scrutinize the relevant subregions. In addition, the Malatya subregion, which is classified as Maverick DMU and included in the first quartile, should also be carefully examined in cross-efficiency evaluation.

Despite being ranked thirteenth and categorized as inefficient in the DEA evaluation, the Hatay subregion ranked fourth in the aggressive model and sixth in the benevolent model when focused on ranking investigation. Similarly, the İzmir subregion was categorized as inefficient and ranked fifteenth, whereas, in the aggressive and beneficent models, it was ranked eighth and ninth, respectively. On the contrary, the Malatya subregion was one of the efficient subregions and ranked first, but its aggressive and benevolent evaluation rankings were twenty-first and fifteenth, respectively. These examples show that the order of subregions varies considerably with the cross-efficiency method. On the one hand, the DEA efficient subregion is the maverick DMU and regresses to the twentieth rank. On the other hand, inefficient subregions can move up the rankings. The main reason for these changes is the replacement of self-evaluation by peer-evaluation.

It is planned to integrate the cross-efficiency method with the variance and cluster analysis in future studies.

Table 5. Aggressive and Benevolent Rankings by Quartiles

Quartile	CRS - Aggressive Cross-Eff. Rankings	CRS - Benevolent Cross-Eff. Rankings
4	Kocaeli CRS (1) Agg (1)	Kocaeli CRS (1) Ben (1)
	Adana CRS (1) Agg (2)	Adana CRS (1) Ben (2)
	Aydın CRS (1) Agg (3)	Tekirdağ CRS (1) Ben (3)
	Hatay CRS (13) Agg (4)	Aydın CRS (1) Ben (4)
	Şanlıurfa CRS (1) Agg (5)	Şanlıurfa CRS (1) Ben (5)
		Hatay CRS (13) Ben (6)
3	Tekirdağ CRS (1) Agg (6)	Gaziantep CRS (1) Ben (7)
	Gaziantep CRS (1) Agg (7)	Trabzon CRS (1) Ben (8)
	İzmir CRS (15) Agg (8)	İzmir CRS (15) Ben (9)
	Bursa CRS (18) Agg (9)	Antalya CRS (14) Ben (10)
	Balıkesir CRS (12) Agg (10)	Bursa CRS (18) Ben (11)
	Trabzon CRS (1) Agg (11)	Samsun CRS (16) Ben (12)
	Antalya CRS (14) Agg (12)	Ankara CRS (1) Ben (13)
2	Samsun CRS (16) Agg (13)	İstanbul CRS (11) Ben (14)
	Mardin CRS (1) Agg (14)	Malatya CRS (1) Ben (15)
	Zonguldak CRS (22) Agg (15)	Kayseri CRS (17) Ben (16)
	Kayseri CRS (17) Agg (16)	Zonguldak CRS (22) Ben (17)
	Ankara CRS (1) Agg (17)	Balıkesir CRS (12) Ben (18)
	İstanbul CRS (11) Agg (18)	
1	Manisa CRS (19) Agg (19)	Mardin CRS (1) Ben (19)
	Malatya CRS (1) Agg (20)	Konya CRS (20) Ben (20)
	Kırıkkale CRS (23) Agg (21)	Manisa CRS (19) Ben (21)
	Konya CRS (20) Agg (22)	Van CRS (25) Ben (22)
	Ağrı CRS (21) Agg (23)	Kırıkkale CRS (23) Ben (23)
	Van CRS (25) Agg (24)	Erzurum CRS (24) Ben (24)
	Kastamonu CRS (26) Agg (25)	Ağrı CRS (21) Ben (25)
	Erzurum CRS (24) Agg (26)	Kastamonu CRS (26) Ben (26)

ETHICS COMMITTEE APPROVAL

* This study does not require Ethics Committee Approval.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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