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High Technology Export Of Countries Comparison With Data Envelopment Analysis

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Abstract – As an example of data envelopment analysis; this study focuses on the comparison of high technology exports of countries with data envelopment analysis. High-tech exports (HTEX) are the outputs of multiple inputs for the countries under consideration. Since a small number of inputs and a large number of outputs were used in the study, data envelopment analysis was considered appropriate. According to data envelopment analysis, it was aimed to compare the relative efficacy of the variables. CCR and BCC models will be used in this study. For this reason, HTEX data envelopment analysis was solved with the help of Excel-Solver plugin and the results were evaluated.

Keywords *– High-tech exports, Data envelopment analysis (DEA), CCR model, BCC model*

I. Introduction

Systems have their own specific objectives. These objectives can be listed as; high efficiency, efficiency, profit maximization, cost minimization, customer satisfaction, growth and respectability. To measure whether the system has achieved its goals, it is necessary to calculate performance measures. One of the methods used to measure system performance is efficiency analysis. Three methods are used in the measurement of efficiency analysis [1]. These are ratio analysis, parametric methods and non-parametric methods.

Although each method has both positive and negative aspects, ratio analysis is a commonly used type of analysis. It is based on monitoring the result of the ratio of a single input and a single output over time. In this analysis, the scale is the ratio scale. The starting point is zero on the ratio scale, and the points on the scale move in multiples of each other. Therefore, all mathematical methods can be easily applied to the data measured using this scale.

In parametric methods, there is an observation set and the best performance within the set is assumed to be above the efficiency limit. According to this assumption, observations deviating from the activity limit line are called active. Observations that do not show success are called ineffective. The most preferred parametric efficiency measurement method is regression analysis. Regression analysis helps to examine the causal structure of the relationships between dependent and independent variables.

Nonparametric methods are used in the analysis where there are multiple output and multiple input variables and these variables are measured with different measurement units.

The distances of the systems to the production limits can be measured by non-parametric methods. Commonly used methods are free-throw envelope method and data envelopment analysis (DEA). In the free-throw envelope method, which is a special case of data envelopment analysis, DEA model does not accept the points on the lines joining the corners on the active boundary. The model cluster takes the DEA corners and points within the area covered by the corners [2].

II. Data Envelopment Analysis

It was first developed by Cooper, Charnes and Rhodes to measure the relative effectiveness of systems that produce similar products or services. It is called decision-making unit (DMU). This method has multiple input and output variables in different units of measurement. In addition, these variables are a linear programming-based approach to measure the relative total factor effectiveness of decision-making units when they cannot be reduced to a common criterion. A DMU is determined as best and the other DMUs are compared to the best DMUs. Effectivity is measured according to the best defined limit. According to the method, the best named DMUs above the activity limit are considered to be relatively effective and are referred to as reference sets. Other DMUs that cannot exceed the activity limit are relatively inactive. DEA at this point sheds light on the decision makers about the improvements that need to be made for relatively inactive units. DEA methods are given below:

- Multiple input and output variables can be used.
- It does not require a functional relationship between inputs and outputs other than linear form.
- Multiple different units of measurement can be used simultaneously for input and output variables. For example, weight, quantity, monetary or proportional size and so on.
- Since it is a deterministic method, it does not include random error and therefore data-centered errors are not selected.

• In DEA, because we calculate events based on the extremes they interact with these extremes. Therefore, it is more accurate to evaluate the calculated results within the scope of relativity rather than absolute.

• DEA is a non-parametric method, so it is difficult to evaluate the results statistically.

• DEA is a static method, so it analyzes data with a single point of time.

• In DEA, the number of input and output variables should be low and they should be able to give the production stages of the DMUs completely. The opposite makes it difficult to distinguish between relatively effective and inactive DMUs.

• DEA often requires a small number of inputs and a large number of output variables [3].

Literature Review on Data Envelopment Analysis

Kılıç et al. For G-8 countries, panel data analysis was applied to the data obtained between 1996 and 2011. Its aim is to find the relationship between R & D (ARGE) expenditures and high technology exports. According to the results of the research, it is determined that R & D expenditures are a two-way causality on high technology exports [4].

Yücel has recreated the portfolio with real data and found that it is necessary to work with low risk in order to make the portfolio effective. The fact that 100% portfolio efficiency does not make the portfolio good and reliable does not directly affect the portfolio. The event is complementary to the portfolio [5].

Avsar, were investigated between 2016 and 2006, high-tech application performance conducted between the BRIC countries and Turkey. As a result, local innovative capacity has been found to have a high impact [6].

Taşköprü has found the energy efficiency of 28 states, which is a member of the European Union and Turkey is a candidate country, with the classic data envelopment analysis and categorical data envelopment analysis [7].

Data Envelopment Analysis Models

Three methods are used in data envelopment analysis.

• CCR (Charnes-Cooper-Rhodes) Method

• BCC (Banker-Charnes-Cooper) Method

• Additive Methods

In all of these methods, fractional programming-linear programming transformation can be used provided that input or output centeredness is considered [3].

CCR Method

This method is based on the constant return hypothesis on the scale. If the efficiency of the decision unit of j is h_j, the objective should be the maximization of this value. In this case, the objective function can be expressed as in formula (2.1) under the assumption of input focus.

$$Maxh_j = \frac{\sum_{r=1}^{n} u_r y_r}{\sum_{i=1}^{m} v_i x_i} \qquad (2.1)$$

Constraints can be shown as in formula (2.2).

$$\frac{\sum_{r=1}^{n} u_r y_r}{\sum_{i=1}^{m} v_i x_i} \leq 1$$

$$u_r \geq 0, v_i \geq 0 \qquad (2.2)$$

The formulas given in Figure (2.1) and (2.2) are formulated according to fractional programming. The solution of these formulas is more difficult than linear programming. Therefore (2.1) and (2.2) formulas expressed in linear programming logic (2.3) and (2.4) formulas can be obtained.

$$Maxh_j = \sum_{r=1}^{n} u_r y_r \qquad (2.3)$$

$$\sum_{i=1}^{m} v_i x_i = 1$$

$$\sum_{r=1}^{n} u_r y_r - \sum_{i=1}^{m} v_i x_i \geq 0$$

$$u_r, v_i \geq 0 \qquad (2.4)$$

(2.3) and (2.4) formulas are given for input-oriented state. If the CCR method is to be used for output focusing, then the linear programming model will be as in (2.5) and (2.6) formulas.

$$Ming_j = \sum_{i=1}^{m} v_i x_i \qquad (2.5)$$

$$\sum_{r=1}^{n} u_r y_r = 1$$

$$-\sum_{r=1}^{n} u_r y_r + \sum_{i=1}^{m} v_i x_i \geq 0 \qquad (2.6)$$

$$u_r, v_i \geq 0$$

Whether a decision maker wants to decide the effectiveness of decision points through the CCR method, both input and output oriented, the model described above should be applied to all decision points.

When the established model is solved for each decision point, total effectiveness criteria will be obtained for each decision point. The fact that these criteria are equal to 1 indicates the effectiveness of the decision points and the fact that they are less than 1 indicates that the decision points are not effective [3].

BCC Method

This model developed by Banker-Charnes-Cooper, was obtained by changing the assumptions of the CCR model. Basically, it is based on the assumption of variable returns to scale. The assumption is that the sum of λ values to be obtained from the results of the linear programming to be solved for each decision unit is 1 [3]. The BBC's limit is below the CCR limit. The BBC activity score is therefore greater than or equal to the CCR activity score.

The method of BCC is given in (2.7) formula.

The objective function,

$$Min\Theta_k$$

Constraints,

$$\sum_{j=1}^{N} y_{rj}\lambda_{jk} \geq y_{rk}$$

$$\Theta_k x_{ik} - \sum_{j=1}^{N} x_{ij}\lambda_{jk} \geq 0 \qquad (2.7)$$

$$\sum_{j=1}^{N} \lambda_j = 1$$

Additive Method

CCR and BCC models evaluate inputs and outputs separately. The additive method evaluates the input and output together. The main purpose of the additive method is to handle the input surplus (s^+) and the output minus (s^-) together and try to reach the maximum distance remaining on the activity limit [3].

III. DATA ENVELOPMENT ANALYSIS AND APPLICATION

The aim of this application is to compare the high tech exports of the countries with data envelopment analysis. A model based on CCR method is discussed. The relative effectiveness of the decision points that present one or more outputs will be evaluated using similar inputs. The application is the problem where the efficiency of each decision variable is maximum. The constraints are that the effectiveness of any decision-making unit should not be greater than 1.

Data envelopment analysis was performed using 69 decision units, one output and nine inputs. In order to implement DEA, decision variables were selected, inputs and outputs were determined, input and output values were normalized, data envelopment analysis was performed with Excel-Solver plugin and the results obtained were evaluated.

The decision-making units used in this study are countries. The research was conducted with 69 countries considering 2016 data.

Accurate determination of inputs and outputs is very important in data envelopment analysis. The input variables used in the application are selected according to the purpose of the application. The inputs and outputs of the application are shown in Table 1.

Table 1. Outputs and Inputs

	Output	Unit
1	High-tech exports [9]	US $
	Input	
1	Internet users [10]	% of population
2	Quality of mathematics and science [11]	Global competiton index
3	R & D expenditures of companies [12]	Global competiton index
4	Available scientist and engineers [13]	Global competiton index
5	Patents granted [14]	Patent applications, residents
6	Foreign direct investment [15]	% of gdp
7	Gross domestic product [16]	US $
8	Inflation consumer price [17]	Annual %
9	Domestic loans to the private sector	

The data used in the application were normalized. The purpose of normalizing is that the data are very large and different from each other. Data were normalized to keep the values in the range of (0.1). Normalized data are given in Table 2.

Table 2. Outputs and Inputs Normalized

0,100012491	0,627336132	0,572727273	0,242408377	0,203225806	0,100013278	0,299175403	0,100228278	0,240632504	0,180589353
0,102097141	0,659731875	0,287559809	0,267539267	0,36953405	0,100586234	0,185890907	0,123157247	0,176686987	0,103087854
0,100033003	0,590012366	0,563157895	0,267539267	0,530107527	0,100082325	0,220268952	0,10017278	0,113319133	0,233011274
0,107373125	0,814450994	0,622488038	0,569109948	0,753763441	0,101738784	0,224136658	0,151480076	0,24034299	0,584747431
0,161397577	0,799720103	0,829186603	0,705235602	0,682078853	0,100699099	0,282554261	0,119826246	0,275000555	0,291562661
0,101911706	0,571412668	0,43492823	0,368062827	0,438351254	0,100152036	0,207267575	0,102006092	0,136881861	0,247993506
0,100033327	0,897946798	0,591866029	0,351308901	0,570250896	0,10000332	0,189571475	0,101101209	0,316188836	0,33371865
0,100149698	0,65271987 3	0,381339713	0,198429319	0,237634409	0,100039171	0,199294683	0,100445119	0,114304441	0,249531876
0,115765345	0,570191192	0,174641148	0,309424084	0,300716846	0,103451676	0,235521179	0,176899458	0,612336332	0,283206523
0,100042723	0,396381358	0,398564593	0,282198953	0,317921147	0,1	0,178878518	0,100388007	0,36458093	0,169219504
0,188524966	0,824432437	0,806220096	0,9	0,770967742	0,100969975	0,142971305	0,128458598	0,155021233	0,705531473
0,100999314	0,624312858	0,297129187	0,231937173	0,676344086	0,100255606	0,243415701	0,110333123	0,365446158	0,469700721
0,9	0,514739464	0,544019139	0,562827225	0,656272401	0,9	0,198122997	0,580938435	0,276383861	0,636214226
0,101191887	0,55696494 1	0,287559809	0,248691099	0,429749104	0,100361168	0,242233194	0,111855726	0,55142026	0,226885381
0,101517746	0,624472923	0,51722488	0,359685864	0,670609319	0,100005311	0,245547685	0,102186462	0,176478303	0,273880966
0,100048022	0,708912416	0,471291866	0,231937173	0,527240143	0,100001328	0,349917418	0,100579902	0,105445263	0,9
0,132722785	0,71388078	0,522966507	0,489528796	0,389605735	0,100525154	0,221969614	0,108110627	0,208557726	0,242561446
0,405875374	0,826498443	0,676076555	0,795287958	0,756630824	0,132185762	0,197936493	0,249157126	0,2007815	0,339349704
0,115003306	0,889117668	0,679904306	0,669633508	0,613261649	0,101029727	0,205589099	0,112905773	0,189149097	0,687743352
0,100006577	0,427025379	0,343062201	0,217277487	0,403942652	0,100069711	0,191599344	0,106552731	0,495603036	0,136881734
0,10016654	0,522120697	0,388995215	0,22565445	0,283512545	0,100029212	0,188105909	0,103955873	0,262647139	0,159794001
0,100082921	0,395105271	0,166985646	0,129319372	0,547311828	0,100608807	0,21019369	0,114018309	0,865325118	0,178457383
0,122904244	0,74878116	0,440669856	0,355497382	0,644802867	0,101821773	0,212306063	0,152882534	0,166584118	0,466768213
0,101577651	0,805885913	0,702870813	0,44973822	0,550179211	0,10001859	0,219999677	0,10072131	0,184119837	0,319589742
0,267480093	0,792070494	0,69138756	0,719895288	0,667741935	0,109430862	0,196975668	0,20565744	0,185825944	0,415467896
0,210126169	0,870368004	0,566985646	0,667539267	0,716487455	0,109211771	0,32427094	0,213496968	0,208670402	0,552919504
0,10003085	0,487381506	0,341148325	0,190052356	0,269175627	0,100063072	0,324042237	0,100336309	0,283109768	0,281932248
0,101917379	0,650640543	0,503827751	0,27591623	0,816845878	0,100401666	0,198988928	0,107998294	0,135529248	0,457216971
0,100679186	0,806424894	0,735406699	0,481151832	0,561648746	0,100154027	0,660428136	0,113507795	0,2956097	0,812052336
0,101701688	0,681514328	0,566985646	0,30104712	0,381003584	0,100115521	0,22658753	0,101897684	0,121853707	0,279760575
0,120069911	0,737644777	0,413875598	0,259162304	0,401075269	0,100408306	0,9	0,105124754	0,196663361	0,17836005
0,121508103	0,312419273	0,553588517	0,543979058	0,624731183	0,108762303	0,203952443	0,196992178	0,423010408	0,236817417
0,154480055	0,762538712	0,66076555	0,636125654	0,796774194	0,100133446	0,521321969	0,112816369	0,176686987	0,228137395
0,10021819	0,9	0,632057416	0,590052356	0,759498208	0,100022573	0,1	0,10057992	0,261165182	0,377057564
0,116577548	0,742087503	0,576555024	0,82460733	0,834050179	0,100862421	0,227511397	0,113371781	0,149522765	0,295863156
0,145007208	0,5842322	0,549760766	0,44973822	0,656272401	0,105873624	0,191041074	0,179594778	0,170538911	0,371072655
0,100002351	0,444598806	0,392822967	0,315706806	0,352329749	0,10001195	0,265262631	0,100322512	0,293801903	0,17067102
0,100135823	0,592597242	0,511483254	0,361780105	0,791039427	0,100013942	0,230619578	0,101379464	0,13743063	0,331449153
0,249808358	0,84662453	0,674162679	0,803664921	0,894265233	0,272778303	0,187330274	0,311993886	0,170871336	0,738609849
0,103317668	0,7166077	0,457894737	0,340837696	0,47562724	0,1006586	0,341461362	0,105617255	0,9	0,175517081
0,100100433	0,354784548	0,256937799	0,152356021	0,249103943	0,100055105	0,272100246	0,1	0,197707049	0,128512163
0,29090728	0,852753672	0,574641148	0,571204188	0,584587814	0,208498398	0,188131611	0,160358795	0,225039971	0,58627787
0,100096056	0,333836465	0,591866029	0,422513089	0,653405018	0,100185231	0,192589284	0,103212843	0,375477402	0,222610918
0,10291685	0,695878959	0,601435407	0,441361257	0,481362007	0,100062408	0,207755533	0,101554957	0,221825821	0,211400275
0,101247282	0,893618174	0,54784689	0,717801047	0,501433692	0,100094275	0,783562366	0,102237845	0,191599978	0,433330178
0,101401024	0,743033376	0,522966507	0,317801047	0,335125448	0,100062408	0,18966471	0,100903276	0,183373565	0,303536646
0,100952999	0,558117496	0,446411483	0,263350785	0,461290323	0,100156683	0,207570589	0,104170391	0,258204692	0,289315195
0,100021135	0,666996007	0,446411483	0,1	0,137275986	0,100059752	0,195807614	0,100008518	0,494924311	0,165041636
0,100005858	0,1	0,413875598	0,292670157	0,378136201	0,10000332	0,249480714	0,10014824	0,508418459	0,1
0,175497223	0,568973983	0,233971292	0,307329843	0,501433692	0,10086906	0,220835115	0,144704079	0,317344708	0,181660713
0,10093177	0,720793856	0,639712919	0,401570681	0,458422939	0,100001328	0,471073556	0,100191117	0,20545226	0,374592028
0,1	0,514963385	0,563157895	0,353403141	0,392473118	0,100000664	0,215951179	0,100241365	0,227725033	0,410833791
0,189656142	0,733615184	0,674162679	0,728272251	0,839784946	0,100735614	0,238245173	0,11246045	0,282747492	0,513708641
0,106311596	0,891943981	0,611004785	0,661256545	0,805376344	0,100813955	0,11946334	0,115663397	0,353648939	0,591749195
0,100488955	0,192388034	0,350717703	0,32617801	0,461290323	0,100134774	0,189005024	0,111703221	0,363748025	0,11257509
0,100264609	0,448548415	0,155502392	0,194240838	0,280645161	0,100047138	0,225192672	0,107977519	0,355928121	0,186156871
0,142159088	0,534413063	0,417703349	0,397382199	0,412544803	0,100216435	0,212587311	0,112820081	0,264758431	0,217920919
0,121480618	0,686675602	0,51722488	0,334554974	0,53297491	0,102828263	0,224989659	0,119972716	0,146295582	0,254693669
0,103629943	0,662065358	0,553588517	0,407853403	0,636200717	0,100480008	0,237457236	0,10852019	0,206964782	0,46934604
0,106930512	0,568661817	0,582296651	0,223560209	0,484229391	0,100666567	0,215854117	0,107779203	0,1	0,156269134
0,11070776	0,713263917	0,540191388	0,328272251	0,498566308	0,117788843	0,211513476	0,154855169	0,528106818	0,25049275
0,100006778	0,230755335	0,524880383	0,328272251	0,455555556	0,100000664	0,218150106	0,100078409	0,462092154	0,129989278
0,30374256	0,752533403	0,9	0,690575916	0,819713262	0,101062258	0,452191363	0,112479346	0,151637522	0,547349994
0,100307587	0,307713948	0,1784689	0,208900524	0,1	0,100001992	0,201989152	0,100869965	0,206792386	0,221119545
0,111048913	0,748050389	0,427272727	0,328272251	0,349462366	0,100145397	0,230247263	0,103575793	0,150765292	0,263804573
0,124161615	0,842406068	0,542105263	0,789005236	0,713620072	0,101348404	0,217387199	0,121824504	0,225751271	0,532042015
0,103519447	0,558771836	0,310526316	0,317801047	0,535842294	0,104135504	0,19682683	0,136831623	0,564265272	0,31181312
0,347071268	0,711276471	0,580382775	0,828795812	0,9	0,296070308	0,212019506	0,9	0,239574938	0,768656634
0,10307314	0,521582455	0,1	0,508376963	0,289247312	0,101847002	0,188058008	0,112414055	0,49204135	0,590319749

IV. DISCUSSION

Stages of the Application in Excel-Solver Solution

Table 3.3 data is placed in the excel table.

At the stage of creating the model, we use the Vlookup formula instead of installing each model separately, since we will evaluate each country separately.

First, we will do input and output calculations based on weights. For the output calculation, each output value is multiplied by the output weight coefficient. The same procedure is used for the input account. Output - Input ’operation was performed for difference calculation.

When we come to the mathematical expression part of the model, we make use of Vlookup formula to make the input and output values for each country from our excel table and then to solve the model with a single operation. We have created a new table of countries, output and input cells.

The part of ‘arrange target’ shows the output cell. Since our model is maximization, the target was chosen as the largest.

Mathematical model:

Maximization

Objective function: $x_ç$

Constraints

$(x_ç-(\sum_{i=1}^{9} xi)) * \sum_{i=1}^{10} wi <= 0$

$\sum_{i=1}^{9} xi = 1$

$x_ç, x_i, w_i > 0$

Notations:

$x_ç$ = Output variable,

x_i = Input variable,

w_i = Weights of output and input variable.

Since our application is a linear model, simple LP is selected from the options.

We write the value we find in the table of countries and effectivity levels by finding the percentage. We repeat this process for all countries. Effectivity levels of the countries are given in Table 3.

Table 3. Effectivity Levels of Countries

Countries	Effectivity level	Countries	Effectivity level
Albania	65%	Israel	51%
Argentina	75%	Italy	57%
Armenia	57%	Jamaica	58%
Australia	38%	Jordan	49%
Belgium	69%	Japan	59%
Bulgaria	51%	Kazakhistan	57%
Bahrain	50%	Kyrgyz Republic	74%
Bosnia and Herzegovina	66%	Korea	100%
Brazil	75%	Sri lanka	53%
Botswana	58%	Lithuania	55%
Switzerland	84%	Luxembourg	45%
Chile	61%	Latvia	54%
China	100%	Morocco	58%
Colombia	59%	Moldova	87%
Costa Rica	50%	Madagascar	87%
Cyprus	61%	Mexican	97%
Czech Republic	65%	Malta	47%
Germany	100%	Mauritius	50%
Denmark	51%	Malaysia	81%
Algeria	63%	Norway	53%
Ecuador	62%	Pakistan	69%
Egypt, Arab Republic	79%	Peru	70%
Spain	57%	Philippines	70%
Estonia	48%	Poland	60%
France	80%	Portugal	47%
United Kingdom	63%	Romania	66%
Georgia	67%	Russian Federation	51%
Greece	57%	Rwanda	62%
Hong Kong	42%	Singapore	100%
Croatia	55%	El Salvador	90%
Hungary	69%	Slovak Republic	58%
India	61%	Swedish	52%
Ireland	75%	Turkey	51%
Iceland	58%	America US	72%
		South Africa	86%

V. CONCLUSION

Data envelopment analysis was used to compare countries' high-tech exports. Our data are from 2016 year. High-tech exports were determined as output variables. Input variables were the users of the Internet, the quality of mathematics and science, R & D spending of companies, existing scientists and engineers, patents granted, foreign direct investment, gross domestic product, inflation consumer price and domestic loans to the private sector.

Data envelopment analysis methods were applied and efficiency levels were calculated. Countries were compared according to the activity levels found. According to the results, countries such as China, Korea, Germany and Singapore have a higher level of high technology exports compared to other countries. As a result, we find that these countries are effective. These countries, which have increased their performance in high-tech exports in recent years and have made a big increase in the economy, prove the result.

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