EVALUATING THE PERFORMANCE AND RANKING OF THE PROVINCES OF THE COUNTRY IN BARLEY PRODUCTION USING THE DATA ENVELOPMENT ANALYSIS WITH REGARD TO WEIGHT RESTRICTIONS

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Abstract
Wheat and barleyhave long been involved and blended into thedaily livesof the people,directlyorindirectly. Breadis the staplenourishment of all inhabitants of the world including Iranians. Therefore, it provision is among thetop priorities ofhuman societies. Given the importance ofbarleyin Iran, thispaper has discussed the performance and ranking evaluation of the provinces of the country in barley production using the data envelopment analysis with regard tohomogeneousallocationof the weights. The advantage of thismethodover the othermethods ofweightrestrictionis that it has no effecton thesolution space of the issue.Theobtained resultscan be used as a reference in evaluating performance and planning for achieving higher efficiency in Barleyproduction inthe provinces of the country. Thispaperhas not only calculated the efficiency using SWAT model but also calculated the efficiency of the units usingdata envelopment analysisin classicalmode in order to determinethe ability ofthe modelin distinguishing betweenthe units.

Keywords:data envelopment analysis technique, efficiency, weightrestrictions, allocating homogeneousweightstechnique, barley

1. Introduction
Data envelopment analysis (DEA), abranchofOperations Research, examinesand assesses similar units. The highpower of this nonparametric method in efficiency assessment and its special features has made it to be used in variousareas ranging from industriesand gas to hospitals, banks, and universities. Thismethodwas first introduced by Carnes, Cooper, RhdoesinOperations Researcharticlesknown asCCRmodel in 1978.It is onlyapplicabletoreturnsto constant scaletechnology. That's whyBCCmodelapplicable toreturnsto diverse scaletechnologywas introduced by Banker, Charnes, andCooper in 1984. Thenthismethodologywas usedinmanystudiesand researches that extending theproblem solving software in Operations Research can be regarded as the mainreason behind it. DEAhas grown dramaticallyinthe past two

decades. [5] [4].One ofthepoints in classicalDEAis that it uses the freedom of scope for weight determination. Thismeans that: a)noprior value or restraintis set for the weight collection; b) weights can be freelyincreased or decreased;c) non-negativity is the onlyapplied limitation. In addition, the input and outputweights maydiffer for variables between different DMUs. This factor can cause some problems in spite of its leastamountof information needed for efficiency evaluation. Some of these problems can be followed as:

1. It is probable that the factors of secondary importance have alarger share in the DMUevaluation.In fact, if the input and output data be of different importance level and if the weights given tothe highlyimportant criteriabe smallandevenzero,it can notbeclaimedthattheobtained efficiency by DMUistotallytrue andtrustworthy.
2. Factors which might be important for all DMUs but be overlooked in analyses. This means that someimportant inputsand outputsare notconsidered becauseof their havingno impacton theefficiency of theDMUs.
3. When we use fullflexibilityinDEA weights, each unit is examined uniquely and with respect toits particularcircumstances. However, these arehomogeneousunits which overall objectivesshouldalso be consideredin their assessment.
4. Finally, in some situations, there is certain informationabout the importance of inputsandoutputswhichshould be cared about. The experts' opinions which might be about the importance of the standards and be inconsistent with DEA outputs can be mentioned among them. [3] [6].

Accordingly,some studies have been conducted overthis problem known as weightrestrictionmethods inDEA. Inthese methods, it is attempted to restrict the rangeofweightfluctuation in order to moderate the weights in accordance with the experts' opinions.Several methodsare presented for enteringweightrestrictions tothemodel. The main purposeofenteringweightrestrictions is buildingaframein which theweighsof input and outputfactors can be changed and thereby reduce the weightsflexibility to some extent. By entering the weightrestrictions tothe original model, the obtained efficiency value of the new formulation would be less than or equal to obtained efficiency value of the original formulation.Sothe number ofthe efficient units would bereduced andthe differencebetween them would becomeobvious.In addition to thementioned issues in the previous section, theweightrestriction is also known as a way todistinguish betweendifferent units. In theclassicalapproach,insome cases,manyunitscould be known as efficientunits (optimal answer isequalto 1).Intheseconditions, we should use secondary methods such as super efficiency for unitsranking.

In general,theweightrestrictionmethods can be classified intofourcategories.

1.1.Direct Weight Restriction(absolute)

ThismethodwasfirstintroducedbyDyson and Thanassouli. Then Beaslyand in particular Roll ,Cook, and Golanybegantospreadthismethod. In this method, theweight restrictionisentered the mainproblem that can be seen in the following:

$\alpha_i < v_i < \beta_i$ for i output

$\alpha_r < u_r < \beta_r$ for r input

As can be seen, theseweights are applied to the weights in numerical limits. The purpose ofthese restrictionsis thatnone of theweights be valued more or less than the defined limitand the weights be prevented from being zero.The value of the limits of this method is dependent on the opinion of experts.Followed by analyzing the created weights by the unrestricted model, this restriction should be entered the model.Another great thingaboutthismethodis thatthis limitation creates different responses depending on theorientationofthe model(input-oriented or output-oriented). Infact,in order to use these types of weight restrictions, firstly we shouldrun the classicalDEAmodelin order todeterminethe extent andlevelof data significance.Afteranalyzing the weights forallvariables andDMUs, the limitations should be presented for the model. If the obtained model was not feasible, we can make the necessary adjustments until we come into a feasible model.Thisis a general methodwhich might cause the loss of solution space.In general, this methodmay bring about the following problems:

- It might cause the solution space to beunjustified.
- Perhaps, it can not calculate the maximumamountofefficiencyfor DMUs. Infact,it is probable that the efficiency amounts be underestimated. [8]

1.2. The Cone Ratio Model: Thismodelwasfirstintroducedby Charnesand was spread by Kornbluth. If theobtainedweights fromthe classical DEAmodel werenotconsistentwith the goalsof someDMUs, DEA might be wronged in unit efficiency estimation.Accordingly,in the Cone Ratio Model the weights are determinedto beadaptedto the purposesof theassessmentunits.This method is taken of observing the u, v weightrooms.

1.3. Assurance Region (AR):This different method can state the efficiency ratio in terms of oneof the factors. In fact, in this method, the output weight can be considered as a basis for comparison with the other outputs.Similarly,all input weights are compared with one inputweight. Thismethodwas firstdevelopedbyThompsonand his colleagues and, in fact, hewas the firstto expressthe Assurance Region concept. This method allows the continuous monitoring of the limitations until the experts' objectives and opinions are fulfilled. The limitationsofARareas follows:

$$\alpha_r u_1 \le u_r \le \beta_r u_1$$

$$\alpha_i v_1 \le v_i \le \beta_i v_1$$

Here, α_r , α_i, β_r, andβ_i show the importance of various factors relative to the base factor. The difference between them specifies the range within which each factorcan be changed. The value of these parametersis set usingthe previous dataorthe experts'opinions. Thismethodis known asARI.

As can be seen in the above formula, the value of ARrange which is sensitive to the measurement scale depends on the input and outputlevels. This is one of the favoritemethods of researchers. Furthermore, manystudies have used this method for entering Weight restrictionintothe DEAmodel.The name, Assurance Region, is derived fromtheconfidencelimitswhich confine thesolution spaceto aspecificarea. Infact,these limitations can make the solution space smaller. [11]

1.4.Virtual Input and Virtual Output Restriction

The previousapproachestoweightrestriction did not consider the numberof inputs and outputs. Theseweightsdepend on these levelsandif number of the levels is not considered, their interpretationwill become difficult.Therefore, in order to investigate the roleofa variable intotal efficiency, at first its importance should be determined using the weight in total efficiency. As a result, we can enter the restrictions on virtual variables instead of direct entering of the weight restrictions. Wong and Beasley have described how to import these types of restrictions. In fact, we can limit theratio of r output to total virtual variable of DMUjrather than the direct weights limit. Sowehavethis formulation for the routput:

$$\alpha_r \le \frac{u_r y_{rj}}{\sum_{r=1}^{s} u_r y_{rj}} \le \beta_r$$

Here, $\sum_{r=1}^{s} u_r y_{rj}$shows the total virtual variable of DMUj. Similarly,we can gain the restrictions for input virtual variables.

$$\alpha_r \le \frac{v_r x_{rj}}{\sum_{r=1}^{m} v_r x_{rj}} \le \beta_r$$

Giventhat these constraintsarenot directlyused,Wong and Beasleyhave multiple definitions which will be referred to here.

- Adding these restrictionstoaDMU,each unitwillbeevaluated with twoadditionalrestrictions.
- Adding these restrictionstototal DMUs,each DNU willbeevaluated with 2 Nadditionalrestrictions(N is the total number DMUs).
- Importing these restrictions as theratio of DMUr output average to total virtualvariablesare as follows:
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$$\alpha_r \le \frac{u_r y_{rj}}{\sum_{r=1}^{s} u_r y_{rj}} \le \beta_r$$

Here, $\sum_{j=1}^{N} y_{rj}/N$representstheDMUr output average.

The point thatcanbenotedhereis thatwe can neglect the denominator of the above fractiondepending on the orientation of the model (input- or output-oriented). For example, since the totalinput weightin an input-oriented model isequal to 1, thedenominatorseemsto beunnecessary. [13]

All the previous methods tried to limit the weightsthrough importing constraints to the restrictions of DEA problem. One of the dark points in the mentioned methods is that they might cause the loss of solution space.Accordingly, inrecentyears, new approaches have been emergedwhich try to limitthe weightsin the case that the solution space ofthe problemdoes not go awayandinfactdoes not cause the problemto be unjustified. Among thesemethods,limiting the weights throughimportingpenaltiesto the objective function is a new methodwhich has been entered the object literaturesince 2005.This method has the advantage that it does not affect the solution space and in effect does not cause the loss of solution space. Therefore, theseareappropriate methodsto be used for performance evaluation.The model introduced by StankoDimitrov and Warren Suttonin 2010 can be enumerated among the models introduced in this context. In this method, the total virtual variables are considered as a penalty in the objective function. This penalty causes more homogeneous allocation of the weights leading to a dramatic increase inthe number of positive valued weights. Given thepower of this method, this model has been used inbarley production studying and the resultshave been analyzed.

2. Model Introduction

The model used inthispaperis the StankoDimitrov and Warren Suttons' model introduced as homogeneous weight allocation model. This method uses virtual weights as a tool for decision-making units'penalty.One of the majoradvantages of thismethod is that adding the restrictions does not affect the response space. In this paper, the model in input nature has been used for performance evaluation.

$$\min_{u.v}\ vx_0 + \alpha e^T Ze$$
Subject to
$$uy_0 = 1,$$
$$-vX + uY \le 0,$$
$$v_i x_{0i} - v_j x_{0j} \le Z_{ij}\ \forall i, j,$$
$$-v_i x_{0i} + v_j x_{0j} \le Z_{ij}\ \forall i, j,$$
$$u \ge 0,\ v \ge 0.$$

Here, v is the input weight vector, u is the output weight vector, $\mathbf{x_0}$and $\mathbf{y_0}$ are respectively the input and output under evaluation units, and x and y are the matrix related to input and output data. The following absolute value has been considered as a penalty for the homogeneity of input weights.

$$|v_i x_{0i} - v_j x_{0j}| = z_{ij}\ \forall i, j$$

Infact,$\mathbf{z_{ij}}$is the homogeneous differenceinthe weights of i inputand j input. Therefore, the sum of ($\sum_{i,j} \mathbf{z_{ij}} = \mathbf{e^T Ze}$)$\mathbf{z_{ij}}$should be in minimum value for homogeneous weight allocation. Sowe can this value to the objective function. In addition, α factor can be added to the model as a scale for measuring the factor effectiveness. The optimumvalue of the above programis between[1, ∞] in which thesmaller value indicateshigherefficiency.Note that the added constraintsto themodel will have no impact on thesolution space. In addition, the uandvwhich are feasible in the classical modelwill befeasibleinthe modeltoo and vice versa.In this method, instead of placing explicit restrictions, α parameter has been presented as a scale for the importance of weight allocation.This factor specifiesthat how much a unit will pay the penalty in case of allocatingheterogeneous weights. This factor is inversely related to the amount of the units'efficiency, that is by increasing the amounts of the factor the units' efficiency will come down [1].

3. DMUs Introduction

Undoubtedly,providing basic needs is the main factor which has drawn the human attention to agricultural. In fact, the other economic sectors were gradually created to suit the needs of the agricultural sector.Requiringtheagriculturaltools and instruments and products exchanging play an important role in machineryindustry andservice sector development, respectively. Although after the Industrial Revolutionand the gradual eliminationof theFeudalismpolitical-economic system, the industry sector and the capitalfactor gained greater relative importanceinmanufacturing. However, today this sector is stillknown as the basis ofeconomic growth and development.The importance of agricultural sector in national economy is due to some reasons:The relativelyhigherpractical degree ofagriculturecompared tothe industryand miningsectorsand in effect its power for job creation, the opportunityto earn moneythrough an increasein domestic production,the strategicnatureofsomeproducts of this sector,the provision of some needed data especially for the industry and services sectors, as well asa market for theoutputof othersectors. Barley has been selected for evaluation because not only it is importantin Iran but also its harvest is of secondary importance in cultivation crops after wheat. Levelsofbarleyharvested in Iran have been estimated as about 1.68million hectaresinthecrop yearof 1377-88 of which 43.16percentwere irrigated and 56.84percent were dry framing.KhorasanRazaviprovincewith13.65% and Hormozgan province with 0.8% of the total barley harvested area compromised thehighest andthe lowestlevels ofthis product, respectively.

4. IntroducingInput and OutputFactors

Inthispaper,we have used the irrigated barley datagenerated in 1388 which is available on the website ofthe Ministry of Agriculture in separated provinces. The used input factors are as follows: the averageof barley productionper hectareas output factor and the average of consumed seeds, the average of working hoursper day,the percent of using machinery in irrigation and fertilizing,the average of consumed urea, the average of consumed phosphate, the amount of consumed herbicide, and the amount of consumed pesticides per hectare.Gams 23.0softwarewas used for model simulation. Regarding theaverage amountof unit’sefficiency fordifferent values ofα,0.05was chosen for α.

valueα	0.01	0.02	0.03	0.04	0.05
average efficiency	0.77	0.744	0.714	0.683	0.671
valueα	0.06	0.07	0.08	0.09	0.1
average efficiency	0.631	0.621	0.604	0.59	0.57

Table1: Theaverage efficiencyfordifferent values ofα

5. Discussion and Conclusions

The weight restriction is one of the methods which can raise the distinction between units [7].The amount ofunits'efficiency in the two classicaland homogeneous weight allocation methodsis demonstrated in Figure 1. Asit can be clearly seen in theobtained efficiency values, a very good distinction has been occurred between the data in the homogeneous weight allocation method.In fact, examining the amount of units' efficiency based on the classical DEA method is associated with optimism to some extent.While theclassical methodrequiresa secondaryprocedureinrankingunits,the SWAT model considers aperfectdistinction betweenthem.

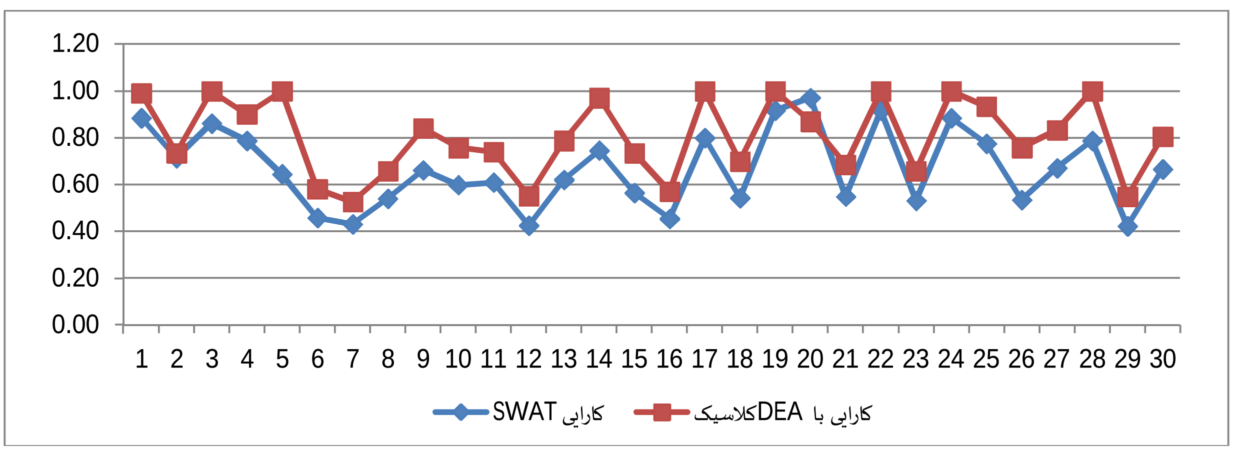

Figure1: Units' efficiency with the twoclassicaland homogeneous weight allocation methods

Table(2) demonstrates the amount of unit performance in the two methods, the efficiency value, and the unitsranking according tothe obtained efficiency value by the homogeneous weight allocation methods. The efficiency value of the units is contrary to the obtained value of the above model. Here the basis of units ranking is on the efficiency values of the provinces in barley production.

Row	Province	SWAT value	SWAT efficiency	Ranking inSWAT	Value of DEA with no weight restriction	Efficiency with classical DEA
1	Ardebil	1.13	**0.88**	**4**	1.01	0.99
2	Isfahan	1.4	**0.71**	**12**	1.36	0.74
3	Ilam	1.16	**0.86**	**6**	1	1.00
4	East Azarbaijan	1.27	**0.79**	**8**	1.11	0.90
5	West Azarbaijan	1.55	**0.65**	**15**	1	1.00
6	Bushehr	2.18	**0.46**	**25**	1.72	0.58
7	Tehran	2.32	**0.43**	**27**	1.9	0.53
8	ChaharMahal and Bakhtiary	1.85	**0.54**	**22**	1.52	0.66
9	South Khorasan	1.51	**0.66**	**14**	1.19	0.84
10	RazaviKhorasan	1.67	**0.60**	**18**	1.32	0.76
11	North Khorasan	1.64	**0.61**	**17**	1.35	0.74
12	Khuzestan	2.35	**0.43**	**28**	1.81	0.55
13	Zanjan	1.61	**0.62**	**16**	1.27	0.79
14	Samnan	1.34	**0.75**	**11**	1.03	0.97
15	Sistan	1.77	**0.56**	**19**	1.36	0.74
16	Fars	2.2	**0.45**	**26**	1.75	0.57
17	Qazvin	1.25	**0.80**	**7**	1	1.00
18	Qom	1.84	**0.54**	**21**	1.43	0.70
19	Kordestan	1.09	**0.92**	**2**	1	1.00
20	Kerman	1.03	**0.97**	**1**	1.15	0.87
21	Kohkeluye and Boyer Ahmad	1.82	**0.55**	**20**	1.46	0.68
22	Golestan	1.09	**0.92**	**3**	1	1.00
23	Lorestan	1.88	**0.53**	**24**	1.52	0.66
24	Mazandaran	1.13	**0.88**	**5**	1	1.00
25	markazy	1.29	**0.78**	**10**	1.07	0.93
26	Hormozgan	1.87	**0.53**	**23**	1.32	0.76
27	Hamadan	1.49	**0.67**	**13**	1.2	0.83
28	Yazd	1.27	**0.79**	**9**	1	1.00
29	Jiroft and Kahnooj	2.36	**0.42**	**29**	1.82	0.55
30	Nationwide average	1.60	**0.67**		1.30	0.80

Table2: Efficiency and ranking results frombothclassicalandSWAT methods

The next issue discussed is the units' ranking using the done evaluation. This kind of ranking can be important for performance identification and proper planning which in effect can give rise to units' performance improvement. The units can be easily classified using the obtained efficiency by the homogeneousweightallocation method. In order to have a more complete examination, the efficiency value and the ranking of each province have been presented in both homogeneous weight allocation and classical methods. As can be seen, Kerman province with the efficiency value of 0.97ranked first in the production of this important crop inIran. The lowest efficiency value is for Jiroft and Kahnooj province which hasa tiny proportion ofbarley production in the country. Furthermore, although we can not observe a district patternof relationship betweenthe units' climate and their efficiency value, this uncontrollable factor can be probably considered as the reason behind the ineffectiveness of some provinces. For example, all provinces ranked between first to sixth have a higher averageof rainfall in comparison with the average of rainfallin the countryin the crop year of 88.

Suggested Studies

During this study, some points were mentioned which can be used for results improvement. One of the most influential factors in efficiency is uncontrollable data. For example,the amount of rainfall, the humidity, and the minimum and maximum of temperature are among the factors which havedirect impactonthe productionofcrops.According to the available methods in DEA, we can add these items to the model in order to gain the net efficiency of the units. Another issue about this model is that we can use other methods in order to getthe importancelevel of homogeneous weight allocation.We can use the available dataof the desired crop production and the statisticalmethods in order to have a good estimate of the importance level of the factors.The next issue which can be mentioned here iscalculatingMlemkouistcoefficientfor getting units' efficiency changes over time. Infact,we can study the units' movement towards efficiency by placing one year as the baseyear. Finally,given thegoodresultsofthismodelit can be used for units' assessment and ranking in other issues.

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