



Efficiency Evaluation of Wheat Farming: A Network Data Envelopment Analysis Approach

Reza Kazemi Matin^{a,*}, Roza Azizi^b

^a Associate professor, Department of Mathematics, Karaj Branch, Islamic Azad University, Karaj, Iran

^b Instructor, Department of Mathematics, Karaj Branch, Islamic Azad University, Karaj, Iran

Received 2 September, 2013; Revised 19 January, 2014; Accepted 15 February, 2014

Abstract

Traditional data envelopment analysis (DEA) models deal with measurement of relative efficiency of decision making units (DMUs) in which multiple-inputs are consumed to produce multiple-outputs. One of the drawbacks of these models is neglecting internal processes of each system, which may have intermediate products and/or independent inputs and/or outputs. In this paper, some methods which are usable for network systems are briefly reviewed. A new unified model is also introduced which can be easily applied for performance measurement of all types of network production process. As an example, for the application of network DEA models, performance evaluation of wheat production in Iran provinces is considered and the results are compared.

Keywords: Data Envelopment Analysis, Network DEA, Efficiency, Wheat production.

1. Introduction

Nutrition has become one of the most important subjects related with health and economic issues. Evaluating agricultural efficiency in different countries and areas and for different crops has strong practical implications and will help governments to meet the demands of the society. Wheat is one of the world's largest cereal grain crops with approximately 674.9 million tons produced in 2012. In human food, wheat is the main source of vegetable protein and it contains higher protein amounts in comparison with other major cereals such as maize or rice. Also along with rice, wheat is considered as the world's most favored staple food. So, it is necessary to evaluate wheat production as one of the most important ingredients of human food.

Decision making units (DMUs) such as wheat producers are the entities which consume some inputs to produce some output and whose efficiencies should be evaluated. Efficiency of each DMU can be assessed by estimating the production frontier which shows the maximum possible production level of one commodity for any given production level of the other, given the existing level of production factors. Application of frontier analysis in efficiency measurement can be categorized into two groups with regard to how the frontier is specified; the parametric, the stochastic frontier function or the nonparametric, linear programming (LP)

approaches. In parametric approach a specific production function is assumed to determine the production frontier and the relation between inputs and outputs. In nonparametric approach, there is no assumption for production function and the production frontier is derived by observed inputs and outputs. Nonparametric approaches have fewer assumptions than parametric ones, so, it makes them more applicable. As a pioneer, Farrell (1957), applied a nonparametric approach to evaluate the efficiency score of systems. Charnes et al. (1978), generalize Farrell's approach and present a new concept which is named data envelopment analysis (DEA).

Data envelopment analysis (DEA) is a nonparametric, mathematical programming approach for evaluating the relative efficiency of a set of decision making units (DMUs) that convert multiple inputs to multiple outputs. Classical DEA models deal with the DMU as a whole system and only consider the inputs consumed and the outputs produced by the system. So, they are not applicable for the systems composed of several processes because of ignoring the internal operations of the components. So, network DEA is presented to handle systems with more than one process. For example, although a network DMU is indeed inefficient, classical DEA models may determine it as efficient one. Generally, the achieved efficiency score of the classical DEA models

*Corresponding author's e-mail: rkmatin@kiau.ac.ir

for multi processes systems are not accurate enough, unlike the network DEA models.

In recent years, many studies have paid particular attention to systems with network structure. Kao and Hwang (2008) developed a relational model to measure the efficiency of a two-stage production unit, under constant returns to scale technology, where the first stage converts some inputs to outputs (intermediate products) and these outputs are used as inputs in the second stage for producing final outputs. A more general situation is a two-stage system in which each stage has exogenous inputs and/or exogenous outputs (See Chen and Guan (2012), Kao and Hwang (2010) and Li et al. (2012) among the others). Azizi and Kazemi Matin (2010) analyzed the efficiency score of two stage systems under variable return to scale technology. Kao (2009,b) considered some network systems with parallel structure and developed a network DEA model for performance evaluation of these systems. Kao (2009,a) introduced a relational method for evaluating general network systems. Lozano (2011) presented a simple model of network systems and used the model to derive cost efficiency and scale efficiency of the network systems. Chen et al. (2013) mentioned some problems of network DEA with regard to divisional efficiency and projection. They pointed that most of network DEA models have weakness in presenting efficient projections. Also, they showed that the multiplier and envelopment network DEA models are different with regard to presenting divisional efficiency. Tone and Tsutsui (2014) used a model in the slack based measure (SBM) framework to combine network SBM with dynamic SBM (Tone and Tsutsui (2009)).Kao (2014,a) evaluated the efficiency score of general multi-stage systems, where each stage consumes exogenous inputs and intermediate products (produced from the former stage) to produce exogenous outputs and intermediate products (for the next stage to use). Kao and Chan (2013) presented a multi- objective model to evaluate performance of a network system in which different objective functions are considered for each process. Moreno and Lozano (2014) proposed a Network DEA approach to assess the efficiency of NBA teams and compared it with a classical DEA approach. A review of studies on network DEA is presented by Kao (2014,b). Rohacova (2015) used a two-stage DEA approach for optimization of urban public transport systems. KazemiMatin and Azizi (2015) introduced a general model which not only deals with special structures of network systems such as series and parallel, but also handles network systems with any structure.

However, few studies have been conducted on the use of DEA to evaluate wheat production. Malana and Malano (2006) used DEA to assess productive efficiency of wheat in selected areas of Pakistan and India. Shang and Mao (2009) applied data envelopment analysis to calculate the efficiency of irrigation-fertilization schemes for winter wheat in North China. Hadi-Venche and KazemiMatin (2011) employed a DEA model with

imprecise data to evaluate the efficiency of Iranian wheat producer provinces.

In this paper, we evaluate the wheat production of Iran provinces using network structure with a new general network DEA. In the presented network structure, each province is considered as a parallel system with two processes in which each process is composed of three series processes. The new general network DEA model is a unified model which is able to evaluate the performance of production systems with any network structure and make up for the flaws and defects of some other common network DEA models. The contributions of this paper are as follows:

- Pointing out some drawbacks associated with some existing network DEA models
- Introducing the network DEA model which fixes other's problems
- Evaluating the performance of wheat producing provinces in Iran using network DEA model
- Comparing the result of classical DEA model and network DEA model

The rest of this paper unfolds as follows. A brief review of some models for estimating network systems are presented in section 2. Section 3 is devoted to the application of the general network DEA model for evaluation of wheat production in Iran and comparing the results. Section 4 concludes.

2. Network DEA Models

Conventionally, a production system is considered as a black box which consumes some inputs to produce some outputs. Throughout this paper, inputs vector and outputs vector are denoted by $\mathbf{x}_l = (x_{1l}, \dots, x_{ml})$ and $\mathbf{y}_l = (y_{1l}, \dots, y_{sl})$, respectively. Using the same notations, Charnes et al. (1978) presented the CCR model under CRS technology to measure the efficiency score of DMU_k via model (1):

$$\theta_k = \text{Max} \frac{\sum_{r=1}^s u_r y_{rk}}{\sum_{i=1}^m v_i x_{ik}}$$

$$s.t \quad \frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1, j = 1, \dots, n$$

$$v_i, u_r \geq 0, r = 1, \dots, s, i = 1, \dots, m \quad (1)$$

For systems consisting of some processes with the interrelationship, the above model ignores the performance of sub-processes. Thus, network DEA is considered to deal with DMUs with complex internal structures.

There are two basic structures in network DEA which are named series and parallel ones introduced by Kao

(2009,a) and Kao (2009,b), respectively. The series structure is the one in the outputs of each process are consumed as the inputs of the next process and these products are introduced as intermediate products. In parallel structure, the production system is composed of some processes with their own inputs and outputs in which the sum of the i th input for all processes is equal to the i th input of the production system and the sum of the r th output for all processes is equal to the r th output of the production system. Although the mentioned structures are applicable for some production systems, there are many network systems which are not included in these structures and have more complicated structures. Therefore, series and parallel structure are not suitable for them. Next part is devoted to reviewing two network

DEA models which can be exploited not only for series and parallel systems but also for some systems without simple structure of series and parallel.

2.1. Relational model

Consider a network system as depicted in Fig. 1, which does not have series or parallel structure. In this system, X_i^p is the i th input which is consumed in p th process, Y_r shows output of the r th process which is divided into y_r^O and y_r^I , and they are the output of system and the input of third process, respectively.

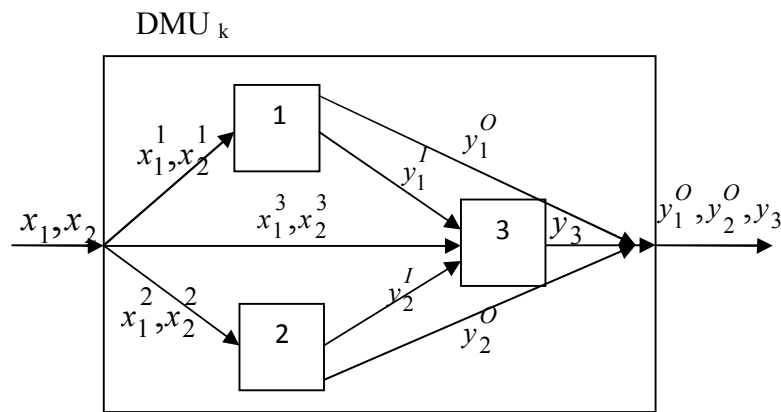


Fig. 1. Network structure

Kao (2009a) presented the following model to evaluate the performance of n network systems with the structure of Fig. 1.

$$\begin{aligned}
 \theta_k &= \max u_1 y_{1k}^O + u_2 y_{2k}^O + u_3 y_{3k} \\
 \text{s.t.} \quad & v_1 x_{1k} + v_2 x_{2k} = 1 \\
 & u_1 y_{1j} - (v_1 x_{1j}^1 + v_2 x_{2j}^1) \leq 0, \quad j = 1, \dots, n \\
 & u_2 y_{2j} - (v_1 x_{1j}^2 + v_2 x_{2j}^2) \leq 0, \quad j = 1, \dots, n \\
 & u_3 y_{3j} - (v_1 x_{1j}^3 + v_2 x_{2j}^3 + u_1 y_{1j}^I + u_2 y_{2j}^I) \leq 0, \\
 & \quad j = 1, \dots, n \\
 & u_1, u_2, u_3, v_1, v_2 \geq 0
 \end{aligned} \tag{2}$$

2.2. Lozano's model

Lozano (2011) introduced model (3) to evaluate the performance of the network production systems (not necessarily series or parallel structure). In the following model, $P_1(i)$ is the set of processes, which consumes i th

input, and, X_i^p is the i th input consumed in p th process and $x_{ik} = \sum_{p \in P_1(i)} x_{ik}^p$. $P_O(r)$ is the set of processes, which produces r th output, and, y_r^p is the r th output produced in p th process and $y_{rk} = \sum_{p \in P_O(r)} y_{rk}^p$. Let $P^{out}(d)$ and $P^{in}(d)$ be the set of processes, which produces d th intermediate product and consumes d th intermediate product, respectively. $Z_d^p, p \in P^{out}(d)$ is the d th intermediate product produced in p th process, and $Z_d^p, p \in P^{in}(d)$ is the d th intermediate product consumed in p th process.

$$\begin{aligned}
 \theta_k &= \min h \\
 s.t \quad & \sum_{p \in P_i(i)} \sum_{j=1}^n \lambda_j^p x_{ij}^p \leq h x_{ik} \quad \forall i = 1, \dots, m \\
 & \sum_{p \in P_o(r)} \sum_{j=1}^n \lambda_j^p y_{rj}^p \geq y_{rk} \quad \forall r = 1, \dots, s \\
 & \sum_{p \in P^{out}(d)} \sum_{j=1}^n \lambda_j^p z_{dj}^p - \sum_{p \in P^{in}(d)} \sum_{j=1}^n \lambda_j^p z_{dj}^p \geq 0 \quad \forall d = 1, \dots, D \\
 & \lambda_j^p \geq 0 \quad \forall j = 1, \dots, n, \forall p = 1, \dots, q
 \end{aligned} \tag{3}$$

2.3. The general model

The structures and models introduced fail to deal effectively with some cases of network systems. Series and parallel structures are special cases of network systems which do not cover all network systems and as we will see in the next part, there are many network systems without series or parallel structure. Although a relational model is useful for all network systems, it is not a unified model and the constraints of each process are set in its body, separately.

For example, in evaluating efficiency score of a network system with 6 processes, a relational model with 7 constraints is needed or a network system with 10 processes needs a relational model with 11 constraints. In other words, this model will be more useful for systems which consist of a few processes, inputs and outputs. Although Lozano's model evaluates efficiency score of some systems having different structure with a unified model, it cannot be used directly for every structure of network production systems.

For example, this model cannot analyze the performance of series systems with more than two processes or the network systems in which the same intermediate product needs to be consumed and produced by a special process. In more details, Lozano's model can be used for two-stage, parallel systems and some network systems which do not have these special structures.

$$\text{Constraint } \sum_{p \in P^{out}(d)} \sum_{j=1}^n \lambda_j^p z_{dj}^p - \sum_{p \in P^{in}(d)} \sum_{j=1}^n \lambda_j^p z_{dj}^p \geq 0 \text{ in}$$

Lozano's model estimates the efficiency score lower than its original one since the aggregation of weighted produced and consumed intermediate products are on all processes, leading to some negative terms in the constraint while the inequality is held.

The negative term means that the produced intermediate products of one process are less than the corresponding consumed intermediate products of the other processes which is not acceptable.

To overcome the mentioned problems, Kazemi Matin and Azizi (2015) presented a general model(model (4))which is applicable for all structures of network systems such as parallel, series (with two or more than two processes) and all network production systems. Also, this model can be simply used for systems consisting of

many processes, inputs and outputs unlike relational model because of its unified structure.

$$\begin{aligned}
 \theta_k &= \min h \\
 s.t \quad & \sum_{p=1}^q \sum_{j=1}^n \lambda_j^p x_{ij}^p \leq h \sum_{p=1}^q x_{ik}^p \quad \forall i = 1, \dots, m \\
 & \sum_{p=1}^q \sum_{j=1}^n \lambda_j^p y_{rj}^p - \sum_{p=1}^q \sum_{p=1}^q \sum_{j=1}^n \lambda_j^c y_{rj}^{lpc} \geq \sum_{p=1}^q y_{rk}^{op} \\
 & \forall r = 1, \dots, s \\
 & \sum_{c=1}^q \sum_{j=1}^n (\lambda_j^p - \lambda_j^c) z_{dj}^{pc} \geq 0 \quad \forall d = 1, \dots, D, \forall p = 1, \dots, q \\
 & \lambda_j^p \geq 0 \quad \forall j = 1, \dots, n, \forall p = 1, \dots, q
 \end{aligned} \tag{4}$$

Here, x_i^p is the i th input consumed in p th process, z_d^{pc} is the d th intermediate product, which is produced in p th process and all or part of it is used in process c ($c=1, \dots, q$). y_r^{Op} is the r th output produced as the final output of p th process, and y_r^{lpc} is the r th output of process p which part of it is consumed as input of only one process (c th process), and unlike intermediate products it cannot be consumed or produced by other processes. y_r^p is the r th output produced by p th process ($y_r^p = y_r^{Op} + y_r^{lpc}$). Also, similar to the Lozano's model, intermediate products are assumed to be produced and consumed among processes, and they are not used as initial inputs or produced as final outputs.

Now, consider the production system of Fig. 1, in which y_1^1 and y_2^2 are the outputs of the first and second processes, respectively, which are divided into two parts; final outputs (y_1^{O1} and y_2^{O2}) and the outputs which are the inputs of process 3 (y_1^{I13} and y_2^{I23}). Model (4) can present the same efficiency score as model (2) for network system of Fig. 1, but Lozano's model cannot evaluate network systems of Fig. 1 because it does not handle y_r^{lpc} .

Although, the purpose of providing the new general model is defining a model that can easily assess the overall efficiency of all structure of network systems, the efficiency score of sub-processes can be calculated as well. To evaluate efficiency score of processes, it is enough to apply dual model (multiplier model) of model (4) to obtain optimal values for input and output weights. Then, efficiency score of each process is simply calculated by ratio of total weighted outputs to total

weighted inputs based on outputs and inputs of under-evaluated process.

3. An Empirical Application

Almost one-third of Iran's total land is suitable for agriculture, but most of these areas are not under cultivation due to poor soil and lack of adequate water distribution. Therefore, only a small part of the suitable land is under cultivation. Some parts of the cultivated areas are irrigated and some parts of the cultivated areas are devoted to rainfed agriculture. Rainfed agriculture is usually performed in areas with adequate precipitation and natural water potential. In Iran, only the Caspian lowlands such as Gilan and Mazandaran receive extensive precipitation and can be considered for natural irrigation agriculture. Winter rains are adequate for growing grains in most of the areas among Azerbaijan, Khorasan and

Fars, so, there is no need for additional irrigation. Areas such as the plateaus of central Iran, eastern and south eastern of Iran like Yazd and Hormozgan are arid. Therefore, rainfed farming cannot be handled in these areas and irrigation can be considered as a choice for farming.

Wheat is considered as one of the main primary food of Iranians and the most important agricultural commodities in Iran in terms of production and consumption. Producing wheat is very important in terms of income, nutrition and employment of people. When it comes to consumption, the per capita consumption for bread wheat in Iran is about 160 kilogram which is higher than most of the other countries. Great demand for wheat in Iran and the difficulties to meet the demand pushed the government to import wheat. So, Iran is one of the largest wheat importers in the world.

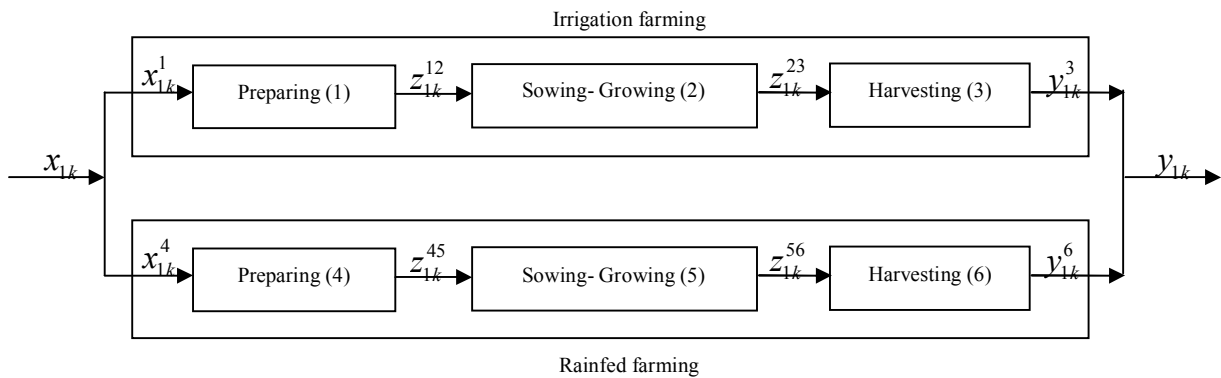


Fig. 2. Network structure of provinces

Iran governments encourage farmers to produce more wheat and they have developed some programs to increase wheat production. Presently, wheat is grown in many areas of Iran under irrigation and/or rainfed farming.

This section analyzes wheat farming efficiency in provinces of Iran in 2008-2009 crop year, starting on 22 September 2008 and ending on 22 September 2009. In this time period, Iran was composed of 30 provinces which were managed by the government. To evaluate the performance of 12 provinces in wheat production more accurately, we apply model (4) and the network structure as depicted in Fig. 2 the obtained results are compared with the ones of models (3) and (1). Fig. 2 is a network system with six processes, represented by two parallel processes where each process in the parallel structure is composed of three processes in series structure. The two parallel processes are irrigation farming and rainfed farming and the three series processes in each parallel process are preparing, sowing-growing and harvesting, respectively.

We present the system of Fig. 2 for Iran wheat farming with available data which were gathered by the Iranian Ministry of Agricultural Jihad (www.maj.ir). In the CCR model, x_{1k} , y_{1k} are only considered which are system's input and output, respectively.

Table 1 summarizes such descriptive statistics related to data set of 12 studied provinces regarding Iran wheat farming in 2008-2009 crop years. In preparing process, suitable land for wheat production is prepared with ploughing, clods crushing and manuring. Manuring is done in two parts, first in preparing step and second in growing step. In the preparation step, all the phosphate fertilizer and half of the nitrogen fertilizer are used. The input of the system, which is the aggregated input of the first and fourth processes, is consumed fertilizer (based on kilogram).

There is one intermediate product in the system which is the output of preparing process as well as the input of sowing-growing process and the output of the sowing-growing process as well as the input of the harvesting process. The intermediate product is land (based on hectare). The intermediate product (land) which is

produced by preparing process is the cultivated area and the one which is produced by sowing-growing process is the harvested area. The output of the system, which is the aggregated output of the third and sixth process, is wheat

production (based on ton). There is no Y_r^{ipc} for evaluating performance of wheat farming of provinces so.

Table 1
Descriptive statistics on a data set of 12 provinces

	Irrigation farming			
	Consumed fertilizer	Cultivated area	Harvested area	Wheat production
Min	13821	16914	16300	39861
Max	31765.5	502325	384678	1154138
Average	18966.75	107779.75	95396.83	334740
	Rainfed farming			
	Consumed fertilizer	Cultivated area	Harvested area	Wheat production
Min	0	0	0	0
Max	12121	368608	344911	512203
Average	6569.83	150210.42	104432.58	126528.25

In the studied provinces, Sistan-Baluchestan is the province which does not use rainfed farming, so its data are set at zero. Both of irrigation and rainfed farming are used in the other provinces. Some provinces are more active in rainfed farming such as Azerbaijan-East, Azerbaijan-West, Ardabil, Ilam, Bushehr, ChaharMahal and Bakhtiari, Golestan and Khuzestan. The other provinces are more active in irrigation farming.

3.1. Results

The software Lingo was used to assess the efficiency of the provinces with the structure (Fig.2). Efficiency scores were calculated based on the assumption of constant returns to scale. The results of general model (model 4), Lozano’s model (model 3) and CCR model (model 1) for determining efficiency of the wheat production in Iran provinces are shown in Table 2. In Table 2, G^* , L^* and C^* represent the efficiency score which are achieved by model (4), (3) and (1), respectively.

First, consider the results of model (4). As it can be seen, most of the provinces using rainfed farming more than irrigation farming have better performance than others. Golestan and Khuzestan are the provinces which have the efficiency score more than 0.3. Isfahan, Tehran, Semnan, Sistan and Baluchestan which are more active in irrigation farming do not have appropriate performance, and Tehran with 0.119 has the best efficiency score among them. Sistan and Baluchestan which does not use rainfed farming, has poor performance, but it performs better than some provinces such as Semnan, Bushehr and ChaharMahal and Bakhtiari. The highest (lowest) efficiency score among all provinces belongs to Golestan

(Bushehr) which is equal to 0.455 (0.016). Now, we compare the results of model (4) and model (1).

Table 2
The results of efficiency calculated by the general model, Lozano’s model and CCR model

Provinces (DMUs)	G^*	L^*	C^*
1. Azerbaijan, East	0.173	0	0.446
2. Azerbaijan, West	0.268	0	0.692
3. Ardabil	0.289	0	0.744
4. Isfahan	0.068	0	0.175
5. Ilam	0.061	0	0.157
6. Bushehr	0.016	0	0.042
7. Tehran	0.119	0	0.306
8. ChaharMahaal and Bakhtiari	0.040	0	0.102
9. Semnan	0.036	0	0.092
10. Sistan and Baluchestan	0.053	0	0.138
11. Golestan	0.455	0	1
12. Khuzestan	0.315	0	0.758

Although Golestan and Bushehr obtained the highest and lowest efficiency scores in both models, their amounts are different, and Golestan is efficient in CCR model unlike the general model. Also, it is obvious that the obtained efficiency score of each province by the CCR model is higher than that of the general model. It provides the decision makers with inaccurate information about the performance of their systems and low information about the inefficiency resources of the systems. To compare model (3) and model (4), pay attention to the results of Table 2. It is clear that model (3) cannot assess network systems with the structure of Fig. 2, but our model evaluates them, enabling us to compare their performances.

For better comparison of models (4) and (1), see the column chart obtained from their results.

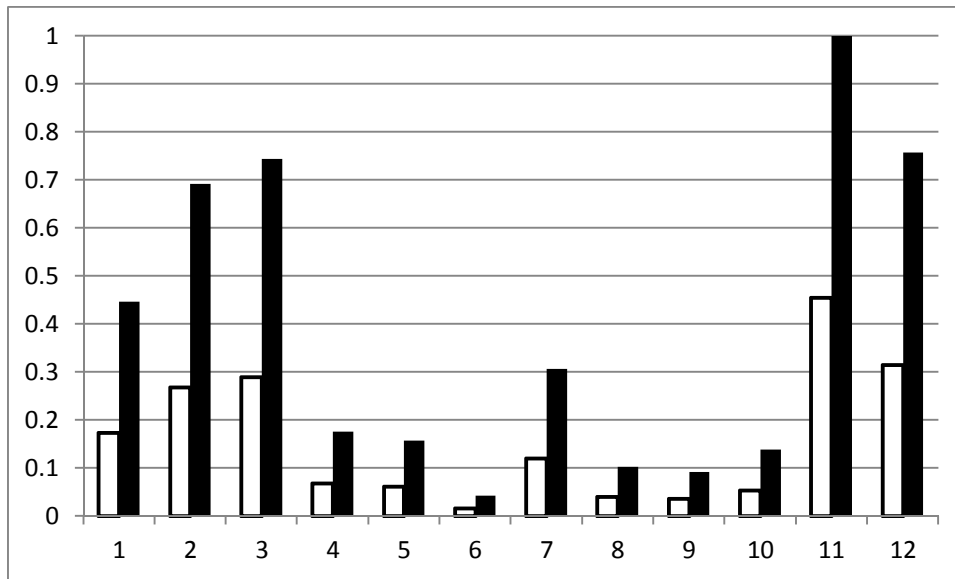


Fig. 3. General and CCR efficiency score of wheat production in 12 provinces of Iran, 2008-2009 crop year

The hollow and solid columns in column Fig 3 show the efficiency score of 12 provinces of Iran in 2008-2009 crop year which are obtained by the general model and the CCR model, respectively. In this chart, the horizontal and vertical axis represent the provinces and their efficiency score, respectively.

As it can be seen by solid columns, six provinces have the efficiency score more than 0.3 while the number of the provinces with this range of efficiency score which are achieved by general model is 2. In this chart, we see that the ranking of provinces based on their CCR efficiency score is the same as their ranking based on their general efficiency score. But this case is not held for all systems with network structures, and ranking obtained by CCR model for a particular unit is not essentially equal to the obtained ranking of the general model for the unit.

4. Conclusion

The conventional DEA models cannot be applied for production systems with network structure. They do not evaluate the performance of network systems accurately as they disregard the internal operations of the network systems. In this article, some common approaches handling network systems are introduced and analyzed based on their usage. These approaches are not applicable for all the network systems and they contain some drawbacks which restrict them. To overcome the problems of other approaches, the general model is introduced. Finally, the general network model is applied to assess the performance of wheat production. To this end, twelve provinces of Iran are considered as production units with complex network structure and the obtained results are compared with classical DEA approach and another network DEA approach to show the superiority of the general model.

References

- Azizi, R., KazemiMatin, R., (2010). Two-stage Production Systems under Variable Returns to Scale Technology: A DEA Approach. *J. ind.eng.* 5, 67-71.
- Charnes, A., Cooper, W.W., Rhodes, E., (1978). Measuring the efficiency of decision making units. *Eur. j. oper. res.* 2, 429 – 444.
- Chen, Y., Cook, W.D., Kao, Ch., Zhu, J., (2013). Network DEA pitfalls: Divisional efficiency and frontier projection under general network structures. *Eur. j. oper. res.* 226, 507-515.
- Chen, K. H., Guan, J. C. (2012). Measuring the efficiency of China's regional innovation systems: Application of network data envelopment analysis (DEA). *Reg. Stud.* 46, 355–377.
- Farrell, M.J., (1957). The Measurement of Productive Efficiency. *J. r. stat. soc.* 120, 253-281.
- HadiVenche, A., KazemiMatin, R., (2011). An application of IDEA to wheat farming efficiency. *Agr.Econ.* 42, 487-493.
- Kao, Ch., (2014),a. Efficiency decomposition for general multi-stage systems in data envelopment analysis. *Eur. j. oper. res.* 232,117-224.
- Kao, Ch., (2009),a. Efficiency decomposition in network data envelopment analysis: A relational model. *Eur. j. oper. res.* 192, 949-962.
- Kao, Ch., (2009),b. Efficiency measurement for parallel production systems. *Eur. j. oper. res.* 196, 1107-1112.
- Kao, Ch., (2014),b. Network data envelopment analysis: A review. *Eur. J. Oper. Res.* 239, 1-16.
- Kao, H.Y., Chan, C.H., 2013. A Discriminative Multi-Objective Programming Method for Solving Network DEA. *Advances in Intelligent Systems and Applications - Volume 1.* Springer Berlin Heidelberg.
- Kao, Ch., Hwang, S.N., (2008). Efficiency decomposition in two-stage data envelopment analysis: An application to non-life insurance companies in Taiwan. *Eur. j. oper. res.* 185, 418-429.
- Kao, Ch., Hwang, S.N., (2010). Efficiency measurement for network systems: IT impact on firm performance. *Decis. Support Syst.* 48, 437–446.

- KazemiMatin, R., Azizi, R., (2015). A unified network-DEA model for performance measurement of production systems. *Measurement*. 60, 186-193.
- Lozano, S., 2011. Scale and cost efficiency analysis of networks of processes. *Expert. Syst. Appl.* 38, 6612–6617.
- Li, Y., Chen, Y., Liang, L., Xie, J. H. (2012). DEA models for extended two-stage network structures. *Omega*. 40, 611–618.
- Malana, N.M., Malano, H.N., (2006). Benchmarking productive efficiency of selected wheat areas in Pakistan and India using data envelopment analysis. *Irrig. Drain.* 55, 383-394.
- Moreno, P., Lozano, S., (2014). A network DEA assessment of team efficiency in the NBA. *Ann. Oper. Res.* 214, 99-124.
- Rohacova, V., (2015). A DEA based approach for optimization of urban public transport system. *Cent. Europ. J. Oper. Re.* 23, 215-233
- Shang, S., Mao, X., (2009). Data Envelopment Analysis on Efficiency Evaluation of Irrigation fertilization Schemes for Winter Wheat in North China. *IFIP Adv. Inf. Commun. Technol.* 293. *Comput. Comput. Technol. Agr. II*, 1, eds. D. Li, Z. Chunjiang, (Boston; Springer), 39-48.
- Tone, K., Tsutsui, M., (2009). Network DEA: A slacks-based measure approach. *Eur. j. oper. res.* 197, 243-252.
- Tone, K., Tsutsui, M., (2014). Dynamic DEA with network structure: A slacks-based measure approach. *Omega*. 42, 124-131.
- <http://amar.maj.ir/portal/Home/Default.aspx?CategoryID=117564e0-507c-4565-9659-fbabfb4acb9blast> access: September 2, (2014).