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A New Approach to Evaluate the Economic Efficiency and Productivity of Agriculture Sector: The Application of Window Data Envelopment Analysis (WDEA)

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Abstract
Wheat is a major agricultural crop in the Sistan region with a key role in local economy. The present study aimed to economically explore the efficiency of wheat production over the 2014-2016 period with the window data envelopment analysis (WDEA) approach. Also, the Malmquist productivity index was employed to assess the productivity of wheat growers in the study site under variable return to scale with the input-oriented approach. The results show that average annual efficiency of Zabol, Zehak and Hirmand counties are 0.96, 0.95, and 0.96, respectively, implying that these agricultural units are efficient. Also, the values for the Malmquist productivity index show that the highest average variation of total productivity of 0.96 was for Hirmand County in the studied period, showing the low productivity. According to the results, an influential factor underpinning the variations of total productivity of wheat growers was found to be technological variations. Thus, it is recommended to develop some plans to improve the efficiency and productivity of wheat in the studied region.

Keywords: Efficiency, Productivity, Window Analysis Approach, Malmquist Index, Wheat

Introduction

The agricultural sector is a main source of income in most countries and is of significant importance among all economic activities. Given its remarkable contribution to the gross domestic product (GDP) and export incomes, this sector plays a key role in determining the orientation and status of the economic development process, especially in developing countries (Bayati et al., 2003). Currently, productivity and efficiency are a culture and perspective in all work and life activities of human and are the source of economic development. This culture and perspective are to organize the activities to yield the best result (Rezaei et al., 2008). Efficiency refers to the extent to which an enterprise can gain maximum output from a certain set of inputs assuming known technology or to the ability of an enterprise to produce a certain return with a minimum set of available inputs. On the other hand, productivity is a concept that shows the efficiency of enterprises with respect to one another within a specific time period (Mehrabi Boshrabadi and Pakravan, 2009). In its broad meaning, productivity delineates the ratio of outputs to inputs. In other words, productivity is

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average production per each unit of total inputs so that if average production per each unit of inputs is increased, productivity will increase; otherwise, it will decrease (Mohammadpour and Arsalan Bod, 2015). The economic growth in each sector requires the increase in the production by that sector. According to the theories of production and supply, production can be grown in two ways: production growth by employing more production factors, or production growth by exploiting more advanced and efficient technologies and more effective use of production factors (Mojaverian, 2003). In the meantime, efficiency indicators are among the hybrid indicators suggested for evaluations as they establish a link between inputs and outputs. In spite of disagreements on how to calculate these indicators, all attempt to provide a better understanding of how resources are allocated and used for various products (Shahnavazi, 2017).

Wheat is one of the most important agricultural crops with a special niche among all products. Irrespective of the political importance of wheat in economic independence and political relations among countries, this commodity can be used as a tool to gain commercial and political advantages. This crop can be considered the most important factor in agricultural policymaking and in domestic security in the context of ensuring food security and economic viability (Shirinbakhsh and Nassabian, 2003). But, decision-making and policymaking should be grounded on an adequate understanding of the issue and its causes and factors including the efficiency and productivity of wheat production.

According to the statistics for the growing year of 2014-2015, wheat had the highest acreage of about 50.24% of total arable lands and accounted for 14.96% of total grain production in Iran. Total acreage of wheat in Iran amounts to 8,175,054 ha and wheat production amounts to 18,241,132 t. In Sistan and Baluchistan province of Iran, the acreage of irrigated wheat is 87,557 ha that produces 183,547 t wheat and the acreage of rain-fed wheat is 175 ha producing 184 t wheat. Also, the yield of irrigated wheat is 2096.3 kg ha^{-1}, but that of rain-fed wheat is 1057.1 kg ha^{-1} (Anonymous, 2016).

The recognition of the importance of productivity and efficiency is not confined to the capitalist societies. The main focus of policymaking in developed countries has been long studied and the adoption of methods to improve the productivity of production factors and efficiency has been regarded as a way to escalate production. Today, given the scarcity of the production resources in all countries, productivity is required more than ever and economists in various systems virtually put equal emphasis on the significance of productivity enhancement (Abtahi and Kazemi, 2004). In this sense, the present work attempts to answer the following questions:

- Do wheat production units in the Sistan region have good technical efficiency?
- Are wheat production units in the Sistan region moving towards improving their productivity?
- How efficient (efficient, inefficient, lowly-efficient) are the wheat production units in the Sistan region?

Data envelopment analysis (DEA) is a non-parametric linear programming approach that can use multiple inputs and outputs. Since this method was first presented, various models have been presented on the basis of Charnes's work, each with its own specific applications. One type of DEA models is window DEA (WDEA). WDEA draws on the notion of moving average and is useful for finding performance trends of a unit over time (Sengupta, 1995). WDEA can be used for time-based analysis. The main assumption of WDEA is that no technical change happens during the window. In fact, to use this technique, the window length should be established so that this assumption is not violated (Hamzehee and Shojaati, 2017). The present research used this technique to explore this assumption. So, we aim to:

- Determine the technical efficiency score of wheat production units of Sistan region,
- Determine the productivity and its trend using the Malmquist index, and

- Determine the efficiency level of wheat production units (if they are efficient, inefficient, or lowly-efficient).

Literature Review

A review of the literature shows that the efficiency of the agricultural crops has been subject to extensive research. What distinguishes this study from the similar works is the use of window data envelopment analysis (WDEA) to determine the efficiency of each agricultural crop. This technique has been employed in studies on other sectors. In the next paragraphs, we briefly review the similar literature.

Akbari and Ranjkesh (2003) addressed the growth of total productivity of production factors in Iran's agricultural sector over the 1966-1996 period. They observed high fluctuations of total productivity growth rate of production factors in the agricultural sector, but productivity had an ascending trend. Bayati et al. (2003) studied the factors underpinning the efficiency of agricultural mechanized service firms in Khorasan province. They found that efficiency was positively influenced by such factors as members' occupation, discounts to member farmers, membership fees, and the presence of representatives and was negatively influenced by such factors as firm ownership, adequacy of facilities, and service to members Croppenstedt (2005) estimated technical efficiency of wheat farmers in Egypt using Cobb-Douglas frontier production function. They reported that the average technical efficiency of the wheat farmers in the study site was 81 percent and that among the considered socio-economic characteristics including age, gender, technical knowledge of irrigation, and farmers' access to credits, their technical efficiency was influenced only by technical knowledge of irrigation. Conceding the fact that rice production is inherently a risky activity, Villano and Fleming (2006) employed stochastic frontier production functions (Translog and quadratic function forms) to concurrently analyze technical inefficiency and production risk of 46 paddy farmers in Central Luzon, the Philippines using an 8-year dataset. Their results showed that the average technical efficiency was 79 percent over the studied period and the average crop was significantly influenced by rice acreage, labor, and chemical fertilizer application. Speelman et al. (2008) employed DEA to analyze irrigation water use efficiency in the farms of Southern Africa and the influential factors. Accordingly, the average water efficiency under constant and variable returns to scale was found to be 43 and 67 percent, respectively. They reported that irrigation water efficiency was dictated with such factors as irrigation method, land ownership, land size, and crop selection. Shajari et al. (2008) determined the economic efficiency of agricultural production cooperatives and focused on the factors influencing their economic efficiency in Fars province, Iran. The results of economic efficiency distribution of the agricultural production cooperatives revealed that their average economic efficiency score was 0.74. Also, the review of factors affecting their economic efficiency indicated that CEO's educational level, the number of the activities of the cooperative, and the distance were factors influencing their efficiency positively. In a study on the efficiency and return to scale of sunflower growers of Khoy County, Iran. Yilmaz et al. (2009) used DEA to explore water use efficiency in Buyuk Menderes basin, Turkey. They assessed the efficiency of decision-making units with respect to weight limitations as specified by value judgments. In a study on wheat farmers' efficiency in Western Australia using stochastic frontier analysis and the dataset for 2004-2007. Mehrabi Boshrabadi and Pakravan (2009) indicated that the average technical, allocative, economic, and scale efficiency scores of sunflower producers were 66, 54.7, 35.9, and 75.9%, respectively. Also, the economic inefficiency in the region was attributed to allocative inefficiency in the first place and to the quality difference of the inputs like water and land in the second place. Pakravan et al. (2010) worked on the efficiency of canola growers in Sari

County. They found that production could be increased and costs could be reduced by implementing the programs for enhancing farmers' allocative efficiency, such as holding extension courses and providing the training on the sound use of inputs. Tozer (2010) reported that inefficiency of local wheat growers had increased from 18 percent in 2004 to 29 percent in 2007. This implied the failure of targeted programs of the state in improving productivity. Torkamani and Mousavi (2011) studied the impacts of crop insurance on production efficiency and risk management of agriculture in Fars province, Iran. They showed that insurance did not influence potato farmers' technical efficiency significantly and positively. However, the coefficients of sample users' risk aversion showed that crop insurance influenced farmers' attitude towards risks positively and was effective in reducing their risk-aversion level. Wang et al. (2012) employed DEA and the fuzzy Delphi technique to explore the efficiency of the agricultural cooperatives and the effective factors in Langao, China. The technical efficiency of the agricultural cooperatives of horticulturists and vegetable growers was found to outperform that of livestock farmers. It was also found that the cooperatives of vegetable growers and horticulturists can improve their efficiency by making more use of vehicles. In another study on the agricultural cooperatives in China, Huang et al. (2013) used DEA to check their technical efficiency. The results showed that managers' technical inefficiency was the source of the technical inefficiency of the cooperatives. Also, the size of the financial leverage and the number of board members were found to be the factors adversely influencing the technical efficiency of the cooperatives. Babai et al. (2015) used DEA to examine water efficiency of the main agricultural crops of Zabol County, Iran. It was found that average efficiency scores of farms were 77 and 98 percent under the constant and variable return to scale, respectively. Mozafari (2015) addressed the economic efficiency of agricultural cooperatives in Buin Zahra County, Iran and ranked their challenges in the marketing system management process. According to his results, he recommended studies on locating before cooperative establishment, the supply of low-interest loans to animal farmers, the transfer of experience of successful cooperatives to inefficient cooperatives, and the support of marketing system in order to meet the challenges faced by the agricultural cooperatives of the study site and to improve their efficiency. Shahnavazi (2017) tried to estimate efficiency scores of irrigated crops in the agricultural sector. The results showed that if profitability is the goal of irrigated farming, then vegetables, industrial crops, summer crops, legumes, forage crops, and grains are in priority for cultivation, respectively, but if the goal is to increase total production, then the priority should be placed on forage crops, vegetables, industrial crops, summer crops, grains, and legumes, respectively. Latruffe et al. (2017) explored the impact of subsidies on the technical efficiency of the European dairy farms and reported that the impact of subsidies on technical efficiency was positive or negative depending on the country. Akamin et al. (2017) analyzed the efficiency and productivity of medicinal plants in the humid tropics of Cameroon using stochastic frontier efficiency. The results indicated that farmers' efficiency was decreased with the increase in land size and that fertilizer availability to smallholders and higher contribution of women in vegetable planting would be beneficial to the efficiency of vegetable production in Cameroon. Zare Mehrjerdi et al., (2017), The effect of the mechanization coefficient on productivity in the agricultural sector of Iran by means of ARDL method and genetic algorithm has been investigated. The results of both approaches indicate that the mechanization coefficient and credit and educational facilities, agricultural extensions have positive effects on productivity growth. The coefficient for long-term mechanization coefficient in ARDL method is 0.99 and in the genetic algorithm method it is 0.98, which shows the relatively high effect of this variable on the productivity of the agricultural sector.

Shahnavazi (2017), To determine the ranking of the provinces of the country in onion production using the data envelopment analysis method. The evaluation of average efficiency rankings showed that the provinces of Ilam, South Khorasan, Golestan and Sistan and Baluchestan had the best ranks from first to forth and the provinces of Rasavi Khorasan, East Azerbaijan, Khozestan and Fars took the least places in ranking, respectively. The comparison between yield and efficiency ranking results showed that only South Kerman district and Hamedan, Kermanshah, Zanjan and Kohgiluye and Boyeramad provinces were in the same ranking groups.Teimuri and Mousavi (2017), To study the factors affecting the productivity of manpower in production in Mamassani. The results indicate that the level of education of the supervisor at the reading and writing level, the size of the vineyards, membership in the cooperative, etc. had a positive and significant effect And variables such as diploma and higher education, experience, and total grapevine assets have a negative and meaningful effect on human resource productivity. Latruff et al., (2017), they have studied the Subsidies and Technical Efficiency in Agriculture: Evidence from European Dairy Farms. Our results show that the effect of subsidies on technical efficiency may be positive, null, or negative, depending on the country. The analysis reveals that the introduction of decoupling with the 2003 CAP reform weakens the effect that subsidies have on technical efficiency**.** Guesmi et al., (2018), they have studied the Efficiency of Egyptian organic agriculture: A local maximum likelihood approach. Results suggest that performance of organic farmers is slightly better than performance of their conventional counterparts. Further, we find a positive relationship between technical efficiency and farm size. Velasco – Munoz et al., (2018), they have studied the Advances in Water Use Efficiency in Agriculture. The results indicate that a remarkable growth in the number of articles published per year is occurring. The main category is environmental science and the main journal Agricultural Water Management. The countries with the highest number of articles were China, the United States of America, and India. The institution that published the most articles was the Chinese Academy of Sciences and the authors from China also were the most productive. The most frequently used keywords were irrigation, crop yield, water supply, and crops. The findings of this study can assist researchers in this field by providing an overview of worldwide research. Van Hung et al., (2018), They have studied the efficiency of Different Integrated Agriculture Aquaculture Systems in the Red River Delta of Vietnam. The study’s results indicate clear evidence that the traditional VAC system and New VAC system are the most efficient and effective models. The findings of this study have shed light on the important role of integrated aquaculture systems to food security and economic development of households and local communities. The VAC systems are likely to propose for improving household food security and developing the local economy. Kourgialas et al., (2018), They have studied the an integrated method for assessing drought prone areas - Water efficiency practices for a climate resilient Mediterranean agriculture. in this study, sustainable agricultural practices that ensure water efficiency especially in drought prone areas are proposed. These practices can be adopted by farmers to promote climate resilient agriculture in the Mediterranean region. Table 1 summarizes some other relevant literature.The examination of the trend of efficiency and productivity over a specific time period can provide users with invaluable information. By this method, not only are the efficiency and productivity of a wheat farmer measured in a specific time period with respect to other users, but the units can be also informed about the variations of their efficiency or productivity and can observe the consequences of their managerial decision in a certain period on their long-term performance so that the managers can proceed towards higher capability and productivity of their respective units. Accordingly, the present study used the WDEA and Malmquist productivity index to explore the efficiency and productivity trend of the wheat crop in the Sistan region across 2014-2016. The contribution of the study is that this is the first work in which WDEA is used to measure the efficiency of the agricultural crops, here wheat in the Sistan region.

Table 1. A list of other relevant literature

Reference	Region/country	Modeling method	Objectives
Da Niel Hollo and Arton Nagy, 2004	European Union countries	Stochastic frontier functions	Measuring the efficiency of EU banks and recognizing the causes of the difference in the technical efficiency of the banks
Zara and Qannadi, 2005	Industries of Khuzestan province, Iran	Cobb-Douglas production function	Exploring labor productivity
Malhotra et al., 2007	Bond firms	Data envelopment analysis	Measuring the bonds of firms
Karimi et al., 2008	Eight bigger provinces of Iran	Interval data envelopment analysis	Estimating the efficiency of wheat farming with respect to time and risk
Kao anzd Hwang, 2008	Telecommunication enterprises of Taiwan	Window data envelopment analysis	Measuring the efficiency assuming a variable return to scale
Guzmán and Arcas, 2008	Agricultural cooperatives of Italy	Data envelopment analysis	Measuring technical efficiency
Sing and Femiling, 2008	Milk production cooperatives in Havana	Data envelopment analysis	Estimating milk production efficiency
Vardinejad et al., 2009	Basin of the Zayanderud river, Isfahan, Iran	Productivity index	Estimating agricultural water productivity
Tayrone et al., 2009	Bank branches in Taiwan	Data envelopment analysis CCR model	Assessing the efficiency of bank branches
Frija et al., 2009	Greenhouses of Tunisia	Data envelopment analysis	Measuring water use efficiency in the greenhouses of Tunisia and the effective factors
Guzmán et al., 2009	Agricultural cooperatives of Spain and Italy	Data envelopment analysis	Estimating the technical efficiency of agricultural cooperatives
Li et al., 2010	Agricultural cooperatives in Danyang	Data envelopment analysis	Estimating the technical efficiency of agricultural cooperatives
Afkhami Ardakani et al., 2011	Commercial banks of Iran	Window analysis and Malmquist index	Estimating efficiency and productivity of the banking industry and identifying the underpinning factors
Sokhanvar et al., 2012	Power distribution companies	Window data envelopment analysis	Vertically separating power distribution companies, ownership change, and exploring environmental factors
Rajabi and Nasrollahi, 2012	Commercial banks of Iran	Window data envelopment analysis	Assessing the performance and efficiency of commercial banks of Iran in terms of stability
Khodadai Kashi and Tavassoli, 2012	Branches of Agribank of Iran	Stochastic frontier functions	Estimating technical efficiency
Mohammadi and Dastyar, 2013	Pharmaceutical firms listed in Tehran Stock Exchange	Window data envelopment analysis	Assessing the efficiency of pharmaceutical firms and comparing their performance
Tahari Mehrjerdi et al., 2013	Banks listed in Tehran Stock Exchange	Interval data envelopment analysis	Assessing the financial efficiency of the banks listed in Tehran Stock Exchange
Amani and Arabzad, 2014	Affiliates of Saipa in Isfahan province, Iran	Window data envelopment analysis	Measuring the efficiency of automotive service companies
Zamani et al., 2015	Hamedan plain, Iran	Productivity indices	Explore the economic productivity of water
Fazel Yazdi and Moeenoddoleh, 2015	Iran Insurance Industry	Window data envelopment analysis	Assessing the efficiency of public and private insurance firms
Alimohammadlou and Mohammadi, 2016	Pharmaceutical firms listed in Tehran Stock Exchange	Window data envelopment analysis	Measuring efficiency dynamism and ranking pharmaceutical firms listed in Tehran Stock Exchange

Theoretical Framework and Methodology

The theoretical framework of efficiency is, indeed, based on optimizing producer behavior, or the theory of production in microeconomics. The concept of efficiency and the methods of its calculation can be approached from different perspectives of the production theory. The process of optimizing a production enterprise can be looked upon from two directions: one through profit-seeking and the other through cost minimization. Efficiency can be measured from both perspectives. In a production theory, the optimum behavior of an enterprise is analyzed through a set of initial assumptions and the hypotheses on producer behavior are tested on the basis of these same assumptions. Empirical evidence shows that producers are not always successful in solving their optimization problem and do not always have perfect efficiency. In addition to these assumptions, if they are technically efficient, it does not prove that they are perfectly efficient in other aspects (Kumbhakar, 1993; Kumbhakar and Lovell, 2000).

The notion of efficiency

The theory of efficiency-related notions was first posed by Forrell. He decomposed economic efficiency into two components of technical efficiency and allocative efficiency and applied the concept of maximum or frontier production to measure them. The model that was first presented by Forrell was a non-parametric model because no specific form of production function was introduced. By Forrell's definition, *technical efficiency* refers to the ability of a production unit to accomplish maximum production with a constant set of available resources, and *allocative efficiency* refers to the ability of the unit to optimally allocate resources among different products in terms of the final production value of the resources and product prices. Economic efficiency is the product of the multiplication of technical and allocative efficiency. Efficiency in production is a method to ensure that the production of an economic unit is in its best form and most profitable state. The efficiency of the economic units is of crucial importance in prohibiting the waste of resources (Kumbhakar, 1993; Kumbhakar and Lovell, 2000).

Window data envelopment analysis (WDEA)

The model was first introduced by Charnes and draws on moving average (Charnes, 1995). This method deals with each unit in each specific period as an independent unit. In this sense, the performance of a unit in a specific period is contrasted with the performance of that unit in other periods in addition to the performance of other units (Asmild et al., 2004; Charnes, 1995). This is beneficial for studies on very few samples. In DEA, the number of the assessed units is recommended to be greater than the double of the sum of inputs and outputs. When the number of the units is few, the model discrimination is reduced and all units are assessed to be efficient (Asmild et al., 2004; Ramazanian et al., 2012). Since the technical efficiency of all units in a single window (a selected time period) is measured with respect to one another, the method implicitly assumes that there is no technical change in any windows. This is a general point in window analysis. However, this problem is attenuated as window width is decreased. To validate the window analysis, the window width is so selected that the ignorance of the technical changes is rendered reasonable (Fazeli, 2011).

This technique assumes that there are *N* decision-making units (DMUs) $(n = 1, \dots, N)$, *T* periods $(t = 1, \dots, T)$, and *r* inputs for the production of *s* outputs. So, the studied sample had $N \times T$ and one observation *n* in period *t*, DEA_t^n had one *r*-dimensional input vector

$X_t^n = (x_{1t}^n, x_{2t}^n, \dots, x_{rt}^n)t$ and one s-dimensional output $Y_r^n = (y_{1r}^n, y_{2r}^n, \dots, y_{st}^n)$. The window in time $1 \le K \le T$ is denoted by K and has $N \times W$ observations. The input matrix for WDEA is as the following equations:

$$X_{KW} = (x_k^1, x_k^2, \dots, x_k^N, x_{k+1}^1, \dots, x_{k+w}^1, x_{k+w}^2, \dots, x_{k+w}^N) \tag{1}$$

and the output matrix as:

$$Y_{KW} = (y_k^1, x_k^2, \dots, y_k^N, y_{k+1}^1, \dots, y_{k+w}^1, y_{k+w}^2, \dots, y_{k+w}^N) \tag{2}$$

An input-based window-DEA problem for DUE_t^n under the assumption of constant return is as below:

$$\begin{aligned} &\underset{\lambda,\theta}{Min}\ \theta = \theta'_{kwt} \\ &S\,t: \\ &\quad -X_{kw\,\lambda} + \theta X_t^{\prime} \ge 0 \\ &\quad Y_{kw\,\lambda} - \theta Y_t^{\prime} \ge 0 \\ &\quad \lambda n \ge 0 \\ &\quad (n = 1.k\ ,\ N \times W) \end{aligned} \tag{3}$$

Figure 1 illustrates the input-based WDEA with two inputs and one constant output. The graph depicts two DMUs d and e, each one in four different time periods, $t = 1, \dots, 4$. The window l_2 is a window that starts at time 1 with window width 2 and includes observations d_2, d_1, e_2, and e_1, and here it has a frontier that is indeed shown like l_2 (Asmild et al., 2004).

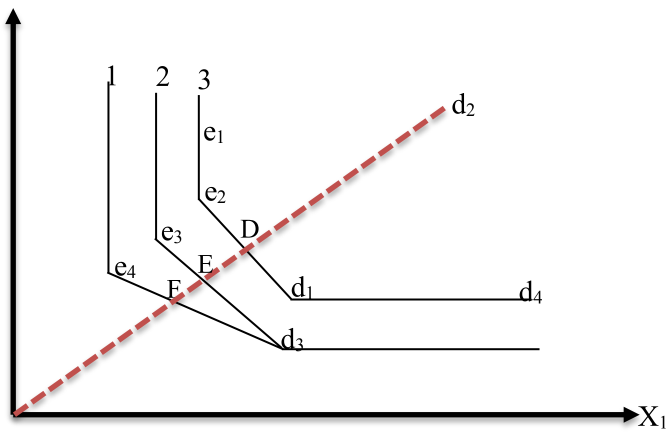

Figure 1. Window DEA

By including the multiplication constraints in the model, the linear programming problem is defined as:

$$\begin{aligned} &\underset{\lambda,\theta}{Min}\ \theta = \theta'_{kwt} \\ &S\,t: \\ &\quad -X_{kw\,\lambda} + \theta X_t^{\prime} + C_Z^i \ge 0 \\ &\quad Y_{kw\,\lambda} - \theta Y_t^{\prime} + C_Z^0 \ge 0 \\ &\quad \lambda_n \ge 0 \\ &\quad Z \ge 0 \\ &\quad (n = 1.k\ ,\ N \times W) \end{aligned} \tag{4}$$

Malmquist productivity index

The Swedish economist, Malmquist, introduced an index named the Malmquist life standard index in 1953. The index was first used in the theory of production in 1982 by Caves et al. Also, they presented an extension of the size of variations of solo technology under multiple-input and multiple-output state. In 1982, Fare et al. used data envelopment analysis (DEA) to calculate the Malmquist index. Then, in 1992, they decomposed this index into two factors of efficiency variation and technology variation. This decomposition was presented by Fare et al. in 1994 with the name of FGNZ decomposition. Following that, descriptions have been provided about the model of Malmquist index productivity growth and how it is decomposed into efficiency variations and technology variations. Let's assume that there are *n* DMUs and the objective is to calculate the Malmquist productivity growth from period *t* (1st period) to period *s* (2nd period) and its decomposition into three mentioned factors. Then, the *P*th DMU is a unit that has the inputs $X^t=(X_1^t,X_2^t,...,X_n^t)$ and the outputs $y^t=(y_1^t,y_2^t,...,y_n^t)$ in period *t* and the inputs $X^s=(X_1^s,X_2^s,...,X_n^s)$ and the outputs $y^s=(y_1^s,y_2^s,...,y_n^s)$ in period *s* (Figure 2).

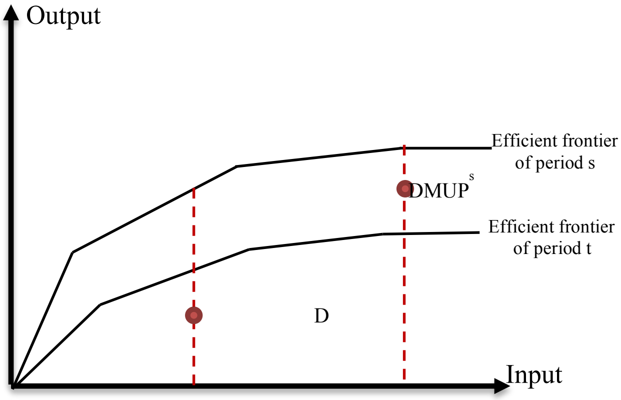

Figure 2. Efficiency frontier of first and second periods in Malmquist index

According to the definition of distance function and assuming the above assumptions, the Malmquist index (with output nature) is defined as:

$$M_0(x^s,x^t,y^s,y^t)=\left[\frac{d^t(x^s,y^s)}{d^t(x^t,y^t)}\times\frac{d^s(x^s,y^s)}{d^s(x^t,y^t)}\right]^{1/2} \quad (5)$$

in which $d^t(x^s,y^s)$ is the TFP value of the *P*th DMU in period *s* using the technology (frontier) of the period *t*, $d^t(x^t,y^t)$ is the TFP value of the *P*th DMU in period *t* using the technology (frontier) of period *t*, $d^s(x^s,y^s)$ is the TFP value of the *P*th DMU in period *s* using the technology (frontier) of period *s*, and $d^s(x^t,y^t)$ is the TFP value for the *P*th DMU in period *t* using the technology (frontier) of period *s*. Equation (5) can be rephrased as:

$$M(x^s,x^t,y^s,y^t)=\frac{d^s(x^s,y^s)}{d^t(x^t,y^t)}\times\left[\frac{d^t(x^s,y^s)}{d^t(x^t,y^t)}\times\frac{d^s(x^s,y^s)}{d^s(x^t,y^t)}\right]^{1/2} \quad (6)$$

in which the Malmquist growth index is decomposed into two factors of efficiency variation and technology variation:

$$EC=\frac{d^s(x^s,y^s)}{d^t(x^t,y^t)} \quad (7)$$

$$TC=\left[\frac{d^t(x^s,y^s)}{d^t(x^t,y^t)}\times\frac{d^s(x^s,y^s)}{d^s(x^t,y^t)}\right]^{1/2} \quad (8)$$

EC > 1 implies that the DMU has had an increasing efficiency between the two periods, but *EC* < 1 means that its efficiency has declined. In other words, the value of *EC* shows the contribution of the efficiency of a DMU to the growth of the total productivity of its factors. When we have *TC* > 1, then the respective DMU has had a progress in technology and technical knowledge between the two periods, but the opposite holds true when *TC* < 1. Thus, *TC* represents the extent to which technology and technical knowledge variations can influence the growth of total productivity of the DMU factors. Finally, when the Malmquist productivity growth index is greater than 1, it means the growth of TFP of the DMU in two consecutive periods, but the value of smaller than 1 shows negative growth (Rezaei et al., 2008).

Statistical data

The statistical population was composed of all wheat growers of the Sistan region. Data were collected with a questionnaire and interview. To this end, 45 questionnaires were administered to the users in three counties including Zabol, Zehak, and Hirmand in 2014-2016. The sample was taken by two-stage cluster sampling in which the main clusters were assigned to Zabol, Zehak, and Hirmand counties and the sub-clusters were assigned to wheat farmers in these three counties.

Input and output indices of the research model

An input index refers to a factor that when one unit of it is added to the system, the efficiency is decreased assuming that all other conditions are constant. An output index is a factor that when one unit of it is added to the system, the efficiency is increased assuming that all other conditions are constant (Siriopoulos and Tziogkidis, 2010). Table 2 shows the input and output indices of WDEA model and the Malmquist productivity index. The reason for the selection of the input-based model was that the inputs are so used that maximum performance and profit are accomplished. Also, the selection of variable return to scale is related to the fact that there is no evidence showing constant return to scale in the function of users, so it is necessary to leave the value of return to scale free so that the type of return to scale of the users is determined in DEA models.

Table 2. Inputs and outputs of window analysis model and Malmquist productivity index

Description	Variable	
Inputs	Acreage (ha)	X_1
	Waged labor (person-days)	X_2
	Family labor (person-days)	X_3
	Irrigation frequency	X_4
	Manure (kg)	X_5
	Herbicide and pesticide (kg)	X_6
	Age (years)	X_7
	Education	X_8
	Experience (years)	X_9
	Family size (persons)	X_{10}
	Number of land pieces	X_{11}
	Attendance in extension training courses	X_{12}
Outputs	Profit	Y_1
	Production yield	Y_2

Results

Considering the inputs and outputs of the research model and using mathematical programming models, especially date envelopment analysis (DEA) and the Malmquist index, the efficiency and productivity growth of the production factors of wheat growers in Sistan were calculated as below. The window width was assumed to be 3 although from a theoretical perspective, there is no method to determine optimum window size. The results of estimating window analysis model for data on farmers in Zabol, Zehak and Hirmand counties are presented in Tables 3, 4 and 5. Table 3 shows the average efficiency of 0.99 for wheat growers of Zabol County in 2014-2015 growing season. This is a value close to 1, implying their perfect efficiency. But, their efficiency shows a descending trend for 2015-2016 and 2016-2017 growing seasons. On the other hand, the average efficiency of each year was 0.96. This means that wheat growers of Zabol County have worked in a relatively perfect manner, so they have enjoyed high profit and crop yield per unit area. Table 4 shows the results for estimating efficiency model by the WDEA for Zehak County. It is evident that average efficiency of wheat growers in Zehak County was 0.99 in 2014-2015, which is greater than that of 2015-2016 and 2016-2017 growing seasons. Also, the average efficiency score of each year was 0.95 for 45 wheat growers. This is an efficiency of close to 1 considering the consumed inputs. So, they show a strong efficiency with a high yield per unit area and profit. In addition, their efficiency has been almost constant across the considered time period. Table 5 shows the results of efficiency assessment by the WDEA for Hirmand County. In Hirmand County, the average efficiency of each year was 0.97 for 45 farmers, which is close to 1 given the consumed inputs.

Table 3. Results of efficiency assessment with window data envelopment analysis in Zabol County

Average efficiency per year	Average efficiency per window	2016-2017	2015-2014	2014-2014	Time period
0.96	0.96	0.92	0.96	0.99	Average

Source: Research findings.

Table 4. Results of efficiency assessment with window data envelopment analysis in Zehak County

Average efficiency per year	Average efficiency per window	2016-2017	2015-2014	2014-2014	Time period
0.95	0.95	0.91	0.95	0.99	Average

Source: Research findings.

Table 5. Results of efficiency assessment with window data envelopment analysis in Zabol County

Average efficiency per year	Average efficiency per window	2016-2017	2015-2014	2014-2014	Time period
0.97	0.97	0.96	0.97	0.96	Average

Source: Research findings.

Total productivity variation (Malmquist index) is decomposed into two components including technical efficiency and technical development (technological improvement). We first examined productivity variations for all 45 wheat farmers separately for Zabol, Zehak and Hirmand counties. Then, technical efficiency and technical development were separately addressed.

Tables 6, 7 and 8 present the variations of productivity of wheat production and its components over the studied years. Accordingly, the variations of total productivity of wheat production factors are the result of the variations of technical efficiency and technological variations. The results in Table 6 for the average total productivity of production factors, average technological growth, and technical efficiency over 2014-2016 show that average total productivity is 0.96 which is close to 1 and it is following a descending trend. This decrease in productivity is caused by low variations of technical efficiency and technology. Therefore, the average performance of wheat growers is assessed to be low in this county. Average total productivity was found to be 0.97 in Zehak County, showing the decline of productivity over the studied time period. Also, average variations of total productivity of the factors were estimated at 0.95, implying the descending order of productivity and yield.

Technical efficiency is separated into pure technical efficiency (managerial) and scale efficiency. Now, we present the results of the Malmquist index for the variations of technical efficiency. The Malmquist index is the product of managerial efficiency variations multiplied by the variations of scale efficiency. Average technical efficiency is 34, 0.99, and 0.99 for Zabol, Zehak and Hirmand counties. These results imply that the technical efficiency for the 2014-2016 period is greater than 1 for Zabol County and is increasing, but it is smaller than 1 for Zehak and Hirmand counties and it is decreasing. Also, the technological improvement was estimated at 0.63, 0.95 and 0.97 for Zabol, Zehak and Hirmand counties, which is smaller than 1 for all three counties. This means that wheat farmers have experienced no growth and development over the studied three seasons.

Table 6. The rate of annual variations of Malmquist productivity index in Zabol County

Average	Variations of total productivity of factors	Technological variations	Technical efficiency variations
Maximum	0.95	0.62	34
Minimum	1	1	1
Standard deviation	0.67	0.01	0.99
Mean	0.08	0.44	47.18

Source: Research findings.

Table 7. The rate of annual variations of Malmquist productivity index in Zehak County

Average	Variations of total productivity of factors	Technological variations	Technical efficiency variations
Maximum	0.94	0.95	0.99
Minimum	1	1	1
Standard deviation	0.65	0.67	0.79
Mean	0.09	0.09	0.03

Source: Research findings.

Table 8. The rate of annual variations of Malmquist productivity index in Hirmand County

Average	Variations of total productivity of factors	Technological variations	Technical efficiency variations
Maximum	0.96	0.97	0.99
Minimum	1.15	1.15	1
Standard deviation	0.66	0.80	0.78
Mean	0.08	0.07	0.03

Source: Research findings.

Conclusions and Recommendations

The present study addressed the efficiency and productivity of wheat farmers in the Sistan region over the 2014-2016 period. The study used data envelopment analysis and Malmquist productivity index. Dynamic window analysis approach is a method based on linear programming that calculated the efficiency of a set of wheat growers in the study site on the basis of input and output indices in comparison to one another and specified efficient and inefficient units.

It is evident that average efficiency of wheat growers in Zehak County was 0.99 in 2014-2015, which is greater than that of 2015-2016 and 2016-2017 growing seasons. Also, the average efficiency score of each year was 0.95 for 45 wheat growers. This is an efficiency of close to 1 considering the consumed inputs. So, they show a strong efficiency with a high yield per unit area and profit. In addition, their efficiency has been almost constant across the considered time period. Table 4 shows the results of efficiency assessment by the WDEA for Hirmand County. In Hirmand County, the average efficiency of each year was 0.97 for 45 farmers, which is close to 1 given the consumed inputs. The results show that average efficiency has been close to 1 in three studied counties (Zabol, Zehak, and Hirmand) in all studied years, showing their relatively constant efficiency. To improve the efficiency of local farmers, the optimum use of inputs should be put in priority.

The results for the average total productivity of production factors, average technological growth, and technical efficiency over 2014-2016 show that average total productivity is 0.96 which is close to 1 and it is following a descending trend. Also average annual Malmquist productivity index versus the year 2014 indicates the average total productivity of the production factors is 0.95, 0.94, and 0.96 for Zabol, Zehak, and Hirmand, respectively. These are all close to 1 and reveal the declining productivity of wheat farmers over the studied period. This is rooted in technological variations and technical efficiency variations. So, programs should be in place to enhance them. Total productivity of production factors has been decreased over the studied period due to the increase in technological variations and the loss of scale efficiency, managerial efficiency, and technical efficiency.

Given the nature of the model (input-oriented), it has been assumed that regional wheat growers improve their profit and yield at a certain level of inputs. Inefficient wheat growers should save on the use of inputs to enhance their technical and scale efficiency. In other words, poor technical efficiency is not merely the result of input scarcity, but the non-optimal use of inputs and their inappropriate combination are among the cause of the low technical efficiency. As a result, instead of increasing inputs in the region, it is imperative to emphasize the optimal use of the current inputs.

All in all, the results indicate that among the studied wheat growers, those who are highly efficient should be selected in order to be supported for increasing their yield and profit per unit area. However, such selection would not be possible if the traditional analysis has been applied. In fact, in traditional analysis, the diverse results of the assessment of the inputs cannot be integrated to be the basis for the comparison of farmers to select the superior ones.

Farmers with the efficiency close to 1 are recommended to attempt to make more efficient and optimal use of varieties and improved seeds, more appropriate irrigation methods, and such inputs as land, water, and labor in order to enhance their efficiency.

Since the variations of total productivity of the counties are close to 1, it is recommended to use modern technologies in the agricultural sector and for strategic crops, such as wheat. Nonetheless, this can improve productivity only if managerial policies and extension training courses are considered for local farmers to maximize their use of these resources.

Given that the technological development is at a low level in the Sistan region (the separated counties), it will be useful to adopt supportive policies in accordance with local conditions to improve technological efficiency.

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