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Presenting a New Technique to Assess the Efficiency of Farms with Window-DEA and Malmquist Productivity Index: The Case of Barley Farms In Khash County, Iran

Ali Sardar Shahraki [a] and Neda Aliahmadi [, b]*

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Abstract

As a major source of income in most countries, the agricultural sector is of a key importance among all economic activities. The improvement in productivity and efficiency is one of the main goals to accomplish economic growth and prosperity. Productivity enhancement has always been a major concern for all economic enterprises that produce commodities and services, and it is imperative to consider all of its aspects when planning for development. The present study aims at analyzing the variations of the productivity of production factors and measuring technical efficiency and productivity of farmers in Khash County, Iran using window data envelopment analysis (WDEA) method. So, the technical efficiency and productivity of the farmers were examined over the 2013-2016 period. The results show that the studied farmers have an average technical efficiency of 0.99, which is relatively high and indicates that the barley farmers are efficient. Indeed, the Malmquist productivity index reveals that the average variation of total productivity in the studied county was 1.95 over the studied period. One of the most effective factors influencing total productivity variations in agriculture is technological change. It is suggested that the new technology of agricultural technology (field integration and use of new irrigation) be used to increase the productivity and productivity of barley crops in the region.

Keywords:
Data envelopment analysis; efficiency; productivity; Malmquist Index; Window-DEA

[a] *Assistant Professor of Agricultural Economics, University of Sistan and Baluchestan, Iran*
[b] *Ph.D. student of Agricultural Economics, University of Sistan and Baluchestan, Iran*

** Corresponding author's email: ahmadi_15877@yahoo.com*

INTRODUCTION

The significance of the agricultural sector in meeting the basic needs of the people and in national development calls for a change in the agricultural structure through long-term scientific planning (Altier, 2018), especially given the fact that a great part of the Gross Domestic Product (GDP) is accounted for the agricultural sector. Iran is a developing country in which 20 percent of GDP is accounted for by the agricultural sector, which relies on modern and traditional methods (Koupaei, 2010; Toma et al., 2017).

The accomplishment of high efficiency and productivity is rendered possible by producing the highest crop with the use of the least production factors. Productivity encompasses efficiency. This means that the increase in productivity will improve the lifestyle and well-being of all people, the goals pursued by policymakers and economists (Abrishami & Niakan, 2010; Guesmi et al., 2017). The efficiency and productivity of an economic system are related to the ratio of its inputs and outputs. On the other hand, productivity is a concept that shows the efficiency of the enterprises as compared to one another in a certain time period (Farrel, 1957; Kneip et al., 2018; Patra & Ray, 2017).

One of the widely used methods to measure efficiency is data envelopment analysis (DEA) that focuses on a set of uniform and homogeneous decision-making units (DMUs) with similar inputs and outputs (Charnes et al., 1978; Mu et al., 2018). Productivity improvement is one of the key criteria showing the progress of the production units. Productivity refers to the application and combination of productivity factors in a production unit. Also, productivity means the optimal and efficient use of the production unit inputs to accomplish efficiency and effectiveness (Díaz-Chao et al., 2015). DEA is a nonparametric linear programming method that can use multiple inputs and outputs. In addition to DEA, various other models have been presented based on Charnes's work with various applications (Sengupta, 1995; Guo et al., 2017). On the other hand, window-DEA (WDEA) analysis is one of the most up-to-date methods of measuring productivity. This approach estimates the performance of a manufacturing unit over time. It is also very appropriate for the measurement of small samples given their greater degrees of freedom (Molaei et al., 2011).

Barley is the only crop in the Khash region of Iran that is planted three times in a growing season. Khash County has the highest plant diversity in Sistan and Baluchestan Province, Iran so that it is called *the rainbow of agricultural and horticultural crops* and is a major center of agricultural production. The total acreage of Iran is 7,715,616 ha. The total barley production of Iran amounts to 11,522,318 tons. The harvesting acreage of barley in Iran is estimated at about 1.8 million ha accounting for 9.99 percent of the total acreage of all crops and 21.56 percent of the total acreage of grains. Forty percent of the acreage is irrigated and the remaining 60 percent is rain-fed. Iran annually produces 3.2 million tons of barley, accounting for 4.16 percent of total crop production and 17.55 percent of total grain production. Irrigated farms contribute 67.63 percent and rain-fed farms contribute 32.37 percent of this crop. The yield of irrigated and rain-fed barley farms is 3,070 and 980 kg ha^{-1}, respectively. The planting area of barley in Sistan and Baluchestan Province is 16,538 ha producing 208,750 tons of barley with the yield of 796.1 kg ha^{-1} (Anonymous, 2016).

The production of the agricultural sector can be escalated by developing production factors and making technological changes, and this can be a suitable method to accomplish higher efficiency, yield, and crop production (Amegnaglo, 2018). This is especially applicable in the context of sustainable development, one of whose economic, environmental and social goals is to improve efficiency and to make less use of inputs and resources (Berimnejad & Mohtashami, 2009; Hazneci & Ceyhan, 2015).

One main constraint of crop production is the scarcity of resources and production factors. So, mankind has no choice for an ideal life, unless the better use of the existing resource for more production with higher quality. In addition, to increase the efficiency and productivity of a production cycle, the first step for performance analysis, planning and improvement is to measure the variations of the technology and efficiency. Window-DEA analysis model (WDEA) allows observing the trend of efficiency variation of the enterprises over time. As such, a question arises as to whether enterprises have proceeded towards productivity enhancement. The present study aims to explore the technical efficiency and efficiency level of barley production units and their productivity as well as their trend using the Malmquist productivity index (MPI).

An essential concept in economics is productivity that is an indicator of how usefully, effectively and efficiently the production resources are exploited to produce commodities and services (Isazadeh & Soufimajidpour, 2018). Productivity refers to the amount of output derived from a certain amount of one or more inputs. This criterion shows how production resources and factors are used in a certain time period, and it involves the impacts of technology change, scale change, and the change in the efficiency of input use (Diewert & Fox, 2017; Torabi Dastgerooyi & Bakhshoudeh, 2007). Productivity is composed of two major components: efficiency that shows higher output versus lower inputs, and effectiveness that reflects the selection of profitable activities to accomplish the goal(s). In other words, productivity refers to doing things rightly (efficiency) and doing the right things (effectiveness) (Bakhtiari et al., 2014; Ekin & Lovely, 2017).

The terms *efficiency* and *productivity* have been used synonymously and interchangeably in most literature, but this is a big mistake. These two terms are not the same. Efficiency expresses a point on the production frontier, but it does not show the maximum productivity. It is only a point on the production frontier in which the productivity is at its highest point. This means that efficiency is a part of productivity (Coelli et al., 2005; Paul & Shankar, 2018).

Economists have suggested two main methods for productivity estimation: econometric method and nonparametric method. In the nonparametric technique, productivity is estimated by using programming models and/or by calculating the index score (Ma et al., 2018; Rao et al., 2005). In the econometric technique, productivity is obtained by estimating a production function or its dual function (cost) (Dashti et al., 2009; Lakner et al., 2017).

In the study of efficiency, it is imperative to specify the efficiency of a manufacturing unit in comparison with that of other manufacturing units. This requires determining an efficient frontier in order to make it possible to make a comparison with the efficiency of other units (Charnes et al., 1978; Chen & Jia, 2017). Multiple techniques have been presented to estimate the efficient frontier in recent years, including both parametric and nonparametric methods. The parametric technique is the stochastic frontier analysis (SFA) of the production function in which the relationship of the inputs and output, i.e. the production function, is used to estimate the parameters of the function by using the statistical methods. The nonparametric technique is the data envelopment analysis (DEA), which is a linear programming method first presented by Farrel in 1957 (Fare et al., 1994; Xu et al., 2017). Two main variants of the nonparametric technique are the CCR (Charnes-Cooper-Rhodes) and the BBC (Banker-Charnes-Cooper). These two techniques are linear models to solve efficiency problems assuming multiple inputs and outputs and employ the technology assuming constant and variable return to scale, respectively (Haynes et al., 1977; Mahate et al., 2017; Ji et al., 2015).

On the other hand, DEA can be applied to estimate the total productivity index of the production factors, which is known as the

Malmquist productivity index (MPI). Unlike other indices, the MPI does not need to have the price of inputs and outputs available (Fare et al., 1994; Krishna et al., 2018). Furthermore, the MPI enables us to divide the total productivity variations of the production factors into technological variations and technical efficiency variations. The MPI can be calculated if we have cross-sectional and time-series data of the economic units (panel data) (Ram Mohan & Ray, 2004).

Rezaee et al. (2008) evaluated the variations of total productivity of the production factors in the agricultural sector using non-parametric techniques. They found that the productivity growth of the production factors in the agricultural sector was annually 0.73 percent. So, there was a deep gap between this growth and the growth targeted by the Fourth Development Action Plan of Iran. Rajabi (2010) used the WDEA to assess the performance of the commercial banks in Iran. He concluded that Bank Melli and Refah Bank were more efficient than other banks, exhibiting higher performance. Taghizadeh Mehrjardi et al. (2013) modeled and predicted the efficiency of the public and private banks in Iran using the artificial neural network, fuzzy neural network, and genetic algorithm models. The sensitivity analysis of the inputs by the neural network showed that the inputs of net profit and loss had the highest impact on the efficiency of the banks. Tahamipour et al. (2014) measured and analyzed the total productivity growth of the production factors of different rice cultivars in Iran. They found that the productivity of rice farmers can be improved as compared to status quo by improving their technical and managerial efficiency, but this needs promotion and training of appropriate techniques to use modern technologies and inputs in a sound way. Parsa et al. (2015) used the distance function to analyze the environmental productivity growth of the production factors in Iran's provinces. The results for a single time period revealed that the total environmental productivity of the production factors was reduced by, on average, 8.47 percent and that this was caused by the drop of the environmental technical efficiency as well as by the increased level of CO_2 emission. Doaei et al. (2016) studied the efficiency and effectiveness of the firms listed in Tehran Stock Exchange using DEA and the MPI. The efficiency of the firms was calculated by DEA in which both diversity types, i.e. diversity in product and international diversity, were directly included as the input variables. The efficient and inefficient firms were presented using diversification strategy in each certain year and the relationship was suggested to improve the efficiency of the inefficient firms. Dashti et al. (2017) used the modified nonparametric methods to evaluate the technical efficiency of beet production in Iran using WDEA. Since the full frontier models have some assumptions when compared to their partial counterparts, making them closer to reality, then they gave more desirable results. So, it is recommended to use full frontier models in future works on measuring technical efficiency and ranking the DMUs. Villano et al. (2006) focused on rice production with risk and used stochastic frontier production functions simultaneously with technical inefficiency and production risk for 46 rice growers in the Philippines for an 8-year period. They reported that the average technical efficiency was 79 percent over the studied period and the crop was influenced by rice acreage, labor, and the rate of chemical fertilizer use. Chen et al. (2008) used cross-sectional data and the MPI to explore productivity growth of the agricultural sector in China over the 1990-2003 period. They reported that technology variations influenced the total productivity growth of the factors significantly. Tozer et al.(2010) studied the efficiency of wheat growers in Australia using the data for 2004-2007 with the SFA technique. The results showed that the inefficiency of wheat production in Australia was increased from 18 percent in 2004 to 29 percent in 2007. Ximing et al. (2011) assessed water productivity for rain-fed and irrigated crops, including wheat, maize, soybean, and rice, in the Yellow River basin in China. They found significant differences in crop harvest between the irrigated system and rain-fed system for maize and soybean. Also, the productivity of water use was slightly higher in the rain-fed system than in the irrigated system for these two crops. In a study using DEA and the fuzzy Delphi technique, Wang et al. (2012) addressed the efficiency of the agricultural cooperatives and the underpinning factors in Langao, China. They reported that horticultural and vegetable cooperatives had higher technical efficiencies than livestock farming cooperatives and that the vegetable and horticultural cooperatives can improve their efficiency by making more use of the vehicles. Huang et al. (2013) examined the technical efficiency of agricultural cooperatives using DEA in China. They found that technical inefficiency of the managers was the main reason for the technical inefficiency of the cooperatives. In a study on factors influencing the efficiency of water use in wheat crop production in Chbika, Tunisia using DEA, Chebil et al. (2014) found that the average efficiency of the local wheat farmers was 41 and 44 percent assuming constant and variable return to scale, respectively. They, finally, showed that wheat variety, irrigation water source, membership in water users associations, irrigation scheduling, and experience influenced water use efficiency positively in this region. Ghosh and Kathuria (2016) estimated the effect of governmental and state regulations on the efficiency of thermal power generation in India using the Translog production function and inefficiency impacts model. They obtained the average technical efficiency as to be 76.7 percent for 77 power plants using the panel data for the period from 1994-1995 to 2010-2011. They concluded that regulation at the state level had a positive impact on power generation performance, but regulation at the central government level should be more of monitoring and experience-sharing nature. AKamin et al. (2017) analyzed the efficiency and productivity of medicinal plants in the tropics of Cameroon using SFA. They found that farmers had lower efficiency due to the increase in farm size. Table 1 summarizes some other relevant studies.

Given the scarcity of the resources to realize economic growth, productivity and efficiency are the best and most effective way to improve production. By calculating and analyzing the productivity indices of the production factors, we can examine the efficiency of different economic sectors in the use of the production resources. Among different economic sectors of a developing country, the agricultural sector is of crucial importance in contributing to the growth and development process. Accomplishing sustainable agricultural growth is a major challenge for all countries. This sort of growth ensures food security, employment creation, sustainable development, environmental conservation and so on. Presently, the agriculture and natural resources sector of Iran is one of the critical economic sectors owing to its vital role in food supply and food security. Due to its considerable potentials in production resources and factors, this sector has won a proper place in the economy of Iran and has played a key role in GDP, the increase in non-oil exports, and employment. In Iran, the agriculture development plans pursue such goals as improving production, increasing farmers' income, hindering immigration, reducing the income gap between urban and rural areas, agricultural mechanization, and so on. A closer look at these goals signals that low productivity at the production level is one of the main challenges of the agricultural sector in Iran. So, the development of this sector requires the improvement of production. According to what was mentioned and the review of the literature, since the optimal use of the inputs and accomplishing the highest crop in the agricultural sector are very important and since the window-DEA (WDEA) analysis is one of the most recent methods of productivity measurement that allows calculating efficiency over time and measuring the

Table 1
A Review of Some Relevant Literature

Source	Country/region	Modeling method	Objectives
Alirezaei et al. (2005)	17 Asian countries	Malmquist index	Studying the characteristics of the Malmquist index, productivity growth
Abbasian and Mehrgan (2007)	Transportation sector	Data envelopment analysis	Total productivity of production factors and its components in the transportation and communications sector
Shoja et al. (2009)	Three academic units in Buin Zahra, Firuzkuh, and Varamin	Data envelopment analysis, Malmquist productivity index	Studying efficiency and estimating productivity
Sokhanvar et al. (2012)	Power distribution companies	Window data envelopment analysis	Vertical separation of power distribution companies, ownership change, and environmental factors
Azimian et al. (2013)	Projects in project-oriented organizations	Data envelopment analysis and Malmquist productivity index	Assessing the performance of the projects in Subsea R&D Center
Amiri et al. (2014)	Cooperatives in South Khorasan Province, Iran	Probit econometric model	Comparative efficiency of agricultural cooperatives in input supply sector
Shakibai and Golmohammadi (2014)	Tehran Stock Exchange (TSE)	Data envelopment analysis	Measuring efficiency dynamic and ranking of pharmaceutical firms in TSE
Mortazavi et al. (2016)	Zaragan of Fars, Iran	Data envelopment analysis and artificial neural network	Calculating the subvector water efficiency and the most effective factors
Sarica and Or (2007)	Turkish power plants	Data envelopment analysis	Estimating efficiency
Kao and Hwang (2008)	Telecommunication enterprise of Taiwan	Window data envelopment analysis	Measuring efficiency assuming variable return to scale
Guzmám and Arcas (2008)	Agricultural cooperatives of Italy	Data envelopment analysis	Measuring technical efficiency
Idris and Ramaha (2009)	Small-scale industry in Malaysia	Data envelopment analysis	Studying the technical effects on labor productivity in industrial factories
Li et al. (2010)	Agricultural cooperatives in Danyang	Data envelopment analysis	Estimating the technical efficiency of agricultural cooperatives

productivity for managers and users. Also, in this method, in addition to the efficiency and productivity of an avid exploiter over a period of time compared to other operators, You can be informed of your unit's efficiency or efficiency changes over the years and the result of managerial decisions taken at a given time point on the long-term performance of the unit so that the manager can provide the fields of higher-level capability and efficiency in the future. so we aim to focus on the efficiency and productivity the Malmquist productivity index (MPI) of barley crop in Khash County, Iran.

Window-DEA index

Data envelopment analysis (DEA) is a nonparametric linear programming approach that can use multiple inputs and outputs. Since DEA was proposed, various models have been presented on the basis of the Charnes model, each one with its own specific applications. Window-DEA (WDEA) is one type of DEA models (Abbas et al., 2018; Sengupta, 1995). WDEA is a specific form of sequential analysis. In this analysis, it is assumed that what has been practical in the past stays the same and so, it encompasses all previous observations (Fazel Yazdi & Moeeinoddin, 2018). WDEA estimates average efficiency assuming constant or variable return to scale and is used to identify the trend of efficiency over time. So, it can be used to reveal the trend of the performance of a certain enterprise over time, but there is no theory as to the optimal size of the window. Since the technical efficiency of the units is compared to one another in a window (a selected time period), it is clearly assumed that no technical changes happen within the windows. This is a general issue in WDEA. Nonetheless, this issue is solved as the window width is reduced. To validate WDEA, the window width should be selected so as to make it reasonable to ignore the technical changes (Fazeli, 2001; Muhammad et al., 2018). DEA was first used for cross-sectional data in which a DMU is compared to all units with similar activities in the same time period and the role of the time is neglected. Panel data are preferred to cross-sectional data because not only can a DMU be compared with another DMU, but the change in the efficiency of a certain DMU can also be assessed over time (Sokhanvar et al., 2012).

To model, we consider N DMUs ($n= 1,...,N$) observed in T periods ($t= 1,...,T$), and all have r inputs and s outputs. Then, we have observations and each observation n in period t, DEU^n_t has one r-dimensional input vector $X^n_t= (X_1^n, X_2^n, ..., X_{rt}^n)$ and one s-dimensional output vector $Y^n_t= (X^n_{1t}, X^n_{2t}, ..., X_{st}^n)$. A window that starts at time K, $1 \le K \le T$, with length W, $1 \le W \le T-K$, is denoted by K_W and has $N \times W$ observations.

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

and the output matrix:

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

The input-oriented window-DEA problem for assuming constant return is given as (Asmild., 2004):

$$\begin{aligned} &\min_{\lambda,\theta} \theta = \theta'_{kwt} \\ &S.t: \\ &\quad -X_{kw\lambda} + \theta X't \ge 0 \\ &\quad Y_{kw\lambda} - \theta Y't \ge 0 \\ &\quad \lambda n \ge 0 \\ &\quad (n = 1k \;,\; N \times W) \end{aligned} \quad (3)$$

The malmquist productivity index

Fare showed that by using DEA, one can obtain an index of total productivity of the production factors that came to be known as the Malmquist productivity index (MPI). This index does not require having the price of the outputs and inputs (Ram Mohan & Ray, 2004) whilst other indices, like the Törnqvist, do.

Also, in the MPI, the variations of total productivity of production factors can be divided into technology variations and technical efficiency variations. To use the MPI, we need panel data, but the Törnqvist index uses time-series data to estimate the productivity of an enterprise in the use of the production factors (Zeranejad & Yousefi Hajiabad, 2009). In addition to investigating the pattern of the productivity variations, the MPI provides a strategic orientation for an enterprise in a time period. The use of the MPI enables one to evaluate the strategic orientation of the organization in the previous period and to choose a correct orientation for future periods (Chen & Aghalqbal, 2004).

The MPI based on maximization between times t and $t + 1$ is defined with respect to the conventional efficiency frontier as Eq. (4):

$$M_0^t\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \frac{D_0^{t+1}\left(X_0^{t+1}, Y_0^{t+1}\right)}{D_0^{t+1}\left(X_0^t, Y_0^t\right)} \quad (4)$$

As well, the MPI based on maximization between times t and $t + 1$ is defined with respect to the conventional efficiency frontier in times t and $t + 1$ as Eq. (5):

$$M_0^{t+1}\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \frac{D_0^{t+1}\left(X_0^{t+1}, Y_0^{t+1}\right)}{D_0^{t+1}\left(X_0^t, Y_0^t\right)} \quad (5)$$

The above two MPIs are equivalent, and the Malmquist productivity variation index is defined as the geometric average of these two MPIs (Eqs. (4) and (5)) as denoted in Eq. (6) (Diao et al., 2018):

$$M_0\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \frac{\left[\frac{D_0^t\left(X_0^{t+1}, Y_0^{t+1}\right)}{D_0^t\left(X_0^t, Y_0^t\right)} \times \frac{D_0^{t+1}\left(X_0^{t+1}, Y_0^{t+1}\right)}{D_0^{t+1}\left(X_0^t, Y_0^t\right)}\right]}{2} \quad (6)$$

which expresses the productivity at point versus point . Values of greater than one show productivity improvement. To make it possible to display the variations of technology, production scale an technical efficiency in the MPI, Eq. (5) is decomposed as Eq. (7):

$$M_0\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \frac{D_0^{t+1}\left(X_0^{t+1}, Y_0^{t+1}\right)}{D_0^t\left(X_0^t, Y_0^t\right)} \left[\frac{D_0^t\left(X_0^{t+1}, Y_0^{t+1}\right)}{D_0^t\left(X_0^t, Y_0^t\right)} \times \frac{D_0^{t+1}\left(X_0^{t+1}, Y_0^{t+1}\right)}{D_0^{t+1}\left(X_0^t, Y_0^t\right)}\right]^{1/2} \quad (7)$$

in which the term outside the brackets denote the variations of technical efficiency in the time interval from t to $t + 1$ and is equal to the ration of technical efficient at time $t + 1$ to technical efficiency at time t. The term inside the brackets represents the variation of technology between these two times. shows that productivity has been increased between these two periods. This increase can be accounted for by technical efficiency enhancement or the development of technology of efficient frontier change (Jesus et al., 2005).

The statistical population of the study was composed of the farmers of Jowkaran Village of Khash County. Data were collected with a questionnaire and interview with farmers. So, 45 questionnaires were filled out by the users in 2013-2016. The sample was selected by two-stage cluster sampling in which the main cluster was the barley farmers Khash County and sub-cluster was the barley farmers of this county.

Analysis

Given the research objectives, Table 2 presents the inputs and outputs of barley farmers with respect to their influence and importance as input and output variables of the WDEA and MPI.

Assessment of barley farmers' efficiency by WDEA

The results of efficiency measurement with WDEA in input-oriented state and assuming constant return to scale are summarized in Table 3. Since the technology transition rate

Table 2
Inputs and Ooutps of Window-DEA Model and the Malmquist Productivity Index

Description	Variable	
Inputs	Labor (person-day)	X_1
	Irrigation frequency	X_2
	Chemical fertilizer (kg)	X_3
	Manure (kg)	X_4
	Pesticide and herbicide (kg)	X_5
	Seed (kg)	X_6
	Land size	X_7
	Age (year)	X_8
	Education	X_9
	Experience (year)	X_{10}
	Family size (person)	X_{11}
	Land ownership	X_{12}
Outputs	Profit	Y_1
	Production yield	Y_2

is lower in the agricultural sector than other economic sectors, the window width was considered as to be 3 years although there is no way to determine optimal size from a theoretical perspective. So, the technical efficiency of 45 barley farmers under dynamic conditions was calculated with a window width of 3 years for the 2013-2016 period. It can be observed that in this period, the performance of the farmers was examined under the assumption of constant return to scale, showing their high efficiency of 0.99 which is close to unit. In other words, given their efficiency in Khash County, the input use in barley farms can be reduced by 0.01 units in each of the studied years. On the other hand, the average efficiency of each year is 0.99. The efficiency score of the studied years reveals that farmers should make, on average, 0.01 saving in their inputs to realize the technical efficiency of the input. Overall, this means that barley farmers of Khash County act relatively efficiently, so they enjoy high profit and yield per unit area.

Malmquist productivity index

The variations of total productivity (MPI) are decomposed into the variations of technical efficiency and the technical progress (technological improvement). We first examined the variations of the total productivity of 45 studied barley farmers, and then we divided it into technical efficiency and technical progress.

Table 4 shows the variations of the productivity in the production of barley and its components in the studied years. As is evident, the variations of total productivity of barley production factors result from the variations of technical efficiency and technological changes. According to Table 4 for the average total productivity of the production factors, average technology growth and technical efficiency in 2013-2016, the average total productivity of the production factors is 1.96 which is greater than 1 and shows the increase in productivity. On the other hand, this increase in productivity is caused by high variations of technical efficiency and technology. Thus, barley farmers of the studied county have high production performance.

Technical efficiency itself is divided into pure technical efficiency (managerial efficiency) and scale efficiency. When the variations of total productivity of the production factors (MPI) are greater than 1, it means the

Table 3
Results of Efficiency Measurement Using Window-DEA in Khash County

Time period	2013	2014	2015	2016	Average efficiency in each window	Average efficiency of the year
Average	0.99	0.99	0.99	0.99	0.99	0.99

Table 4
The Rate of Annual Variation of the Malmquist Productivity Index and Its Components in Khash County

	Technical efficiency variation	Technological changes	The variation of total productivity of the factors
Average	1.001	1.95	1.95
Maximum	1.05	12.92	12.92
Minimum	0.98	1	1
Standard deviation	0.008	2.14	2.14

improvement of productivity and performance; but, when they are smaller than 1, it means the loss of productivity and performance over time. Also, when MPI is equal to 1, it reflects the fact that productivity has not changed over the studied period. Table 4 presents the mean, maximum, minimum and standard deviation of MPI for barley farmers of Khash County in 2013-2016. The results of MPI for the variations of technical efficiency are discussed. This is the sum of the variations of managerial efficiency and scale efficiency. The average technical efficiency was found to be 1.001 for Khash County. This means that technical efficiency is greater than 1 for Khash County in 2013-2016. So, average technical efficiency shows an ascending trend.

The technical progress has shown a very positive performance. In agriculture, the growth of the technical progress has been almost at a plateau. Results for technological improvement shows that it is 1.95 which is greater than 1, meaning that barley farmers have been developed considerably over the studied period.

CONCLUSIONS AND RECOMMENDATIONS

The present study reviewed the efficiency and productivity of barley farmers in Khash County in 2013-2016 using WDEA and MPI. The key assumption in WDEA is the lack of any technical changes during a window so that the efficiency of farmers can be compared across different periods. To estimate the efficiency by dynamic WDEA approach, the efficiency of barley farmers in the studied region is determined on the basis of the input and output indices as compared to one another and the efficient units are distinguished from the inefficient ones. The results can contribute to managing each unit, using the inputs optimally, and identify the weaknesses and strengths. Then, approaches can be found to improve the efficiency of the unit and thereby realize the maximum efficiency and attain more profit or utility. Waged labor, irrigation frequency, manure rate, chemical fertilizer rate, herbicide and pesticide, age, educational level, experience, family size, land size, and ownership were included as the inputs, and crop yield and profit were considered as the outputs.

The results show that the average efficiency in all studied years has been close to 1 (0.99), showing a relatively strong efficiency. In total, the efficiency index of barley farmers in Khash County indicates that this index is almost at a plateau for the farming in Iran. To improve the efficiency of local farmers, it is suggested making optimal use of the inputs and modern farming practices.

Also, we employed MPI to investigate the variations of total productivity of production factors, technical progress, and the variations of technical efficiency of barley production in Khash County during the four year period. Total productivity of the production factors was calculated by MPI, which is based on the distance function. The results can be used to identify the trend of the variations of the productivity of each production factor and the influence of technical and managerial factors on the variations and to find out how to accomplish the optimal level of productivity and efficiency. The annual average of MPI shows that average total productivity of production factors in the studied region is 1.95 which is greater than 1. This shows the increasing productivity of barley farmers in the studied period. This improvement is rooted in technological changes and the variations of technical efficiency. So these two factors should be enhanced to attain higher total productivity. Thus, it can be concluded that the increase in technological changes, scale efficiency, managerial efficiency and technical efficiency has resulted in the enhancement of total productivity of the production factors over the studied period.

Since we used the input-oriented model, it has been assumed that barley farmers of the studied region improve their profit and yield at a certain level of inputs. On another hand, inefficient barley farmers should save in their inputs in order to improve their technical and scale efficiencies. In other words, the poor technical efficiency may be caused by the non-optimal use of the inputs and their inappropriate mixture in addition to the scarcity of the inputs.

In general, the results show that among barley farmers, barley farmers who have a strong performance can be selected and they will receive even more support to increase performance and profit per unit area. This would not be possible, however, if the traditional analysis was used. In fact, in the traditional analysis, we can not combine the various results from the evaluation of inputs. And can easily be compared based on the results of this assessment on the superiority of exploitation. So, instead of increasing input use in the region, it is necessary to make optimal use of the inputs.

The results lead us to the following recommendations:

Given the results about the relative strong efficiency of barley farmers in Khash County, farmers should try to increase their efficiency in order to be more efficient. On the other hand, poorly efficient farmers should follow efficient units to move towards relative efficiency frontier.

Since the efficiency of barley farmers in the studied region is close to 1, they are recommended to use improved inputs (improved cultivars and seeds) more optimally, to apply appropriate irrigation methods, and to use inputs like land, water, and labor more optimally to make an improvement in their efficiency.

Since the variations of the total productivity in Khash County are close to 1, the farmers are recommended to move along with the technological developments in order to keep their current efficiency. They should also take actions to enhance their scale and managerial efficiencies.

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