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Measuring and decomposing total productivity growth of sugar beet production factors in Iran

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ABSTRACT

The purpose of this study was to estimate the rate of growth of total productivity factors in sugar beet production for different provinces and the decomposition of productivity growth rate into technological changes, changes in management efficiency and scale efficiency changes components. The method used to measure the total productivity growth of production factors and its components, was the Malmquist productivity index, in which the Data Envelopment Analysis method is used for the measurement of distance functions. The results showed that the total productivity of sugar beet production factors between the years 2000 and 2007 have grown by nearly 47%. Comparison among all sugar beet production factors throughout the study period showed that in three provinces of Ghazvin, Markazi and Hamedan, the productivity situation has been worsened and the main reason was the lack of management efficiency in these provinces. Therefore, these provinces are suggested to consider successful provinces in productivity of production status as their models to improve their productivity.

Keywords: Iran, Malmquist index, productivity growth, sugar beet, total factors productivity

INTRODUCTION

Sugar beet is of the main and industrial products in Iran with a production history dating back to 115 years ago. In Table 1, the acreage, production and yield of sugar beet is shown during 1993-2010. As seen in this Table, the average yield of sugar beet per hectare in the country during the period under study has been increased, while the average growth rate of production and the acreage were negative. In recent years, reduced tariffs on sugar imports resulted in the reduction of production capacity of the sugar factory and increase in cane acreage, which are the most important reasons for the reduction in sugar beet acreage (Peymaneh News Magazine of Iran's Economics 2011). In previous internal studies, this issue has been partially discussed. Ghorbani and Dehghanian (2006) reported that factors such as sugar content, the type of seed, and irrigation system had the most positive effects and factors such as the distance between field and sugar factories and farmer's age had the greatest negative impact on sugar beet cultivation.

In previous years, the production growth and the added value in agriculture could be gained through acreage expansion and products replacement with high economic value to products with a low value but the potential for continuity of this growth was decreased rapidly. Thus, for creating the high economic growth in agricultural sector, we should move towards increasing production per unit area through the increase of productivity (yield increase) (Gerdin 2002).

In this regard and according to Table 1, the question is which factors have caused an increase in sugar beet yield over time? And is there similar situation in different sugar beet producing provinces in the country? In other words, how differ-

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Table 1. Acreage, production, and yield of sugar beet and their growth rate during the period 1993-2010.

Agronomy year	Acreage (1000 ha)	Acreage growth rate (%)	Production (1000 t)	Production growth rate (%)	Yield (t/ha)	Yield growth rate (%)
1993-94	179	-	5407	-	30	-
1994-95	203	13.4	5294	-2.1	25	-16.7
1995-96	202	-0.5	5521	4.3	27	8.0
1996-97	149	-26.2	3686	-33.2	24	-11.1
1997-98	191	28.2	4754	29.0	24	0.0
1998-99	184	-3.7	4987	4.9	26	8.3
1999-2000	186	1.1	5548	11.2	29	11.5
2000-01	162	-12.9	4332	-21.9	26	-10.3
2001-02	171	5.6	4649	7.3	27	3.8
2002-03	191	11.7	6097	31.1	31	14.8
2003-04	178	-6.8	5933	-2.7	33	6.5
2004-05	156	-12.4	4916	-17.1	31	-6.1
2005-06	152	-2.6	4902	-0.3	32	3.2
2006-07	185	21.7	6709	36.9	36	12.5
2007-08	159	-14.1	5407	-19.4	33	-8.3
2008-09	53	-66.7	1829	-66.2	33	0.0
2009-10	56	5.7	2015	10.2	35	6.1
Mean		-3.7		-1.8		1.4

Source: Ministry of Agriculture

ent factors such as technology changes, correct and efficient management and also optimal scale production may affect sugar beet yield over time, and how the proportion of them can be determined and make a pattern of achievement from successful provinces for unsuccessful provinces, and finally contribute in the increase of sugar beet production in the country?

For answering the above questions, it is necessary to identify the resource of productivity growth and yield increase per unit area of sugar beet and the proportion of the productivity growth components to be determined in order to eliminate the weaknesses and to reinforce the strengths for planning the upgrade of productivity in sugar beet production. Internal review of the studies show that despite the fact that several studies have been done on the economics of sugar beet production and productivity, measurement and analysis of the productivity growth of total productivion factors in the provinces has received less attention. In this regard, using Cobb Douglas production function and transcendental function, Mohamadi et al. (2005) measured the partial productivity of sugar beet production factors in Eghlid city of the Fars province. The results showed that labour input, machinery, and seeds were used more than optimal limit and fertilizer inputs were used less than optimal limit.

Alizadeh and Khalili (2009) studied the water and energy use efficiency in sugar beet production in Khorasan Razavi province. In their study, by considering water requirements and also required power to pump water from ground-water resources, water amount and consumed energy for producing one kg sugar from sugar beet was calculated in this province. According to the results, water and electrical energy efficiency in sugar beet production in Khorasan Razavi province for furrow irrigation were 1.683 kg/m^3 and 1.754 kg/kWh, respectively, and for pressurized irrigation were 1.915 kg/m^3 and 1.265 kg/kWh, respectively. Reyhani (2006) studied the role of management factors on the productivity of sugar beet in Mashad city. His results showed that among the characteristics of unit production managers, background, income level, and family number had positive effect on sugar beet yield. Among agronomic characteristics, the number of sugar beet production segments and the amount of applied seed had negative effect, whereas the amount of chemical pesticides and herbicides, type of irrigation and the possession of land and agricultural machinery had a positive impact on yield and productivity of sugar beet. Seyedan (2002) measured and analysed the production factor productivity in sugar beet production in Hamedan city. Results showed that the irrigation frequency in sample units was too close to the economic, optimal level but labour and animal manure usage was more than economic, optimal level. Also, 76.1% of the farmers were in the third stage of production function in using the land which reflects an appropriate situation of productivity in this crop.

Thus, given the gaps existing in the current studies, the aim of this study was to evaluate the efficiency of sugar beet production factors in different provinces over the past years and to identify the reasons for its inefficiency and low productivity in the form of mathematical models. The findings can be helpful in different policies such as protection policies, planning for cultivation of the crop, and resource allocation among provinces. For efficiency measurement, particularly measurement of the productivity growth of the total production factors, several studies were conducted, and a variety of methods were proposed such as growth accounting method (Tahami Pour and Shahmoradi Fard 2007), the index number approach (salami 1997; Tahami Pour and Karbasi 2006; Heydari 1998), production function approach (Pirasteh 2003; Akbari and Ranjkesh 2003), and Malmquist productivity index method (Data Envelopment Analysis). Since Malmquist method has less restrictive assumptions and in addition to the measurement of productivity oftotal production factors, also specifies the source of productivity growth which indicates its special position among the other methods. This method was used for comparing the efficiency of agricultural products among different provinces. For instance, in a study by Zare et al. (2005), the productivity growth of total production factors in cotton production was compared for various provinces. The results of Malmquist index usage during the period of 1984-2002 showed that the average annual growth of total factor productivity in cotton production was positive in the whole period. Also, the Fars province had the highest average annual growth rate of cotton crop productivity among provinces. Using distance function, Data Envelopment Analysis (DEA), and Malmquist index methods, Moradi and Mortazavi (2003) measured the productivity of total production factors in wheat production for different provinces in 2000-01 and 2001-02. Results confirmed that the West Azerbaijan province had the maximum productivity growth and Fars province had the minimum productivity growth. Mojaveryan (2003) measured and analysed the productivity of total production factors and technology changes in strategic agricultural products using nonparametric and Malmquist index methods. Period examined in his study was 1991-2000 and the studied crops were wheat, barley, cotton, rice and sugar beet. The results of his study illustrated that the productivity in irrigated crops (except barley) increased and for all the products, in which productivity growth achieved, technology has progressed. Productivity changes are greatly under the influence of fluctuations in the technical efficiency of selected products, and the only exceptions are barley and sugar beet. In most of the products, the efficiency and technology changes are opposite to each other. It can be concluded that the technical efficiency of producers in modern technology is lower than the old technology. In a study by Coelli and Rao (2003) entitled ‘productivity growth of total production factors in agriculture, Malmquist index analysis of 93 countries during 1980-2000, the rates and trends of productivity and agricultural output were examined in 93 developed and developing countries. The results showed that the studied countries had an average decline in productivity growth of total production factors (TFP). Average productivity growth of total production factors in Iran over the period 1980-2000 was 2% which was due to technical efficiency growth (1.3%) and growth in technical changes (0.7%).

MATERIALS AND METHODS

In overall classification, productivity is divided into two kinds of partial factor productivity (PFP) and total factor productivity (TFP). Partial factor productivity is the proportion of the value or output rate to the value or rate of an especial input and the total factor productivity is the proportion of the value or rate of all outputs to the sum value or weighing rate of all applied inputs in output production. In partial factor productivity usage, the risk of ignorance to the issue of how to increase production efficiency through effective utilization of production factors or in clear definition, ignorance to production factors replacement exist (Heydari 1998). Therefore, due to partial productivity defects, total factor productivity usage is necessary.

From the perspective of economics, two methods have been proposed for the measurement of total factor productivity, which are parametric and nonparametric methods. In parametric method through estimating the production function, cost function, or profit function, partial and total productivity are calculated, whereas in nonparametric methods through mathematical programming models, index number theory and growth accounting method are determined. After calculating the productivity, measurement of productivity growth rate and its trend over time is very valuable for firms and institutions and gives good information available to managers. However, the productivity improvement programming needs the determination of productivity growth source and this issue is addressed in productivity literature as productivity growth decomposition.

Several studies were done on the analysis of productivity growth and many methods were proposed in the economics literature; For instance, the most important ones are Fisher's ideal index (Kuosmanen. and Sipilainen 2004) using regression method (Shih H et al. 2003) Solow residual model (Asian Productivity Organization 2004), management indicators (Elia 2006; National Iranian Productivity 2007), estimation of stochastic frontier production function (Kalirajan et al. 1996), estimation of distance function (Karagiannis et al. 2004; Nigel et al. 2008), and Malmquist index which had more application than the other methods due to the simplicity in calculation and low restrictive assumptions, such as no need to specify the type of technology (production function of the form) in calculation and analysis of the efficiency.

History of Malmquist index for the measurement of productivity returns to 1953 when Malmquist proposed this index in the form of theory of average consumption. Also in 1982, it was proposed in the form of theory by Caves, Christensen and Diewert. In 1978, this index within the Data Envelopment Analysis with assumption of constant returns to scale (CRS) was introduced by Fare et al. (1984), and in the framework of DEA with assumption of constant returns to scale (VRS) was considered.

To measure the productivity of a hypothetical firm i using Malmquist index, four distance functions should be calculated in order to determine the productivity index changes for the two times period. This requires the following four-point linear programming (via data envelopment analysis) to be solved (Emami Meybodi 2000):

$$\begin{aligned}
&\left[d_0^t(Yt, Xt)\right]^{-1} = \max \Phi \\
&s.t. \\
&-\Phi Yit + Yt\lambda \geq 0 \\
&Xit - Xt\lambda \geq 0 \\
&\lambda \geq 0
\end{aligned} \tag{1}$$

$$\begin{aligned}
&\left[d_0^t(Yt, Xt)\right]^{-1} = \max \Phi \\
&s.t. \\
&-\Phi Yit + Ys\lambda \geq 0 \\
&Xit - Xs\lambda \geq 0 \\
&\lambda \geq 0
\end{aligned} \tag{2}$$

$$\begin{aligned}
&\left[d_0^t(Ys, Xs)\right]^{-1} = \max \Phi \\
&s.t. \\
&-\Phi Yis + Yt\lambda \geq 0 \\
&Xis - Xt\lambda \geq 0 \\
&\lambda \geq 0
\end{aligned} \tag{3}$$

$$\begin{aligned}
&d_0^t(Ys, Xs)]^{-1} = \max \Phi \\
&s.t. \\
&-\Phi Yis + Ys\lambda \geq 0 \\
&Xis - Xs\lambda \geq 0 \\
&\lambda \geq 0
\end{aligned} \tag{4}$$

Then in terms of the below relation, the productivity index was measured (Emami Meybodi 2000):

$$M_0(Ys, Xs, Yt, Xt) = \frac{d_0^t(Yt, Xt)}{d_0^s(Yt, Xt)}\left[\frac{d_0^s(Yt, Xt)}{d_0^t(Yt, Xt)} \times \frac{d_0^s(Ys, Xs)}{d_0^t(Ys, Xs)}\right]^{\frac{1}{2}} \tag{5}$$

In this relation, the first term on the left represents changes in relationship between technical efficiency, and the second term (in parentheses) represents changes in technology. Furthermore, technical efficiency changes is decomposed into management technical efficiency and scale efficiency changes and in any case, can analyse negative or positive reasons of productivity and identify the weaknesses and the potential to increase productivity and planning for them. In fact, total factor productivity growth in this index is achieved through multiplying technology changes, scale efficiency changes, and management efficiency changes.

Based on the assumption of maximizing the product, M (index rate) less than one represents the yield reduction (reduction of total factor productivity growth) between the two periods studied, and M greater than one, represents yield improvements (increased growth of total factor productivity) and M = 1 represents fixed yield over two compared times. Wen the Malmquist index equals one, it indicates that there was no change in productivity situation.

If the productivity changes were less than 1 (M<1) for a product, it means that the productivity condition has been worsened during the period of interest owing to the three components that can be sought. The technological changes smaller than one means that the technology growth change was negative and caused a decrease in productivity growth. In other words, the technical changes which were applied in the production of that

Table 2. Statistical description of the variables used in the model

Year	Statistics	Production (ton)	Water price (Rial)	Chemical fertilizer (kg)	Seed (kg)	Animal manure (ton)	Chemical pesticides	labour	Machinery cost
2000	Mean	326028	649418	557	21.9	1.6	5.2	21.1	41327
	Minimum	24673	88460	386	12.5	0.0	1.8	11.2	28523
	Maximum	1502577	1845340	772	42.7	7.6	15.0	30.9	77994
	Standard deviation	427772	491884	139	8.1	2.3	4.0	6.7	13858
2007	Mean	426405	1357728	777	8.3	1.9	5.5	20.9	166883
	Minimum	27668	298940	562	1.8	0.0	2.0	11.5	61239
	Maximum	2056784	2467280	990	21.8	6.2	16.7	34.1	236290
	Standard deviation	604193	757330	162	6.6	1.9	4.0	7.1	59162

Source: Ministry of Jihad-e-Agriculture and research computations.
Note: The information listed are in the unit area (per ha).

product like bred seed, mechanisation, irrigation systems, production methods, etc., were not successful or that during the technology improvement or the entry of new technology, there were not enough training or experience. If the technical efficiency changes were less than one, it indicates that a part of negative growth is related to the lack of technical efficiency or in another words, lack of technical efficiency resulted in partly neutralized productivity growth. Negative growth in technical efficiency returns to both management inefficiency and scale inefficiency. Management inefficiency means that the production unit manager did not operate properly in combination of inputs to achieve a certain level of product. These types of inefficiency can be caused by the lack of on time input consumption, less than or more than enough inputs consumption, inappropriate use of inputs, and so on. Scale inefficiency means that the unit does not operate at optimal scale, i.e. the acreage of the farms are small and there is no way to use modern inputs and mechanization in an advanced level. In each of the above items, to overcome the efficiencies, programming not only improves the status of productivity and increases the production of specified input but also causes an achievement to a certain level of product with reduced input consumption. The geometry of the Malmquist index for the two time periperiods (t) and (s) is as follows:

According to the chart above, Malmquist productivity index and the sources of productivity growth are displayed in equation 6:

$$M_0(Ys, Xs, Yt, Xt) = \frac{Yt/Yc}{Ts/Ya}\left[\frac{Yt/Yb}{Yt/Yc} \times \frac{Ys/Ya}{Ys/Yb}\right]^{\frac{1}{2}} \quad (6)$$

By using this relation, the total factor productivity changes are decomposed into technical efficiency changes and technological changes. In this study, Malmquist index is calculated for sugar beet in different producing provinces for the period 2000-07. To calculate the distance functions and Malmquist index, computer software DEAP2.1 was used. Required information for the measurement and analysis of total factor productivity growth in different provinces were extracted from generated expense reports of the Ministry of Jihad-e-Agriculture for period 2000-07 (Office of Statistics and Information Technology). Statistical descriptions used for variables in Malmquist index for the measurement and decomposition of productivity growth, are presented in Table 2.

Table 2 shows that in 2007 compared with 2000, the average production was about one and half times higher. While on average, the price of water was about twice and the machine costs were about four times more but the seed has reached to a third of its value in 2000. These variations show the production technology changes and the effects of different price and non-price policies in the use of inputs in sugar beet production units in the country which shows its effect in the form of decrease or increase in productivity growth and will be addressed in the following section.

Results and Discussion

According to the description given in the Materials and Methods part, the results of the total factor productivity growth of sugar beet production and the analysis of it based on each province will be discussed. In Table 3, the total factor productivity of sugar beet is decomposed into technical efficiency changes and technology changes. Also, technical efficiency change is divided up into two components, management efficiency changes (pure technical efficiency change) and scale efficiency changes.

Table 3. Results of the analysis of total factor productivity growth in sugar beet production during the period 2000-07.

Province	Technical efficiency changes	Technology changes	Management efficiency changes	Scale efficiency changes	Total factor productivity changes
West Azerbaijan	1.00	1.95	1.00	1.00	1.95
Isfahan	4.15	0.89	4.39	0.95	3.68
Chaharmahal and Bakhtiari	1.28	1.89	0.11	12.19	2.42
Khorasan	1.00	1.05	1.00	1.00	1.05
Semnan	8.16	0.65	1.00	8.16	5.34
Fars	0.59	1.85	0.57	1.04	1.09
Qazvin	0.14	0.59	0.44	0.32	0.08
Lorestan	1.06	2.26	1.00	1.06	2.39
Markazi	0.04	0.87	0.02	2.46	0.04
Hamedan	0.25	1.72	0.13	1.91	0.42
Kerman	2.31	0.46	1.00	2.31	1.06
Kermanshah	1.28	1.54	1.00	1.28	1.98
Mean	1.23	1.36	0.99	1.40	1.47

As can be seen in the Table 3, the total factor productivity status of sugar beet in all provinces was improved during the period of study except for three provinces of Qazvin, Markazi and Hamedan. On average of the whole country, the average weight (sugar beet acreage in different provinces is considered as a weight) of total factor productivity changes of sugar beet production during the study period was greater than one (1.47) which indicates the positive growth and also shows that on average the productivity status of this product is improved over time in the whole country, meaning that from 2000 to 2007 about 47% positive productivity growth was experienced. The negative productivity growth rate of Qazvin province is related to technology changes and negative technical efficiency changes and can be concluded that in the time of technology improvement and arrival of the new technologies into production in the province, essential training and enough experience were not existed and also production unit managers were not successful in usage of inputs and the production scale in the province was not optimal. The negative productivity growth in Markazi province is due to the negative growth of technical management efficiency as well as inappropriate usage of new technologies in this province. In other words, the sugar beet farmers in the province were not successful in appropriate and timely use of inputs. In fact, the management technical inefficiency shows that the production unit manager did not use a proper composition of inputs or inputs were not used in a proper time or rate for prevention of damages and production risks. For Hamedan province, decline in productivity over time is simply due to the lack of technical efficiency management. Positive growth in total factor productivity of sugar beet production in the whole country was resulted from the positive growth of both technical efficiency and technological changes. In Fig. 2, sugar - producing provinces were ranked in terms of productivity changes between 2000 and 2007. As shown, the highest rate of growth in total factor productivity over the period of study belonged to Semnan province and the lowest was allocated to Markazi Province. In Fig. 2, the efficiency of sugar beet production is decomposed into its components.

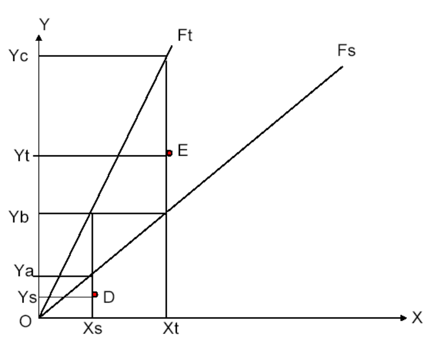

Fig. 1. Components of the total factor productivity growth rate in Malmquist index.

As shown in Fig. 3, the contribution of technical efficiency changes in productivity changes of Semnan and Isfahan provinces, as holders of the highest rates of productivity changes in the country, is more than technological changes.

CONCLUSIONS

As discussed before, the total factor productivity status of sugar beet was worsened only in three provinces of Qazvin, Markazi, and Hamedan in the course of the study, in which the productivity decline in Hamedan and Markazi provinces was largely due to the lack of technical management efficiency, and in Qazvin province was owing to both technical inefficiency and inappropriate technological changes. In the whole country, the results also represent one percent negative growth in technical management efficiency during the study period. These results show that the production unit managers of the above provinces did not work successfully in proper and timely usage of production inputs which may be due to the lack of experience and enough knowledge or the problems related to proper access to inputs and can be considered more accurate in the form of supplementary studies in different provinces. However, according to the results of this study, it can be recommended that these provinces consider the successful provinces in this regard as their models. Also, the promotional training, especially for new technologies, can help the productivity increase of sugar beet. One of the important issues in productivity which has been considered by planners in recent years is providing some economic growth (increased value growth) through the promotion of total factor productivity (total factor productivity growth) which has also been targeted in the fourth development plan for the agricultural sector. Sugar beet production should inevitably provide the part of total factor productivity growth of the agricultural sector and this growth should be through the promotion of total factor productivity growth of sugar beet. So, the results of this study and other studies through using presented methodologies can be considered as a model in planning and goal setting of productivity in the agriculture sector by planners and policy makers.

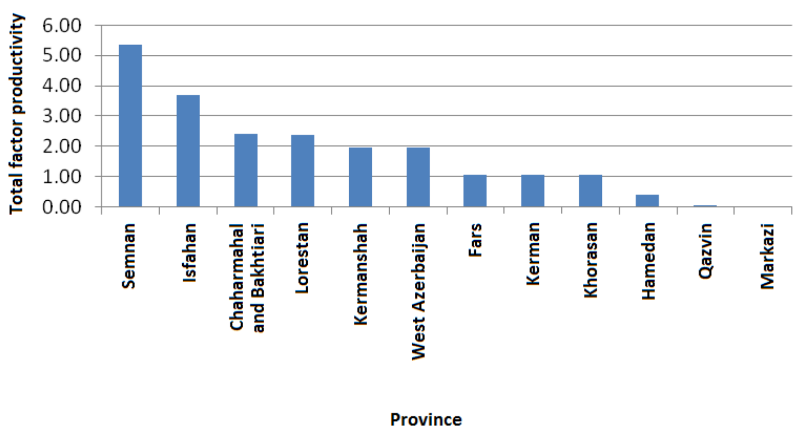

Fig. 2. Comparison of total factor productivity growth for different provinces during the period 2000-07

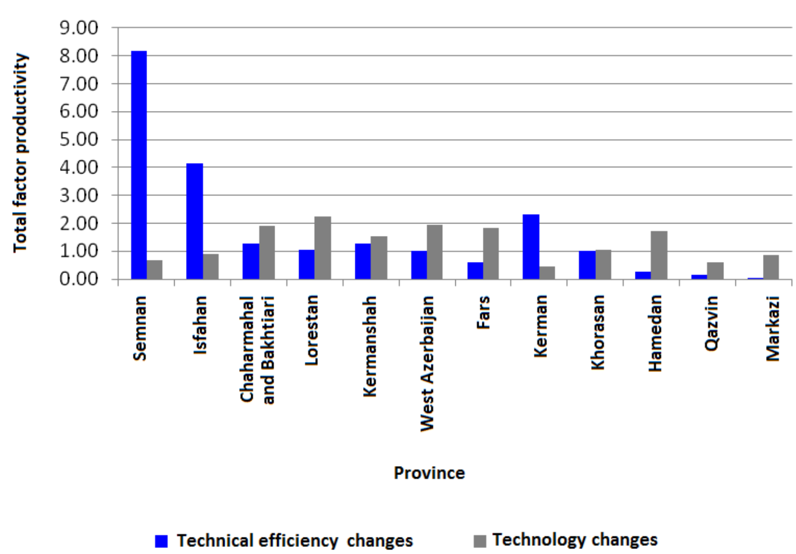

Fig. 3. Decomposition of total factor productivity growth of various provinces into its components during the period 2000-07

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