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Decomposition of Factor Productivity Growth of Rice in Iran: Application of Stochastic Frontier Analysis Approaches

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Abstract

Rice is a crucial agricultural product, and enhancing its productivity is essential for increasing production. This study aims to analyze the total factor productivity growth of rice production in Iran from 2000 to 2020. Using parametric (stochastic frontier analysis) approaches, the research evaluated the rice productivity growth and its components, including scale and technological changes. Based on the estimated Translog Cost Function, the annual total factor productivity growth was 2.1%, with positive technological change as the primary driver of these improvements. To further enhance productivity, the study recommends utilizing improved seeds, modern machinery, fertilizers, and nutritional solutions during rice cultivation. Additionally, the research suggests the application of parametric approaches in future studies to assess the impact of technological changes on crop yields.

Keywords: Iran, Productivity growth, Rice, SFA, Technological changes

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Introduction

Economically, increasing agricultural production to feed boosting population is an important priority to deal with food insecurity. One of the best solutions to increase production is to improve total factor productivity. Because the increasing food demand of a growing population, combined with limited resources, productivity in the process of sustainable development is desirable. Economists believe that achieving a high economic boom, most often measured by Gross Domestic Product (GDP), is no longer the best reflection of wealth, social welfare, and the potential to expand entrepreneurship, but it's also important to continuously balance economic, environmental, and social development (e.g. Surya *et al.*, 2021).

Improving the production and factor productivity of rice can help to match the four dimensions of food security, i.e. food availability, food access, food use and quality, and food stability because of its range of distribution pattern, and its current production and demand, especially in developing countries where poverty, hunger and malnutrition ensues (Mijena *et al.*, 2022). In order to achieve sufficient productivity growth in different sectors of the country, including agriculture, it is necessary to have a true understanding of the productivity growth rate of all factors of production and to know its components. Therefore, it is very important and necessary to calculate productivity by separating different sectors of the economy through an appropriate quantitative measure (Ansari *et al.*, 2017). Total factor productivity (TFP) growth is the ratio of total output to all inputs used in the production process and measures the efficiency of all factors of production (Houedjofonon *et al.*, 2020) and represents the combination of technological change, efficiency change and scale change that determine the productivity growth rate altogether (Li *et al.*, 2017). Limited overall productivity growth is currently a major economic challenge for many countries. To address this issue, planners and administrators are prioritizing productivity growth in all sectors, but particularly in agriculture. Increasing productivity in this sector can support economic growth while meeting nutritional needs, given the unique economic make-up of nations (Duernecker *et al.*, 2017).

Considering the importance and position of productivity growth and its determinants, several researches have been carried out on productivity growth and the factors influencing it. Datta and Christoffersen (2005) investigated the scale and technological changes in order to found the TFP growth of US in textile and apparel industries. The results with translog cost function revealed that the rate of technical change is higher in textiles than in apparel, however, scale effect is more important in apparel industry. Dashti *et al*. (2015) investigated the direction and trend of total factor productivity change of production and the factors affecting the Iranian cotton product applying non-parametric (Tornqvist-Theil index) and parametric (Translog cost function) approaches. The results showed that the annual growth of total factor productivity increased by 1.7% according to the Tornqvist-Theil index and by 1.53% according to the annual growth of translog cost function, which was mainly due to technological change. Translog distance function and Malmquist index were used to calculate total factor productivity (TFP) growth and its components by Xie *et al*. (2021) in China's electricity industry. It was found that scale effect, technological change and efficiency change affect productivity growth, and scale effect has the largest impact on productivity growth. Raei *et al.* (2021) investigated the analysis of the total factor productivity growth of the wheat production by translog cost function in the counties of Fars province. They found that total factor productivity grew by 0.029% on average over the period considered, and thus the contribution of scale effect to total factor productivity growth was greater than the contribution of technological change. Djoumessi, (2022) calculated the trend in total factor productivity growth in the agricultural sector and the factors influencing it were assessed in 23 African countries using the translog cost function. The results showed that most of the changes were mainly due to technological change.

Iran's production and yield of rice were respectively 1.9 million ton and 3571 Kg/ha in 2010 and 3 million ton and 5395 Kg/ha in 2020 (Ministry of Agriculture Jihad, 2022). Therefore, due to the growing population and the resource constraint, it is necessary to identify the factors that affect the total factor productivity growth of this product in the country, so that production can be increased through investment and planning in this sector. This research, at the micro-level research helps farmers to understand the productivity process of production factors and the factors influencing it and at the macro level, it also helps policy makers in the agricultural sector by identifying the main factors affecting productivity growth and studying them in order to plan how to increase agricultural productivity. In this study, we want to measure the total productivity growth of rice production factors from a parametric approach, decomposing it into its components and analyzing the rate of productivity growth and the most important factor affecting the rice crop during the years 2000-2020.

Materials and Methods

There are two main methods of measuring total factor productivity: the parametric approach indirectly estimates total factor productivity after estimating the respected function and the non-parametric approach directly calculates total factor productivity without using a function (Murray & Sharpe, 2016). In this study we estimated the total factor productivity with parametric method and decompose it to scale and technological changes. In parametric methods a cost or production function can be used to estimate the productivity growth and its components. In the economic literature, the cost function is said to have a number of advantages over the production function, the most important of which is the lack of collinearity between input price variables. Therefore, the cost function approach is used. In this study, a translog cost function, which does not impose any restrictions on the structure of production and shows substitution between inputs, was considered as a suitable functional form to estimate total productivity growth. The flexibility and reliability of the results are the main reasons for the widespread use of this function by researchers (Datta & Christoffersen, 2005).

The empirical form of the Translog Cost Function can be given as follows (Kamruzzaman *et al.*, 2021):

$$LnC_{it} = \alpha_0 + \alpha_{qi} lnQ_{it} + \alpha_l lnP_{lit} + \alpha_f lnP_{fit} + \alpha_m lnP_{mit} + \beta_t lnT + \frac{1}{2}\gamma_{qq}(lnQ_{it})^2 + \frac{1}{2}\gamma_{il}(lnP_{lit})^2 + \frac{1}{2}\gamma_{if}(lnP_{fit})^2 + \frac{1}{2}\gamma_{im}(lnP_{mit})^2 + \frac{1}{2}\beta_{tt} lnT^2 + \gamma_{lf}\, lnP_{lit} lnP_{fit} + \gamma_{lm}\, lnP_{lit} lnP_{mit} + \gamma_{fm}\, lnP_{fit} lnP_{mit} + \gamma_{lq}\, lnP_{lit} lnQ_{it} + \gamma_{fq}\, lnP_{fit} lnQ_{it} + \gamma_{mq}\, lnP_{mit} lnQ_{it} + \theta_{lt}\, lnP_{lit} lnT + \theta_{ft}\, lnP_{fit} lnT + \theta_{mt}\, lnP_{mit} lnT + \theta_{qt} lnQ_{it} lnT \quad (1)$$

In Eq. (2), P_{lit} is the price of labor in the province at time *t*, P_f is the price of chemical fertilizer, P_m is the price of farmyard manure, Q is the quantity of product and T is the time trend variable, i is the target area, α, β, γ and θ are the parameters of the model. After estimating the parameters of the cost function, the rate of technological change can be calculated by taking the derivative of the estimated cost function with respect to the time trend variable in the form of Eq. (2) (Kant & Nautiyal, 1997):

$$TC = -\frac{\partial \ln C_{it}}{\partial \ln T} = \beta_t + \beta_{tt} \ln T + \theta_{lt} \ln P_{lit} \theta_{ft} \ln P_{fit} + \theta_{mt} \ln P_{mit} + \theta_{qt} \ln Q_{it}$$
(2)

The basic assumption is that cost will decrease with time and that as a consequence technology will improve. A negative value on the right-hand side indicates technology improvement, while a positive value indicates deterioration in the technology. The cost elasticity reveals the percentage rise in cost associated with a one percent change in production (Datta & Christoffersen, 2005) which offers information on returns to scale (Kuroda, 1989). The cost elasticity is given by Eq. (3). If EC is less than one, it indicates that the product is economically efficient to produce

$$EC = \frac{\partial \ln C_{it}}{\partial \ln Q_{it}} = \alpha_{qi} + \gamma_{qq}\ln Q_{it} + \gamma_{lq}\ln P_{lit} + \gamma_{fq}\ln P_{fit} + \gamma_{mq}\ln P_{mit} + \theta_{qt}\ln T \qquad (3)$$

Productivity growth of production factors is one of the most important and fundamental aspects of economic production. By estimating the cost function the changes in the productivity growth index are estimated in the form of Eq. (4) (Datta & Christoffersen, 2005):

$$T\dot{F}P = \left(1 - \frac{\partial \ln C}{\partial \ln Q}\right)\frac{\partial \ln Q}{\partial T} + \frac{\partial \ln C}{\partial T} \qquad (4)$$

The scale effect , indicating that the rate of increase in costs was higher than the rate of increase in the quantity of product, this variable is the product of (scale economies +1) the output growth rate, so the sum of the scale effect and technological change variables equals total factor productivity growth (Datta & Christoffersen, 2005). Eq (5) is used to calculate the production growth rate:

$$\dot{Q} = \frac{\partial \ln Q}{\partial T} = \frac{\ln Q_t - \ln Q_{t-1}}{\ln Q_{t-1}} \qquad (5)$$

where, $\ln Q_t$ is the logarithm of the product value in year t and LnQ_{t-1} is the logarithm of the product value in year t-1.

As the data were collected from five major rice producing provinces (Mazandaran, Guilan, Golestan, Khuzestan and Fars) over a period of 21 years (2000-2020), they can be classified as panel data. Limer's F-test is used to confirm this classification. When working with panel data, the first step is to determine whether to use a fixed or random effects model before estimating the function. In this study, real prices are used for the estimation, with the year 2000 serving as the base year. Since relative prices are used in cost estimation, the costs and prices of all facilities are normalized by dividing them by the input price of pesticides.

Data

The necessary statistics and information at the national level for this study were obtained from the Ministry of Agricultural Jihad and the Statistical Center of Iran. The variables used in this research, including price, rice production, prices and cultivated area, chemical fertilizers, manure, pesticides, labor and seeds, were collected for the period of 2000 to2020. The data were analyzed in Excel 2017 and STATA 17 software to calculate total factor productivity.

Results and Discussion

Before estimating the translog cost function, we ensured that the data were either panel data or pool data based on the information available. For this purpose, the Limer's F test was used as part of our research. Note that in this test we rejected the null hypothesis based on pooling data at a 5% significance level and thus, the model was used for further analyses. Then, the Hausman test was applied for testing whether our panel data is a fixed effect (FE) or random effect (RE), and accepting the null hypothesis the model was realize to be FE. Based on the results, the cost of rice production is significantly affected by input prices (labor, farmyard manure and chemical fertilizer), product quantity, and the time trend variable (technology). Therefore, the translog cost function was estimated using these three inputs. In addition, the quantity of product and the time trend variable (t) were also included in the cost function. The estimated coefficients are shown in Table 1.

Considering the obtained coefficients from Table 1, the trend of total factor productivity change, including scale and technological change, are calculated for the years 2000-2020 and shown in Table 2. As shown, the annual technological change is -0.206 on average implying that technological change has led to cost reductions over time. In fact, the use of new technologies has had a positive impact on the quantity of rice produced in the country and on total productivity growth. Dashti *et al.* (2015), Vahidi *et al.* (2022), Bragagnolo *et al.* (2010) and Djoumessi (2022) found similar results and identified technological change as the main factor in total factor productivity growth in their researches. The annual average of the scale effect is 1.223, indicating that the rate of increase in costs was higher than the rate of increase in the quantity of product during the studied years. The total factor productivity growth over this period was subject to irregular fluctuations and finally resulted in a slight increase of 2.1%, which shows a positive and growing rate of total factor productivity.

Table 1- Coefficients of the translog cost function

Parameters	Coefficients	t-statistic	Parameters	Coefficients	t-statistic
γ_{lf}	-0.2^{***}	-3.33	α_0	39.4^{***}	2.67
γ_{lm}	-0.84^{***}	-2.68	α_{qi}	1.3	-0.67
γ_{fm}	0.004	0.09	α_l	-6.39^{**}	-2.01
γ_{lq}	0.6^{*}	1.73	α_f	2.9^{***}	3.20
γ_{fq}	-0.2^{***}	-2.74	α_m	4.1^{*}	1.89
γ_{mq}	-0.1	-0.70	β_t	-0.7^{***}	3.36
θ_{lt}	-0.01	-0.12	γ_{qq}	0.02	0.17
θ_{ft}	0.04	0.86	γ_{il}	0.05^{***}	6.38
θ_{mt}	-0.84^{***}	-3.71	γ_{if}	0.1^{***}	3.84
θ_{qt}	-7.2^{***}	-3.8	γ_{im}	-0.1	-0.89
			β_{tt}	0.3^{***}	5.65

Table 2- Decomposition of rice TFP in Iran during 2000-2020

Year	Scale change	Technological change	Productivity growth
2000	-	0.520	-
2001	0.118	-0.433	-0.437
2002	0.516	-0.056	-0.057
2003	0.681	0.398	0.7
2004	0.821	-0.845	-0.477
2005	1.06	-0.495	-0.123
2006	1.437	-0.856	-1.007
2007	1.640	-1.250	-1.117
2008	1.240	0.543	0.591
2009	1.395	-0.035	0.083
2010	1.304	-0.094	0.177
2011	1.612	-0.605	-0.640
2012	1.682	-0.665	-0.807
2013	1.211	0.771	0.943
2014	1.342	0.058	0.070
2015	1.35	-0.236	0.080
2016	1.247	0.367	0.834
2017	1.466	-0.741	0.236
2018	1.344	-0.559	-0.005
2019	1.658	-0.080	0.692
2020	1.344	0.420	0.448
Average	1.223	-0.206	0.021

Conclusion

In this study, the total factor productivity of rice production in the main producing provinces of Iran, including Mazandaran, Guilan, Golestan, Fars and Khuzestan, was calculated over a period of 21 years (2020-2000) using parametric methods. The prices of labor, manure, chemical fertilizer, product and technology are used to estimate the cost production function. The results show that total factor productivity growth in rice production is positive. Therefore, the total factor productivity of the production in the country had increased during the studied years, and the most of this growth had been due to technological change. Technological change according to the parametric method had a negative sign, which confirm the positive effect of new technologies on rice production and therefore improved productivity. According to parametric approaches, since technological change has a positive effect on the total factor productivity in rice production, it is recommended to pay attention to new technologies such as machines, improved seeds and the use of nutritional supplements on farms. The scale effect has caused a decrease in total factor productivity growth, so it is recommended that studies be carried out at farm level to have a better understanding of its effect, in order to be more confident about the direction and extent of the impact of scale change on total factor productivity that can be expressed.

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مقاله پژوهشی

جلد ۳۸ شماره ۲، تابستان ۱۴۰۳، ص. ۱۶۹-۱۷۶

تجزیه رشد بهره‌وری عوامل تولید محصول برنج در ایران: کاربرد رهیافت تحلیل مرزی تصادفی

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چکیده

برنج یکی از محصولات مهم کشاورزی بوده که بهبود بهره‌وری عوامل آن پیش‌شرط اساسی افزایش تولید این محصول است. هدف مطالعه حاضر تجزیه رشد بهره‌وری کل عوامل تولید محصول برنج در ایران است. داده‌های موردنیاز برای استان‌های مختلف و مربوط به دوره زمانی ۱۳۹۹-۱۳۷۹ از وزارت جهاد کشاورزی و مرکز آمار ایران تهیه گردید. با بکارگیری رهیافت پارامتریک (رهیافت مرزی تصادفی)، رشد بهره‌وری و مؤلفه‌های اثرگذار آن ازجمله تغییرات مقیاس و تکنولوژی مورد ارزیابی قرار گرفتند. با برآورد تابع هزینه ترانسلوگ، میانگین رشد سال‌های مورد مطالعه بهره‌وری کل عوامل ۲/۱ درصد محاسبه شد. بر طبق یافته‌ها، رشد بهره‌وری عوامل تولید در کشور مثبت بوده است وعمده این تغییرات ناشی از بهبود تکنولوژی‌های مورد استفاده بوده است. از آنجائی‌که تغییر تکنولوژی سهم قابل ملاحظه‌ای در ارتقای بهره‌وری عوامل در این رهیافت دارا است لذا توصیه می‌شود که در فرآیند تولید محصول برنج از نمادهای فناوری شامل بذر اصلاح شده، ماشین‌های مناسب، کودها و محلول‌های تغذیه‌ای بهره‌گرفته شود. نتایج حاصله از اطمینان کافی برخوردار بوده و پیشنهاد می‌شود در مطالعات آتی نیز حتی‌الامکان از رویکرد پارامتری استفاده به عمل‌آید.

واژه‌های کلیدی: برنج، تحلیل مرزی تصادفی، تغییرات تکنولوژی، رشد بهره‌وری، ایران

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