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

Samaneh Nikan[1]- Ghader Dashti[2]- Javad Hosseinzad[3]- Mohammad Ghahremanzadeh[4]

Abstract

Rice is one of the most important agricultural products, and improving productivity of its factors is a prerequisite for increasing its production growth. The objective of this research is to decompose total factor productivity growth of rice production in Iran. The required data for the period of 2000-2020 were collected from the Ministry of Agricultural Jihad and the Statistics Center of Iran. The rice productivity growth and its components, including scale and technological changes, were evaluated applying parametric (stochastic frontier analysis) approaches. Based on estimated translog cost function, the annual growth of the total factor productivity was calculated to be 2.1% and technological change was realized to be positive in the country throughout the years and the most of these changes are due to the improvement of the technologies used .Since the technological change has made a significant contribution to improving the total factor productivity growth in this approaches, utilizing, improved seeds, modern machines, fertilizers and nutritional solutions, etc. are recommended in the process of rice production. Therefore, the results obtained have sufficient confidence and it is suggested to use parametric approaches as much as possible in future studies.

Keywords: Productivity Growth, SFA, Technological Changes, Rice, Iran

Subject classification code: Q100, ….

Introduction

Food production can be seen as a vital task of the agricultural sector, as increasing production is the most important way to meet the growing food needs of the human population. Increasing production in the agricultural sector to an economically viable level is therefore seen as a necessary objective. One of the best ways to increase production is to improve total factor productivity. For this purpose, existing deterrents must be identified and eliminated through the design and implementation of optimal policies (Dashti et al., 2019). This is because the increasing food demand of a growing population, combined with limited resources, demonstrates the importance and necessity of paying attention to productivity in the process of sustainable development. Economists believe that achieving a high economic boom, most often measured by GDP (Gross Domestic Product), 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 Agricultural 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. Many studies have been carried out to calculate productivity changes in a parametric method inside and outside the country, also, in this research an attempt is made to use parametric approaches in order to decompose total factor productivity growth of rice production in Iran and to evaluate the alignment of stochastic frontier analysis approaches.

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 and Sharpe, 2016). In this study we estimated the total factor productivity with parametric method and dicompose 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 and Christoffersen, 2005).

The empirical form of the translog cost function can be given as follows (Kamruzzaman et al, 2021):

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

In Eq. (2), P_{lit} is the price of labor in *i*th 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 and Nautiyal, 1997):

$$\mathrm{TC} = -\frac{\partial \mathrm{lnC_{it}}}{\partial \mathrm{lnT}} = \beta_t + \beta_{tt}\mathrm{lnT} + \theta_{lt}\,\mathrm{lnP_{lit}}\theta_{ft}\,\mathrm{lnP_{fit}} + \theta_{mt}\,\mathrm{lnP_{mit}} + \theta_{qt}\mathrm{lnQ_{it}} \tag{2}$$

In this notation, 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 and Christoffersen, 2005) which offers information on returns to scale (Kuroda, 1989). The cost elasticity is given by Eq. (3):

$$\mathrm{EC} = \frac{\partial\,\mathrm{Ln\,C_{it}}}{\partial\,\mathrm{Ln\,Q_{it}}} = \alpha_{qi} + \gamma_{qq}\mathrm{lnQ_{it}} + \gamma_{lq}\,\mathrm{lnP_{lit}} + \gamma_{fq}\,\mathrm{lnP_{fit}} + \gamma_{mq}\,\mathrm{lnP_{mit}} + \theta_{qt}\mathrm{lnT} \tag{3}$$

If EC is less than one, it indicates that the product is economically efficient to produce.

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 and Christoffersen, 2005) :

$$\dot{\mathrm{TFP}} = \left(1 - \frac{\partial\,\mathrm{Ln\,C}}{\partial\,\mathrm{Ln\,Q}}\right)\frac{\partial \mathrm{LnQ}}{\partial \mathrm{T}} + \frac{\partial \mathrm{Ln\,C}}{\partial \mathrm{T}} \tag{4}$$

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 and Christoffersen, 2005). Eq (5) is used to calculate the production growth rate:

$$\dot{\mathrm{Q}} = \frac{\partial \mathrm{LnQ}}{\partial \mathrm{T}} = \frac{\mathrm{Ln\,Q_t} - \mathrm{LnQ_{t-1}}}{\mathrm{LnQ_{t-1}}} \tag{5}$$

Where, LnQ_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, Gilan, 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 panel data are obtained, the first step is to determine the fixed or random effect and then to estimate the function. In this study, real prices are used for the estimation and 2000 is taken as the base year. As relative prices are used in the cost estimation, the costs and prices of all facilities are divided 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 include price, quantity of rice produced, prices and quantities of inputs including cultivated area, chemical fertilizers, farmyard manure, pesticides, labor and seeds, which were collected for the period of 2000-2020.

The data were analyzed in Excel 2017 and STATA 17software 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 (2).

Table (2): Coefficients of the translog cost function

Parameters	Coefficients	t-score
α_0	39.4^{***}	2.67
α_{qi}	1.3	-0.67
α_l	-6.39^{**}	-2.01
α_f	2.9^{***}	3.20
α_m	4.1^{*}	1.89
β_t	-0.7^{***}	3.36
γ_{qq}	0.02	0.17
γ_{il}	0.05^{***}	6.38
γ_{if}	0.1^{***}	3.84
γ_{im}	-0.1	-0.89
β_{tt}	0.3^{***}	5.65

γ_{lf}	-0.2***	-3.33
γ_{lm}	-0.84***	-2.68
γ_{fm}	0.004	0.09
γ_{lq}	0.6*	1.73
γ_{fq}	-0.2***	-2.74
γ_{mq}	-0.1	-0.70
θ_{lt}	-0.01	-0.12
θ_{ft}	0.04	0.86
θ_{mt}	-0.84***	-3.71
θ_{qt}	-7.2***	-3.8

With coefficients obtained from Table. (2). the trend of total factor productivity change, including scale and technological change, are calculated for the years 2000-2020 and shown in Table. (3). 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. 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. (3). 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, Gilan, 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. Dashti and et al (2015), Vahidi and et al (2022), Bragagnolo and 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 average scale effect for the parametric method was 1.223 over the study period, which shows that as scale increased, the rate of increase in costs was higher than the rate of increase in output.

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

چکیده

برنج یکی از محصولات مهم کشاورزی بوده که بهبود بهره وری عوامل آن پیش شرط اساسی افزایش تولید این محصول است. هدف مطالعه حاضر تجزیه رشد بهره‌وری کل عوامل تولید محصول برنج در ایران است. داده‌های موردنیاز برای استان های مختلف و مربوط به دوره زمانی ۱۳۹۹-۱۳۷۹ از وزارت جهاد کشاورزی و مرکزآمار ایران تهیه گردید. با بکارگیری رهیافت پارامتریک (رهیافت مرزی تصادفی)، رشد بهره‌وری و مولفه‌های 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 آنجائی که تغییرتکنولوژی سهم قابل ملاحظه‌ای در ارتقای بهره‌وری عوامل در این رهیافت دارا است لذا توصیه می‌شود که در فرایند 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.