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Decomposition total factor productivity of Indonesian rice production

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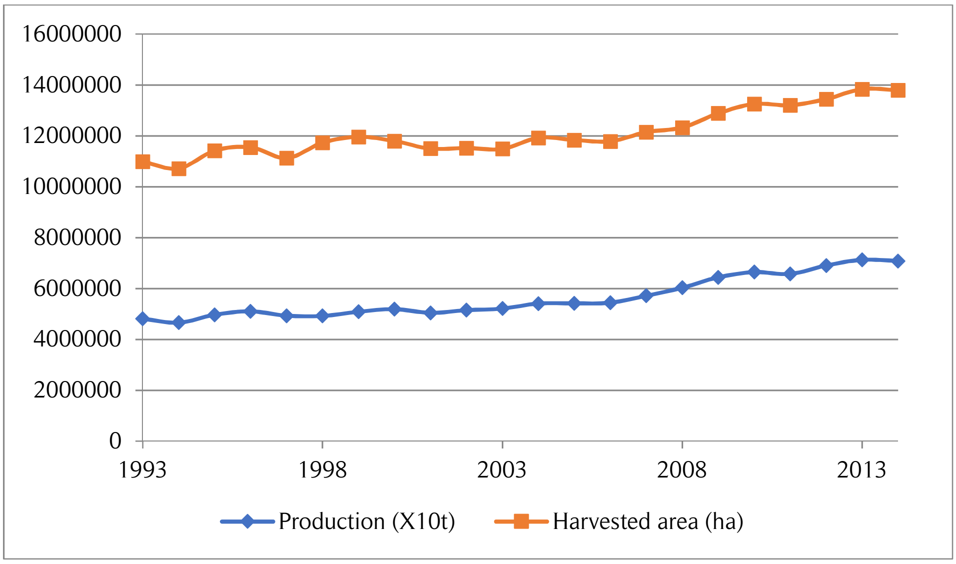
Abstract

This paper analyzes the growth of total factor productivity of paddy farming efforts. Total productivity is decomposed into four parts: the advancement of technology, technical efficiency, allocative efficiency and the effect of business scale. If each component of productivity growth is known, strategies to increase rice production can be determined. This paper uses secondary data published by the Indonesian Statistics Agency. The analyses were performed using an econometric approach. The results show that growth in total factor productivity declines with a declining rate. The positive contributors to the growth of total factor productivity are the change in the technical and business scale effects; whereas the negative contributors are the technical and allocative efficiency. The growth in rice production is mainly due to the use of inputs and other factors such as the expansion and increase in cropping index. The growth in total factor productivity can be increased by improving technical and allocative efficiencies.

Introduction

In Indonesia, rice is a strategic commodity. Either a shortage or a highly fluctuated price of rice in the domestic market will distract political stability. Rice is important as a staple food and represents the largest caloric intake for more than 250 million people, despite the fact that corn, cassava, soybean and sweet potato are important supplementary food. Rice is needed to supply calorie, while vegetables, as the complement of rice, is also important to supply vitamins and micro nutrients (Mariyono, 2016). For that reason, Indonesian government has applied policies to maintain stability of domestic rice market.

The dynamics of rice production and harvested area during last two decades is described in Figure 1. The growth rate of production is about similar to the growth rate of harvested areas, meaning that the productivity of rice is relatively stagnant.



Source: Indonesian Statistical Agency (2016)

Figure 1. The dynamics of rice production in Indonesia

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Indonesian rice production faces a challenge of population growth leading to an increase in demand for food. This requires continually increase in agricultural productivity; despite the increased growth rate of agricultural land conversion (Mariyono, Harini, & Agustin, 2007). Increase in intensive agricultural productivity is still important because it has a number of substantial effects. First, it releases resources that can be used by other sectors thereby generating economic growth. Second, higher levels of agricultural productivity result in lower food prices that increase consumers' welfare. And third, in the context of an open economy, productivity growth improves the competitive position of a country's agricultural sector. Mariyono and Sumarno (2015) identify the importance of intensive agricultural productivity in relieving rural poverty alleviation. Against this background, it is clear that productivity measures provide a key indicator of the performance of a country's agricultural sector.

The aims of most productivity studies have been to monitor the performance of the agricultural sector and finally to help policymakers to design optimal policies to enhance productivity. This paper aims to determine the drivers of productivity growth of rice production in Indonesia.

Most of the previous studies on growth which develop the neo-classical Solow-Swan models make the strong assumption that producers operate on full technical efficiency, using best practice methods and state-of-the-art technology. However, for various reasons, producers often do not operate on their frontier or use best practice agricultural methods. The economy therefore does not operate as it would if all technological and methodological innovations had been fully diffused throughout it. In this interpretation, innovation drives technological change captured in the production technology. The issue of diffusion would then arise in the form of the presence of firms producing at points inside the production possibility frontier. Stochastic frontier estimation techniques would be needed to measure the extent to which such sub-frontier behaviour is occurring. In this formulation, observed movements of the frontier – measuring technological change — comprise the combined impacts of the invention, innovation and diffusion processes.

Fox, Grafton, Kompas, and Che (2006) propose a method for analysing the productivity of resource-based firms through the decomposition of productivity from a profit function. This is a deterministic approach that needs no functional form of the production function. The applicability of deterministic approaches to cases of agricultural production is questionable, however, due to the stochastic nature of agriculture.

By using a frontier technique, Kalirajan (2004) proposes a method of decomposition of agricultural total factor productivity that has been applied in Chinese agriculture. The same technique is used in decomposing total factor productivity in Indian agriculture. The differences between these methods originate in the specification of the production function and the stochastic model.

Regardless of the differences in specification, however, there remains the strong assumption in all these studies that every producer is allocatively efficient. The studies have furthermore not accounted for returns to scale of production technology. Thus, both the effects of allocative efficiency and scale resulting from input growth are neglected. By comparison, Bauer (1990) proposes an approach to decompose total factor productivity which has theoretical and empirical advantages on these grounds. In this approach, total factor productivity is decomposed into technological change, returns to scale and economic efficiency. This approach has been applied empirically to estimate total factor productivity in US airlines.

Technically, the approach of Bauer (1990) is superior to the approach of others in terms of accuracy and consistency in decomposing total factor productivity. Bauer (1990) decomposes total factor productivity into technological progress, economic efficiency and scale effect. The last term is not found in the other models. In addition, the efficiency term estimated in Bauer's (1990) approach has also accounted for the weakness of technical efficiency estimated in, which assumes allocatively efficient producers.

Regardless of the procedure used, there is a larger debate around the role of total factor productivity in determining major discrepancies in economic growth across countries. Felipe and McCombie (2003) see problematic as the use of a production function to estimate and interpret total factor productivity as a rate of technological progress. This is because the production function estimation is usually estimated with data in value terms, rather than physical quantities. The production function estimated with such data will generate coefficients which are exactly the same as factor shares if the production function takes a Cobb-Douglas technology form. Consequently, there is no difference between growth accounting and econometric estimation.

Research Method

In general, there are two models of measuring productivity growth. The first method requires the functional form of production technology, while the second requires no functional form. Within the first method, there are two basic approaches to the measurement of productivity. The first approach is the growth accounting approach, which relies on neoclassical production theory under constant returns to scale for the proposition that the output elasticities with respect to inputs are equal to the corresponding factor shares (Mariyono, 2013). Total factor productivity is thereby calculated as an arithmetic residual after share-weighted input growth rates are subtracted from the growth rate of output. The second approach is the econometric approach, which estimates the parameters of elasticity from time series data and infers the magnitude of total factor productivity as an econometric residual after allowing for the estimated effects of all measurable inputs on output. For both of these approaches, much attention has focused on the difficulties of appropriately measuring both inputs and outputs.

This paper uses econometric approach to decompose total factor productivity (TFP). Graphically, productivity growth can be decomposed as shown in Figure 2.

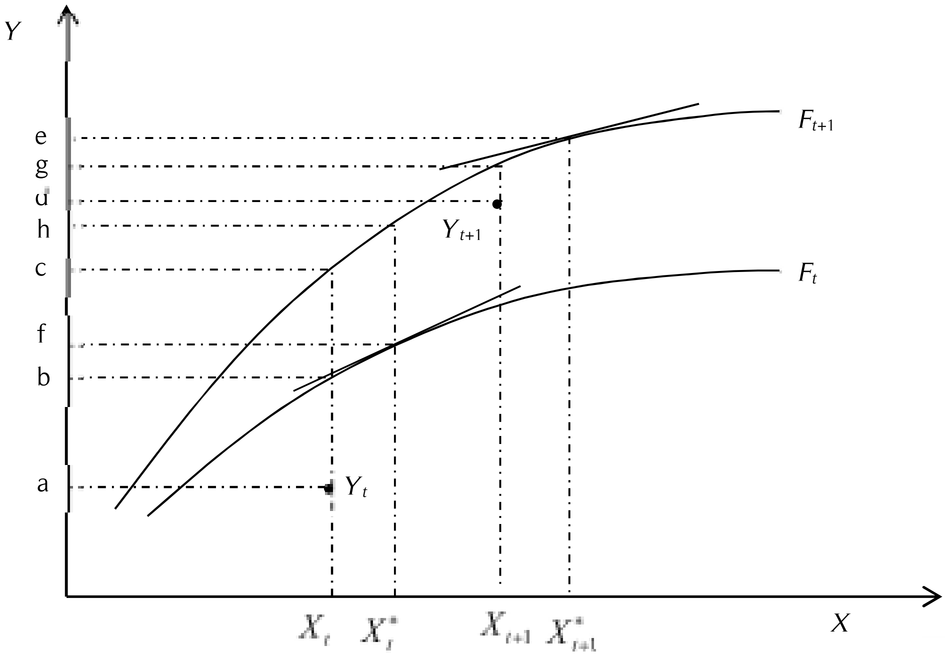

Figure 2. Decomposition of productivity growth

Let Y be a single output produced using a single input X with production technology F. At time t, suppose the allocatively efficient level of input use is X_t^* where the marginal product of the input is equal to the relative price of the input. At time $t+1$, the allocatively efficient level is X_{t+1}^* where the marginal product of the input is equal to its relative price. The relative price at time t, is not always the same as that at time t + 1. The output growth is decomposable as follows:

$$\begin{aligned}\dot{Y} &= d-a = (b-a)+(f-b)+(c-f)+(h-c)+(d-h)\\ &= \big((b-a)-(g-d)\big)+\big((f-b)-(e-g)\big)+\big((c-f)+(h-c)\big)+(e-h)\\ &= \Delta TE+\Delta AE+TC^*+\dot{X}^* \qquad (1)\end{aligned}$$

Total factor productivity growth is output growth unexplained by input growth, and then total factor productivity growth is expressed as:

$$T\dot{P}F = \Delta TE+\Delta AE+TC^*+\Delta SE \qquad (2)$$

Where ΔSE is change in scale effect. Scale effects result from input growth, which is due to returns to scale. When the production technology exhibits constant, increasing or decreasing returns to scale, the effect will be zero, positive or negative correspondingly.

In a mathematical approach, to decompose productivity growth, a stochastic production function is used. The deterministic production frontier with input X and Z, technology parameter vector β, time trend t as a proxy for technological change, and output-oriented technical inefficiency $u \geq 0$ is represented as:

$$Y_{it} = f(X_{it}, Z_{it}, t;\, \beta)exp\{-U_{it}\} \qquad (3)$$

Total factor productivity growth is defined as the growth in output which is unexplained by growth in inputs, that is:

$$T\dot{F}P == \dot{Y} - S_x\dot{X} - S_z\dot{Z} \quad (4)$$

Technical efficiency is expressed as $\varphi_{it} = \frac{y_{it}}{f(x_{it}, z_{it};\beta)} = exp\{-U_{it}\} \leq 1$, which allows it to vary over time. A primal measure of the rate of change in technical efficiency is given as:

$$\dot{\varphi} = \frac{\partial \varphi_{it}}{\partial t} = \frac{\ln exp\{-U_{it}\}}{dt} \quad (5)$$

$\dot{\varphi}$ can be interpreted as the rate at which a producer shifts towards or away from the production frontier, keeping everything else constant. Taking the log and totally differentiating equation (3) and then differentiating with respect to t, we have:

$$\dot{Y} = \frac{\partial \ln(\cdot)}{\partial t} + \frac{\partial f(\cdot)}{\partial X}\frac{X}{f(\cdot)}\frac{\partial \ln X}{dt} + \frac{\partial f(\cdot)}{\partial Z}\frac{Z}{f(\cdot)}\frac{\partial \ln Z}{dt} + \frac{\partial \ln exp\{-U\}}{\partial t} \quad (6)$$

Where $\dot{Y} = \frac{\partial \ln Y}{\partial t}$ is output growth, $f(\cdot) = (X, Z, t; \beta)$ is the deterministic kernel of the stochastic production frontier, $\frac{\partial \ln(\cdot)}{\partial t}$ is the rate of technological change, $\frac{\partial \ln X}{\partial t} = \dot{X}$ is the growth rate of input X, $\frac{\partial \ln Z}{dt} = \dot{Z}$, is the growth rate of input Z, $\frac{\partial f(\cdot)}{\partial X}\frac{X}{f(\cdot)} = \theta_X$ is output elasticity with respect to input X, $\frac{\partial f(\cdot)}{\partial Z}\frac{Z}{f(\cdot)} = \theta_Z$ is output elasticity with respect to input Z, $\frac{\partial \ln exp\{-U\}}{dt} = -\frac{\partial u}{\partial t} = \dot{\varphi}$ is the rate of change in technical efficiency. Substituting the expression for $\dot{Y}$ into equation (4) yields:

$$T\dot{F}P = \Delta TC + (\theta - 1)\left(\frac{\theta_X}{\theta}\dot{X} + \frac{\theta_Z}{\theta}\dot{Z}\right) + \left(\frac{\theta_X}{\theta} - S_X\right)\dot{X} + \left(\frac{\theta_Z}{\theta} - S_Z\right)\dot{Z} + \dot{\varphi} \quad (7)$$

Where $\theta = \theta_X + \theta_Z$ is the scale elasticity that provides a primal measure of returns to scale of the production frontier.

Data and model

This paper uses panel data during 1999-2014 consisting of 23 provinces in Indonesia. The total number of observations used is 368. The database is established from various publications of the Indonesian Statistical Bureau (BPS) and Indonesian Agricultural Reports.

The stochastic frontier translog production technology is specified as:

$$\ln Y_{it} = \beta_0 + \sum_{k=1}^{5}\beta_k \ln X_{kit} + \frac{1}{2}\sum_{k=1}^{5}\sum_{j=1}^{5}\beta_{kj} \ln X_{kit} \ln X_{jit} + \sum_{k=1}^{5}\beta_{kt} t \ln X_{kit} + \beta_t t + \beta_{tt} t^2 + v_{it} - u_{it} \quad (8)$$

The full translog production technologies captures more accurate estimates and more precise technical efficiency, which will be subsequently used for calculating decomposition of productivity growth of rice production.

Result and Discussion

A result of this study is mostly derived from the full translog production function estimated at the potential level, or the frontier, as shown in Table 1. Some of coefficients are positive and some others are negative. With respect to time trend, Indonesian rice production faces input augmenting technical change, except for use of pesticide; and there is technological regress with increasing rate. This analysis does not make interpretation related to individual coefficients. But, all coefficients will be used for calculating output elasticity with respect each input. The mean output elasticity is calculated at average level of input uses and time trend during the period, which is divided four-yearly. The mean output elasticity is shown in Table 2.

The mean output elasticity with respect to productive inputs: seed and fertilizers, the output elasticity is negative in the first period. This is an indication that both inputs were overused. After those periods, there was agricultural policy change, that is, the goal of rice production has considered economic aspect, such that high production was no longer the main objective.

Table 1. Estimated *translog* production frontier

	Coefficients	Std. Error	z-ratio	(p>z)
Constant	1.9928	12.1424	0.16	0.870
S	3.8081	4.0204	0.95	0.344
F	0.3819	0.6944	0.55	0.582
P	0.7554	0.7427	1.02	0.309
C	0.4573	0.2861	1.60	0.110
L	-0.3848	1.3598	-0.28	0.777
1/2 S*S	-0.2094	0.2934	-0.71	0.475
1/2 F*F	-0.0126	0.0182	-0.69	0.488
1/2 P*P	0.0208	0.0106	1.95	0.051
1/2 C*C	-0.0017	0.0022	-0.79	0.431
1/2 L*L	0.1406	0.0639	2.20	0.028
S*F	0.2976	0.1659	1.79	0.073
S*P	-0.0473	0.1314	-0.36	0.719
S*C	0.0344	0.0632	0.54	0.586
S*L	-0.4074	0.3309	-1.23	0.218
F*P	0.0810	0.0234	3.46	0.001
F*C	0.0519	0.0136	3.81	0.000
F*L	-0.1532	0.0825	-1.86	0.063
P*C	-0.0220	0.0125	-1.77	0.077
P*L	-0.0731	0.0610	-1.20	0.231
C*L	-0.0738	0.0180	-4.10	0.000
S*t	0.0621	0.0305	2.04	0.042
F*t	0.0066	0.0089	0.74	0.458
P*t	-0.0024	0.0057	-0.43	0.671
C*t	0.0019	0.0015	1.22	0.222
L*t	0.0041	0.0121	0.34	0.736
t	-0.2759	0.1249	-2.21	0.027
t*t	-0.0020	0.0007	-2.96	0.003
μ	0.2665	0.1254	2.12	0.034
η	0.0123	0.0030	4.06	0.000
γ	0.9750	0.0135	72.22	0.000
Log-likelihood	538.50024			
Likelihood test (χ^2)	730.57			

Source: Author's analysis

Table 2. Mean elasticity of rice production with respect to each input,1999-2014

Period	Seed	Fertilisers	Pesticides	Compost	Labour	Scale
1999-2002	-0.2290	-0.0251	0.0150	0.0437	0.1045	-0.0908
2003-2006	-0.1595	0.0283	0.0662	0.0084	0.0401	-0.0164
2007-2010	-0.0213	0.0169	0.0300	-0.0039	0.0836	0.1052
2011-2014	0.1470	-0.0299	-0.0026	-0.0185	0.2069	0.3029

The mean elasticity is calculated at average input used and time trend during each period

Scale elasticity, which is the sum of mean output elasticity with respect to all inputs (Kumbhakar & Lovell, 2000), is very small (even negative) at the two first periods. This is somehow not a puzzling phenomenon. This is because the aggregate production function is assumed to exhibit CRS (Mariyono, 2013); such that it is allowable to estimate production function is an intensive form. In many cases of agricultural production technology, output elasticity with respect to land is likely to be very high.

Table 3. Source of productivity growth of rice production during 1999-2014

Period	Technical change	Scale effect	Technical efficiency	Allocative efficiency	TFP
1999-2002	0.0159	0.4725	-0.0028	-0.7174	-0.2318
2003-2006	0.0129	0.7231	-0.0029	-0.7899	-0.0569
2007-2010	0.0057	-0.1016	-0.0031	0.0234	-0.0756
2011-2014	-0.0117	-0.0285	-0.0032	-0.0164	-0.0598

Table 3 shows the TFP growth. Rate of technical change is decreasing. Technological change in Asian agriculture (Teruel & Koruda, 2004) and particularly in Indonesia (Mariyono, 2009; 2015) was exceptional when the Green Revolution started, but it was decreasing afterward. According to (Kalirajan, Mythili, & Sankar, 2001), the decreasing growth in technical change is due partly to environmental degradation; and this has been causing a high value of dead weight lost in Indonesia (Mariyono, 2014). Scale effect fluctuated overtime because it is dependent on output elasticity and growth rate of input use. Technical efficiency has negative growth. This means that farms in each region became less technically efficient. Rate of change in allocative efficiency in two first periods is very high. This is reasonable since at the time, economic factor has not been a goal. The goal at those periods was high production. Thus the level use of input tended to be higher than what was allocatively efficient.

The four components have driven total productivity growth of rice production, which is on average, declining at a decreasing rate. The fact that rice production steadily increase was not due to TFP growth. But, the increase in rice production is mostly driven by growth in input use, expansion of agricultural land (Mariyono, 2015). Since the components of productivity growth are decreasing, there is still enough room to increase TFP growth by enhancing technical and allocative efficiency. Shapiro (1983) and Belbase and Grabowski (1985) suggest that efforts to improve efficiency may be more cost-effective than introducing new technologies as a mean of increasing agricultural productivity. Using more advanced and improved agronomical technology is alternative to increase productivity through higher efficiency (Mariyono, 2016).

Conclusion

TFP of rice production in Indonesia grows negatively, but the rate of slowdown tends to decrease very slowly. It seems that growth in rice production during the period is due mostly to growth of input, expansion of land and increase in cropping intensity. The TFP is decomposed into four components: technical change, scale effect, technical efficiency, and allocative efficiency. Technical change and scale effect have contributed positive growth. In contrast, technical and allocative efficiency contribute negative growth. Technical and allocative efficiencies are reasonable options to increase TFP because both components are less costly than introduction of new technology.

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