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Determinants of Green Total Factor Productivity of Agricultural Sector in Indonesia, 1980–2018

Ahmad Satria IRMANTO[1], Siskarossa Ika OKTORA[2]

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Abstract

Purpose: This study aims to analyze the determinants of Green Total Factor Productivity (Green TFP) growth in the agricultural sector in Indonesia from 1980–2018. **Research design, data, and methodology:** The growth of Green TFP in the agricultural sector is calculated using the Growth Accounting Method. Moreover, this study uses multiple linear regression to analyze the determinants of the growth of Green TFP in the agricultural sector in Indonesia. **Results:** The survey results show that the average growth of Green TFP in the agricultural sector in Indonesia is still negative, which indicates that the efficiency of production factor or mastery of technology is still low. Inflation and patent applications are variables that significantly affect the growth of Green TFP in the agricultural sector, where the inflation variable has a negative effect. In contrast, the variable growth of patent applications has a positive impact. **Conclusions:** The government needs to continue to improve efficiency by organizing various programs related to increasing mastery of technology in the agricultural sector. The government also needs to advance research and development by promoting patents to become research incentives and impact the improvement of new technologies, especially those related to the environment. Moreover, economic stability needs to be maintained through inflation control.

Keywords : Green TFP; Agriculture; Multiple Linear Regression

JEL Classification Code: C39, D24, Q15

1. Introduction

Indonesia is an agricultural country that prioritizes agriculture. Hence, to ensure its role's stability, it is necessary to continue developing the agricultural sector. In the development process, the agricultural sector faces various challenges related to the provision of community food needs, along with an increase in population, a decrease in the number of workers in the agricultural sector, and the conversion of agricultural land. Based on Kementerian Pertanian Republik Indonesia (2020), the United Nations states food security is a significant challenge concerning Indonesia's population growth, reaching 322 million in 2050. Along with the increase in population, the need for non-agricultural land will tend to increase, which will encourage the conversion of agricultural land (Kamilah & Yulianah, 2016). In addition, Susilowati (2016) states that labor in the agricultural sector continues to decline due to the declining

1 First Author. Departement of Applied Statistics, Politeknik Statistics STIS, Indonesia. Email: ahmadsatria48@gmail.com
2 Corresponding Author or Second Author, Assistant Professor, Department of Applied Statistics, Politeknik Statistika STIS, Indonesia. Email: siskarossa@stis.ac.id

interest of young workers working in the agricultural sector. These challenges can be met by applying technology to the production process of the agricultural sector. This statement is in line with Malthus' prediction. Malthus states that population growth follows a geometric progression while food increases arithmetically, where Malthus prediction can be refuted along with technological developments, which are then expected to increase the productivity of the agricultural sector (Dya & Budyanra, 2020).

Productivity can be measured in various ways, one of which is Total Factor Productivity (TFP), where TFP also describes the production technology used. According to Organisation for Economic Co-operation and Development (2001), technological parameters cannot be observed directly, so TFP growth is necessary. The growth of Indonesian agricultural TFP over the last 20 years has shown a downward trend, indicating the need for capital accumulation to encourage technological change to increase productivity (Arifin, 2021). This is in line with the direction of the national policy of the agricultural sector on “Increasing Agricultural Productivity and Efficiency Towards Sustainable Agriculture” (Kementerian Pertanian Republik Indonesia, 2020). According to Balitbangtan Kementerian Pertanian (2018), sustainable agriculture is an agricultural business that can provide optimal yields in quantity and quality, accompanied by efforts to preserve agricultural and environmental resources so that agricultural resources remain productive and the environment is maintained. This understanding shows that increasing the agricultural sector's productivity is closely related to environmental sustainability.

The practice of implementing sustainable agriculture can be seen from the results of the publication of Badan Pusat Statistik (2020) regarding the indicators of the Sustainable Development Goals (SDG) for the Agriculture Sector 2020. The publication shows that land productivity and management of fertilizer use are unsustainable indicators. Furthermore, CO2 emission increases by 122 percent during 2015-2019. The CO2 emission intensity index in the agricultural sector is the highest for the 2015-2019 period when compared to other business fields (Badan Pusat Statistik, 2021). Of the various challenges and sustainable agricultural practices that have not been good, the development of green productivity needs to be done. Calculating green productivity through Green TFP will be more useful as an indicator of sustainable agricultural development. Therefore, this study aims to (i) find the general description of the growth of Green TFP in the agricultural sector in Indonesia from 1980–2018 and (ii) analyze the variables that affect the growth of Green TFP in the agricultural sector in Indonesia from 1980–2018. This research data considers the development of the Green Revolution program in the 1980’s so that the development of Green TFP can be more clearly seen.

2. Literature Review

According to Organisation for Economic Co-operation and Development (2001), productivity measurement has various purposes, including detecting changes in technology, detecting changes in efficiency, saving actual costs, comparing production processes, and comparing living standards. Along with the times, the concept of productivity has also developed with the emergence of the term Green Productivity (GP). According to Ahmed (2012), Green Productivity is taken from integrating two essential development strategies: increasing productivity and protecting the environment.

Green productivity through Green TFP demonstrates sustainable development with technological advances and ensures future rights to future generations (Ahmed, 2012). Rusiawan et al. (2015) concludes that Green TFP is essential to increase productivity growth and reduce CO_2 emissions simultaneously. Tzouvelekas et al. (2007) argue that CO_2 emissions are seen as "energy use”, where energy is an input to the production function with CO_2 as the product.

Various studies have been conducted on calculating productivity, or TFP, in the agricultural sector by considering environmental impacts. Chi et al. (2021) have calculated an agriculture Green TFP and found that within the early stages of production, compromising the environment and overexploiting natural assets. Calculations of Green TFP have also been carried out by Ahmed (2012) and Tzouvelekas et al. (2007) using the Growth Accounting Method (GAM). The result of the study confirms that CO_2 emissions, which describe the environmental impact, affect output growth.

Many kinds of research on TFP in the national agricultural sector have been carried out but have not considered the environmental impact. Research by Dya & Budyanra (2020) calculates TFP using the Cobb-Douglas production function and shows that inflation harms TFP. Another study by Mayashinta & Firdaus (2013) have used the Ordinary Least Square (OLS) method in calculating TFP and the Error Correction Model (ECM) in determining the determinants of growth of TFP. The results show that exports and imports affect the growth of TFP. On the other hand, measurement of growth of TFP that does not consider environmental factors can be biased in estimating the contribution of technological advances (Tzouvelekas et al., 2007).

Rusiawan et al. (2015) investigates the growth of Green TFP in the Indonesian economy using GAM. The result shows that the average TFP during 1976–2010 was -0.62

percent, while the average growth of Green TFP was -1.83 percent. This indicates that the growth value of Green TFP is lower than that of TFP, where both have the same pattern. This phenomenon is thought to also occur in the agricultural sector. Sustainable agricultural practices are still harmful and are believed to lower the growth of Green TFP in the agricultural sector than its growth of TFP.

Mankiw (2006) suggests several government policies to increase productivity and living standards, including encouraging savings and investment, supporting foreign investment, growing the role of education, protecting property rights and political stability, allowing free trade, supporting research and development of new technologies, and controlling population growth. In addition, the study of Ali et al. (2012) also considers economic stability in determining the determinants of growth of TFP, where the variable used to describe economic stability is the inflation variable.

3. Research Methods and Materials

This research covers the Indonesian agricultural segment, with the investigated period being 1980-2018. The data used in this study are secondary data collected from various sources, such as Badan Pusat Statistik (BPS), Food Agriculture Organization (FAO), World Bank, Organization for Economic Co-operation and Development (OECD), and United Nations Educational Scientific and Cultural Organization (UNESCO). Table 1 shows the details of the data used.

Table 1: List of Variables in the Study

Variable Name	Data Source	Unit
Agricultural Real GDP (Q)	World Bank	Rupiahs
Fertilizer Consumption (K)	FAO	Kilogram
Agricultural Labor (M)	FAO	Person
Agricultural CO_2 Emissions (CO2)	World Bank	Metric tons CO_2e
Population Growth (PG)	World Bank	%
Inflation (INF)	BPS	%
Patent Application (PT)	OECD	Score
Export (EXP)	BPS	Million USD
Import (IMP)	BPS	Million $
Educational Participation (EDC)	UNESCO	%
Domestic Investment in Agriculture (DI)	BPS	Billion Rupiahs
Foreign Direct Investment in Agricultural (FDI)	BPS	Million USD

In this study, the growth of Green TFP is calculated first. One of the calculations used in this study was a non-frontier approach with the Growth Accounting method, as was done in Ahmed (2012). The Green TFP calculation was done with the Cobb-Douglas production function as follows:

$$Q = f(K, L, CO2, T) \quad (1)$$

$$Q = TK^{\alpha}L^{\beta}CO2^{\lambda} \quad (2)$$

$$lnQ_t = lnT_t + \alpha lnK_t + \beta lnL_t + \gamma lnCO2_t \quad (3)$$

According to Mankiw (2015), T is a parameter greater than zero that measures the productivity of available technology. Beveren (2012) also argues that T describes the level of efficiency where the variable cannot be observed, and is stated as follows:

$$lnT_t = lnTFP_t = a + \varepsilon_t \quad (4)$$

The intercept represents the average efficiency or productivity with a time deviation of ε_t. As a result, the form of equation (3) becomes

$$ln\,Q_t = a + \alpha lnK_t + \beta lnL_t + \lambda lnCO2_t + \varepsilon_t \quad (5)$$

where a is intercept; α is the elasticity of output to capital (fertilizer consumption); β is the elasticity of output to labor; and λ is the elasticity of output to CO_2 emission in agriculture.

The term "per worker" is intended to describe productivity and standard of living. According to Ahmed (2012), the standard of living in an economy is not determined by its total output but by the total available output per person. Assuming Constant Return to Scale $(1 - \alpha - \lambda = \beta)$, equation (5) can be expressed as the equation "per worker".

$$ln\,Q_t = a + \alpha lnK_t + (1 - \alpha - \lambda)lnL_t + \lambda lnCO2_t + \varepsilon_t \quad (6)$$

$$ln\,Q_t = a + \alpha lnK_t + lnL_t - \alpha lnL_t - \lambda lnL_t + \lambda lnCO2_t + \varepsilon_t \quad (7)$$

$$ln\,Q_t - lnL_t = a + \alpha(lnK_t - lnL_t) + \lambda(lnCO2_t - lnL_t) + \varepsilon_t \quad (8)$$

$$ln(Q/L)_t = a + \alpha ln(K/L)_t + \lambda ln(CO2/L)_t + \varepsilon_t \quad (9)$$

$$ln(Q/L)_t = \alpha ln(K/L)_t + \lambda ln(CO2/L)_t + lnTFP_t \quad (10)$$

Equation (10) can also be presented in terms of productivity growth as in the framework of the Growth Accounting model first introduced by Robert Solow. Solow's residual theory, often called Solow Residual, shows changes in technological progress in the production process. The Solow Residual is obtained by subtracting equation (10) from the lag of the previous period so that it becomes

$$\Delta ln(Q/L)t = \alpha \Delta ln(K/L)t + \lambda \Delta ln(CO2/L)t + \Delta ln\,(TFP)t \quad (11)$$

Then the equation is estimated to obtain the parameters or contribution (share) of capital per worker and CO_2 emissions per worker. From the estimated share received, the growth of TFP calculation is calculated using the following formula:

$$\Delta ln(TFP)t = \Delta ln(Q/L)t - [\alpha \Delta ln\ (K/L)t + \lambda \Delta ln\ (CO2/L)t] \quad (12)$$

Equation (12) shows the decomposition of output growth per worker into capital contribution per worker, increased use of CO_2 emissions per worker, and the quality contribution of these factors simultaneously depicted in the growth of TFP. This research uses descriptive analysis and inferential analysis. In inferential analysis, multiple linear regression analysis methods are used to analyze the variables that are thought to affect the growth of Green TFP in the agricultural sector. The steps of multiple linear regression analysis in this study are as follows:

1. Testing the stationarity of the variables used with the ADF test
2. Regressing independent variables to the dependent variable
3. Testing classical assumptions on the model
4. Conducting the model's significance test
5. Interpreting the obtained model

The specification of the model used is the following:

$$GreenTFPG_t = \beta_0 + \beta_1 EXPG_t + \beta_2 IMPG_t + \beta_3 EDCG_t + \beta_4 INF_t + \beta_5 FDIG_t + \beta_6 DIG_t + \beta_7 PG_t + \beta_8 PTG_t + \varepsilon_t \quad (13)$$

where $GreenTFPG_t$ is the growth of Green TFP in the agricultural sector; $EXPG_t$ is the growth of export; $IMPG_t$ is the growth of import; $EDCG_t$ is the growth of education participation; INF_t is inflation rate; $FDIG_t$ is the growth of foreign direct investment in the agricultural sector; DIG_t is the growth of domestic investment in the agricultural sector; PG_t is the growth of population; PTG_t is the growth of patent applications; and ε_t is an *error* at time t.

4. Results and Discussion

4.1 Overview of Growth of Green TFP Indonesia's Agricultural Sector

Green TFP in the agricultural sector is an indicator that measures total productivity that describes the level of efficiency and technological progress by internalizing CO_2 emissions as the impact of production activities on the environment. Based on Figure 1, it can be seen that the growth of Green TFP in the agricultural sector has fluctuated. During the period of 1980-2018, the average growth of Green TFP in the agricultural sector is -0.275 percent. According to Mayashinta and Firdaus (2013), the negative growth indicates that the efficiency of production factors or mastery of technology in the agricultural sector is still weak. The highest growth occurs in 1997, which was 15.6 percent. Arifin (2004) argues that the exchange rate weakening during the 1998 economic crisis benefited export-oriented agricultural sectors such as coffee, rubber, pepper, palm oil, and fishery products. These commodities experience a boom that brought profits to farmers at the beginning of the monetary crisis. In addition, Suryana and Kariyasa (1997) state that in 1997, the government implemented the "Sistem Usaha Tani Berbasis Padi dengan Berwawasan Agribisnis" (SUTPA) program, which introduced various technologies to improve business efficiency. The technology components used are new high-yielding varieties, direct seed planting methods, site-specific fertilization, the introduction of agricultural machinery, annual farming patterns, and control of weeds, pests, and diseases.

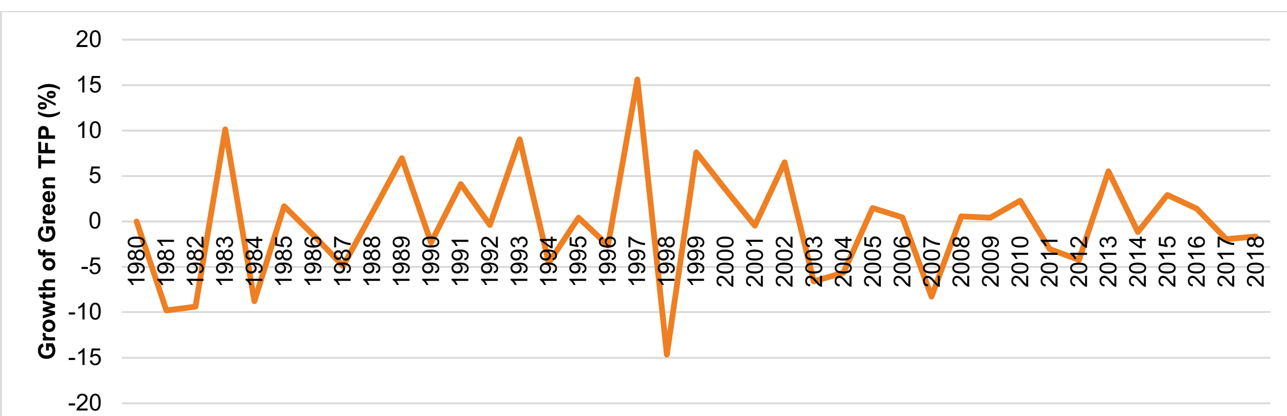

Figure 1: Development of Growth of Green TFP Indonesia's Agricultural Sector 1980-2018

The increase in export-based agricultural sector income through the weakening of the exchange rate and the implementation of the SUTPA program is guessed to increase productivity growth in the agricultural sector. However, this high growth does not last long because, in 1998, Indonesia experienced an economic crisis that caused a decline in people's purchasing power. The economic crisis is followed by an el Nino phenomenon that triggered crop failure (Arifin, 2004). The multidimensional problem causes productivity growth to drop considerably to -14.7 percent.

4.2 Determinants of Growth of Green TFP Indonesia's Agricultural Sector

In this study, stationarity testing was carried out on the variables used in the study. The stationarity test was carried out using the Augmented Dickey-Fuller (ADF) Test.

Table 2: Stationarity Checking Results with ADF Test

Variable	p-value	Conclusion
	Level	
Green TFPG	0.0000	I(0)
EXPG	0.0017	I(0)
IMPG	0.0006	I(0)
EDCG	0.0075	I(0)
INF	0.0015	I(0)
FDIG	0.0002	I(0)
DIG	0.0001	I(0)
PG	0.0000	I(0)
PTG	0.0000	I(0)

Table 2 shows that the p-value of all variables is at the level of less than 10 percent. Therefore, all variables do not contain a unit root or are stationary at the level. Furthermore, the growth of the Green TFP regression model for the agricultural sector is estimated with the variables tested for stationarity.

Table 3: The Estimation Results of the Green TFP Growth Regression Model for the Agricultural Sector

Variable	Coefficient	SE	t_{hit}	p-value
C	0.064814	0.051220	1.265413	0.2158
EXPG	0.076277	0.130549	0.584273	0.5636
IMPG	-0.075593	0.086973	-0.869156	0.3919
EDCG	-0.195242	0.236822	-0.824425	0.4164
INF	-0.296440	0.116535	-2.543789	0.0166*
FDIG	0.000656	0.004274	0.153571	0.8790
DIG	-0.002941	0.012955	-0.226996	0.8220
PG	-2.613949	3.441796	-0.759472	0.4537
PTG	0.051121	0.018941	2.699025	0.0115*
Coefficient of Determination (R^2)	0.3573			
Prob. F-statistic	0.0802			

Based on the test results as shown in Table 4, it can be concluded that the model has met the assumptions of normality, homoscedasticity, and non-autocorrelation. Further, the results of multicollinearity detection show that all VIF values are less than 10, so it can be concluded that the model has met the non-multicollinearity assumption.

Table 4: Classical Assumption Test Result

Classical Assumption	Stat.	Prob.	Conclusion
Normality (Jarque-Bera)	2.988	0.2252	Satisfy
Homoskedastisity (Breusch-Pagan-Godfrey)	2.951	0.9573	Satisfy
Non-Autocorrelation (Breusch-Godfrey)	5.558	0.1352	Satisfy

Based on the estimation results in Table 3, the R^2 value of 0.3573 shows that the independent variables in the study can explain 35.73 percent of the variation of growth of Green TFP. The probability value of the F-Statistic is 0.0802 < 0.1, so it can be concluded that at least one independent variable in the study affects the growth of Green TFP in the agricultural sector.

Furthermore, testing the significance of each variable can be done with a partial test by looking at the probability value of the t-statistic. With a significance level of 10 percent, it can be concluded that the variables that significantly affect the growth of Green TFP are the growth variables of patent applications and inflation. The growth of export and import did not significantly affect the growth of Green TFP in the agricultural sector. According to Mayashinta and Firdaus (2013), although the export value of industrial agricultural products continues to increase, exports are still dominated by industrial products of semi-finished materials or low-tech and labor-intensive raw materials that do not encourage technology absorption. It is suspected that the growth of export does not significantly affect the growth of Green TFP. In addition, Nasrudin et al. (2015) found that the performance of the Indonesian agricultural sector is worse than before the implementation of ASEAN-China Free Trade Area (ACFTA). Moreover, competitive pressures and inflexibility from domestic producers cause the agricultural sector's performance to be worse than before the full implementation of ACFTA. The agricultural sector has not benefited from ACFTA due to inadequate infrastructure and logistics systems and government policies that have not been able to encourage competitiveness. Thus, the tight competition and the rigidity of domestic producers towards trade openness cause the growth of imports and exports not to significantly impact the growth of green TFP in the agricultural sector. In addition, Nasrudin et al. (2015) also argue that there is a tendency that the positive impact of agricultural trade liberalization will be enjoyed more by developed countries than by developing countries.

The growth of education does not significantly affect the growth of Green TFP in the agricultural sector. These results align with the research of Chi et al. (2021), which shows that the level of education does not have a significant positive relationship to the growth of Green TFP in the agricultural sector in China. This is because well-educated farmers have more opportunities to have non-agricultural jobs, thus leading to an outflow of high-quality rural labor, which hinders the growth of Green TFP agriculture. This is also supported by the statement of Isaksson (2007) that at low-income levels, human capital or education is not positively related to TFP growth, while for middle and high-income countries, the effect is positive.

Inflation significantly affects the growth of Green TFP in the agricultural sector. The coefficient value of -0.2964 means that every 1 percent increase in inflation will reduce the growth of Green TFP by 0.2964 percent with the assumption that the influence of other variables remains constant. The results obtained are also in line with the research of Ali et al. (2012) and Dya and Budyanra (2020), which show that village inflation hinders the growth of TFP in western Indonesia. Economic instability and high prices create uncertainty, thereby encouraging capital outflows that harm investment in the agricultural sector and reduce the growth of TFP. Saleem et al. (2019) use inflation as a proxy for macroeconomic stability, regulatory quality, and uncertainty, where stable monetary conditions are the substance for efficient market operations in the economy of Pakistan. Olomola & Osinubi (2018) suggest that moderate and stable inflation rates increase demand for final goods and services, leading to increased production and productivity.

The growth of FDI does not significantly affect the growth of Green TFP in the agricultural sector. According to Isaksson (2007), the positive impact of FDI on TFP is difficult to be detected in the case of developing countries. This is supported by research of Olomola & Osinubi (2018), which shows that FDI had a positive but insignificant effect on TFP in Indonesia and Nigeria from 1980-2014. This can happen due to the lack of a good investment climate, such as good governance, effective institutions, security, accountability, the absence of political and religious violence, and bureaucratic inertia.

The growth of DI did not significantly affect the growth of Green TFP in the agricultural sector. According to Adnan et al. (2019), FDI inflows can crowd out investment by increasing competition among local competitors or push domestic investment by driving local competitors out of the market. In addition, the government's investment policy, especially in the food, horticulture, and plantation sub-sectors, favors DI more than FDI. Still, the realization of DI is always smaller than FDI (Balitbangtan Kementerian Pertanian, 2018). The tiny realization of DI can be caused by leaks in its use so that investment from DI does not affect the output growth of the Indonesian agricultural sector (Raswatie, 2013). Therefore, the tiny realization of DI can result in the growth of DI in the agricultural sector, not significantly affecting the growth of Green TFP in the agricultural sector.

The population growth does not significantly affect the growth of Green TFP in the agricultural sector. This is in line with research by Akinlo (2005), which states that population growth shows negative and insignificant results on TFP. This indicates that the population, considered a country measure, does not offer any efficiency or productivity gains In addition, government programs related to the population from 1980 to 2018 can reduce the negative impact of population growth. Hence, Indonesia's population growth becomes insignificant to the growth of Green TFP. This shows that controlling population growth must continue to be carried out by the policy advice of Mankiw (2006).

The growth of patent applications significantly affects the growth of Green TFP in the agricultural sector. The coefficient value of 0.0511 means that every 1 percent increase in patent application growth will increase Green TFP by 0.0511 percent, assuming the influence of other variables remains. These results align with the research of Saleem et al. (2019), which shows that patents describing innovations have a significant and positive effect on the growth of TFP in Pakistan. Another finding from Seenaiah and Rath (2018) shows that innovation activities, one of which is described by patents, positively influenced the growth of TFP in India from 1980-2014. The results obtained are also in line with the research by Lee and Xuan (2019) that the growth of patent applications has a positive and significant effect on the growth of TFP in the manufacturing sector in China. According to Lee and Xuan (2019), improving the patent system is one form of intervention that can be done to support a competitive production environment. In addition, implementing improved technology and innovation management and promoting R&D assistance can reduce additional costs in conducting R&D so that technology and innovation and R&D activities increase, increasing TFP growth. Improvements to the patent system can also increase incentives for individuals or companies to conduct research.

5. Conclusions

The growth of Green TFP in the agricultural sector in Indonesia was very volatile from 1980-2018. During this period, the average Green TFP growth in the agricultural sector in Indonesia was still negative, indicating that the efficiency of production factors or mastery of technology in the agricultural sector was still weak. Variables that significantly affect the growth of Green TFP in the agricultural sector are inflation and growth in patent applications. In contrast, export growth, import growth, education growth, population growth, and FDI and DI growth do not significantly affect the growth of Green TFP in the agricultural sector.

The government needs to continue to improve efficiency by organizing various programs related to increasing mastery of technology in the agricultural sector. In addition, it is necessary to advance research and development by promoting the patent system to become an incentive for researchers and impact the improvement of new technologies related to the environment. In addition, economic stability needs to be maintained by controlling inflation to increase the demand for final goods and services, which will lead to an increase in production, which in turn increases the productivity of the agricultural sector.

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