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Determinants of Green Total Factor Productivity in Indonesia: The Role of Environment in Economic Development with A Parametric Approach

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ABSTRACT

Environmental degradation occurs during economic development. Green Total Factor Productivity (TFP) was developed by incorporating environmental variables into traditional TFP to measure the efficiency of using technology to produce output, while balancing environmental quality. This study aims to determine the general description of economic development in Indonesia in 2015–2021, estimate economic development, and calculate Green TFP in Indonesia in 2015–2021, know the general description of Green TFP, and the variables that are thought to influence Green TFP in Indonesia in 2015–2021. 2021 and analyzed the variables influencing Green TFP in Indonesia in 2015–2021. The estimation results of the economic growth model showed a trade-off between economic growth and environmental quality in Indonesia. The Green TFP results for provinces in Indonesia are obtained using the Cobb-Douglas production function and panel data regression. The value of Green TFP in Indonesia is stagnant, at approximately 0.002. The analysis of variables affecting Green TFP using panel data regression shows that HDI, government spending on education, electricity consumption, industry share, capital structure, and trade openness have significant effects on Green TFP.

Introduction

Sustainable development has been reported globally. This policy considered the integration of development and environmental sustainability [1]. Sustainable development is important because economic growth and future quality of life are determined by the quality of the environment [2]. The Organization for Economic Co-operation and Development (OECD) has developed green growth indicators as a standard measure for comparing economic and environmental conditions between countries. One of the green growth indicators is the Gross Domestic Product (GDP) at constant 2015 prices per unit of energy-related CO_2 emissions. Based on OECD data, Indonesia's GDP per CO_2 emissions unit in 2019 was the fourth-highest in the ASEAN region. However, Indonesia had the highest CO_2 emissions in the ASEAN region (Figure 1). Many studies have stated that economic growth is usually followed by environmental degradation [3]. Environmental damage reduces the level of productivity of natural resources and causes various health problems and disturbances in the comfort of life [2].

One of the steps taken by the Indonesian government to realize sustainable development is to make the 2020-2024 National Medium Term Development Plan which prioritizes Sustainable Development Goals (SDGs). The target for improving the quality of the environment set out in the 2020–2024 National Medium Term Development Plan is an Environmental Quality Index (EQI) of 69.7 in 2024, and there are still many regions in Indonesia that have not yet reached this target. The EQI is an index that describes environmental conditions in Indonesia nationally and provincially developed by the Ministry of Environment and Forestry since 2009. Given the different economic and environmental conditions, it is necessary to increase development efforts to adapt to the conditions of each province. This is intended so that each province can maximize the potential of the area and maintain environmental quality.

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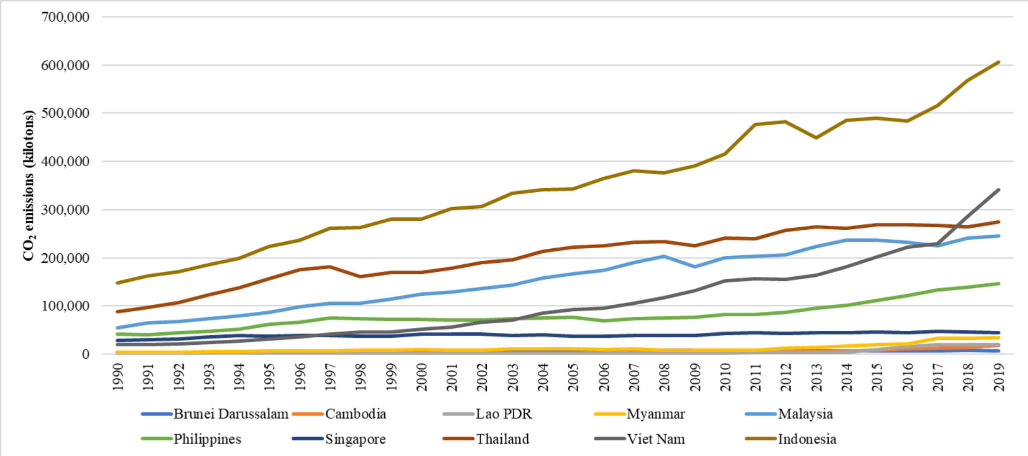


Figure 1. CO_2 emissions of ASEAN countries in 1990–2019.

Economic growth that is too dependent on labor and capital will experience diminishing returns [4]. Dimming returns are a condition when a production input increases with the same addition (with other inputs fixed) and reaches a certain point where the result of adding this input to the output decreases [5]. Therefore, Total Factor Productivity (TFP) must be increased to maintain long-term economic growth that can offset inputs that experience diminishing returns [6]. TFP is the proportion of output that is not explained by the amount of input used in the production process, such as technological advances [7]. Low technological progress in the production process can lead to low productivity [2]. TFP is a measure of productivity that describes the use of technology in a production process. TFP measurements that do not include environmental factors may have produced biased results [8]. Therefore, it is necessary to perform calculations to include environmental indicators that can be seen through the Green TFP measure, which can be used to evaluate sustainable development by simultaneously increasing productivity and environmental quality.

Several studies have analyzed the factors that influence Green TFP have been carried out. The results of research in China state that trade openness can increase Green TFP [9]. Internet, human capital, urbanization, energy efficiency, and external dependence have a significant positive effect on Green TFP, but government intervention has a significant negative effect in China [10]. Industry structure, energy structure, and significant opening-up degree harm inclusive Green TFP, while factor structure, labor structure, urban and rural structures, GDP per capita, the proportion of R&D, and some patents have a significant positive effect on Inclusive Green TFP [11]. Research on Green TFP in Indonesia has not been conducted yet. This is an urgent requirement for sustainable economic development. Therefore, this study examined the variables that influence Green TFP in Indonesia. Before that can be done, we must first calculate the Green TFP using an economic development model that includes environmental variables. This study is expected to contribute to the data related to the environment, which is still relatively rare in Indonesia. In addition, it is expected to provide important recommendations for sustainable development in Indonesia, which can be concurrent with linking environmental aspects as important resources in development.

Material and Methods

Data Collection

This study covers 34 provinces in Indonesia with a research period of 2015 to 2021. The dependent variable was Green TFP, which was obtained from the calculation results. In the calculation of Green TFP, the dependent variable used is Gross Regional Domestic Product (GRDP) Based on Constant Prices in 2010 in units of billions of rupiah, while the independent variable is Gross Fixed Capital Formation (GFCF) with units of billions of rupiah, the labor force with units of people (LF), and the Environmental Quality Index (EQI), with a value range of 1–100. To determine the factors that influence Green TFP, the independent variables used were the Human Development Index (HDI) with a value range of 1–100, electricity consumption in gigawatt hours (GWh) units, government spending on education in million rupiah units, industry share in percent units, capital structure calculated from the ratio of Foreign Direct Investment (FDI) and Domestic Investment to labor (in percent units), and trade openness (calculated from the ratio of total exports and imports to GRDP in percent units).

Data Analysis

Graphs and quadrant analyses were used to describe data conditions. Panel data regression is used in the first model which will be used to calculate the Green TFP value, and in the second model to determine the variables that affect Green TFP. The first stage of the panel data regression analysis in this study was based on the specification of the model used by selecting the relevant variables. The specifications of the equation model used to estimate Green TFP are as follows [12]:

$$lnGRDP_{it} = \alpha + \beta_1 lnGFCF_{it} + \beta_2 lnLF_{it} + \beta_3 EQI_{it} + \varepsilon_{it} \tag{1}$$

The Green TFP value is calculated using the coefficient value from equation (1), and the formula for calculating the Green TFP value is as follows:

$$lnGTFP_{it} = \hat{\beta}_0 + \hat{\varepsilon}_{it} = lnGRDP_{it} - \left(\hat{\beta}_i lnGFCF_{it} + \hat{\beta}_2 lnLF_{it} + \hat{\beta}_3 EQI_{it}\right) \tag{2}$$

The model used to determine the factors influencing provincial Green TFP in Indonesia is as follows.

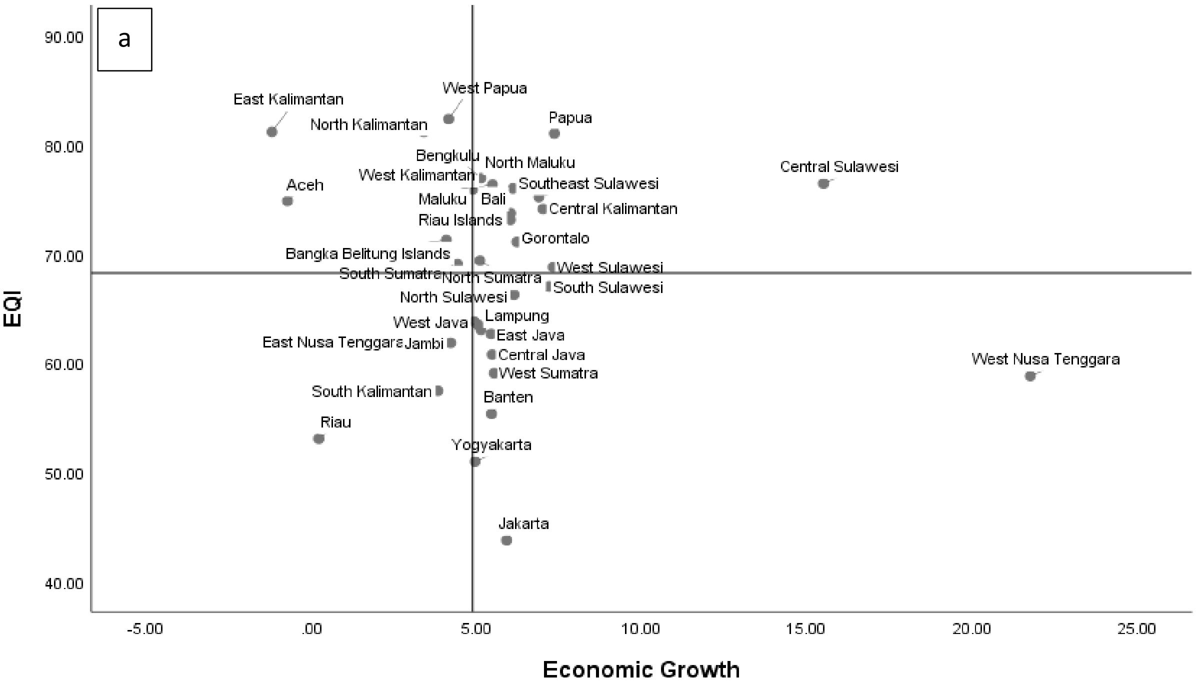
$$\begin{aligned} lnGTFP_{it} = \alpha + \beta_1 HDI_{it} + \beta_2 Education_{it} + \beta_3 Electricity_{it} + \beta_4 Manufacture_{it} \\ + \beta_5 CS_{it} + \beta_6 TO_{it} \end{aligned} \tag{3}$$

Variation of models in panel data regression, namely the Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM) [13]. Selection of the best model from these models was performed using Chow and Hausman tests. If the best model chosen is the FEM, it is necessary to test the structure of the variance-covariance matrix. Meanwhile, if the best model chosen is CEM or REM, then it is not necessary to test the structure of the variance-covariance matrix [14]. The next step is to test the classical assumptions of the selected model. Furthermore, a model that satisfies these assumptions must be tested for its significance. Finally, the results are interpreted.

Results and Discussion

Overview of Indonesia's Economic Development

Natural resources form the basis of life, and decreasing their quality of life is a challenge for economic development. Indonesia's economic development during the research period was dominated by economic growth in the western part of Indonesia, especially in Java (Figure 2). Efficient management of natural resources is indispensable and is the goal of public policy [15]. Therefore, countries must rethink their work plans to support long-term economic development in line with environmental protection [16]. Management of natural resources is necessary [17]. Figure 2 shows a quadrant analysis of Indonesia's economic growth and EQI in 2015 and 2021, which is limited by national values.



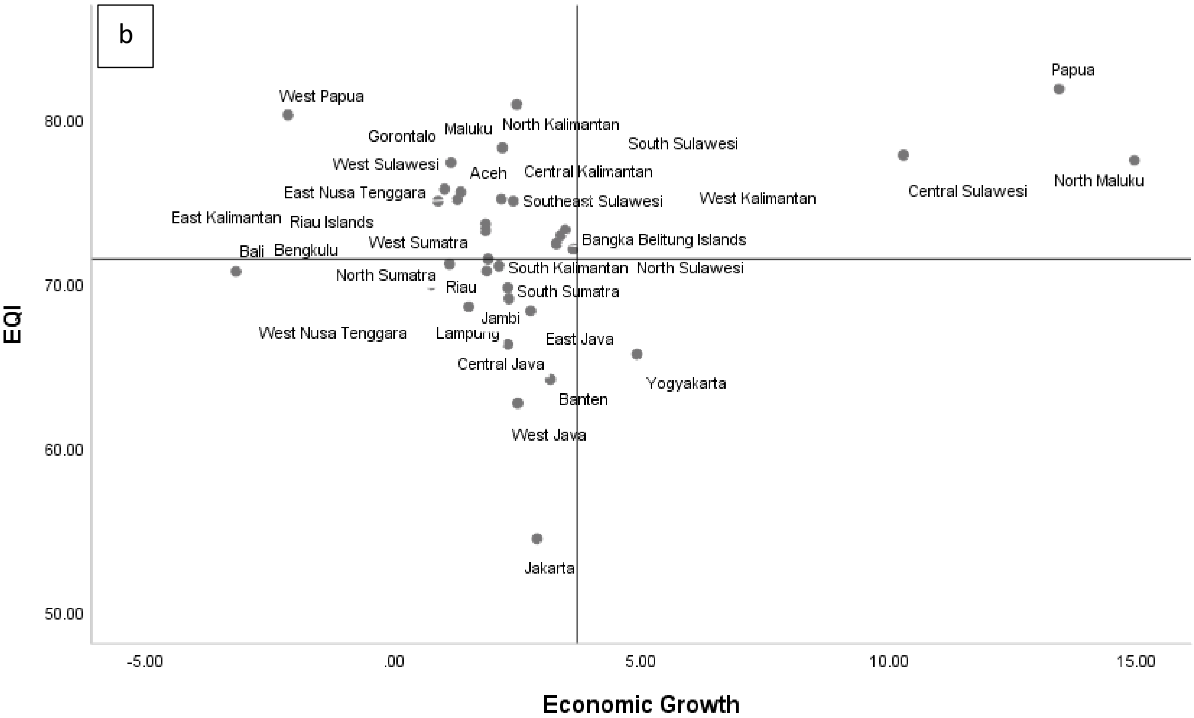


Figure 2. Quadrant analysis of economic growth (%) and Indonesia's EQI at (a) 2015 and (b) 2021.

The trade-off between economic growth and EQI occurs because of efforts to increase economic growth that harm the environment, resulting in a dilemma between efforts to increase economic growth and to maintain environmental sustainability. This condition is indicated by the areas of quadrants II and III. In 2015, most provinces in Indonesia were in quadrants I and II. Although there are provinces with high economic growth and EQI, there are still provinces that experience trade-offs between economic growth and EQI. If the conditions in 2015 were compared to those in 2021, there was an increase in provinces in quadrant II and a decrease in provinces in quadrant I. In general, there was an increase in provinces experiencing trade-offs from 17 provinces in 2015 to 19 provinces in 2021. In 2021, provinces with high economic growth and EQI, as shown in quadrant I, are reduced compared to 2015. This shows that there has been an increase in provinces that experienced trade-offs between economic growth and environmental quality.

Estimation Model of Economic Development in Indonesia

The economic development model, which includes environmental indicators, is used to obtain Green TFP values both nationally and provincially, which will later be used as the dependent variable in the next equation model. The selection of the best model using the panel data analysis method was performed using Chow and Hausman tests. The Chow test showed an F-statistic value of 143.9558 and a p-value of 0.0000. The value of the F-statistic results in a decision to reject H_0. This indicates that the FEM model is better than the CEM model. Furthermore, tests using the Hausman Test are required, resulting in the decision to reject H_0. This means that the individual effects for all the provinces in Indonesia were fixed. Thus, the FEM model performs better than the REM model.

Based on testing the best model, FEM was chosen as the best model. Therefore, it is necessary to test the structure of the residual covariance variance in the selected model to obtain the correct estimation method. The LM test results indicated a decision to reject H_0. Thus, there is sufficient evidence to say that the residuals of the variance-covariance matrix are heteroscedastic. We then proceed with the λ_{LM} test to determine whether there is a cross-sectional correlation in the residual variance-covariance matrix. The decision is to reject H_0. Thus, sufficient evidence indicates that the residual covariance matrix has cross-sectional correlation. Based on the results of testing the residual covariance variance structure, an appropriate estimation method was used, namely, the Feasible Generalized Least Square (FGLS) cross-section Seemingly Unrelated Regression (SUR) or Panel-Corrected Standard Errors (PCSE). The model shows that the characteristics of the provinces that cannot be observed in the inputs used for economic development in this study are different.

Assumptions were tested to ensure that the model was a residual normality test and non-multi-collinearity detection. The Jarque–Bera test was used to test for normality. For the detection of non-multicollinearity using the variance inflation factor (VIF) value, both assumptions were met. A test for the significance of the model was then conducted (Table 1). In the simultaneous test, an F-statistic value of 6801.286 or a p-value of 0.0000 was obtained. The value of the F-statistic is greater than the statistical value of $F_{(0,1;36,201)} = 1.3539$, so decision is to reject H_0. This result indicates that at least one independent variable in the model influences economic growth. Meanwhile, the absolute value of the t-statistic for each independent variable is greater than the statistical value $t_{(\frac{0,1}{2},201)} = 1.6525$ or the p-value is smaller than the 10% significance level. This value results in the decision to reject H_0 so that the independent variables have a partially significant effect on economic growth. The estimation results of the economic growth model, including environmental inputs, show an adjusted R^2 value of 0.9990. That is, 99.90% of the diversity in economic growth can be explained by GFCF growth, labor force growth, and EQI, while the remaining 0.10 is explained by other variables outside the model.

Table 1. Estimation results of economic growth models.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	–5.1512	1.397722	–3.6855	0.0003**
LnGFCF	0.1340	0.045109	2.9699	0.0033**
LnLF	1.0781	0.101413	10.63071	0.0000**
EQI	–0.0011	0.000689	–1.6655	0.0974**
Adjusted R-squared	0.999033			
Prob (F-*statistic*)	0.0000			

**) significant at the 10% significance level.

Based on the results of the panel data regression estimation, the economic growth model equation was as follows:

$$ln\left(\widehat{GRDP_{it}}\right) = (-5.1512 + \hat{\mu}_i) + 0.1340lnGFCF_{it} + 1.0781lnLF_{it} - 0.0011EQI_{it} \tag{4}$$

As shown in Table 1, GFCF has a significant and positive effect on GRDP, with a coefficient value of 0.1340. That is, every 1% increase in GFCF will increase the GRDP by 0.1340%, assuming, ceteris paribus. Workforce also had a significant and positive effect on GRDP, with a coefficient value of 1.0781. That is, every 1% increase in the labor force will increase the GRDP by 1.0781%, ceteris paribus. EQI as a proxy for environmental variables, has a significant and negative effect on GRDP, with a coefficient value of -0.001147. That is, every increase in the EQI score by one unit will reduce the GRDP by 0.001147 × 100 = 0.1147%. This shows that there is a trade-off between environmental quality and the GRDP in Indonesia. The Indonesian government is faced with the choice of increasing the GRDP or maintaining environmental quality.

Overview of Indonesia's Green Total Factor Productivity

Green TFP is an extension of TFP, which describes the efficiency of the production process by considering environmental quality. Green TFP, which includes environmental quality, can be used to determine the direction of development carried out by a country, whether in the long term towards sustainable development. A higher Green TFP value indicates that a country's production process is efficient and sustainable. This is because the use of technology in the production process does not worsen the environmental quality. Meanwhile, a negative Green TFP value indicates that the production process is inefficient because the increase in production output is smaller than the increase in the input used [18].

The formula used to estimate the value of provincial green TFP in Indonesia is as follows:

$$\begin{aligned} ln\left(\widehat{GTFP_{it}}\right) = (-5.1512 + \hat{\mu}_i) = ln\left(\widehat{PDB_{it}}\right) - 0.1340lnPMTB_{it} - 1.0781lnAK_{it} \\ +0.0011IKLH_{it} \end{aligned} \tag{5}$$

The development of Indonesia's Green TFP from 2015 to 2021 is shown in Figure 3. The development of the Green TFP value tends to stagnate at around 0.002, which indicates that the use of technology in the production process in Indonesia has not developed rapidly. The largest growth in Green TFP (2.5%) was observed in 2019. In that year, there was an increase in GFCF a 4.45% and that of the workforce by 1.88%.

Furthermore, Green TFP growth by 2020 decreased by 2.80%. This value showed the largest decrease during the study period. This decline was followed by GFCF, which fell by 4.96%, while the labor force continued to grow by 1.74%. This makes a part of the output that cannot be explained by conventional input or in this study, as described by Green TFP, decrease. This condition indicates that the output described by Indonesia's GDP still depends on conventional inputs and does not make good use of technological advances in the production process.

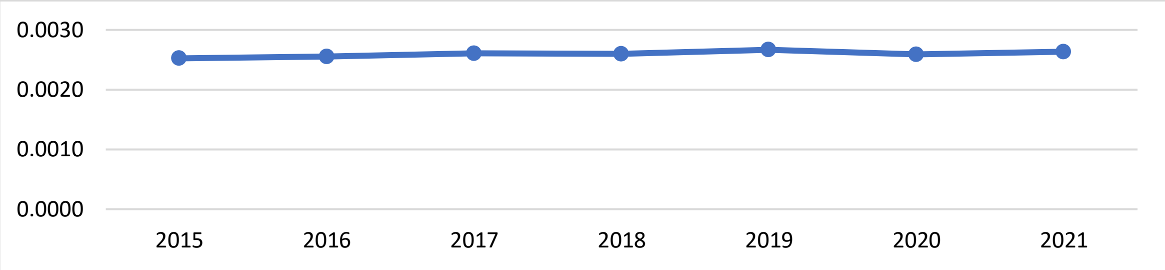


Figure 3. Trends of Indonesia's Green TFP, 2015 – 2021.

Figure 4 shows the Green TFP value by province in Indonesia in 2015 and 2021. In general, the Green TFP value in 2015 was not significantly different from that in 2021. Central Sulawesi Province has the largest growth in Green TFP value in 2021, which is 43.04% when compared to 2015. Meanwhile, the Riau Archipelago had the lowest decline in the value of Green TFP in 2021 (17.73%) compared with that in 2015. The value of provincial Green TFP in Indonesia is above the national value. However, there is a large difference in the Green TFP score between the province with the highest Green TFP score and the province with the lowest Green TFP score. This indicates that the technological progress in each province of Indonesia is not evenly distributed.

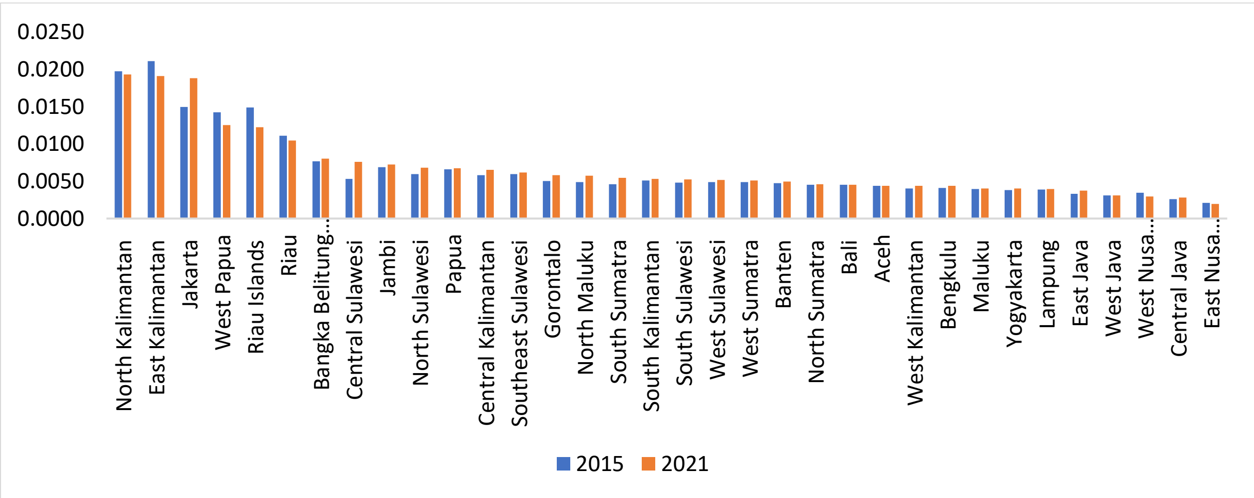


Figure 4. Green TFP by the province in Indonesia, 2021.

Overview of Determinants of Green TFP in Indonesia

This section describes the relationship between the dependent variables explained in this study and independent variables. In general, no obvious independent variable has a negative relationship with Green TFP. Green TFP and HDI were positively related. In this study, we describe human capital. The HDI explains how residents can access development outcomes in the form of income, health, and education. Nonetheless, the relationship between Green TFP and government spending on education tends to be sloping (weak linkage), although still positive. Public spending in developing countries has a great opportunity to increase, so SDGs goals are archived [19]. This study used electricity consumption variables to explain proxies in terms of the energy sources used in the production process concerning environmental management. Green TFP and electricity consumption have a negative relationship, but it is very sloping, so the relationship cannot be determined graphically. Electricity is an important and commonly used energy source in the production process, and is considered environmentally friendly for reducing carbon emissions [20].

Changes in the share of the manufacturing sector can indicate the transformation of a country's economic structure. Green TFP and manufacturing share have a positive relationship. The manufacturing sector has the largest contribution to Indonesia's GDP. If a country has a high share of processing manufacturing, it indicates that the country has experienced technological advances in production. The development of digital technology has strengthened its negative impact on carbon intensity [21]. Green TFP and capital structure had a positive relationship. Capital structure reflects the allocation of resources used, namely, capital and labor. A high capital structure indicates that an area relies more on capital as an input in the production process than on labor. This explains how technology is used in the production process. In an open economy like what happened in Indonesia, trade openness is the level of participation of a region in trade with other regions, both domestically and abroad. A high number indicates a greater trade contribution in a region; in other words, the level of regional openness is high. In this study, green TFP and trade openness show a positive relationship. A high degree of openness within a region can increase the exchange of knowledge and technology.

Determinants of Green TFP in Indonesia

Indonesia still experiences a trade-off between increasing economic growth and preserving the environment. Therefore, this research is continued by identifying the technological variables that are expected to explain the role of these variables in increasing Green TFP. The analytical method used in this section is the same as that used in the economic development model, namely, panel data. The steps taken were selecting the best model, testing the residual covariance variance structure, selecting an estimation method, testing classical assumptions, and interpretation. The best model used to determine Green TFP is FEM with a heteroscedastic variance-covariance matrix structure and cross-sectional correlation; therefore, the estimation method used is FGLS cross-section SUR. Similar to the first model, the characteristics of the Green TFP in Indonesia's province, which cannot be explained by the independent variables in the second model, are also different.

Table 2. The estimation results of the variable models that affect Green TFP.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	–6.4793	0.309461	–20.937400	0.0000*
HDI	0.0113	0.004956	2.273193	0.0241*
LnEducation	0.0103	0.004946	2.073217	0.0394*
LnElectricity	0.0288	0.010366	2.777013	0.0060*
Manufacture	0.0075	0.002796	2.692986	0.0077*
CS	–0.0163	0.004397	–3.699440	0.0003*
TO	0.0006	0.000160	3.826435	0.0002*
Adjusted R-squared	0.995526			
F-statistic	1129.758			
Prob (F-statistic)	0.0000			

*) significant at the 5% significance level.

The estimation results of the TFP Gren-determinant model are presented in Table 2, showing an F-statistic value of 1129.758 or a p-value of 0.00000. The F-value was greater than the statistical value $F_{(0,05;39,198)} = 1.4661$. That is, there is sufficient evidence that all the independent variables contained in the model simultaneously have a significant effect on Green TFP. The partial test results show that all independent variables affect Green TFP, as evidenced by the t-statistic value being greater than the $t_{\left(\frac{0,05}{2},198\right)} = 1.972$ statistics or the p-value being less than 5%. The adjusted R^2 value is 0.9946, which means that 99.46% of the variation or diversity of Green TFP can be explained by the HDI variable, government spending on education, electricity consumption, industry share, capital structure, and trade openness. The remaining 0.54% is explained by other variables outside the model. Thus, the FEM equation resulting from the estimated panel data regression is as follows:

$$\begin{aligned} ln\left(\widehat{GTFP}_{it}\right) = {} & (-6.4793 + \hat{\mu}_i) + 0.0113HDI_{it}^{*} + 0.0103lnEducation_{it}^{*} \\ & +0.0288lnElectricity_{it}^{*} + 0.0075Manufacture_{it}^{*} - 0.0163CS_{it}^{*} \\ & +0.0006TO_{it}^{*} \end{aligned} \quad (6)$$

HDI, as a proxy for human capital, has a significant effect on Green TFP with a coefficient value of 0.0113. Thus, every point increase in HDI will increase Green TFP by 0.0113 × 100 = 1.13%, assuming ceteris paribus [22]. The most important reason human capital can influence Green TFP is that high human capital can encourage innovation in energy conservation and pollution reduction, so that it can introduce clean energy and technology that enhances green economic growth [10]. Government spending on education has a significant effect on Green TFP [11]. With a regression coefficient value of 0.0103, this means that every 1% increase in government spending on education will increase Green TFP by 0.0103% in Indonesia, assuming ceteris paribus. Labor-oriented and technology-oriented government spending drive a sustainable green economy [23]. Renewable energy consumption is required to improve environmental quality [24]. Electricity consumption in Indonesia has a significant effect on Indonesia's Green TFP, with a coefficient value of 0.0288, and it can be interpreted that every 1% increase in electricity consumption will increase Green TFP by 0.0288%, assuming ceteris paribus. Significant and positive effects of electricity consumption have been reported in China [25]. These results indicate that electrical energy is clean energy, which can increase the Green TFP.

Planning and production revolutions with technological advances have mostly been conducted in the manufacturing sector [26]. This sector also dominates the Indonesian economy; therefore, the role of industry share can be used as an indication of the use of technology. Indonesia's manufacturing share has a significant effect on Green TFP, with a coefficient value of 0.0075. Every 1% increase in industry share will increase Green TFP by 0.0075 × 100 = 0.75%, assuming ceteris paribus. The significant and positive influence of industry share is due to Green TFP research in China, which is closely related to the use of technology in large quantities, so that a large share of industry to GDP can increase Green TFP [27]. The composition of the inputs used in the production process is important for determining the characteristics of the industry. Industries with a large capital composition (capital-intensive) have different behaviors compared to industries that are labor-intensive. In this study, Indonesia's capital structure had a significant effect on Green TFP, with a coefficient value of -0.0163. Thus, every 1% increase in capital structure will reduce Green TFP by 0.0163 × 100 = 1.63%, assuming ceteris paribus.

Research in the lower reaches of the Yellow River also shows that capital structure harms China's Green TFP [28], in contrast to [11]. These results indicate that the production process in Indonesia is still driven by a high number of workers compared to capital, which reflects the investment in technology in the production process. This causes an increase in the capital structure that can reduce the Green TFP in Indonesia [29]. Economic openness had no impact on the environment. Trade openness had a significant effect on Green TFP, with a coefficient value of 0.0006. This means that every 1% increase in trade openness will increase Green TFP by 0.0006 × 100 = 0.06%, assuming ceteris paribus. This result is in line with related research [9,11]. Trade openness can increase the efficiency of resource allocation, production efficiency, and stimulate further economic development. However, trade openness encourages the inclusion of green technologies, increases the possibility of cleaner production, and simultaneously improves pollution control capabilities [9]. Even trade openness facilitates the reduction of carbon emissions [30].

Conclusion

The indicators of Indonesia's economic development increased every year during the analysis period. Most provinces with the highest indicators of economic development were on Java. Indonesia's economic development still experiences a trade-off between economic growth and environmental quality. Indonesia's Green TFP value from 2015 to 2021 is stagnant in the range of 0.002, indicating that technological developments in Indonesia are still low. Provincial Green TFP values in Indonesia vary, but in general, provincial Green TFP values are above national Green TFP values. The HDI values, government spending on education, electricity consumption, industry share, capital structure, and trade openness of provinces in Indonesia vary. In general, the difference between the provinces with the highest and lowest scores on these variables was quite large. HDI variables, government spending on education, electricity consumption, industry share, capital structure, and trade openness have significant effects on Green TFP in Indonesia.

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