Determinants of Biofuels Production and Consumption, Green Economic Growth and Environmental Degradation in 6 Asia Pacific Countries: A Simultaneous Panel Model Approach

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ABSTRACT

This study aims to fill the gaps in previous research in the form of development studies between production and consumption biofuels, green economic growth and environmental degradation in 6 selected Asia Pacific countries (Australia, China, India, Indonesia, South Korea and Thailand) by considering the determinants during the period 2007-2020. This study used a simultaneous panel model approach. The important findings of this study are grouped into 4 analysis models. First, biofuels consumption, capital formation, labor and foreign direct investment have a positive effect on biofuels production. Second, biofuels production, foreign direct investment, GDP per capita and trade openness have a positive effect on biofuels consumption. Third, biofuels production, biofuels consumption and technological innovation have a positive effect on green economic growth, while militarization has a negative effect. Fourth, biofuels production, biofuels consumption, green economic growth and cleaner energy have a negative effect on environmental degradation, while population and poverty have a positive effect. The development of biofuels oil is aimed at realizing the transition from fossil-based energy to biomass-based energy which is expected to be environmentally friendly and sustainable. Biofuels oil has great potential in supporting renewable energy development to increase green economic growth and reduce environmental degradation.

Keywords: Biofuels Production, Biofuels Consumption, Green Economic Growth, Environmental Degradation, Simultaneous Panel Model, Asia Pacific
JEL Classification: C33, C51, Q21, Q43

1. INTRODUCTION

Biofuels production and consumption conditions, as well as green economic growth are very important for the formulation of energy policies and optimal environmental conditions. Climate change occurs because the use of large amounts of non-renewable energy, especially fossil fuels, will increase greenhouse gas emissions which have an impact on environmental quality such as further warming and long-term changes to the climate (Chen et al., 2019). Increasing global awareness about the issue of climate change is driven by the Kyoto Protocol agreement in 1997 which obliges industrialized countries to limit their greenhouse gas emissions and start shifting from dependence on fossil fuels to using renewable energy sources because renewable energy sources are carbon-free energy sources. Thus, increasing the share of renewable energy in total energy consumption is very effective in reducing environmental degradation (Bhat, 2018; Kang et al., 2019; Rasoulinezhad, 2018).

Within the scope of macroeconomics, energy is an input that plays an important role in economic growth affecting the growth process. It serves as a complement to labor and capital inputs. However, the trend of public consumption in the energy sector is currently still dominated by non-renewable energy sources (Dogan and Ozturk, 2017), thus the rate of growth in CO_2 emissions due to consumption of non-renewable energy has caused many problems

in environmental quality (Lau et al., 2018), as happened in the Asia Pacific group that the contribution of CO_2 emissions it produces to the world is very high compared to other groups of countries, which can be seen in Figure 1:

The information in Figure 1 shows the contribution of CO2 emissions is dominated by the member states of Asia Pacific Group by 51% of the total CO_2 emissions in the world, so Asia Pacific is a group of countries that have the potential to increase environmental degradation at the world level. Based on the phenomenon elaborated in the background, our research examines 6 countries in the Asia Pacific group for being the highest CO_2 emitters, including Australia, China, India, Indonesia, South Korea and Thailand.

The relationship between energy, environmental degradation and economic growth has been extensively investigated in the previous literature. Some empirical literature studies investigated multi-country cases using panel data and others investigated single country cases using time series analysis. First, renewable energy production studies have been carried out by Azretbergenova et al. (2021). Second, renewable energy consumption has been carried out by (Akar, 2016; Ergun et al., 2019). Third, several development studies have been carried out by examining the relationship between energy consumption and economic growth (e.g. Burakov and Freidin, 2017; Fotourehchi, 2017; Khobai, 2021; Magazzino, 2017; Rezitis and Ahammad, 2015; Umurzakov et al., 2020). Fourth, research development continues to be carried out by examining the relationship between energy consumption and economic growth and environmental quality (e.g. Banday and Aneja, 2020; Batool et al., 2021; Bozkurt and Akan, 2014; Hasnisah et al., 2019; Mbarek et al., 2017; Muhammad, 2019; Waheed et al., 2019). Fifth, several studies on green growth have recently been carried out (e.g. Hongxian, 2018; Sohag et al., 2019). The description for the development of this research will be discussed in the next section.

Based on the gaps of previous research, this study aims to analyze the relationship between biofuels production and consumption, green economic growth and environmental degradation has become an important issue for policy makers in recent years to achieve a sustainable development context. This study received special attention from researchers, policy makers and the global community for the increasing threat of global warming and climate change due to the consumption of non-renewable energy. Based on this explanation, the conditions that occur in the countries analyzed in the study can be seen in Figures 2-5:

The information displayed in Figures 2-5 shows the growth conditions for biofuels production and consumption, green economic growth and environmental degradation in 6 Asia Pacific countries for the period 2008-2020. In general, the condition that has occurred is that green economic growth for the whole country during the last 3 years has decreased which has implications for an increase in environmental degradation. However, the problem that becomes a phenomenon is that biofuels consumption tends to increase, which should contribute to increasing green economic growth and biofuels production and reducing environmental

Figure 1: Contribution of CO_2 Emissions in Different Groups of Countries to the World in 2020
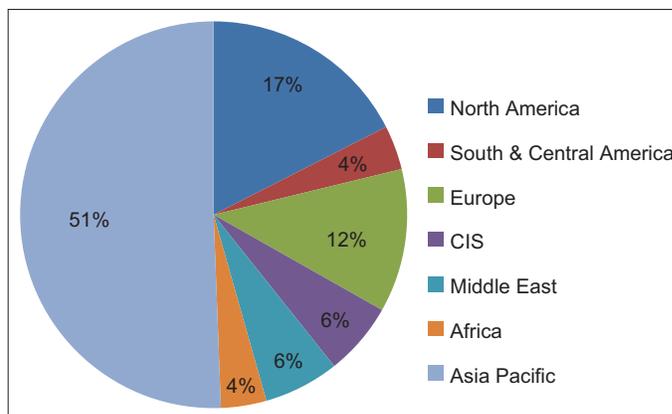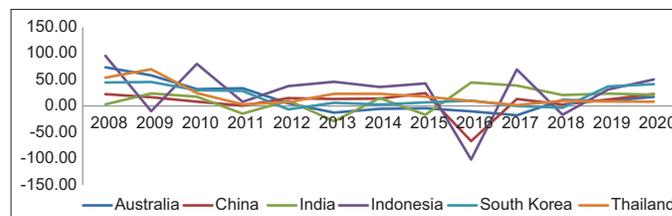
Source: BP Statistical Review of World Energy

Figure 2: Growth of biofuels production in Asia Pacific
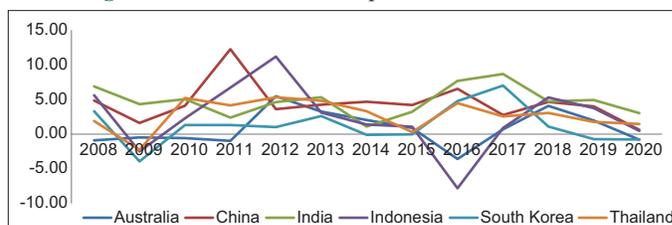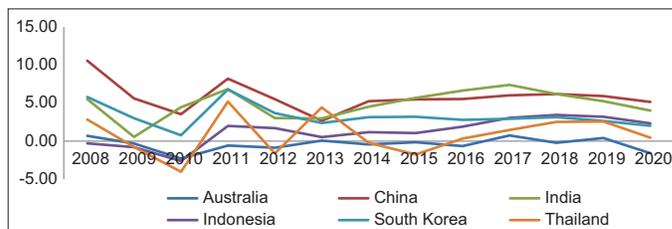
Source: BP Statistical Review of World Energy

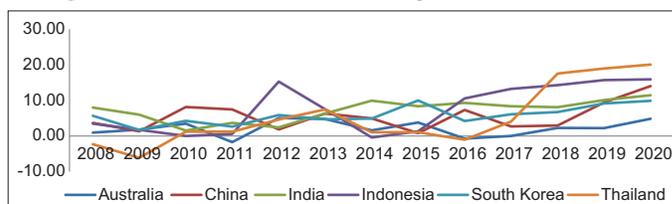**Figure 3:** Growth of biofuels consumption in Asia Pacific

Source: BP Statistical Review of World Energy

Figure 4: Green economic growth in Asia Pacific

Source: Author's work

Figure 5: Growth of environmental degradation in Asia Pacific

Source: International Energy Agency

degradation. Based on this explanation, there is an important phenomenon that requires further study, namely analyzing production and consumption biofuels, green economic growth and environmental degradation by considering the determinants that influence them.

2. LITERATURE REVIEW

This section describes the development of the relevant literature, which was mentioned in the previous section to determine the novelty of the research based on the gaps of previous research. Renewable energy production studies have been carried out by Azretbergenova et al. (2021) in 27 EU member states to explore their impact on employment for the period 2006-2019 by applying an ARDL approach. The result of the research shows that renewable energy generation has a positive effect on the absorption of labor in European Union countries in the long term. Furthermore, a study of renewable energy consumption has been carried out by (Akar, 2016; Ergun et al., 2019). Akar (2016) analyzed the determinants of renewable energy consumption in the Balkans for the period 1998-2011 by applying a panel data analysis approach. The results show that there is a negative and significant relationship between economic growth and renewable energy consumption. On the other hand, trade openness and natural gas leases certainly have a positive impact on renewable energy consumption. Ergun et al. (2019) explored the relationship between the share of renewable energy in energy consumption and social and economic variables, for a panel of 21 African countries for the period 1990-2013 by applying a random-effects generalized least squares regression approach. The result of the research is that the increase in foreign direct investment has an effect on higher integration of renewable energy. The level of democracy as measured by the Freedom House's ranking of political rights and civil liberties does not affect the level of integration of renewable energy sources.

Then, several development studies have been carried out by examining the relationship between energy consumption and economic growth (e.g. Burakov and Freidin, 2017; Fotourehchi, 2017; Khobai, 2021; Magazzino, 2017; Rezitis and Ahammad, 2015; Umurzakov et al., 2020). The study on the relationship between CO2 emissions and economic growth was carried out by (Muse, 2021) and the study on the relationship between foreign direct investment and energy consumption was conducted by (Aali-Bujari and Venegas-Martínez, 2021). Rezitis and Ahammad (2015) investigated the dynamic relationship between energy consumption and economic growth in nine South and Southeast Asian countries (Bangladesh, Brunei Darussalam, India, Indonesia, Malaysia, Pakistan, Philippines, Sri Lanka, and Thailand) for the period 1990-2012 by applying a panel vector autoregression model. The result of this research is that there is a two-way causality between energy consumption and economic growth which supports the feedback hypothesis. Burakov and Freidin (2017) explored the causal relationship between financial development, economic growth and renewable energy consumption in Russia for the period 1990-2014 by applying a vector error correction model. The result of the research is that there is a two-way causality between economic growth and financial development, while the consumption of renewable energy has no effect on economic growth or financial development. Fotourehchi (2017) analyzed renewable energy consumption and economic growth for the case of 42 developing countries for the period 1990-2012 by applying a causality test. The result of the research is that there is a long-term positive causality that runs from renewable energy to real gross domestic product (GDP).

Magazzino (2017) examined the relationship of economic growth in the consumption of renewable energy in Italy for the period 1970–2007 by applying a cointegration test. The result of this research is that there is a direct causal flow between renewable energy consumption and aggregate income which is in line with the growth hypothesis. Umurzakov et al. (2020) explored the relationship between energy and economic growth in post-communist countries for the period 1995-2014 by applying a panel cointegration test and a Dynamic OLS Panel estimation to assess the long-term relationship between the variables. The results of the study show that economic growth has a positive effect on energy consumption in post-communist countries. Economic growth leads to increased energy consumption in post-communist countries, which confirms the conservation hypothesis. Khobai (2021) analyzed renewable energy consumption and economic growth in Argentina for the period 1990-2018 by applying a multivariate cointegration analysis. The results of this research indicate that there is a unidirectional causality flowing from economic growth to renewable energy consumption. Meanwhile, (Muse, 2021) analyzed CO2 emissions and economic growth as potential determinants of renewable energy demand in Nigeria for the period 1990-2019 by applying a nonlinear autoregressive distributed lags approach. The results of the research show that the enhanced responsiveness of the consequences of climate change has led to an increase in demand for renewable energy, especially when the source of the underlying emissions comes from transportation activities. Furthermore, this study shows economic growth as another potential to explain renewable energy demand but it varies for the boom and recession phases of the business cycle. Furthermore, (Aali-Bujari and Venegas-Martínez, 2021) analyzed the relationship between foreign direct investment and energy consumption in Mexico for the period 1970-2014 by applying a cointegration approach and a Granger causality analysis. The results of this research indicate that a Granger causality from foreign direct investment to energy consumption occurs in the short term, while in the medium and long term a two-way causality takes place.

Furthermore, research development continues to be carried out by examining the relationship between energy consumption and economic growth and environmental quality (e.g. Banday and Aneja, 2020; Batool et al., 2021; Bozkurt and Akan, 2014; Hasnisah et al., 2019; Mbarek et al., 2017; Muhammad, 2019; Waheed et al., 2019). (Hasnisah et al. (2019) examined the relationship between environmental quality, economic development, renewable and non-renewable energy consumption in 13 developing countries in Asia for the period from 1980-2014 by applying a panel cointegration. The results of the study are to better understand the potential factors affecting CO2 emissions, the sample countries can design strategic plans to mitigate the rate of global warming and climate change, while stimulating economic development and

promoting energy from environmentally friendly sources. Batool et al. (2021) explored the relationship between economic growth, energy consumption, urbanization and environmental quality in ASEAN-5 countries for the period 1980-2018 by applying the Granger causality approach. The results of the study are that energy consumption, urbanization and population causes CO2 emissions. Waheed et al. (2019) examined the literature survey on economic growth, energy consumption and carbon emissions in single and multi-country countries until the period 2019. The literature survey is based on the direction of causality between economic growth and carbon emissions, economic growth and energy consumption and energy consumption and carbon emissions. First, economic growth and energy consumption are significant sources of carbon emissions; however, the role of economic growth in carbon emissions is highly reported in developing countries. On the other hand, in developed countries, carbon emissions are not related to economic development. Second, higher energy consumption increases economic growth in developing countries. For developed countries, there is less evidence of a dependency between energy consumption and economic growth. Finally, in developing and developed countries, higher energy consumption is reported as a major cause of carbon emissions.

Muhammad (2019) tested the effect of economic growth, energy consumption and CO2 emissions in 68 countries for developed countries, developing countries, and Middle East and North Africa (MENA) countries during the period 2001-2017by applying SUR, GMM and Sys GMM approaches. The results show that economic growth increases with an increase in energy consumption in developed and developing countries, while it decreases in MENA countries. CO2 emissions increase in all countries due to increased energy consumption. CO2 emissions increase while energy consumption decreases in developed and MENA countries. Bozkurt and Akan (2014) analyzed economic growth, CO2 emissions and energy consumption in Turkey for the period 1960-2010 by applying a cointegration approach. The results show that CO2 emissions have a negative effect on economic growth while energy consumption has a positive effect on economic growth. Mbarek et al. (2017) investigated the relationship between economic growth, renewable energy consumption and CO2 emissions in Tunisia for the period 1990-2015 by applying a cointegration approach. The results show that economic growth affects CO2 emissions in the short and long term. Furthermore, there is a unidirectional relationship that runs from energy use to economic growth in the short term. Banday and Aneja (2020) analyzed the relationship between energy consumption (renewable energy and non-renewable energy), economic growth and carbon dioxide emissions for Brazil, Russia, India, China and South Africa for the period 1990-2017 by applying a causal approach. The results show that there is a unidirectional causality from GDP to CO2 for India, China, Brazil, and South Africa, but there is no causality for Russia. In the case of the consumption of renewable energy and non-renewable energy against CO2 emissions, the results find convergence in India, Russia and South Africa and divergence in China and Brazil.

Finally, several studies on green growth have recently been carried out (e.g. Hongxian, 2018; Sohag et al., 2019). Hongxian

(2018) analyzed energy consumption on green growth in China for the period 1997-2016 by applying a path analysis approach. The results show that the proportion of natural gas consumption and other energy consumption are the two main drivers of green economic growth, while the proportion of coal and oil consumption inhibits green economic growth. Sohag et al. (2019) examined the role of clean energy, technological innovation and militarization of green growth in Turkey for the period 1980-2017 by applying an ARDL approach. The research found that cleaner energy and technological innovation are the driving factors for long-term green growth, while militarization is detrimental to green growth in the long term.

Considering the previous studies elaborated above, this study aims to fill in the gaps left in those studies. Most of them focused on analyzing the relationship between energy consumption, economic growth and environmental degradation without considering the exogenous variables that influence them. Meanwhile, our research adds biofuels production as the focus of research and replaces the concept of economic growth into green economic growth which has been neglected so far. In fact, the analysis of green economic growth is very important to determine the direction of policies in increasing the consumption of renewable energy as a substitute for non-renewable energy to reduce environmental degradation in order to achieve sustainable development. Furthermore, this study needs to use specific and consistent indicators to determine the role of renewable energy consumption such as biofuels oil as a substitute for non-renewable energy consumption in maintaining environmental quality. Finally, it is necessary to conduct a simultaneous analysis to determine how exogenous variables affect production and consumption biofuels, green economic growth and environmental degradation.

3. METHODOLOGY

3.1. Data and Variables

The type of data in this study is secondary data published by certain agencies. The data used is panel data with a total time series of 14 years during the period 2007-2020 and the number of cross sections is 6 selected Asia Pacific countries, namely Australia, China, India, Indonesia, South Korea and Thailand.

The variables in this study were endogenous and exogenous variables. The endogenous variables were those that were influenced by changes in the exogenous variables, including biofuels production and consumption, green economic growth and environmental degradation. Meanwhile, the exogenous variables were those that experienced such changes that they affect the endogenous variables, including capital formation, labor, foreign direct investment, GDP per capita, trade openness, technological innovation, militarization, cleaner energy, poverty and population. Nevertheless, the endogenous variables such as biofuels production and consumption and green economic growth also acted as the exogenous variables in several equations. The relationship between the variables in this study is shown in Figure 6:

Based on the research conceptual framework displayed in Figure 6, the variables used in this study were measured using certain indicators as summarized in Table 1:

Figure 6: Research conceptual framework
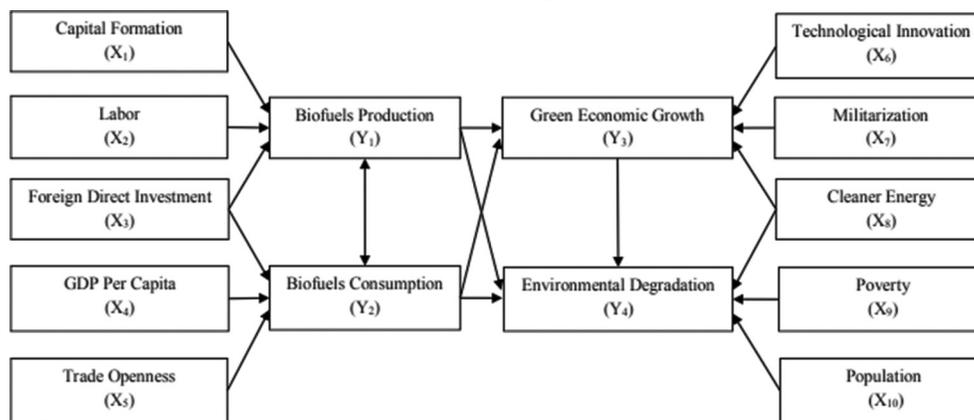
Source: Author's work

Table 1: Operational definition of the research variables

Variable	Symbol	Indicator	Source
Biofuels production	Y_1	The production of environmentally friendly fuels derived from biomass such as plants and animals whose unit of measurement is the equivalent of one thousand barrels of oil per day	BP Statistical Review of World Energy
Biofuels consumption	Y_2	The consumption of environmentally friendly fuels derived from biomass such as plants and animals whose unit of measurement is the equivalent of one thousand barrels of oil per day	BP Statistical Review of World Energy
Green economic growth	Y_3	The economic growth of cocoa separated from negative externalities to the environment, such as depreciation of natural resources and the cost of degradation to CO2 emissions whose unit of measurement is percentage	World Bank
Environmental degradation	Y_4	CO2 emissions from the production and consumption of fuel derived from petroleum as an energy source whose unit of measurement is kilo ton	International Energy Agency
Capital formation	X_1	The annual growth in gross capital formation based on the US dollar in constant 2010 prices whose unit of measurement is the percentage of GDP	World Bank
Labor	X_2	The work force aged 15 years and over that supplies labor for the production of goods and services during a certain period whose unit of measurement is the total	World Bank
Foreign direct investment	X_3	The net foreign direct investment inflows whose measurement is the percentage of GDP	World Bank
Gdp per capita	X_4	The growth rate of GDP divided by the mid-year population whose unit of measurement is percentage	World Bank
Trade openness	X_5	The total number of exports and imports of goods and services measured as a share of GDP whose unit of measurement is the percentage of GDP	World Bank
Technological innovation	X_6	The patent application filed through a patent cooperation agreement procedure to obtain an exclusive right for an environmentally friendly technology invention whose unit of measurement is the citizen patent application	World Bank
Militarization	X_7	The capital expenditures for the armed forces whose unit of measurement is the percentage of GDP	World Bank
Cleaner energy	X_8	The contribution of renewable energy to the total final energy consumption whose unit of measurement is percentage	International Energy Agency
Poverty	X_9	The percentage of the population living below the national poverty line whose unit of measurement is the percentage of the population	World Bank
Population	X_{10}	The de facto total population regardless of legal status or citizenship whose unit of measurement is the total	World Bank

3.2. Analysis Model

Based on the conceptual framework displayed in Figure 6, this study has four types of analysis models, consisting of biofuels production and consumption, green economic growth and environmental degradation. The econometric equations for the entire model are shown in equations (1) to (4) as follows:

$$\log(Y_{1it})=\alpha_{1.0}+\alpha_{1.1}\log(Y_{2it})+\alpha_{1.2}X_{1it}+\alpha_{1.3}\log(X_{2it})+\alpha_{1.4}X_{3it}+\varepsilon_{1it} \quad (1)$$

$$\log(Y_{2it})=\alpha_{2.0}+\alpha_{2.1}\log(Y_{1it}+\alpha_{2.2}X_{3it}+\alpha_{2.3}X_{4it}+\alpha_{2.4}X_{5it}+\varepsilon_{2it} \quad (2)$$

$$Y_{3it}=\alpha_{3.0}+\alpha_{3.1}\log(Y_{1it})+\alpha_{3.2}\log(Y_{2it})+\alpha_{3.3}\log(X_{6it})+\alpha_{3.4}X_{7it}+\alpha_{3.5}X_{8it}+\varepsilon_{3it} \quad (3)$$

$$\log(Y_{4it})=\alpha_{4.0}+\alpha_{4.1}\log(Y_{1it})+\alpha_{4.2}\log(Y_{2it})+\alpha_{4.3}Y_{3it}+\alpha_{4.4}X_{8it}+\alpha_{4.5}X_{9it}+\alpha_{4.6}\log(X_{10it})+\varepsilon_{4it} \quad (4)$$

Where: α is the parameter; i is the cross section; t is the time series; and ε is the error term

3.3. Data Analysis Technique
This study used a simultaneous panel model approach to achieve the predetermined research objectives. The explanation of the econometric stages of the model approach included:

3.3.1. Panel analysis
Panel regression is a panel data analysis which is a combination of time series and cross sectional data consisting of:

First, the common effect model (CEM) is the simplest panel data model approach because it only combines time series and cross section data. This model does not pay attention to the time or country dimensions, so it is assumed that the behavior of data in a country is the same in various time periods.

Second, the fixed effect model (FEM) assumes that differences between countries can be accommodated from differences in interceptions. To estimate the data, the FEM panel uses dummy variable techniques to capture intercept differences between countries, but the slop is the same between countries.

Third, the random effect model (REM) estimates panel data where the disturbance variables may be interrelated over time and between countries. In the REM model, the specific effects of each country are treated as part of the error component which is random and uncorrelated with the observed explanatory variables.

Furthermore, among the three models, it is necessary to select the most appropriate panel analysis model to be interpreted is the model was obtained through the following tests:

First, the Chow test was conducted to select whether CEM or FEM was the most appropriate model to be used. The decisions were taken by comparing the p-values of the cross-sectional chi-square at $\alpha = 0.05$. The hypothesis in this test was:

- H_0: The best model is CEM
- H_a: The best model is FEM.

Second, the Hausman test would be carried out if the Chow test results chose FEM as the best model. Then, further testing was carried out regarding whether FEM or REM was the most appropriate model to be used. The decisions were taken by comparing the p-values of random cross-section at $\alpha = 0.05$. The hypothesis in this test was:

- H_0: The best model is REM
- H_a: The best model is FEM.

Third, the Langrange multiplier test would be carried out if the Hausman test results chose REM as the best model. Then, further testing was carried out regarding whether REM or CEM was the most appropriate model to be used. The decisions were taken by comparing the p-values of the cross-sectional test hypothesis for Breusch-Pagan at $\alpha = 0.05$. The hypothesis in this test was:

- H_0: The best model is CEM
- H_a: The best model is REM.

3.3.2. Simultaneous equation analysis
Simultaneous equation is a model that has more than one equation that is interrelated and has a causal relationship between endogenous and exogenous variables, so that a variable can be expressed as an endogenous or exogenous variable in another equation. In a system of simultaneous equations containing two or more equations, it is not possible to get the numerical value of each parameter in each equation because these equations cannot be distinguished by observation or are very similar to one another. Therefore, it is necessary to carry out an identification test using order condition shown in equation (5):

$$K–k\geq m–1 \quad (5)$$

Where: M is the number of endogenous variables in the model; m is the number of endogenous variables in the equation; K is the number of predetermined variables in the model; and k is the number of the predetermined variables in the equation.

If $K–k=m–1$, this equation is identified. It is followed by the simultaneous equation estimation of an indirect least square (ILS) method.

If $K–k>m–1$, this equation is overidentified. It is followed by the simultaneous equation estimation of a two-stage least square (2SLS) method.

If $K–k<m–1$, this equation is unidentified.

The equation that can be solved using the simultaneous equation system is the equation whose results of order condition are identified and overidentified.

4. RESULTS AND DISCUSSION

4.1. Panel Analysis Results
The pre-requisite in panel analysis requires selecting the most appropriate panel data model to be interpreted. After carrying out the Chow test as the first test, all the equations in this study use CEM model whose results are shown in Table 2:

The information in Table 2 shows that the entire model has a p-value. Chi-square cross-section is more than $\alpha = 0.05$, the

Table 2: Chow's panel analysis model test results

Equation	P-values of cross-sectional Chi-square
Biofuels Production (Y_1)	0.5450
Biofuels Consumption (Y_2)	0.8555
Green Economic Growth (Y_3)	0.7264
Environmental Degradation (Y_4)	0.3625

Source: Author's work

conclusion is accept H0, which CEM is the most appropriate model to be used in all analysis models without being followed by the Hausman test and Langrange multiplier test.

4.2. Simultaneous Equation Analysis Results

The pre-requisite in simultaneous equation analysis requires performing an identification test using the order conditions shown in (6) to (9) as follows:

Equation (1)→10–3>2–1

$$7>1 \text{ (overidentified)} \tag{6}$$

Equation (2)→10–3>2–1

$$7>1 \text{ (overidentified)} \tag{7}$$

Equation (3)→10–3>3–1

$$7>2 \text{ (overidentified)} \tag{8}$$

Equation (4)→10–3>4–1

$$7>3 \text{ (overidentified)} \tag{9}$$

The identification test above informs that all the analysis models used in this study are estimated using the two-stage least square (TSLS) method because all equations are over identified.

Based on the final results of the panel analysis and simultaneous equation analysis that has been carried out in accordance with the predetermined stages, the simultaneous panel model analysis interpretation for each analysis model is shown in equations (10) to (13) as follows:

$$\log(Y_{1it})=-8.86782+0.68869 \log(Y_{2it})+0.07387 X_{1it}+0.68673$$
$$\quad (0.0000) \quad (0.0000) \quad\quad (0.0000) \quad (0.0000)$$
$$\log(X_{2it})+0.22179 X_{3it}+\varepsilon_{1it}$$
$$\quad (0.0000) \tag{10}$$

Where, the value in () is p.

Equation (10) summarizes the results of the simultaneous panel model estimation for the production of biofuels equation. Biofuels consumption, capital formation, labor and foreign direct investment have a significant effect of $\alpha = 0.01$ on biofuels production.

Biofuels consumption increases 1 percent, so biofuels production will increase by 0.6889 percent. Energy has become a basic need for society and is also the main input in producing output in the form of goods or services. Energy is no longer a commodity but a basic need whose supply availability must be prioritized in the future. The trend of using renewable energy sources such as biofuels consumption must be optimized for the coming period because it is renewable and low in air pollution. The demand for biofuels consumption in the future will increase due to the increasingly complex human needs, so this must be responded by increasing the production of biofuels. This is consistent with the results of research by Faizah and Husaeni (2018).

Capital formation increases by 1 percent, so biofuels production will increase by 0.07387 percent. High capital formation will contribute to enlarging production capacity to produce more goods and services. Increasing capital formation will require a large number of inputs, including energy sources such as biofuels production. This is consistent with the results of research by Azretbergenova et al. (2021).

Labor increases 1 percent, so biofuels production will increase by 0.68673 percent. Labor is an important input in production activities because, with their soft skills, they can produce good and higher quality output. The role of labor in production activities includes their thought and energy. Without labor, all production factors cannot be worked out because production activities are influenced by the ability of labor whose main assets are their mind and energy in carrying out the processes of economic and business activities. Without labor, a company cannot run according to the predetermined target. This is consistent with the results of research by Azretbergenova et al. (2021).

Foreign direct investment increases by 1 percent, so biofuels production will increase by 0.22179 percent. The activities carried out by foreign direct investment will have the potential to produce waste that damages the environment, so that every investor tries to avoid imposing environmental costs through the integration of renewable energy which is responded to by increasing biofuels production. This is consistent with the results of research by Doytch and Narayan (2016).

$$\log(Y_{2it})=-0.35556+1.10113 \log(Y_{1it})+0.44485 X_{3it}+0.22621$$
$$\quad (0.0856) \quad (0.0000) \quad\quad (0.0000) \quad (0.0000)$$
$$X_{4it}+0.00153 X_{5it}+\varepsilon_{2it}$$
$$\quad (0.0340) \tag{11}$$

Where, the value in () is p.

Equation (11) summarizes the results of the simultaneous panel model estimation for the biofuels consumption equation. Biofuels production, foreign direct investment, GDP per capita and trade openness have a significant effect at $\alpha = 0.01$ on biofuels consumption.

Biofuels production increases 1 percent, so biofuels consumption will increase by 1.10113 percent. Renewable energy development such as biofuels production is a priority for energy development in each country because the potential for renewable energy is abundant so that it is not exhausted. The increase in biofuels production will trigger an output expansion in a country which results in an increase in biofuels consumption. This is consistent with the results of research by Abid and Mraihi (2015).

Foreign direct investment increases by 1 percent, so biofuels consumption will increase by 0.44485 percent. Foreign direct investment is a productive asset in a country by foreign investors through the formation of capital, so that foreign direct investment activities will carry out the production process to produce output. Production activities carried out will have the potential to produce waste that can damage the environment, resulting in

environmental costs imposed on investors who carry out these investment activities. As a result, every investor tries to avoid the imposition of environmental costs through the integration of renewable energy such as biofuels consumption because it is environmentally friendly. This is consistent with the results of research by Mert and Bölük (2016)

GDP per capita increases by 1 percent, so biofuels consumption will increase by 0.22621 percent. GDP per capita acts as a benchmark for the economy, especially welfare and development, so that this makes it an important component in the economy. If a country has a high GDP per capita figure, then that country will be seen as a prosperous country. Based on the economic theory, the higher the income, the greater the expenditure for consumption will be, especially for biofuels consumption. This is consistent with the results of research by Campo and Sarmiento (2013).

Trade openness increases by 1 percent, so the biofuels consumption will increase by 0.00153 percent. Trade openness facilitates the movement and exchange of goods and services between countries for both consumption and production purposes. As long as the consumption and production of tradable goods and services involves the effective use of energy, trade openness can have a significant impact on total energy demand, particularly renewable energy such as biofuels consumption. This is consistent with the results of research by Alola et al. (2019).

$$Y_{3it} = -5.15514 + 0.71963 \log(Y_{1it}) + 0.70210 \log(Y_{2it}) + 0.67371$$
$$(0.0015) \quad (0.0826) \quad (0.0552) \quad (0.0000)$$
$$\log(X_{6it}) - 0.20208 \ X_{7it} + 0.00292 \ X_{8it} + \varepsilon_{3it} \quad (12)$$
$$(0.0037) \quad (0.9342)$$

Where, the value in () is p.

Equation (12) summarizes the results of the simultaneous panel model estimation for the green economic growth equation. Biofuels production and biofuels consumption have a significant effect at $\alpha = 0.10$ on green economic growth. Furthermore, technological innovation and militarization have a significant effect at $\alpha = 0.01$ on green economic growth. Meanwhile, cleaner energy does not have a significant effect on green economic growth.

Biofuels production increases 1 percent, so green economic growth will increase by 0.71963 percent. Biofuels production is an alternative energy for the development of various existing resources due to the increasing demand for non-renewable energy, resulting in demands for the development of resources that can be used continuously for a long time without having to be afraid of being run out and are environmentally friendly. Furthermore, the component of calculating green economic growth considers the cost of depreciation of natural resources and the cost of damage to CO2 emissions, in which biofuels production does not cause both types of costs. This is a finding from the novelty of this study.

Biofuels consumption increases 1 percent, so green economic growth will increase by 0.70210 percent. The use of biofuels consumption does not cause depreciation of natural resources and does not cause damage to CO2 emissions because the energy can

be recovered and is also environmentally friendly. Furthermore, the component of the calculation of green economic growth considers the cost of depreciation of natural resources and the cost of damage to CO2 emissions, in which biofuels consumption does not cause both types of costs. This is a finding from the novelty of this study.

Technological innovation increases by 1 percent, so green economic growth will increase by 0.67371 percent. Technological innovation is an important foundation in reducing carbon emissions through increasing efficiency and productivity of the use of non-renewable natural resources for efficient and optimal use. Technological innovation is one of the driving factors in encouraging sustainable development because efficient and environmentally friendly technology can harmonize development activities and the environment simultaneously. Furthermore, the component of the calculation of green economic growth considers the cost of depreciation of natural resources and the cost of damage to CO2 emissions, in which technological innovation will tend to reduce both types of costs. This is consistent with the results of research by Sohag et al. (2019).

Militarization increases by 1 percent, so green economic growth will decrease by 0.20208 percent. Military bases require maintenance that relies on the consumption of non-renewable natural resources and on intensive equipment from the waste of non-renewable energy resulting in environmental degradation such as the greenhouse effect and carbon emissions. Furthermore, the component of calculating green economic growth considers the cost of depreciation of natural resources and the cost of damage to CO2 emissions, so militarization will tend to increase both types of costs. This is consistent with the results of research by Sohag et al. (2019).

Cleaner energy has a positive effect but does not have a significant effect on green economic growth because the role of cleaner energy will be achieved if the contribution of renewable energy is higher than the total of final energy consumption (Sohag et al., 2019). Meanwhile, the conditions that occur in Asia Pacific, especially for the countries analyzed in this study, are that final energy consumption is still dominated by the contribution of non-renewable energy. These conditions are shown in Figures 7-12:

Based on information presented in Figures 7-12, the total final energy consumption from the sourcesin the countries analyzed in this study tends to be dominated by non-renewable energy, so the increase in cleaner energy has not contributed to the increase in green economic growth.

$$\log(Y_{4it}) = -11.20876 - 0.55319 \log(Y_{1it}) - 0.37429 \log(Y_{2it}) - 0.05042$$
$$(0.0000) \quad (0.0000) \quad (0.0002) \quad (0.0403)$$
$$Y_{3it} - 0.02521 \ X_{8it} + 0.03441 \ X_{9it} + 1.01319 \log(X_{10it}) + \varepsilon_{4it}$$
$$(13)$$
$$(0.0004) \quad (0.0286) \quad (0.0000)$$

Where, the value in () is p.

Equation (13) summarizes the results of the simultaneous panel model estimation for the environmental degradation equation.

Figure 7: Total Contribution of final energy consumption from the Source in Australia
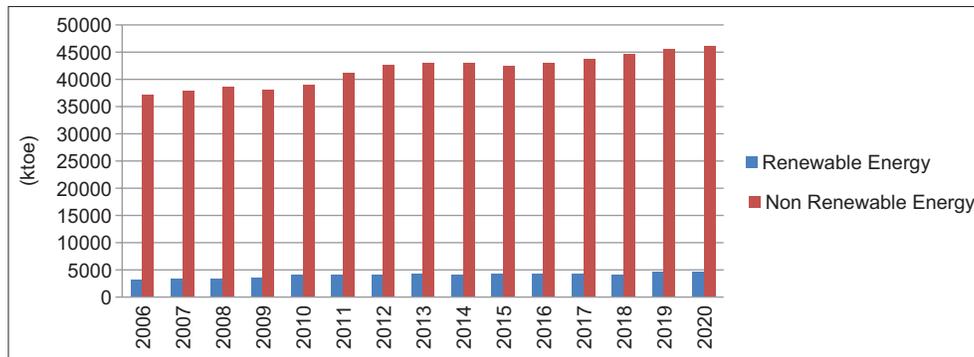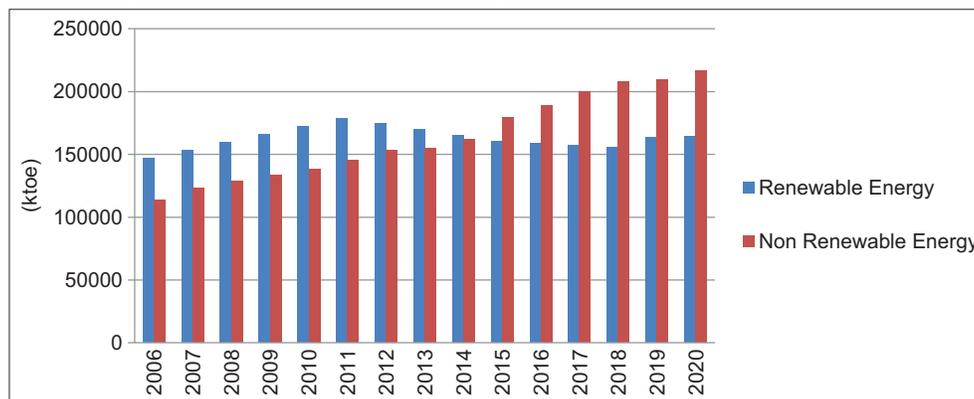

Source: International Energy Agency

Figure 8: Total contribution of final energy consumption from the Source in China
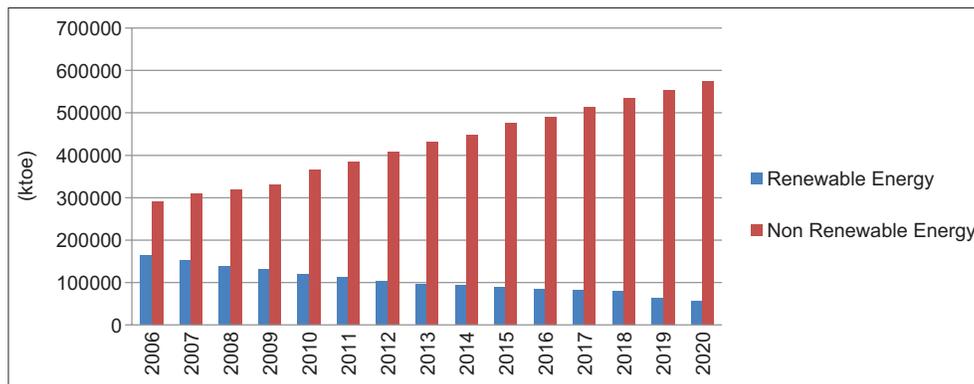
Source: International Energy Agency

Figure 9: Total contribution of final energy consumption from the Source in India

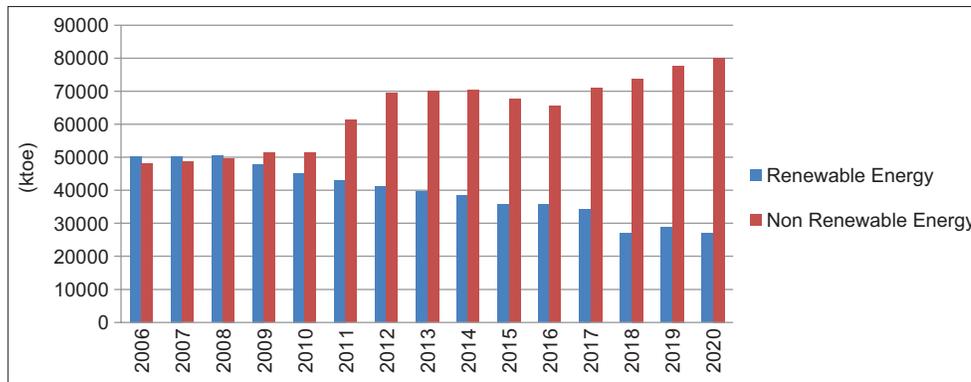Source: International Energy Agency

Biofuels production, biofuels consumption, cleaner energy and population have a significant effect at $\alpha = 0.01$ on environmental degradation. Meanwhile, green economic growth and poverty have a significant effect at $\alpha = 0.05$ on environmental degradation.

Biofuels production increases 1 percent, so environmental degradation will decrease by 0.55319 percent. The benefit of biofuels production is to help humans in dealing with environmental crises. The environment is filled with years of harmful chemical toxins and carbon dioxide emissions. This pollution also has an impact on increasing sea levels, depletion of the ozone layer, global warming, drought, and extinction of

flora and fauna. The production of renewable alternative energy such as biofuels oil can certainly reduce or even eliminate various factors that cause the decrease in the carrying capacity of the environment. This is consistent with the results of research by Cao and Pawłowski (2013).

Biofuels consumption increases 1 percent, so environmental degradation will decrease by 0.37429 percent. Biofuels oil is one of the renewable energies used today. Besides having the ability to be produced and recovered, biofuels consumption is also a solution to reduce pollution because it is environmentally friendly, is low in emissions and does not have the potential to cause environmental

Figure 10: Total contribution of final energy consumption from the source in Indonesia
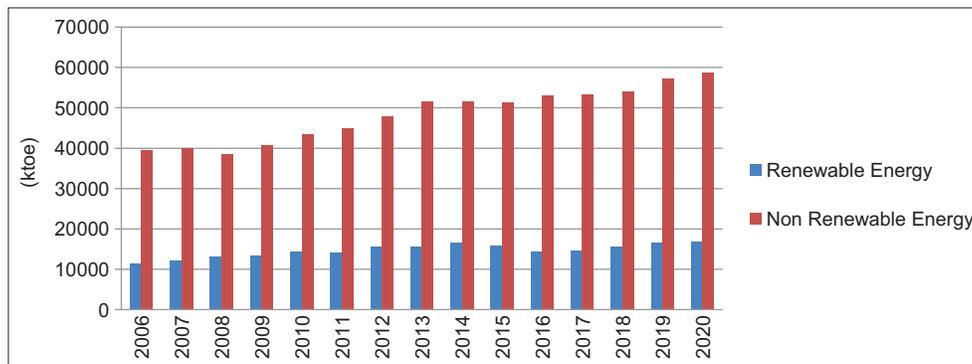

Source: International Energy Agency

Figure 11: Total contribution of final energy consumption from the Source in South Korea
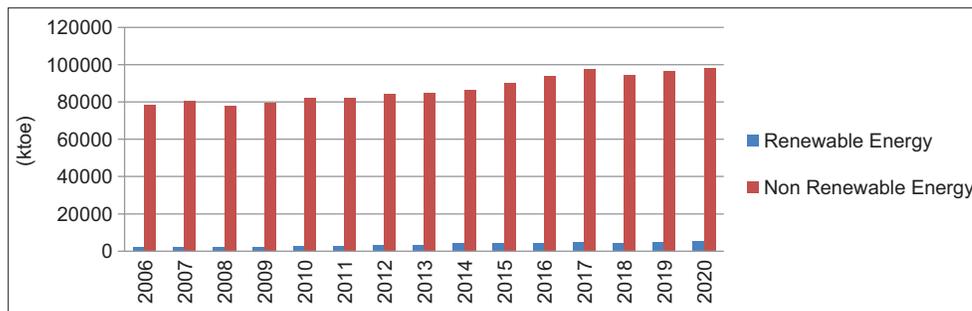
Source: International Energy Agency

Figure 12: Total contribution of final energy consumption from the Source in Thailand

Source: International Energy Agency

degradation. This is consistent with the results of research by Brini et al. (2017).

Green economic growth increases by 1 percent, so environmental degradation will decrease by 0.05042 percent. Green economic growth is economic growth that is environmentally friendly and socially inclusive which is achieved if the input used in the production process does not cause a reduction in the number of non-renewable stock of resources and does not create a cost of environmental damage that must be paid. This applies because the components of the calculation of green economic growth consider the cost of depreciation of natural resources and the cost of damage to CO2 emissions. This is a finding from the novelty of this study.

Cleaner energy increases by 1 percent, so environmental degradation will decrease by 0.02521 percent. Cleaner energy is an effort to utilize renewable energy sources and use efficient energy technology with an energy-saving culture which has implications for the use of environmentally friendly energy and does not cause environmental damage costs that must be paid and has implications for reducing environmental degradation. This is consistent with the results of research by Apergis and Payne (2012).

Poverty increases by 1 percent, so environmental degradation will increase by 0.03441 percent. The poor are very vulnerable to changes in natural resource use patterns and changes in the environment. The main problems faced by the poor are limited

access to natural resources and decline in the quality of the environment, both as a source of livelihood and as a support for their daily life. An increase in the number of poor people has also occurred due to the narrowing of land ownership and loss of livelihoods for the poor as a result of environmental quality degradation, especially forests, sea and mining areas. The poor are considered to be very dependent on the environment and natural resources to support their lives so that the environment and natural resources are still exploited without paying attention to their sustainability. This is consistent with the results of research by Kartiasih and Pribadi (2020).

The population increases by 1 percent, so environmental degradation will increase by 1.01319 percent. A high population will have an impact on the exploitation of natural resources to meet community needs which will have an impact on increasing environmental degradation. This is consistent with the results of research by Shastri et al. (2020).

5. CONCLUSION AND POLICY IMPLICATIONS

Biofuels production and consumption, green economic growth and environmental degradation are four points that cannot be separated in achieving sustainable development. So, if one of them encounters a problem, it will have an impact on imbalance in economic activities and environmental conditions. Thus, biofuels production and consumption are the main steps in carrying out environmentally friendly economic activities as reflected in the condition of green economic growth, where these three points reinforce one another in the form of positive effects to reduce environmental degradation. Biofuels oil plays an important role in overcoming the energy crisis in the future as economic activities become increasingly complex.

There are several policies that can be taken by the government in supporting the use of biofuels oil to achieve sustainable development. First, biofuels production must be developed properly through a mutually supportive policy framework, so that this condition will encourage biofuels consumption and green economic growth and reduce environmental degradation. Second, technology for production of biofuels must be advanced in order to avoid some technical problems, so that the process becomes as simple as expected. Third, in energy development activities, it is necessary to harmonize the division of affairs of the central and regional governments by providing strong policy support to promote biofuels oil through various channels, including using various technologies and using raw materials to make environmentally friendly fuels.

6. ACKNOWLEDGMENTS

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