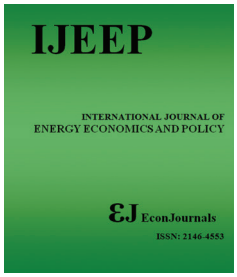

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Production, Consumption, Export and Carbon Emission for Coal Commodities: Cases of Indonesia and Australia

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ABSTRACT

The contribution of this study is to analyze the impact of a series of economic activities from the coal commodity on carbon emission. This research specifically focuses on coal exporting countries in Asia Pacific, including Indonesia and Australia during the period 2000-2022. The purpose of this study is to investigate the influence between production, consumption and export of coal and its determinants, and also the effect on carbon emission. This study applies the simultaneous equation approach and panel regression. The main findings of this study are that coal consumption, coal export, technological innovation and coal price have a positive and significant effect on coal production. Furthermore, coal production, domestic income and domestic investment have a positive and significant effect on coal consumption, while coal export has a negative and significant effect. Then, coal production and coal stock have a positive and significant effect on coal export, while coal consumption and domestic investment have a negative and significant effect. Finally, production, consumption and export of coal commodities contribute to increasing carbon emission. We recommend the coal exporting countries analyzed in this study to implement coal energy control in addressing increasing carbon emission at the global level.

Keywords: Coal Production, Coal Consumption, Coal Export, Carbon Emission
JEL Classification: C33, C51, Q21, Q43

1. INTRODUCTION

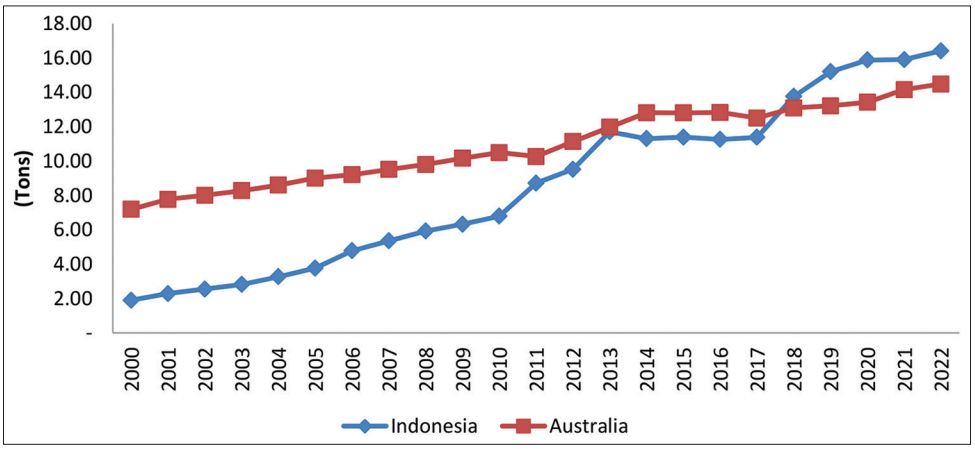
Coal is one of the world's energy drivers in the midst of efforts to shift to green energy because coal energy plays an important role as a power plant, to a staple energy source for various industries at a global level (Arinaldo and Adiatma, 2019; Cronshaw, 2015; Hudaya and Madiutomo, 2019). According to the projections of the World Energy Agency (International Energy Agency/IEA), until 2030 world energy demand will increase by 45% or an average increase of 1.6% per year, which means that around 80% of the world's energy needs will be supplied from fossil fuels, including the commodity coal (Aimon et al., 2022; Fitzpatrick, 2018). This was due to the increasing demand for the construction of power plants and industry in a number of areas driven by economic and income growth (Al-Mulali and Ozturk, 2015; Kumar and Shahbaz, 2012; Shahbaz et al., 2013).

The availability of coal energy has so far been inseparable from a series of economic activities, namely the existence of a production process and a distribution process consisting of internal and external consumption. Furthermore, if in a country the amount of coal production produced is higher than the total internal and external consumption, coal stocks will occur which will accumulate every year (Aimon et al., 2023; Qaisar and Ahmad, 2014; Shahbaz et al., 2015). This condition occurs in the Asia Pacific group of countries, namely Indonesia and Australia. The two countries in the activities of the coal trade movement only export and do not act as importers. The problem that has occurred in Indonesia and Australia over the past few years is that coal production has increased which has also been responded to by increases in domestic consumption and export (Statistical Review of World Energy, 2023). Furthermore, another phenomenon that occurs due to the rapid series of economic activities from coal

energy also causes an increase in carbon emission (World Bank, 2023). These conditions can be seen in Figures 1-4.

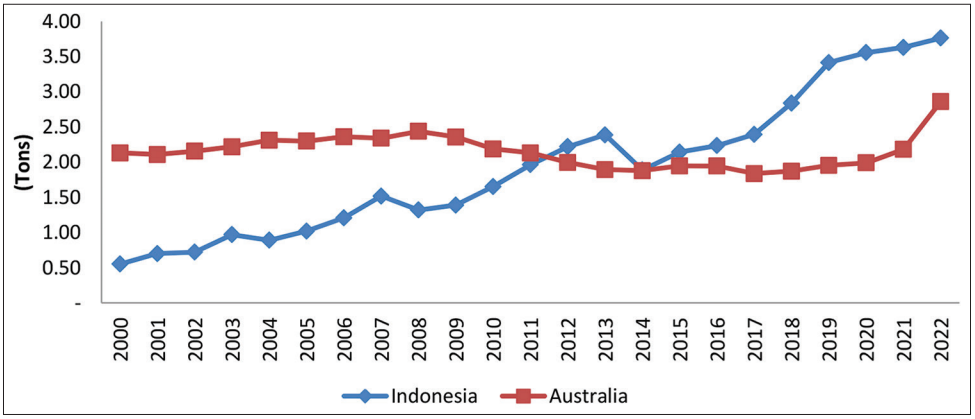
Figures 1-4 are the main focus in this study to investigate the interdependence of a series of coal energy economic activities and carbon emission. Based on the problems from Figures 1-4, a special study is needed to analyze a series of economic activities from coal energy to emission which have tended to increase over the past few years by considering several control variables such as technological innovation, coal price, coal stock, domestic income, domestic investment and real exchange rates (Aimon et al., 2021; Bildirici and Bakirtas, 2014; Bloch et al., 2015; Kim and Yoo, 2016; Kurniadi et al., 2022; Kurniawan and Managi, 2018; Lin and Jia, 2020; Raza and Shah, 2020; Rehman et al., 2021). The

Figure 1: Conditions of coal production in Indonesia and Australia



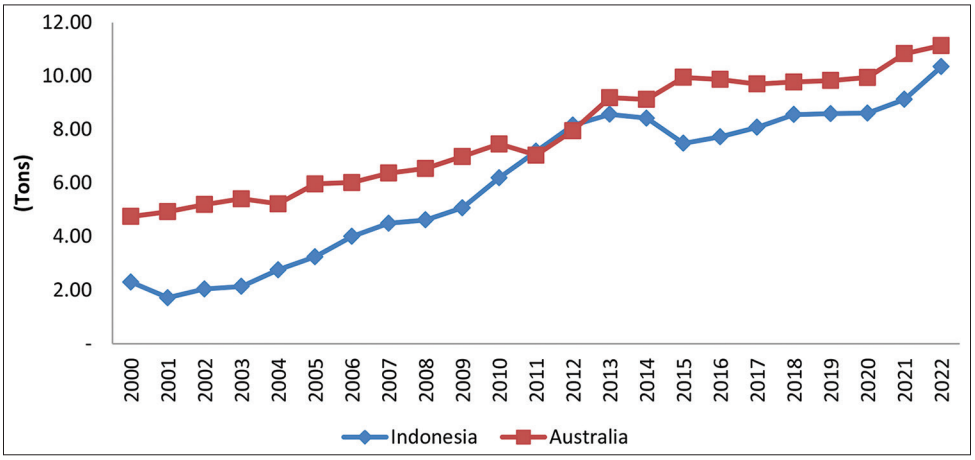
Source: Statistical Review of World Energy

Figure 2: Conditions of coal consumption in Indonesia and Australia



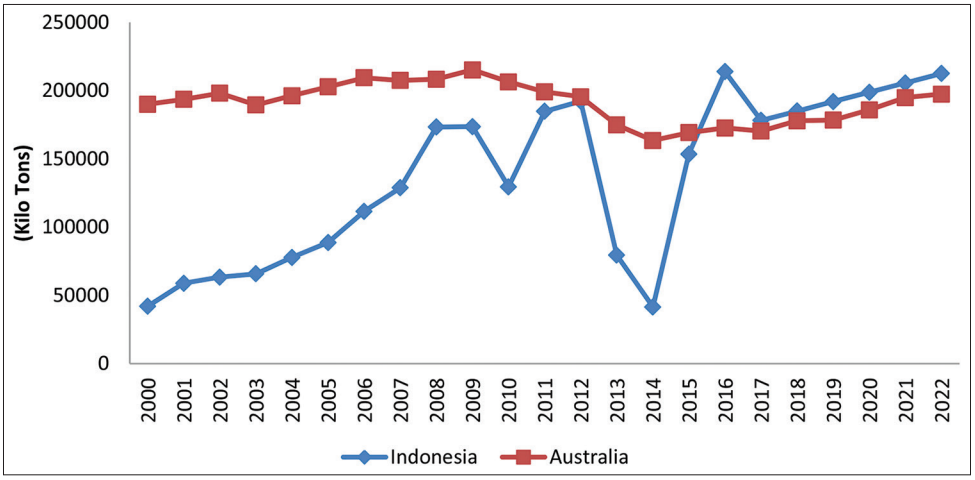
Source: Statistical Review of World Energy

Figure 3: Conditions of coal export in Indonesia and Australia



Source: Statistical Review of World Energy

Figure 4: Conditions of carbon emission in Indonesia and Australia



Source: Statistical Review of World Energy

motivation for this study is that the contribution of coal energy at the global level is very large for various aspects of life which are still difficult to replace with other energy alternatives, so that its use for the future must consider environmental elements through the formulation of policies in dealing with high emission.

2. LITERATURE REVIEW

Coal mining activities are long-term activities, which involve high technology and are capital intensive. In addition, the fundamental characteristics of the coal mining industry are clearing land and changing the landscape, so that it has the potential to have an impact on the environment. Coal mining activities are non-renewable natural resource exploitation activities because mining activities can have an impact on ecosystem damage. A damaged ecosystem is defined as an ecosystem that can no longer carry out its functions optimally as a result of the wastes generated by mining activities and their use in domestic and foreign markets. Research on the topic of coal energy and carbon emission has been carried out by various researchers. However, studies regarding the interdependence of coal energy activity ranges and carbon emission are still limited because this is the main void from previous studies. Previous researchers tended to only analyze the linkage of coal consumption to carbon emission, so they have neglected analysis for other activities of coal energy, such as coal production and coal export.

Various relevant studies related to coal commodities and carbon emission, including the impact of coal consumption and non-carbohydrate energy on carbon emission in Turkey which are associated with the Environmental Kuznets Curve (EKC) hypothesis, where the findings are that the EKC hypothesis is proven and there is an inverted U-shaped relationship between income per capita and carbon (Pata, 2018). Further research was conducted on the BRICS country group regarding modeling of coal leasing, economic growth and carbon emission, it was found that regulation on coal leasing had a positive and significant impact on carbon emission (Adedoyin, 2020). Then, a broader study was conducted for the China, India and the United States country groups to predict the relationship between solar energy production, coal consumption, GDP, and carbon emission, they found that although China and the United States had stronger sustainable development stipulations than India, but carbon emission cannot be reduced without a shift from non-renewable energy to renewable energy (Magazzino et al., 2021). Further studies were conducted for Pakistan regarding the role of economic growth and consumption of non-renewable energy, including coal commodities. The results of the study show that economic growth and energy consumption, especially coal, have a positive and significant impact on increasing environmental degradation in the short and long term (Khan et al., 2019). Furthermore, the same results are found for the impact of coal consumption on the Chinese economy, which has an impact on reducing the carrying capacity of the environment (Wang et al., 2019). Further studies were also carried out for China as an effort to achieve the carbon neutrality target by 2060, it was found that the use of coal needs to be substituted with environmentally friendly energy to support this target (Jia and Lin, 2021). Then, further studies are still being carried out for China, which analyzes the impact of carbon emission on coal use. The results of the study found that the government must implement an electricity-saving policy to reduce coal use, so that carbon emission can be reduced (Yu et al., 2014). Then, for China, a comprehensive assessment analysis of land use carbon emission from cities based on coal resources has also been carried out, it was found that land use carbon emission increased significantly and the carbon source of land use was always higher than the carbon sink due to the high use of coal energy (Wu et al., 2022). Different studies were carried out for the newly industrialized country groups consisting of Brazil, China, India, Mexico, Malaysia, the Philippines, South Africa, Turkey, India and Thailand concerning the relationship between geothermal energy and coal to carbon emission. The results of the study confirmed that it is necessary to reduce the use of coal through the energy shift towards geothermal energy (Adebayo et al., 2022). In addition, a study for the emerging industrialized seven (E7) economies also found the same result that coal energy drives increased carbon emission, so clean energy conversion is needed (Gyamfi et al., 2021).

Based on this explanation, the latest contribution of this research is to fill in the gaps in previous research, namely to examine a

series of economic activities from coal energy consisting of coal production, coal consumption, coal export in the Asia Pacific group of countries which in the coal trade movement activities only export and does not act as an importer. In addition, the urgency of this research is to examine the effect of a series of economic activities from coal energy to the level of carbon emission to produce solutions in achieving sustainable development, especially in Indonesia and Australia.

3. METHODOLOGY

3.1. Data and Variable

The data analyzed in this study are secondary data in the form of panel data, which is a combination consisting of time series data and cross section data. The time series data used are annual data for the last 23 years, namely from 2000 to 2022. Meanwhile, the cross section data used is 2, namely Indonesia and Australia as countries that focus on coal exporters in Asia Pacific. Sources of data in this study were obtained from various agencies and from the results of several sources that we believe in the validity of the data. The agencies and media in question are the Statistical Review of World Energy, the International Energy Agency, and the World Bank. Furthermore, this study focuses on four main types of variables, which consist of coal production, coal consumption, coal export and carbon emission. Besides that, this study also considers several determinants to determine the fluctuations of the main variables in this study, which are summarized in Figure 5.

The basic research framework in Figure 5 shows the relationship between the variables analyzed in this study, for which indicators have been set for each of these variables in Table 1.

3.2. Data Analysis Approach

The analysis model in this study consists of four equations, including coal production, coal consumption, coal export and carbon emission. Furthermore, the simultaneous equation approach is used to analyze a series of economic activities from coal energy (production, consumption and export), while panel regression is used to analyze carbon emission. This is in line with the research objective, which is to analyze the endogeneity test of a series of economic activities from coal energy and the exogenous variables that influence it (Equations 1 to 3). Then, this study also analyzes the effect of a series of economic activities from coal energy to carbon emission (Equation 4).

$$Y_{1it} = \alpha_1 + \alpha_2 Y_{2it} + \alpha_3 Y_{3it} + \alpha_4 X_{1it} + \alpha_5 X_{2it} + \alpha_6 X_{3it} + U_{1it} \quad (1)$$

$$Y_{2it} = \beta_1 + \beta_2 Y_{1it} + \beta_3 Y_{3it} + \beta_4 X_{2it} + \beta_5 X_{4it} + \beta_6 X_{5it} + U_{2it} \quad (2)$$

$$Y_{3it} = \gamma_1 + \gamma_2 Y_{1it} + \gamma_3 Y_{2it} + \gamma_4 X_{3it} + \gamma_5 X_{5it} + \gamma_6 X_{6it} + U_{3it} \quad (3)$$

$$Y_{4it} = \delta_1 + \delta_2 Y_{1it} + \delta_3 Y_{2it} + \delta_4 Y_{3it} + U_{4it} \quad (4)$$

Information:
α, β, γ, δ: intercepts
i: the cross section (Indonesia and Australia)
t: the time series (2000-2022)
U: residuals

The first analysis applied in this study is the simultaneous equation (Equations 1 to 3). The basic nature of the simultaneous equation model, including a set of equations where the endogenous variables in one or more equations are also exogenous variables in several other equations, so that in a system of equations a variable simultaneously has two roles, namely as an endogenous variable and an exogenous variable. Then, the simultaneous equation is a two-way equation between endogenous variables and several other endogenous variables, so that this condition describes the dependency relationship between one endogenous variable and another. The characteristic of the simultaneous equation is that the endogenous variable of an equation can be an exogenous variable from other equations in one system or model. Furthermore, the application of the simultaneous equations in this study uses the Two Stage Least Square (2SLS) equation, which is a method used to estimate the parameters of a structural equation whose estimates have more than one value or are over identified. The 2SLS method is used to obtain structural parameter values in the excess identified equations.

The second analysis applied in this study is panel regression (Equation 4). The concept of panel regression is a method used to model the effect of a predictor variable on the response variable in several observed sectors of an object of research over a certain period of time. Furthermore, to choose the most appropriate model there are several tests that can be done. First, the Chow test is a test to determine whether the Common Effect (CE) or Fixed Effect (FE) model is the most appropriate to use in estimating panel data. Second, the Hausman test is a statistical test to choose whether the FE or Random Effect (RE) model is the most appropriate to use. Third, the Lagrange Multiplier Test is a test to find out whether the RE model is better than the CE method used. Based on this explanation, a series of tests have been carried out for panel regression analysis in this study, in which the best model for interpreting panel regression in this study is FE, which assumes that differences in individuals can be accommodated from differences in intercepts. In addition, the FE approach is that an object has a constant magnitude for various time periods.

4. RESULTS AND DISCUSSION

4.1. Simultaneous Equation Analysis of Coal Production

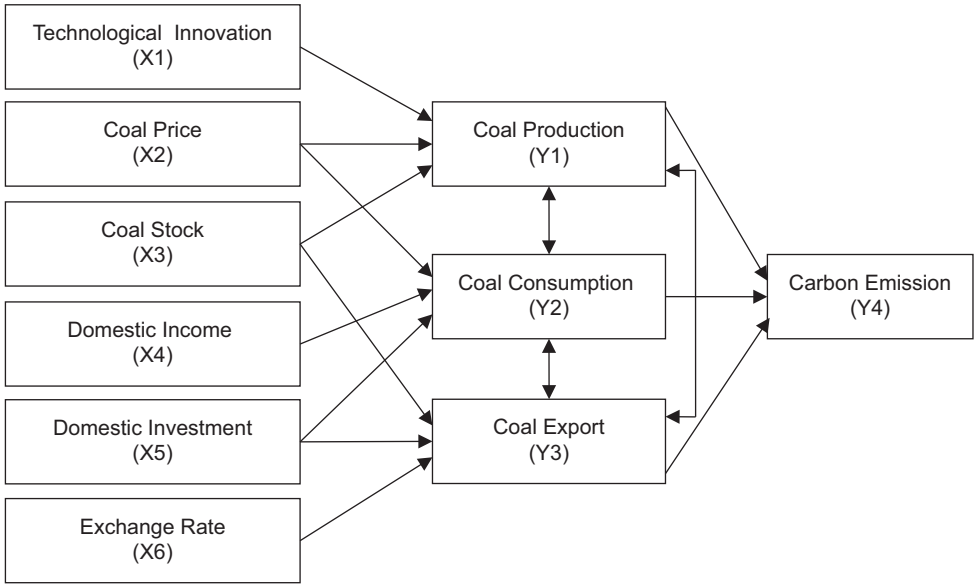
Analysis for the coal production equation and some of the determinants that influence it (coal consumption, coal export, technological innovation, coal price and coal stock) can be seen in Equation (5).

$$Y_{1it} = -2.05 + 0.32 Y_{2it}^{**} + 0.11 Y_{3it}^{**} + 0.45 X_{1it}^{**} + 0.26 X_{2it}^{*} - 0.41 X_{3it} \quad (5)$$

**significant at α=5%, * significant at α=10%

Based on Equation (5), it can be seen the significance and direction coefficient of each determinant of coal production for panels between Indonesia and Australia. First, coal consumption (Y_2) has a positive and significant effect on coal production (Y_1) in

Figure 5: Basic research framework



Source: Author's work

Table 1: Variable indicator

Variable	Indicator	Source
Coal production (Y1)	Coal production calculated in tons for Indonesia and Australia during the period 2000-2022	Statistical review of world energy
Coal consumption (Y2)	Coal consumption calculated in tons for Indonesia and Australia during the period 2000-2022	Statistical review of world energy
Coal export (Y3)	Coal export calculated in tons for Indonesia and Australia during the period 2000-2022	Statistical review of world energy
Coal emission (Y4)	Carbon dioxide emission from the use of coal as an energy source calculated in kilo tonnes for Indonesia and Australia for the period 2000-2022	Statistical review of world energy
Technological innovation (X1)	Patent applications counted in residency for Indonesia and Australia for the period 2000-2022	World bank
Coal price (X2)	Coal prices calculated in US Dollars per tonne for Indonesia and Australia during the period 2000-2022	Statistical review of world energy
Coal stock (X3)	The difference between coal production to coal consumption and coal export calculated in tons for Indonesia and Australia during the period 2000-2022	Statistical review of world energy
Domestic income (X4)	Total GDP and terms of trade adjustments calculated in constant local currencies for Indonesia and Australia over the period 2000-2022	World bank
Domestic investment (X5)	Total domestic trade investment calculated in local currency constant for Indonesia and Australia over the period 2000-2022	World bank
Exchange rate (X6)	The real effective exchange rate calculated in the index for Indonesia and Australia during the period 2000-2022	World bank

GDP: Gross domestic product

Indonesia and Australia. Coal is an important energy source for the world, which is used as a potential fuel for power generation at the global level. Coal not only generates electricity, but is also the main fuel for various industries. The strategic function of coal energy will encourage its use every year, so that it will have an impact on increasing domestic and foreign aggregates for coal energy exporting countries. In addition, the use of coal also has a very strategic role in promoting energy sovereignty and independence and increasing the competitiveness of a country's economy, so that the use of coal will open up opportunities for better regional development. In line with this, Indonesia and Australia as coal producing countries will respond to the increase in world aggregate consumption by increasing coal production. The results of this study are also supported by several relevant studies such as Nyamoga and Solberg, 2019; Soni et al. (2016), they found that coal consumption will increase coal mining exploitation activities. Second, coal export (Y_3) has a positive and significant effect on coal production (Y_1) in Indonesia and Australia. The high export of coal indicates that foreign consumers have a large aggregate demand for coal to meet their needs in supporting more advanced economic activities. The increase in coal export will be responded by coal exporting countries by increasing coal production. Furthermore, the implementation of coal export activities can increase the income of the country concerned, especially through

foreign exchange earnings from importing countries. Coal export can also increase economic growth and employment, because coal mining and its related industries can create many job vacancies. With these various multiplier effects, Indonesia and Australia as coal producing countries will respond to increased export by increasing coal production. The results of this study are also supported by relevant research such as Susanto and Admi (2021), who found that coal export will have a positive and significant effect on coal production. Third, technological innovation (X_1) has a positive and significant effect on coal production (Y_1) in Indonesia and Australia. Technological innovation is a creative process that originates from expertise or skills, which is closely related to activities to produce and modify products to provide more use in meeting market needs. Technological innovation has a close relationship with technological progress because it makes a country's economy more productive. Furthermore, with technological innovation, it will encourage coal production in a relevant manner because a technological innovation is able to make it easier for a country to adapt to current conditions, so that a country is able to survive in running its economy. Then, an increase in technological innovation will improve the efficiency of coal production, so that this condition will encourage increased productivity for coal production. The results of this study are also supported by relevant research such as Wang et al. (2019), who found that technological innovation is a driver of coal production. Fourth, coal price (X_2) has a positive and significant effect on coal production (Y_1) in Indonesia and Australia. The price of a product is one of the determining factors for the level of production by producers because an increase in product prices will push up production levels, including the commodity coal. This condition is also in line with the law of supply that when the price of output increases, it will encourage an increase in the supply of output through the production of more output. Furthermore, an increase in coal prices will motivate producers to increase coal production because of the large profits to be obtained. The results of this study are also supported by relevant studies such as Wang et al. (2020), who found that an increase in coal prices will encourage an increase in coal production. Fifth, coal stock (X_3) has a negative but not significant effect on coal production (Y_1) in Indonesia and Australia. The increase in coal stocks does not contribute to reducing coal production in Indonesia and Australia because these two countries not only meet domestic needs, but also meet foreign needs. Moreover, these two countries do not import coal, but only export coal. Based on these conditions, an increase in coal stocks does not guarantee the ability to meet coal energy needs for domestic and foreign markets because so far coal has played an important role in the world energy mix which serves as capital for the development of a country and its utilization is very wide. The results of this study are also supported by relevant studies such as Lin and Chen (2019), who found that coal stock does not contribute to coal production.

4.2. Simultaneous Equation Analysis of Coal Consumption

Analysis for the coal consumption equation and some of the determinants that influence it (coal production, coal export, coal price, domestic income and domestic investment) can be seen in Equation (6).

$$Y_{2it} = -3.71 + 0.95Y_{1it}^{*} - 0.64Y_{3it}^{**} - 0.52X_{2it} + 0.23X_{4it}^{*} + 0.89X_{5it}^{*} \quad (6)$$

** significant at α=5%, * significant at α=10%

Based on Equation (6), it can be seen the significance and direction coefficient of each determinant of coal consumption for panels between Indonesia and Australia. First, coal production (Y_1) has a positive and significant effect on coal consumption (Y_2) in Indonesia and Australia. Large coal production will tend to lead to waste and inefficiency in use, so this will trigger an increase in consumption. This condition occurs because there is an assumption that the stock of coal will increase if the production level is higher. Furthermore, this condition also does not require a shift in the transformation of coal energy to renewable energy sources due to the increase in production. Furthermore, a country's economy tends to be driven for expansion, thus requiring a large amount of coal use. The results of this study are also supported by relevant studies such as Chen et al. (2022), who found that coal production will encourage high coal use. Second, coal export (Y_3) has a negative and significant effect on coal consumption (Y_2) in Indonesia and Australia. An increase in coal export indicates that a country prioritizes the needs of foreign markets over the domestic market. This condition will lead to an efficient use of coal energy in the domestic market, so that aggregate consumption will decrease. This step was taken because coal energy is a non-renewable energy source, so to achieve the targeted export quantity, it is necessary to economize on the use of coal in the domestic market. The results of this study are also supported by relevant studies such as Wu and Zhang (2016), who found that an increase in coal export will have an impact on a decrease in domestic coal consumption. Third, coal price (X_2) has a negative but not significant effect on coal consumption (Y_2) in Indonesia and Australia. The price of coal does not affect coal consumption because the development of alternative energy for coal is not yet optimal. When coal prices increase, economic actors do not have sufficient choices to substitute their energy needs. This condition causes coal consumption not to be affected due to changes in coal prices. Moreover, coal energy is the main energy in driving a country's economic activities. The results of this study are also supported by relevant studies such as Bhattacharya et al. (2015), who found that an increase in coal prices does not contribute to a decrease in coal consumption. Fourth, domestic income (X_4) has a positive and significant effect on coal consumption (Y_2) in Indonesia and Australia. An increase in domestic income indicates that there is an increase in the welfare and purchasing power of a country, in which this condition will encourage economic expansion to offset the increase in aggregate demand for output. Furthermore, this will also encourage an aggregate increase in coal consumption to boost production in order to produce an increase in output. The results of this study are also supported by relevant research such as Magazzino et al. (2020), who found that high domestic income will encourage coal consumption. Fifth, domestic investment (X_4) has a positive and significant effect on coal consumption (Y_2) in Indonesia and Australia. Increased domestic investment means an increase in economic activity such as the development of various industries. The implementation of activities to increase the industry

requires various factors of production, including natural resources in the form of the coal energy sector. Coal's role in supporting domestic investment includes being the cheapest primary energy for power generation, industrial supporting fuel and economically valuable liquid fuel. The results of this study are also supported by relevant research such as Liu et al. (2017), who found that domestic investment activities will encourage the use of coal energy.

4.3. Simultaneous Equation Analysis of Coal Export

Analysis for the coal export equation and some of the determinants that influence it (coal production, coal consumption, coal stock, domestic investment and exchange rate) can be seen in Equation (7).

$$Y_{3it} = -1.15 + 0.17Y_{1it}^{**} - 0.77Y_{2it}^{*} + 0.20X_{3it}^{*} - 0.16X_{5it}^{**} - 0.93X_{6it} \quad (7)$$

**significant at α=5%, *significant at α=10%

Based on Equation (7), it can be seen the significance and direction coefficient of each determinant of coal export for panels between Indonesia and Australia. First, coal production (Y_1) has a positive and significant effect on coal export (Y_3) in Indonesia and Australia. An increase in coal production will produce a large quantity of coal, in which this condition will not only meet the needs of domestic consumption but also foreign consumption. In particular, Indonesia and Australia are countries that have specifications for coal export, so that large coal production is also a source of foreign exchange for them to improve economic conditions for the better. The results of this study are also supported by relevant studies such as Bai et al. (2018), who found that an increase in coal production will increase the quantity for coal export to foreign markets. Second, coal consumption (Y_2) has a negative and significant effect on coal export (Y_3) in Indonesia and Australia. When coal consumption increases, this condition will reduce the quantity for export activities. This happened because the governments of Indonesia and Australia prioritized the needs for the domestic market over the needs for foreign markets. Furthermore, the increase in coal energy consumption in the domestic market has reduced the quantity for export activities. The results of this study are also supported by relevant research such as Wang et al. (2020), who found that increasing the use of coal in the domestic market will reduce the quantity of coal export. Third, coal stock (X_3) has a positive and significant effect on coal export (Y_3) in Indonesia and Australia. Conceptually, coal stock is an excess quantity of coal from the total production of coal produced because it is not consumed by domestic consumers. The increase in coal stock indicates that there is overproduction because the aggregate supply is greater than the aggregate demand, so that there are a number of coal commodities used as reserves. However, these reserves can be used to meet the needs of foreign markets for coal energy through export activities, so that an increase in coal production will encourage an increase in coal export. The results of this study are also supported by relevant studies such as Sunardi et al. (2023), who found that increasing the accumulation of coal stock will encourage coal export activities. Fourth, domestic investment (X_5) has a negative and significant effect on coal export (Y_3) in Indonesia and Australia. Increased domestic investment indicates that increasing domestic economic activity is due to additional investment in boosting the economy, in which this activity will also encourage an increase in the use of inputs, particularly coal energy as the main source of power generation in the domestic market. This condition causes the quantity of coal for foreign markets to decrease because the government's top priority is the domestic market. The results of this study are also supported by relevant research such as Liu et al. (2017), who found that an increase in domestic investment will reduce coal export. Fifth, the exchange rate (X_6) has a negative but not significant effect on coal export (Y_3) in Indonesia and Australia. An increase in the exchange rate indicates that a country is experiencing appreciation, so that the domestic currency has strengthened against the US dollar. As a coal commodity exporting country, an increase in the exporting country's exchange rate causes the price of coal to increase for the importing country. This condition causes a decrease in demand for coal energy for importing countries, but not significantly. This is due to the effect of their dependence on Indonesia and Australia, where the need for coal energy has a large contribution to the running of their economies. The results of this study are also supported by relevant studies such as Chi and Cheng (2016), who found that the exchange rate does not contribute to fluctuations in demand for coal by foreign markets.

4.4. Panel Regression of Carbon Emission

Analysis for the carbon emission equation and some of the determinants that influence it (coal production, coal consumption and coal export) can be seen in Equation (8).

$$Y_{4it} = -1.28 + 0.51Y_{1it}^{**} + 0.89Y_{2it}^{**} + 0.19Y_{3it}^{*} \quad (8)$$

** significant at α=5%, * significant at α=10%

Based on Equation (8), it can be seen the significance and direction coefficient of each determinant of carbon emission for panels between Indonesia and Australia. First, coal production (Y_1) has a positive and significant effect on carbon emission (Y_4) in Indonesia and Australia. Coal production activity is mining which is a pioneer of the economy because it encourages regional development, provides regional and national economic benefits, provides supporting business opportunities, builds new infrastructure, provides employment opportunities, opens isolation of remote areas and increases knowledge by transferring technology to communities around mining. However, the environmental contrast is that the existence of coal mining has an impact on decreasing air quality due to high carbon emission. In addition, coal mining also causes changes in the landscape, decreases soil fertility, poses a threat to biodiversity and decreases water quality. The results of this study are also supported by relevant studies such as Jiang et al. (2019), who found that an increase in coal production will increase carbon emission. Second, coal consumption (Y_2) has a positive and significant effect on carbon emission (Y_4). Burning coal causes the release of carbon dioxide and nitrogen oxides into the air. Both are classified as greenhouse gases that have serious impacts on nature, such as global warming and extreme climate change. Global warming that occurs for a long time can cause various other problems, such as increasing earth temperatures,

melting polar ice and depletion of the ozone layer. Furthermore, the impact of using other coals is causing sulfur in the form of sulfur gas to be oxidized, so that coal produces black carbon particles in large quantities. The results of this study are also supported by relevant research such as Kurniadi et al. (2021), who found that the use of non-renewable energy sources, including coal, tends to encourage an increase in carbon emission. Third, coal export (Y_3) has a positive and significant effect on carbon emission (Y_4). Coal commodity export activities contribute to increasing the use of coal energy, especially in foreign markets, where this condition indicates that the level of use in the form of burning coal is increasing because it facilitates other countries to use energy sources that are not environmentally friendly. The more rapid the export of non-renewable energy such as coal, it will accelerate the accumulation of carbon emission because the impact of its combustion on the environment has occurred in various countries, so that this condition encourages an increase in global emission. The results of this study are also supported by relevant studies such as Stretesky and Lynch (2009), who found that coal export activities will accelerate the increase in carbon emission at the global level.

5. CONCLUSION

Based on the analysis that we have done, coal is the main source of energy for various needs of the world community because it contributes to driving the economy of a country. However, the high use of coal energy creates a problem, especially in the environmental field due to the lack of renewable energy sources to meet the demand for industrial base loads at the global level, so that coal energy will remain a source of energy in the future. This is because the commodity coal is an important source of energy for output growth, creation of employment income and industrial growth. Based on these conditions, it is necessary to establish a policy for implementing a series of economic activities from coal energy that are environmentally sound as a solution to increasing carbon emission which have the potential to encourage environmental degradation.

Our research recommends to the governments of Indonesia and Australia as countries that focus on coal exporters to implement a sustainable development strategy for the coal mining sector, which needs to balance economic, ecological and social integration. In addition, coal mining has environmental, social and economic impacts. These three impacts can be suppressed by implementing good coal mining practices because the coal mining industry will continue in line with the increasing human civilization, so it is necessary for all parties to pay attention to encouraging the coal mining industry as an industry that can maximize positive impacts and reduce negative impacts. negatively through the concept of managing the coal mining business with a long-term perspective. Furthermore, good mining techniques need to be carried out from exploration, construction, exploitation, processing or refining, transportation to the post-operation stage. In addition, to support post-mining sustainable development, it is necessary to have a mine closure policy from the start so that it can encourage every mining activity to have the concept of structuring ex-mining land so that it is safe and still has an ecological function.

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