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Article

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Nuclear Energy Generation, Fossil Fuel Price, Energy Mix Generation, Economic Growth, FDI Inflow and CO_2 Emission: A Case Study on Developed and Developing Countries in the Asia Pacific Region

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ABSTRACT

The net-zero scenario by 2050 (NZE) is a normative scenario that sets the stage for the global energy sector to reach net-zero emissions by 2050. This research aims to explore nuclear energy generation as a potential technological change in a future power generation base load, the factors that are affected and the effects on economic growth, FDI inflow, and CO_2 emission in developed and developing countries in the Asia Pacific. The empirical analysis uses time-series data of nuclear energy generation, fossil fuel price, energy mix generation, economic growth, FDI inflow, and CO_2 emission in the period 2001 – 2021. The inferential statistical method used to analyse in this research is a component-based using SmartPLS 3.2.9. This research find that Fossil fuel prices have no significant positive effect on nuclear energy generation in developed countries, and the opposite in developing countries, while a negative not significant effect on CO_2 emission in both developed and developing countries, with a positive significant effect on economic growth in developed countries and the opposite in developing countries, with a negative significant effect on FDI inflow in developed countries and the opposite in developing countries, with a negative not significant effect on energy mix generation in developed countries and the opposite in developing countries. Nuclear energy generation has a negative not significant effect on energy mix generation in developed countries and the opposite in developing countries, with a negative not significant effect on economic growth in developed countries and the opposite in developing countries, with a positive not significant effect on FDI inflow in developed countries and the opposite in developing countries, with a positive significant effect on CO_2 emission in developed countries and the opposite in developing countries. The energy mix generation find has a negative significant effect on economic growth in developed countries and the opposite in developing countries, with a positive significant effect on FDI Inflow and CO_2 emission in both developed and developing countries. Economic growth has a negative not significant effect on CO_2 emission in both developed and developing countries. FDI inflow has a negative significant effect on CO_2 emission in developed countries and the opposite in developing countries.

Keywords: Nuclear Energy Generation, Fossil Fuel Price, Energy Mix, Economic Growth, FDI, CO_2 Emission
JEL Classifications: F21, F43, K32, L94, O11, O13, Q43

1. INTRODUCTION

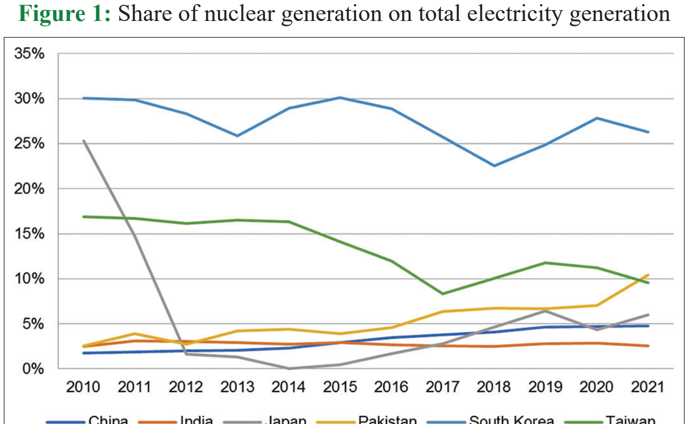
Electricity is the final energy needed by all humans both in economic activities and other general activities. Electricity can be produced from primary energy and renewable energy. There are various sources of power generation, including coal-fired power plants, gas turbines, gas engines, diesel engines, nuclear power plants, hydroelectric power plants, wind turbines, solar PV and others. The fuel used by power plants is non-renewable and some are renewable. The choice of energy mix is based on several considerations, including the investment costs of the generator, cheap fuel costs, generator reliability, and carbon emissions. Cheap fuel prices and low investment costs for generators will ultimately result in low electricity rates.

Several countries in Asia Pacific such as China, India, Japan, South Korea, Pakistan and Taiwan have Nuclear Power Plants which are already operating as one of the power plants to meet the electricity needs in their countries. The portion of nuclear power generation to total electricity generation in Asia Pacific countries in 2021 is as follows, China is 5%, India is 3%, Japan is 6%, Pakistan is 10%, South Korea is 26% and Taiwan is 10% (processed from BP Statistic, 2022). Based on Figure 1, the share of nuclear generation on total electricity generation in China has increased slightly, namely 2% in 2010 and increased to 5% in 2021. India has increased slightly, namely 2% in 2010 and increased to 3% in 2021. Japan has decreased drastically from 25% in 2010 and fell to 6% in 2021. Pakistan has a significantly increased namely 3% in 2010 and increases to 10% in 2021. South Korea has decreased from 30% in 2010 and fell to 26% in 2021. Taiwan has decreased from 17% in 2010 and fell to 10% in 2021. What's interesting here is that developed countries in Asia Pacific reduce the share of nuclear generation to total electricity generation, but developing countries tend to increase the share of nuclear generation to total electricity generation.

Levelized costs for the combined cycle gas plant is in the range 4.5–8 US cents/kWh, with a most probable value of about 5.8 US cents/kWh; for coal-fired plants the corresponding values are 4.5–6.3 US cents/kWh and 5.2 US cents/kWh and for the nuclear power plant the corresponding values are in the range 4.2-5.8 US cents/kWh and a most probable value of about 4.8 US cents/kWh (Feretic and Tomsic, 2005). Nuclear Power Plant is one of the generators that has high reliability and low generation costs compared to the cost of generation from fossil fuel power plants, especially coal. Vujić et al. (20120) capacity availability factors in the US case for coal and nuclear are 85% and 90%, respectively, the capacity availability factor for hydro is 52%, for offshore wind 34%, for solar thermal 18%, and for photovoltaic 24%.

Nuclear energy has been a huge driver of economic growth in France and at the same time, leads to an environment with lower CO_2 emissions (Marques et al., 2016). The nuclear power plant is one of the power plants that has a low LCOE with high reliability. For this reason, several countries in Asia Pacific are building new nuclear power plants. Based on data from the World Nuclear Association (2023), Numbers of Nuclear Power Plant Under Construction in the Asia Pacific Countries is as follows, in China is 21,867MWe, India is 6,028MWe, South Korea is 4,020MWe, Japan is 2,653MWe, and Bangladesh is 2,160MWe.

Figure 1: Share of nuclear generation on total electricity generation



The primary source of greenhouse gas (GHG) emissions are fossil fuels with about 66% share of global electricity generation. Despite the challenges it faces today, nuclear energy is considered an effective technology that can be used in mitigating climate change with specific characteristics that underpin the commitment of some countries to maintain it as a future option (Siqueira et al., 2019). Among the 10 SEA states, Vietnam, Indonesia and Malaysia seem to have made the greatest progress in developing their nuclear infrastructure, of these three countries, Vietnam has moved closer to building its first nuclear power plant. Between Indonesia and Malaysia, Indonesia has the highest public acceptance in nuclear power while Malaysia seems to be fighting for public support (Putra, 2017). Sustainable electricity supply is one of the drives of nation's economic development because the shortage of electricity can force hundreds of industries to close. One of the sources that play a large role in electricity generation is nuclear energy (Yoo and Ku, 2009).

Research results regarding nuclear energy consumption/generation, economic growth, FDI inflow and CO_2 are not yet conclusive. Alam (2013) found short-run causality running from CO_2 emissions to economic growth in developed countries, and both the short-run and strong-form causality estimates indicate that economic growth causes CO_2 emissions in developing countries. While Saini and Sighania (2019), cleaner FDI as a measure to mitigate the negative effects of economic growth on the ecological environment. Yoo and Ku (2009), the causal relationship between nuclear energy consumption and real GDP is not uniform across countries.

For this reason, the author feels need to conduct research on the effect of Nuclear Energy Generation on Economic Growth, FDI inflow and CO_2: A Case Study on Developed and Developing Countries in The Asia Pacific regions.

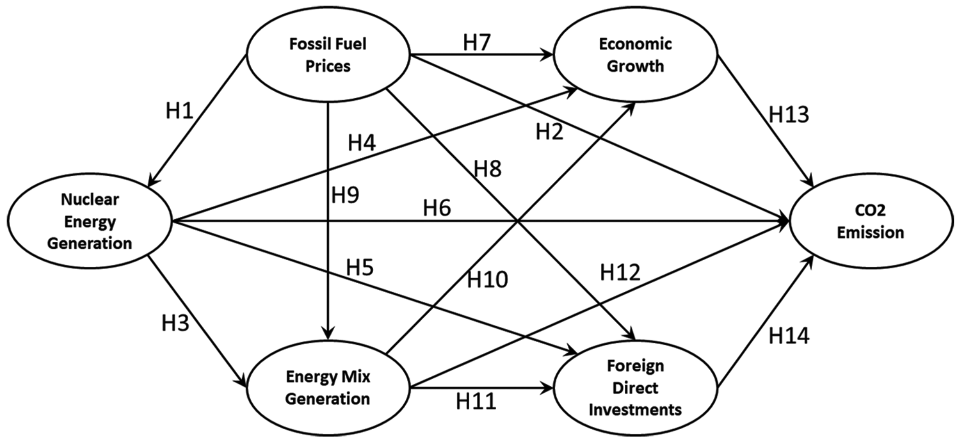
2. LITERATURE REVIEW

Energy economics is the grand theory of this research and then electricity economics theory to understand the links between energy, macro-economic, and state power. Energy is undoubtedly the key to the sustainability of the economic growth of a country. Nuclear energy is currently one of the most up-to-date and debated issues, including carbon dioxide emissions, radiation doses, energy demand and macro-economic including economic growth and FDI inflow.

2.1. Fossil Fuel Price, Nuclear Energy Generation and CO_2

Generating costs are assessed according to the Levelized Cost of Electricity (LCOE). LCOE is a very important parameter that offers the selling price at equilibrium, and it makes it possible to compare the production costs of. The LCOE describes the generation costs at the plant level (bus bar costs) and does not include transmission and distribution costs and possibly any network infrastructure adjustments (Mari, 2004). Fuel price increase sensitivity impact of a 50% increase in fuel price in generating cost is 3% on Nuclear Power Plants, 20% on Integrated

Figure 2: Research structural model



Gasification Combined Cycle coal, 22% on Coal Steam Power Plants, and 38% on Combined Cycle Gas Turbines (Brook et al., 2014). Gas Price has a significant negative effect on International Coal Demand, bidirectionally (Adi, 2022).

Linn and Muehlenbachs (2018) found that low natural gas prices increase gas-fired electricity generation, reduce coal-fired electricity generation, and reduce wholesale electricity prices. However, not all regions experience the same degree of coal-to-gas generation switching or electricity price declines. Specifically, regions experiencing more coal-to-gas switching experience smaller electricity price drops. Gao et al. (2013) found substitutability between oil and gas, and between coal and gas. Gyamfi et al. (2021) found a weak correlation between nuclear power generation with energy from oil, gas, and coal. While Malik et al. (2020) found symmetric results indicating that the oil price enhances carbon emissions in the short-run while reducing carbon emissions in the long-run in Pakistan. Oil price has a negative significant correlation with CO_2.

The relationship between nuclear power and coal and natural gas is less well documented. To the best of the researcher's knowledge, there is currently no study on the effect of fossil fuel prices on nuclear generation. This research wants to examine the effect of fossil fuel prices on nuclear electricity generation is the same as the effect of coal prices on gas prices and then on the electricity generated. Therefore, Hypothesis below is one of the novelties of this research.

2.2. Nuclear Energy Generation and Energy Mix Generation

The cross-price elasticity is substantial substitutability between oil and gas, as some units are designed to operate with either fuel, giving operators the flexibility to choose the most cost-effective fuel. Coal is used in baseload generators that never shut down, gas used as a peak fuel is not designed to run continuously, and switching fuels is costly or impossible except between coal and oil. Coal is used in baseload generators that never shut down, gas used as a peak fuel is not designed to run continuously, and switching fuels is costly or impossible except between coal and oil (Gao et al., 2013) in the US Energy mix.

Nuclear power is currently the only technology with a secure baseload electricity supply and no greenhouse gas emissions that have the potential to expand on a large scale. Another base-load electricity source - the fossil-burning power plants - although affordable, emits various air pollutants (chemical and radioactive effluents, dust, ash, etc.), which are dispersed from a power source and transported through various pathways that could lead to the general population exposure. The capacity factor is generally used to measure the plant's operational efficiency. capacity availability factors in the U.S. for coal and nuclear are 85% and 90%, respectively, the capacity availability factor for hydro is 52%, for offshore wind 34%, for solar thermal 18%, and for photovoltaic 24% (Vujić et al., (2012).

According to NEA/IEA (2015), considering a scenario of limiting temperature rise by 2°C until 2050, it will be necessary to increase the installed capacity of nuclear power plants from 396 to 930 GW, which will imply a 17% share of nuclear energy in the world's electricity production (Siqueira et al., 2019). While the empirical results also reveal the beneficial effect of nuclear energy consumption on air quality, thereby suggesting an accelerated adoption of nuclear energy in the Indian energy mix (Bandyopadhyay and Rej, 2021). Nuclear energy has a positive correlation with coal energy in Pakistan (Rehman et al., 2021).

2.3. Nuclear Energy Generation and Economic Growth

Yoo and Ku (2009) investigated the causal relationship between nuclear energy consumption and economic growth using the data from six countries among 20 countries that have used nuclear energy for more than 20 years until 2005 and found that the causal relationship between nuclear energy consumption and economic growth is not uniform across countries. In the case of Switzerland, there exists bi-directional causality between nuclear energy consumption and economic growth. This means that an increase in nuclear energy consumption directly affects economic growth, and that economic growth also stimulates further nuclear energy consumption. The uni-directional causality runs from economic growth to nuclear energy consumption without any feedback effects in France and Pakistan, and from nuclear energy to economic growth in Korea, while causality between nuclear energy consumption and economic growth in Argentina and Germany is not detected.

Nuclear energy showed a dynamic association with the economic growth (Rehman et al., 2021). Yoo and Jung (2005) found unidirectional causality runs from nuclear energy consumption to economic growth in Korea without any feedback effect, and Wolde-Rufael (2010) found a positive and a significant uni-directional causality running from nuclear energy consumption to economic growth without feedback in India. This implies that economic growth in India is dependent on nuclear energy consumption where a decrease in nuclear energy consumption may lead to a decrease in real income. Bauer et al. (2012) found indicated that early retirement of nuclear power plants leads to discounted cumulative global GDP losses of 0.07% by 2020. If, in addition, new nuclear investments are excluded, total losses will double. While Lee and Chiu (2011) found no causality between nuclear energy consumption and economic growth in the short-run.

2.4. Nuclear Energy Generation and FDI

The adoption of nuclear energy in Indian national energy portfolio may help in fulfilling the requirement of SDG-7 by inviting "international co-operation" by promoting "investment in clean energy technologies" through FDI. Moreover, full-fledged nuclear energy adoption can accelerate economic growth, FDI inflow, and international trade; on the other hand, it reduces the share of GHG emission from the energy generation process (Bandyopadhyay and Rej (2021). While several studies show the effects of investment minimization policies and the replacement of nuclear power plants with renewables (Siqueira et al., 2019).

2.5. Nuclear Energy Generation and CO_2

The need to reduce emissions interferes with fossil energy markets and leads to significant reductions in the use of coal, oil, and gas. Additional nuclear power is of only moderate importance for achieving strong emission reductions. Decommissioning existing nuclear power capacities induces a shortfall of electricity production that is partially compensated by natural gas power (Bauer et al., 2012).

Muellner et al. (2021), studied about nuclear energy as a solution to climate change, the results found that the contribution of nuclear power to mitigate climate change, and will be very limited. Currently nuclear power annually avoids 2-3% of total global GHG emissions. Lau et al. (2019) found that electricity generated by nuclear sources leads to lower CO_2 emissions without retarding the long-run growth in OECD countries. Their finding also provides important policy insights and recommendations not only for OECD countries but also for developing countries in designing appropriate energy and economic policies. Danish et al. (2022) The Driscoll-Kraay regression method reveals that nuclear energy is beneficial for the reduction of production-based CO_2 emissions. Bandyopadhyay and Rej (2021) found Nuclear Energy Consumption has as negative significant effect on CO_2 emission in the long-run but and short-run in India.

Apergis and Payne (2010) examined the relationship between nuclear energy consumption, renewable energy consumption, CO_2 emissions and economic growth. They found a negative association between nuclear energy consumption and CO_2 emissions was estimated in the long-run. In the short-run, nuclear energy consumption was observed to reduce CO_2 emissions, namely a negative association between the use of nuclear energy consumption and CO_2 emissions has been estimated in the long-run. In the short-run, the use of nuclear energy consumption reduced CO_2 emissions. While Wolde-Rufael and Menyah (2010) found uni-directional causality between the consumption of nuclear energy and CO_2 emissions. Alarm (2013) found a strong form of causality indicated the dependence of CO_2 emissions on nuclear energy consumption was seen to impact CO_2 emissions in the developed countries. Sims et al. (2003) Current nuclear power plants avoid carbon emissions of 600 Mt/year compared with using coal-fired plant to generate the same quantity of power.

2.6. Fossil Fuel Price, Economic Growth and FDI

Coal has the main position in energy structures and coal price fluctuations will not only affect the coal industry itself but also relates to the development of the national economy and social stability in China (Zhu and Wang, 2017). Oil prices have a unilateral cause-and-effect link to economic growth, energy consumption (fossil fuel) and carbon emission across all country groups in the long and short terms. (Mensah et al., 2019). While Malik et al. (2020) found that oil price has a positive significant correlation with economic growth and FDI in Pakistan.

2.7. Energy Mix, Economic Growth, FDI and CO_2 Emission

Energy mix generation has different impacts on economic growth, nuclear energy has a positive correlation with economic growth in Pakistan, but coal energy has a negative correlation with economic growth (Rehman et al., 2021). The fossil electricity has a positive relationship with economic growth and CO_2 emission in the short-run and insignificant in the long-run, while renewable electricity has a negative effect on CO_2 emission in the long-run in South American countries (Hdom, 2019). The results of another study by Oryani et al. (2020) found that renewable electricity in the energy mix in Iran had a positive impact on increasing economic growth but did not reduce lower CO_2 levels.

In almost developing countries, foreign direct investment (FDI) inflow fills the local financial gap and helps fuel the economy. The energy mix of Chinese overseas investment is analogous to the world portfolio (Li et al., 2020). Coal consumption in the South Africa energy mix has a positive significant correlation with FDI inflow (Joshua and Alola, 2020). Usman et al. (2022) found that nuclear energy production in the G7 country's energy mix has a significant positive correlation with FDI inflow, while fossil fuel energy has a not significant negative correlation with FDI inflow.

2.8. Economics Growth, FDI and CO_2 Emission

Bandyopadhyay and Rej (2021) found a J-shaped relationship between foreign direct investment inflows and CO_2 emissions in India, which indicates that the transient phase moving from pollution halo towards pollution heaven with progressive foreign direct investment development. While Adi et al. (2022) examined the Influence of Electricity Consumption of Industrial and Business, Electricity Price, Inflation and Interest Rate on GDP and Investments in Indonesia and found that GDP growth has an insignificant effect on FDI inflow in Indonesia.

Alam (2013) found short-run causality running from CO_2 emissions to economic growth was estimated in the developed countries, whereas a strong form of causality indicated the dependence of CO_2 emissions on economic growth was seen to impact CO_2 emissions. While, in developing countries, both the short-run and strong-form causality estimates indicate that economic growth causes CO_2 emissions. Apergis and Payne (2010) and Wolde-Rufael and Menyah (2010) found a bi-directional estimated causality between economic growth and CO_2 emissions. Malik et al. (2020) found symmetric results that economic growth and FDI intensify carbon emission in both the long and short-run. While Houg and Ucal (2019) found FDI has not statistically significant long-run effects on CO_2 and increases in real GDP per capita have led to reductions in CO_2 emissions in Turkey. Joshua and Alola (2020) found FDI inflow discourages carbon emission in the short-run and long-run so that a 1%increase in FDI inflow causes a reduction in CO_2 by about 0.003% and 001% in South Africa.

Based on previous studies, a summary of the findings is shown in Table 1.

3. RESEARCH METHOD AND HYPOTHESIS

This research is the kind of explanatory research that describes the influence of the dependent variable on the independent variable through hypothesis testing. The unit of analysis in this research is secondary data of China, India, Japan, South Korea, Pakistan and Taiwan, the data is represented by the countries statistical data from 2010 to 2021. Inferential statistical analysis is an analysis that focusses on the areas of analysis and interpretation of data to draw conclusions. The inferential statistical method is used to analyse the variance in this study-based or component-based with partial least square (PLS). Analysis of PLS is a multivariate statistical technique that performs multiple comparisons between the dependent variable and multiple independent variables (Adi et al., 2013).

3.1. Research Variables

The problem in this research is formulated into a simultaneous model, which is a model formed through more than one dependent variable that is explained by one or several independent variables, where the dependent variable will at the same time act as an independent variable for other tiered relationships. Verify the theoretical research model and hypotheses using the software of SmartPLS 3.2.9. PLS is a SEM tool that uses a component-based approach for estimation, so it places minimal restrictions on sample size and residual distribution and is especially useful in areas where there are weak theories and limited understanding of relationships among variables in the Tabel 2.

Variables in this research consisted of Nuclear Power Generation (X1) and Nuclear Energy Consumption (X2), Fossil Fuel Price (X3), Energy Mix Generation (X4), Economic Growth (X5), Foreign Direct Investment (X6) and CO_2 Emission (X7) with the following indicators:

3.2. Analysis Measurement Model and Hypothesis

The assessment of reflective dimension models contains three necessary tests, namely, average variance extracted (AVE) to evaluate the convergent validity (Hair et al., 2014). Composite reliability values of 0.60-0.70 in exploratory research and values from 0.70 to 0.90 in more advanced stages of research are regarded as satisfactory, whereas values below 0.60 indicate a lack of reliability (Nunnally and Bernstein, 1994).

Reflective measurement models' validity assessment focusses on convergent validity and discriminant validity. For convergent validity in this research, researchers must examine AVE. The AVE value is 0.50 and higher indicates a sufficient level of convergent validity, meaning that the latent variable explains more than half of the indicator variance. The primary evaluation criteria of the structural model are the R^2 measures and the level and significance of the path coefficients (Hair et al., 2011). Discriminant validity is the extent to which a construct is correct and distinct from other constructs by empirical standards. The Fornell–Larcker criterion is a more conservative approach to assess discriminant validity, and the square root of each construct's AVE should be higher than the highest correlation of any other construct (Hair et al., 2014).

Referring to the literature review and previous studies, the research discusses thirteen hypotheses as below:

- H1A: Fossil fuel price has a significant effect on nuclear energy generation
- H1B: Fossil fuel price has a significant effect on nuclear energy generation
- H2A: Fossil fuel price has a significant effect on CO_2 emission
- H2B: Fossil fuel price has a significant effect on CO_2 emission
- H3A: Nuclear energy generation has a significant effect on energy mix generation
- H3B: Nuclear energy generation has a significant effect on energy mix generation
- H4A: Nuclear Energy Generation has a significant effect on economic growth
- H4B: Nuclear Energy Generation has a significant effect on economic growth
- H5A: Nuclear energy generation has a significant effect on FDI inflow
- H5B: Nuclear energy generation has a significant effect on FDI inflow
- H6A: Nuclear energy generation has a significant effect on CO_2 emission
- H6B: Nuclear energy generation has a significant effect on CO_2 emission
- H7A: Fossil fuel price has a significant effect on economic growth
- H7B: Fossil fuel price has a significant effect on economic growth
- H8A: Fossil fuel price has a significant effect on FDI inflow
- H8B: Fossil fuel price has a significant effect on FDI inflow
- H9A: Fossil fuel price has a significant effect on energy mix generation
- H9B: Fossil fuel price has a significant effect on energy mix generation
- H10A: Energy mix generation has a significant effect on economic growth
- H10B: Energy mix generation has a significant effect on economic growth

Table 1: Summary finding of the selected literatures

Author (s)/year	Methodology	Finding
Adi et al. (2022)	A component-based approach to SEM	GDP growth has an insignificant effect on FDI inflow
Alam (2013)	Short-and long-run causalities	For the developed countries, short-run causality running from CO_2 emissions to economic growth was estimated, whereas strong form of causality indicated the dependence of CO_2 emissions on economic growth and nuclear energy consumption was seen to impact CO_2 emissions. For the developing countries, both the short-run and strong-form causality estimates indicate that economic growth causes CO_2 emissions
Apergis and Payne (2010)	Panel co-integration and vector error correction model	Bi-directional causality between nuclear energy consumption and economic growth in the short-run. Uni-directional long-run causality moving from nuclear energy consumption to economic growth
Bandyopadhyay and Rej (2021)	EKC framework; ARDL bounds test co-integration technique; canonical co-integration regression technique	Confirmed the existence of a J-shaped relationship between FDI inflows and CO_2 emissions GDP has as negative significant effect on CO_2 emission in the long-run but has a positive significant effect in the short-run. FDI has as negative significant effect on CO_2 emission in the long-run but has a positive significant effect in the short-run. Nuclear energy consumption has as negative significant effect on CO_2 emission in the long-run but and short-run
Gao et al. (2013)	SUR; Dynamic Hicksian conditional price elasticity and Allen elasticities	Coal is used in baseload generators and gas used as a peak fuel Substitutability between oil and gas, and between coal and gas
Haug and Ucal (2019)	ARDL	Increases in FDI have no long-run statistically significant effects on CO_2 emissions per capita Increases in real GDP per capita lowered CO_2 emissions per capita
Hdom (2019)	ADRL	The pollution has a relationship with economic growth, and the fossil electricity in short-run. Renewable energy has a negative effect on CO_2 emissions in long-run. In the long-run, fossil electricity has shown results become statistically insignificant
Lee and Chiu (2011)	Panel data analysis	Long-run causality running from economic growth to nuclear energy consumption whereas no evidence for short-run causality was estimated between the two variables
Malik et al. (2020)	ADRL	Symmetric results indicate that the oil price enhances emissions in the short-run while reducing emissions in the long-run Asymmetric results show that a rise in oil price lowers emission while a fall in oil price raises emission in the long-run
Mensah et al. (2019)	PMG panel ARDL	A unilateral cause-and-effect link from oil prices to economic growth, energy consumption (fossil fuel) and carbon emission across all country groups in the long and short terms
Oryani et al. (2020)	SVAR	Renewable had a positive impact on increasing economic growth but did not reduce lower CO_2 levels
Rehman et al. (2021)	ADRL, correlation	Nuclear energy and coal energy have a positive correlation with economic growth Nuclear energy has a positive correlation with economic growth
Usman et al. (2022)	FMOLS, DOLS, correlation	Nuclear energy production has a significant positive correlation with FDI inflow. Fossil fuel energy has a not significant negative correlation with FDI inflow
Wolde-Rufael and Menyah (2010)	Granger causality and variance decomposition approach	Uni-directional causality running from nuclear energy consumption to economic growth
Wolde-Rufael and Menyah (2010)	Granger causality	Uni-directional causality running from nuclear energy consumption to economic growth was estimated for Japan, The Netherlands and Switzerland. Reverse causality running from economic growth to nuclear energy consumption was found for Canada and Sweden, whereas bi-directional causality evidence was collected for France, Spain, the UK and the USA
Yoo and Jung (2005)	Modem time-series techniques and granger causality	Unidirectional causality runs from nuclear energy consumption to economic growth in Korea without any feedback effect
Yoo and Ku (2009)	A time-series analysis and granger-causality	Bi-directional causality between nuclear energy consumption and economic growth was estimated for Switzerland. For Pakistan and France, economic growth affected nuclear energy consumption whereas reverse causality from nuclear energy consumption to economic growth was found in the case of Korea. Argentina did not show any signs of causality evidence between the two variables

SEM: Structural equation modeling, FDI: Foreign direct investment, EKC: Kuznets curve, SUR: Seemingly unrelated regression

- H11A: Energy mix generation has a significant effect on FDI inflow
- H11B: Energy mix generation has a significant effect on FDI infloe
- H12A: Energy mix generation has a significant effect on CO_2 emission
- H12B: Energy mix generation has a significant effect on CO_2 emission
- H13A: Economic growth has a significant effect on CO_2 emission
- H13B: Economic growth has a significant effect on CO_2 emission

Table 2: Research variables and indicators

Code	Latent variable	Indicator/s		Sources
X1	Nuclear energy generation	X1.1	Nuclear generation (Terawatt-hours)	BP statistical
X2	Fossil fuel price	X2.1	Dubai spot crude prices (USD per barrel)	BP statistical
		X2.2	Brent spot crude prices (USD per barrel)	BP statistical
		X2.3	Nigerian spot crude prices (USD per barrel)	BP statistical
		X2.4	West Texas spot crude prices (USD per barrel)	BP statistical
		X2.5	Average German natural gas prices (USD per MBtu)	BP statistical
		X2.6	UK natural gas prices (USD per Mbtu)	BP statistical
		X2.7	Netherlands TTF natural gas prices (USD per MBtu)	BP statistical
		X2.8	US natural gas prices (USD per MBtu)	BP statistical
		X2.9	Canada natural gas prices (USD per MBtu)	BP statistical
		X2.10	Northwest Europe marker price (USD per tonne)	BP statistical
		X2.11	US Central Appalachian coal spot price index (USD per tonne)	BP statistical
		X2.12	Japan steam spot CIF price (USD per tonne)	BP statistical
		X2.13	China Qinhuangdao spot price (USD per tonne)	BP statistical
		X2.14	Japan coking coal import CIF price (USD per tonne)	BP statistical
		X2.15	Japan steam coal import CIF price (USD per tonne)	BP statistical
		X2.16	Asian marker price (USD per tonne)	BP statistical
X3	Energy mix generation	X3.1	Electricity generation from oil	BP statistical
		X3.2	Electricity generation from natural gas	BP statistical
		X3.3	Electricity generation from coal	BP statistical
		X3.4	Electricity generation from hydroelectric	BP statistical
		X3.5	Electricity generation from renewables	BP statistical
		X3.6	Electricity generation from other	BP statistical
X4	Economic growth	X4.1	GDP growth (%)	World bank and UNTAD
X5	FDI	X5.1	FDI inflow	World bank and UNTAD
X6	CO_2 emission	X6.1	CO_2 emission	BP statistical

FDI: Foreign direct investment

- H14A: FDI inflow has a significant effect on CO_2 emission
- H14B: FDI inflow has a significant effect on CO_2 emission.

The research structural model in this study is shown in Figure 2.

4. RESULTS AND DISCUSSIONS

4.1. Results

4.1.1. Measurement model

Before the path analysis test, we need validity and reliability tests to test if the indicator is valid and reliable for explaining each variable. Test composite reliability to assess external consistency, reliability of individual indicators, and AVE to assess the convergent validity of reflective models. If any indicators have values below the critical value, they are removed from the model. The results analysis in this research is divided into two analysis groups, namely in developed countries (Model A) and developing countries (Model B) in Asia Pacific.

4.1.2. Outer model evaluation

According to Tables 3 and 4, all indicators have a loading factor value >0.7, therefore each indicator is valid for describing a variable. In addition to the validity test, a reliable test is also required by looking at the construct's reliability value, if the construct's reliability value is >0.7, the variable is said to be reliable. The results of the reliability test showed that the construct reliability value of all variables was >0.7. Therefore, all variables were said to be reliable.

The model measurement results show that all indicators have a p-value of <0.05 so that all significant indicators measure research variables.

According to Table 3, the test results show that for the Fossil Fuel Price variable (X2), the strongest measurement indicator is the US Central Appalachian coal spot price index (X2.11) with a loading factor value of 0.914. Whereas in the Energy Mix Generation variable (X3) the strongest measurement indicator is Natural Gas (X3.2) with a loading factor value of 0.970. According to Table 4, the test results show that for the Fossil Fuel Price variable (X2), the strongest measurement indicator is the Average German Natural Gas Prices (X2.5) with a loading factor value of 0.915. Whereas in the Energy Mix Generation variable (X3) the strongest measurement indicator is Coal (X3.3) with a loading factor value of 0.978.

Explained variance values (R^2) were evaluated using a threshold of 0.25, 0.50 and 0.75, meaning small, moderate and significant, respectively (Hair et al., 2013). Referring to the Table 5, the R^2 figures for X1, X3, X4 and X5 are small, whereas X6 is substantial. The Q^2 value of model A can be calculated as follows:

$$Q^2 = 1 – (1 – 0.021) (1 – 0.023) (1 – 0. 0.449) (1 – 0.478) (1 – 0.956)$$

$$Q^2 = 0.9878953556$$

This shows that the model can explain the phenomenon studied by 98.79%.

Referring to the Table 6, the R^2 figures for X1 and X4 are small, whereas X3, X5 and X6 are substantial. The Q^2 value of model B can be calculated as follows:

$$Q2 = 1 – (1 – 0.023) (1 – 0.910) (1 – 0. 0.400) (1 – 0.842) (1 – 0.986)$$

$$Q2 = 0.9998832993$$

Table 3: Validity and reliability result model A (developed countries)

Variable	Indicator	Loading factor	P	Conclusion	Construct reliability	Conclusion
Nuclear energy generation (X1)	Nuclear energy generation (X1.1)	1.000		Valid	1.000	Reliable
Fossil fuel price (X2)	Dubai spot crude prices (X2.1)	0.867	0.000	Valid	0.969	Reliable
	Brent spot crude prices (X2.2)	0.873	0.000	Valid		
	Nigerian spot crude prices (X2.3)	0.860	0.000	Valid		
	West Texas spot crude prices (X2.4)	0.890	0.000	Valid		
	Average German natural gas prices (X2.5)	0.907	0.000	Valid		
	UK natural gas prices (X2.6)	0.779	0.000	Valid		
	Netherlands TTF natural gas prices (X2.7)	0.789	0.000	Valid		
	US natural gas prices (X2.8)	0.808	0.000	Valid		
	Canada natural gas prices (X2.9)	0.718	0.000	Valid		
	Northwest Europe marker price (X2.10)	0.890	0.000	Valid		
	US Central Appalachian coal spot price index (X2.11)	0.914	0.000	Valid		
	Japan steam spot CIF price (X2.12)	0.750	0.000	Valid		
	China Qinhuangdao spot price (X2.13)	0.793	0.000	Valid		
	Japan coking coal import CIF price (X2.14)	0.727	0.000	Valid		
	Japan steam coal import CIF price (X2.15)	0.871	0.000	Valid		
	Asian marker price (X2.16)	0.771	0.000	Valid		
Energy mix generation (X3)	Oil (X3.1)	0.719	0.000	Valid	0.931	Reliable
	Natural gas (X3.2)	0.970	0.000	Valid		
	Coal (X3.3)	0.904	0.000	Valid		
	Hydroelectric (X3.4)	0.959	0.000	Valid		
	Renewables (X3.5)	0.876	0.000	Valid		
	Other (X3.6)	0.747	0.000	Valid		
Economic growth (X4)	GDP growth (X4.1)	1.000		Valid	1.000	Reliable
FDI inflow (X5)	FDI net inflow (X5.1)	1.000		Valid	1.000	Reliable
CO_2 emission (X6)	CO_2 from energy (X6.1)	1.000		Valid	1.000	Reliable

FDI: Foreign direct investment

Table 4: Validity and reliability result model B (developing countries)

Variable	Indicator	Loading factor	P	Conclusion	Construct reliability	Conclusion
Nuclear energy generation (X1)	Nuclear energy generation (X1.1)	1.000		Valid	1.000	Reliable
Fossil fuel price (X2)	Dubai spot crude prices (X2.1)	0.864	0.000	Valid	0.969	Reliable
	Brent spot crude prices (X2.2)	0.870	0.000	Valid		
	Nigerian spot crude prices (X2.3)	0.857	0.000	Valid		
	West Texas spot crude prices (X2.4)	0.888	0.000	Valid		
	Average German natural gas prices (X2.5)	0.915	0.000	Valid		
	UK natural gas prices (X2.6)	0.806	0.000	Valid		
	Netherlands TTF natural gas prices (X2.7)	0.814	0.000	Valid		
	US natural gas prices (X2.8)	0.805	0.000	Valid		
	Canada natural gas prices (X2.9)	0.712	0.000	Valid		
	Northwest europe marker price (X2.10)	0.888	0.000	Valid		
	US Central Appalachian coal spot price index (X2.11)	0.907	0.000	Valid		
	Japan steam spot CIF price (X2.12)	0.749	0.000	Valid		
	China Qinhuangdao spot price (X2.13)	0.791	0.000	Valid		
	Japan coking coal import CIF price (X2.14)	0.700	0.000	Valid		
	Japan steam coal import CIF price (X2.15)	0.866	0.000	Valid		
	Asian marker price (X2.16)	0.768	0.000	Valid		
Energy mix generation (X3)	Oil (X3.1)	0.763	0.000	Valid	0.964	Reliable
	Natural gas (X3.2)	0.966	0.000	Valid		
	Coal (X3.3)	0.978	0.000	Valid		
	Hydroelectric (X3.4)	0.973	0.000	Valid		
	Renewables (X3.5)	0.881	0.000	Valid		
	Other (X3.6)	0.961	0.000	Valid		
Economic growth (X4)	GDP growth (X4.1)	1.000		Valid	1.000	Reliable
FDI inflow (X5)	FDI net inflow (X5.1)	1.000		Valid	1.000	Reliable
CO_2 emission (X6)	CO2 from energy (X6.1)	1.000		Valid	1.000	Reliable

FDI: Foreign direct investment

This shows that the model can explain the phenomenon studied by 99.99%.

4.2. Discussion

4.2.1. Fossil fuel price on nuclear energy generation

Referring to the Table 7, Fossil fuel price has a positive not significant effect on nuclear energy generation in developed countries, thus Hypothesis 1A is not supported. This shows when the price of fossil fuels increases, electricity generation from fossil fuel power plants will be reduced and as a substitute, electricity generation from nuclear power plants will be increased not significantly.

Referring to the Table 8, Fossil fuel price has a negative not significant effect on nuclear energy generation in developing countries, thus Hypothesis 1B is not supported. The negative effect of fossil fuel prices on nuclear energy generation shows that nuclear power generation is a substitute for fossil fuel power plants in developing countries but is not significantly, vice versa. When the fossil fuel price increases, then power generation from fossil fuel bases has decreased.

The effect of increasing fossil fuel prices on nuclear energy generation in developed countries is different from developing countries.

Table 5: Goodness of fit model A

Endogenous variables	R^2
X1 nuclear energy generation	0.021
X3 energy mix generation	0.023
X4 economic growth	0.449
X5 FDI inflow	0.478
X6 CO_2 emission	0.956

FDI: Foreign direct investment

Table 6: Goodness of fit model B

Endogenous variables	R^2
X1 nuclear energy generation	0.023
X3 energy mix generation	0.910
X4 economic growth	0.400
X5 FDI inflow	0.842
X6 CO_2 emission	0.986

FDI: Foreign direct investment

4.2.2. Fossil fuel price on CO_2 emissions

Referring to Tables 7 and 8, the fossil fuel price has a negative not significant effect on CO_2 emission in both developed and developing countries thus Hypothesis 2A and Hypothesis 2B are not supported. When the price of fossil fuels increases, the optimized power plant is a non-fossil fuel power plant with a lower CO_2 emission level, vice versa.

4.2.3. Nuclear energy generation on energy mix generation

Referring to Table 7, Nuclear energy generation has a negative not significant effect on energy mix generation in developed countries, thus Hypothesis 3A is not supported. The negative effect of nuclear energy generation on energy mix generation shows that nuclear power generation is a substitute for fossil fuel power plants in developing countries, especially when the fossil fuel price increase not significantly, vice versa.

Referring to Table 8, nuclear energy generation has a positive significant effect on energy mix generation in the developing countries, thus hypothesis 3B is supported. The positive effect of nuclear energy generation on energy mix generation shows that nuclear generation as a base load of electricity generation is the same with fossil power generation and other renewable base load generation such as hydroelectric power.

The effect of nuclear energy generation on energy mix generation in developed countries is different from developing countries.

4.2.4. Nuclear energy generation on economic growth

Referring to Table 7, Nuclear energy generation has a negative not significant effect on economic growth in developed countries, thus Hypothesis 4A is not supported. The negative effect of nuclear energy generation on economic growth shows that nuclear power generation is not the main base load of electricity generation in the Asia Pacific developed countries for supported economic growth.

Referring to the Figure 1, Nuclear energy generation experienced a decline in energy mix generation in Japan after the Fukushima nuclear disaster and started to increase slightly since 2016. Nuclear energy generation in South Korea and Taiwan fluctuates in energy mix generation and tends to have a decreasing trend from 2010 to 2021.

Table 7: Path coefficients and the significance of the structural model A (developed countries)

Path directions	Beta	t statistics	P	Hypothesis decisions
X1 nuclear energy generation → (X3) energy mix generation	−0.141	0.848	0.397	Not supported
X1 nuclear energy generation → (X4) economic growth	−0.003	0.022	0.982	Not supported
X1 nuclear energy generation → (X5) FDI inflow	0.026	0.205	0.837	Not supported
X1 nuclear energy generation → (X6) CO_2 emission	0.201	4.641	0.000	Supported
X2 fossil fuel price → (X1) nuclear energy generation	0.144	0.880	0.379	Not supported
X2 fossil fuel price → (X3) energy mix generation	−0.035	0.181	0.856	Not supported
X2 fossil fuel price → (X4) economic growth	0.348	3.088	0.002	Supported
X2 fossil fuel price → (X5) FDI inflow	−0.318	2.426	0.016	Supported
X2 fossil fuel price → (X6) CO_2 emission	−0.006	0.150	0.881	Not supported
X3 energy mix generation → (X4) economic growth	−0.555	6.286	0.000	Supported
X3 energy mix generation → (X5) FDI inflow	0.602	5.777	0.000	Supported
X3 energy mix generation → (X6) CO_2 emission	1.080	13.814	0.000	Supported
X4 economic growth → (X6) CO_2 emission	−0.014	0.338	0.735	Not supported
X5 FDI inflow → (X6) CO_2 emission	−0.182	2.337	0.020	Supported

FDI: Foreign direct investment

Table 8: Path coefficients and the significance of the structural model B (developing countries)

Path directions	Beta	t statistics	P	Hypothesis decisions
X1 nuclear energy generation → (X3) Energy mix generation	0.963	36.720	0.000	Supported
X1 nuclear energy generation → (X4) economic growth	−1.144	2.109	0.035	Supported
X1 nuclear energy generation → (X5) FDI inflow	−0.590	2.401	0.017	Supported
X1 nuclear energy generation → (X6) CO_2 emission	−0.401	2.891	0.004	Supported
X2 fossil fuel price → (X1) nuclear energy generation	−0.153	0.606	0.545	Not supported
X2 fossil fuel price → (X3) energy mix generation	0.077	1.239	0.216	Not supported
X2 fossil fuel price → (X4) economic growth	0.313	1.608	0.108	Not supported
X2 fossil fuel price → (X5) FDI inflow	0.108	1.603	0.109	Not supported
X2 fossil fuel price → (X6) CO_2 emission	−0.053	1.815	0.070	Not supported
X3 energy mix generation → (X4) economic growth	1.449	2.813	0.005	Supported
X3 energy mix generation → (X5) FDI inflow	1.456	6.767	0.000	Supported
X3 energy mix generation → (X6) CO_2 emission	0.971	6.042	0.000	Supported
X4 economic growth → (X6) CO_2 emission	−0.010	0.394	0.694	Not supported
X5 FDI inflow → (X6) CO_2 emission	0.417	5.722	0.000	Supported

FDI: Foreign direct investment

Referring to Table 8, Nuclear energy generation has a negative significant effect on economic growth in developing countries, thus Hypothesis 4B is supported.

The negative effect of nuclear energy generation on economic growth shows that nuclear power generation is not the main base load of electricity generation in the Asia Pacific developing countries for supported economic growth. Referring to the Figure 1, Nuclear energy generation in energy mix generation in China has increased slightly from 2010 to 2021, while in India there was no significant increase, Only Pakistan has a significant increase of around 7%.

4.2.5. Nuclear energy generation on FDI inflow

Referring to Table 7, Nuclear energy generation has a positive not significant effect on FDI in developed countries, thus Hypothesis 5A is not supported. The positive effect of nuclear energy generation on FDI inflow means when nuclear energy generation has increases then FDI inflow increase not significantly.

Referring to Table 8, Nuclear energy generation has a negative significant effect on FDI inflow in developing countries, thus Hypothesis 5B is supported. The negative effect of nuclear energy generation on FDI inflow means when nuclear energy generation has increases then FDI inflow decreases, vice versa. The effect of increasing nuclear energy generation on FDI inflow in developed countries is different from developing countries. These findings need to further research in future research, especially related to the foreign investor perception of nuclear energy generation in the investment destination country.

4.2.6. Nuclear energy generation on CO_2 emission

Referring to Table 7, Nuclear energy generation has a positive significant effect on CO_2 emission in developed countries, thus Hypothesis 6A is supported. These findings indicate that the increase in nuclear energy generation is in line with the increase in the use of fossil fuels for other activities so that CO_2 emissions continue to increase.

Referring to Table 8, Nuclear energy generation has a negative significant effect on CO_2 emission in developing countries, thus Hypothesis 6B is supported. The negative effect of nuclear energy generation on CO_2 emission means when nuclear energy generation has increase then CO_2 emission would decrease, vice versa. This result indicates that the increase in nuclear energy generation is replacing the use of fossil fuels, thus reducing CO_2 emissions.

The effect of increasing nuclear energy generation on CO_2 emission in developed countries is different from developing countries.

4.2.7. Fossil fuel price on economic growth

Referring to Table 7, Fossil fuel price has a positive significant effect on economic growth in developed countries, thus Hypothesis 7A is supported. These findings indicate that economic growth in developed countries in the Asia Pacific region is still very dependent on the need for electricity from fossil fuel power plants, so that an increase in economic growth will be followed by an increase in fossil fuel prices. Developed countries in the Asia Pacific region are generally importers of fossil fuels. The author suggests for further research using covariance-based statistical analysis tools to ensure the two-way effect of these variables.

Referring to Table 8, Fossil fuel price has a positive not significant effect on economic growth in developing countries, thus Hypothesis 7B is not supported. Developing countries in the Asia Pacific region that have nuclear power plants such as China, India and Pakistan are countries that have fossil energy sources, especially coal. The increase in fossil fuel prices increases the economics of fossil fuel production which ultimately increases economic growth in these developing countries, but the increase is not significantly.

The effect of increasing fossil fuel price on economic growth in developed countries is different from developing countries.

4.2.8. Fossil fuel price on FDI

Referring to Table 7, Fossil fuel price has a negative significant effect on FDI inflow in developed countries, thus Hypothesis 8A is supported. The negative effect of fossil fuel price on FDI inflow means when the fuel price decreases then FDI inflow increases, vice versa, due to the electricity price cheaper, and investors could reduce an electricity cost. Low electricity costs are one of the investors' considerations in investing. These findings confirm that developed countries in the Asia Pacific region still rely on fossil fuel electricity generation as their base load.

Referring to Table 8, Fossil fuel price has a positive not significant effect on FDI inflow in developing countries, thus Hypothesis 8B is not supported. The positive effect of fossil fuel price on FDI inflow means when the fuel price increase then FDI inflow increases not significantly.

The effect of increasing fossil fuel price on FDI inflow in developed countries is different from developing countries.

4.2.9. Fossil fuel price on energy mix generation

Referring to Table 7, Fossil fuel price has a negative not significant effect on energy mix generation in developed countries, thus Hypothesis 9A is not supported. The negative effect of fossil fuel price on energy mix generation means when the fossil fuel price decreases then energy mix generation would increase fossil fuel power generation since these cheaper power generation, vice versa.

Referring to Table 8, Fossil fuel price has a positive not significant effect on energy mix generation in developing countries, thus Hypothesis 9B is not supported. The positive effect of fossil fuel price on energy mix generation means when the fuel price increase then on energy mix generation increases not significantly.

The effect of increasing fossil fuel price on energy mix generation in developed countries is different from developing countries.

4.2.10. Energy mix generation on economic growth

Referring to Table 7, Energy mix generation has a negative significant effect on economic growth in developed countries, thus Hypothesis 10A is supported. The negative effect of energy mix generation on economic growth means when the energy mix generation decreases then economic growth would increase, vice versa. This finding indicates that fewer combinations of energy generation mix result in more economical electricity generation costs thereby increasing economic growth in these countries.

Referring to Table 8, Energy mix generation has a positive significant effect on economic growth in developing countries, thus Hypothesis 10B is supported. The positive effect of energy mix generation on economic growth means when the energy mix generation increases then economic growth would increase, vice versa. These findings indicate that more combinations of the energy generation mix result in more economical electricity generation costs thereby increasing economic growth in these countries.

The effect of increasing energy mix generation on economic growth in developed countries is different from developing countries.

4.2.11. Energy mix generation on FDI

Referring to Tables 7 and 8, Energy mix generation has a positive significant effect on FDI Inflow in both developed and developing countries thus Hypothesis 11A and Hypothesis 11B are supported. The positive effect of energy mix generation on FDI inflow means when the energy mix generation has more combination, then FDI inflow would increase, vice versa. The impact of the increase in developing countries is higher than in developed countries.

4.2.12. Energy mix generation on CO_2 emission

Referring to Tables 7 and 8, Energy mix generation has a positive significant effect on CO_2 emission in both developed and developing countries thus Hypothesis 12A and Hypothesis 12B are supported. The positive effect of energy mix generation on CO_2 emission means when the energy mix generation has more combination, then CO_2 emission would increase, vice versa. The impact in developed countries is higher than in developing countries.

4.2.13. Economic growth on CO_2 emission

Referring to Tables 7 and 8, Economic growth has a negative not significant effect on CO_2 emission in both developed and developing countries thus Hypothesis 13A and Hypothesis 13B are not supported. The negative effect of economic growth on CO_2 emission means when the economic growth increase then CO_2 emission would decrease not significantly, vice versa.

4.2.14. FDI on CO_2 emission

Referring to Table 7, FDI inflow has a negative significant effect on CO_2 emission in developed countries, thus Hypothesis 14A is supported. The negative effect of FDI inflow on CO_2 emission means when the FDI inflow increase then CO_2 emission would decrease, vice versa.

Referring to Table 8, FDI inflow has a positive significant effect on CO_2 emission in developed countries, thus Hypothesis 14B is supported. The positive effect of FDI inflow on CO_2 emission means when the FDI inflow increase then CO_2 emission would increase.

The effect of increasing FDI inflow on CO_2 emission in developed countries is different from developing countries.

5. CONCLUSION AND SUGGESTIONS

5.1. Conclusion

Based on the results and analytical findings, the conclusions are as follows, the fossil fuel price has a positive not significant effect on nuclear energy generation in developed countries, while a negative not significant effect in developing countries. The fossil fuel price has a negative not significant effect on CO_2 emission in both developed and developing countries.

Nuclear energy generation has a negative not significant effect on energy mix generation in developed countries, while a positive significant effect in developing countries. Nuclear energy generation has a negative not significant effect on economic growth in developed countries, while a negative significant effect in developing countries. Nuclear energy generation has a positive not significant effect on FDI inflow in developed countries, while a negative significant effect in developing countries. Nuclear energy generation has a positive significant effect on CO_2 emission in developed countries, while a negative significant effect in developing countries.

The fossil fuel price has a positive significant effect on economic growth in developed countries, while a positive not significant effect in developing countries. The fossil fuel price has a negative significant effect on FDI inflow in developed countries, while a positive not significant effect in developing countries. The fossil fuel price has a negative not significant effect on energy mix generation in developed countries, while a positive not significant effect in developing countries.

Energy mix generation has a negative significant effect on economic growth in developed countries, while a positive significant effect in developing countries. Energy mix generation has a positive significant effect on FDI Inflow and CO_2 emission in both developed and developing countries. Economic growth has a negative not significant effect on CO_2 emission in both developed and developing countries. FDI inflow has a negative significant effect on CO_2 emission in developed countries, while a positive significant effect in developing countries.

The limitation of this study's use of analysis of the variance of component-based with partial least squares (PLS) is that it can only analyze a one-way path, for future research, it is recommended to use covariance based so that it can analyze two-way paths.

To the best of the authors' knowledge, this is the first research of nuclear energy generation, fossil fuel price, energy mix generation, economic growth, FDI Inflow and CO_2 emission using a comprehensive variance-based analysis PLS.

5.2. Suggestion

Nuclear energy generation has a negative significant effect on CO_2 emission in developing countries. This result indicates that the increase in nuclear energy generation is replacing the use of fossil fuels, thus reducing CO_2 emissions. This finding could be a recommendation for developing countries that will build a nuclear power plant to reduce CO_2 emissions while maintaining the reliability of a reliable base load of electricity generators. Nuclear energy generation is suggested as one of the alternatives that will be built as a substitute for coal-fired power plants which are generally base-load power plants in the Asia Pacific.

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