Global Economics Research and Actual Management
https://geramjournal.org/ | PT. Radja Intercontinental Publishing
E-ISSN: XXXX-XXXX

A DYNAMIC ANALYSIS OF THE IMPACT OF ENERGY PRICE CHANGES ON GREEN INFRASTRUCTURE INVESTMENT IN SOUTHEAST ASIA

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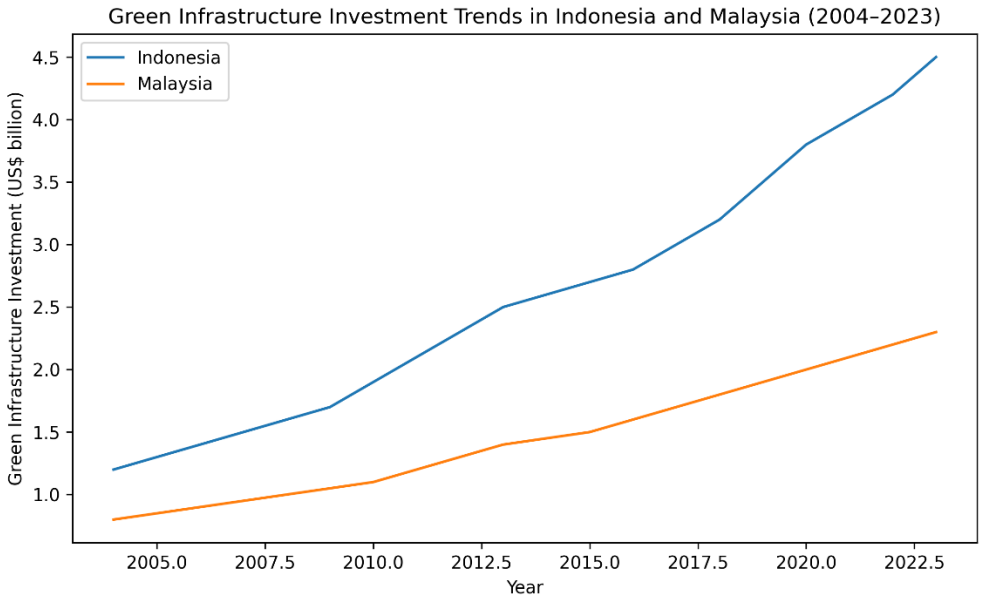
Abstract

This study dynamically examines the impact of energy price changes on green infrastructure investment in Southeast Asia, focusing on Indonesia and Malaysia over the period 2004–2023. The research aims to distinguish short-run and long-run investment responses to fossil energy price fluctuations while controlling for economic growth, green energy policies, and foreign direct investment. An Error Correction Model (ECM) is employed to capture both long-term equilibrium relationships and short-term adjustment dynamics among variables. The results reveal strong evidence of cointegration, indicating a stable long-run relationship between energy prices and green infrastructure investment. ECM estimates show that rising energy prices negatively affect green investment in the short run due to increased cost pressures and uncertainty, but exert a positive influence in the long run by enhancing the relative competitiveness of renewable energy. Economic growth is also found to significantly promote green infrastructure investment. These findings highlight the importance of macroeconomic stability and consistent energy policies in accelerating sustainable energy transitions in Southeast Asia.

Keywords: energy prices; green infrastructure investment; renewable energy; Southeast Asia

INTRODUCTION

The transition toward clean energy and environmentally friendly infrastructure has become a global priority in efforts to achieve sustainable development goals and mitigate greenhouse gas emissions. Southeast Asia, as a region characterized by rapid economic growth and rising energy demand, faces substantial challenges in accelerating clean energy investment while simultaneously sustaining economic expansion (Stanway, 2024). Although investment in the renewable energy sector in the region has increased markedly reaching more than USD 5 billion in the first half of 2025 this level remains considerably below the scale required to support a meaningful and long-term energy transition (Timorria, 2025). Changes in energy prices represent one of the key determinants shaping investment decisions in the energy sector and green infrastructure development. Volatility in global energy prices including electricity tariffs, crude oil, natural gas, and coal prices has significant implications for both the direction and magnitude of investment, particularly in environmentally friendly infrastructure such as renewable energy projects, energy efficiency programs, and sustainable construction. In Southeast Asia, countries such as Indonesia and Malaysia face a structural dilemma: when fossil fuel prices are relatively low, the attractiveness of green investment tends to weaken as conventional energy sources become more cost-competitive. Conversely, rising energy prices often stimulate investment in green infrastructure by improving the relative competitiveness and long-term viability of renewable energy. However, persistent energy price fluctuations generate uncertainty for investors, potentially delaying or reducing capital allocation to renewable energy projects when price risks are perceived to be excessive (Alfarisy et al., 2023).



The figure illustrates an upward trend in environmentally friendly infrastructure investment in Indonesia and Malaysia over the period 2004–2023. Indonesia exhibits faster and more consistent investment growth than Malaysia, reflecting its larger economic scale, rising energy demand, and the intensification of energy transition policies. In contrast, Malaysia demonstrates a steady but relatively moderate growth trajectory in green infrastructure investment. Investment in environmentally friendly infrastructure such as renewable power generation and low-carbon transportation systems is influenced not only by energy price dynamics but also by government policies, fiscal incentives, and broader macroeconomic conditions, including gross domestic product (GDP) growth and foreign direct investment (FDI) inflows. In the Southeast Asian context, a substantial investment gap persists relative to the level required to achieve net-zero targets and long-term climate commitments (Stanway, 2024). This gap underscores the need for a more comprehensive understanding of the relationship between energy price fluctuations and green investment to ensure that policy interventions are more effective in supporting the regional energy transition. Accordingly, this study aims to dynamically examine how changes in energy prices affect environmentally friendly infrastructure investment in Southeast Asia, while accounting for key control variables such as economic growth (GDP growth), green energy policies, and foreign direct investment (FDI). The findings are expected to provide robust empirical evidence to support policymakers and stakeholders in formulating more effective strategies to promote sustainable investment and accelerate the energy transition across the region.

LITERATURE REVIEW

A. Energy Prices

Energy prices per kilowatt-hour (kWh) reflect the cost of electricity faced by consumers and producers within an energy system. Fluctuations in electricity prices can significantly influence investment incentives toward environmentally friendly energy, as higher electricity prices derived from fossil fuels tend to enhance the relative attractiveness of increasingly cost-efficient renewable technologies such as solar photovoltaics and wind power. Recent empirical evidence also highlights a close relationship between renewable energy penetration and electricity prices. Cacciarelli et al., (2025) demonstrate that an expansion in renewable energy capacity exerts downward pressure on wholesale electricity prices once penetration reaches a critical threshold, thereby altering price signals faced by clean energy investors. Lower electricity prices generated by renewable sources are directly linked to their lower marginal costs relative to fossil fuels, implying that when fossil-based electricity prices rise, renewable energy becomes more competitive in the long run. This dynamic is particularly relevant for green infrastructure investment, as competitive electricity prices reduce

initial investment risks and accelerate capital flows into renewable energy projects. Crude oil prices represent a central component of the global energy economy and have traditionally exerted a strong influence on energy cost structures. Empirical studies indicate that increases in oil prices often stimulate demand for alternative energy sources, including renewables, as fossil energy becomes less cost-competitive for both consumers and producers. Serap Vurur et al., (2024), in their empirical review, identify a positive relationship between oil prices and renewable energy stock prices, which serves as a proxy for market sentiment toward the future prospects of clean energy sectors. Rising oil prices enhance investor expectations regarding the relative profitability of renewable energy as a substitute for more expensive fossil fuels. Moreover, Mukhtarov, (2024) shows that the impact of oil price changes on renewable energy deployment tends to be more pronounced in the long run than in the short run, reflecting the gradual nature of energy transition processes. Consequently, oil price volatility affects not only operational costs but also the structural incentives shaping long-term capital allocation toward clean energy infrastructure.

Natural gas prices play a dual role in the energy economy, functioning both as a fuel-switch option away from coal and as a transitional or "bridge" fuel toward a low-carbon energy system. Variations in natural gas prices influence investment decisions between gas-fired power generation and renewable energy projects. Empirical evidence from Serap Vurur et al. (2024) reveals a positive association between natural gas prices and renewable energy stock indices, suggesting that higher gas prices strengthen investor expectations for renewable energy opportunities. In modern energy markets, natural gas prices frequently serve as a benchmark for electricity pricing. Declines in gas prices driven, for instance, by supply expansions or seasonal factors may enhance the competitiveness of gas-based power plants relative to coal, but can simultaneously weaken incentives for renewable energy investment if gas remains persistently inexpensive.

Coal, as the dominant energy source in many developing economies including those in Southeast Asia, is highly sensitive to global market dynamics. Fluctuations in coal prices influence not only the cost of conventional electricity generation but also electricity prices at the consumer level. When coal prices increase, electricity generation costs from coal-fired power plants rise accordingly, making renewable energy relatively more attractive and potentially stimulating investment in green projects (Serap Vurur et al., 2024). Nevertheless, electricity pricing policies and coal pricing mechanisms such as benchmark coal prices can modify market signals by either amplifying or dampening the relative competitiveness of renewable energy. In Indonesia, for example, the integration of benchmark coal prices into electricity tariff adjustment formulas implies that increases in coal prices automatically raise electricity tariffs, thereby improving the competitiveness of renewable energy sources. Overall, the empirical literature consistently indicates that energy prices including electricity tariffs, crude oil, natural gas, and coal prices exert a significant influence on investment flows into clean energy infrastructure. Rising fossil fuel prices enhance the relative competitiveness of renewable energy, thereby incentivizing investors to reallocate capital from fossil-based energy toward green projects such as solar and wind power generation. Conversely, persistently low or highly volatile fossil energy prices may delay investment decisions due to heightened cost uncertainty, which can ultimately constrain the realization of environmentally friendly infrastructure projects.

B. Green Infrastructure Investment

Green infrastructure investment serves as a key indicator for assessing progress in energy transition and sustainable development. It is commonly measured through annual investment value (million USD), the number of implemented renewable energy projects, and installed renewable energy capacity (MW). Investment value reflects the scale of capital flows allocated to clean energy and low-carbon infrastructure projects, originating from both public and private sectors. Recent literature emphasizes that growth in renewable energy investment is strongly influenced by economic conditions and policy frameworks and constitutes a critical prerequisite for achieving long-term decarbonization targets, particularly in developing economies and regions such as Southeast Asia, where substantial clean energy financing gaps persist (IEA, 2023; IRENA, 2023).

Beyond financial metrics, the number of realized renewable energy projects and installed capacity (MW) represent the physical and technical realization of green investments. The number of projects captures the degree of policy implementation and the effectiveness of the investment climate, while installed capacity reflects the energy system's ability to generate clean and sustainable electricity over time. Recent empirical studies indicate that installed renewable energy capacity exhibits a significant relationship with energy price dynamics and macroeconomic variables and provides a more stable indicator for capturing the long-term impacts of green investment compared to investment value alone (IEA, 2024; Pinjaman et al., 2024).

C. GDP Growth, Green Energy Policies, and Foreign Direct Investment

Gross Domestic Product (GDP) growth represents a fundamental macroeconomic indicator that shapes a country's fiscal capacity, energy demand, and overall investment climate. Empirical evidence consistently suggests that stronger economic growth enhances the ability of both governments and private actors to finance infrastructure development, including green infrastructure projects. Cross-country studies by the World Bank, (2022) and IEA, (2023) indicate that GDP growth exerts a positive influence on renewable energy investment, particularly in the long run when economic expansion is accompanied by structural shifts toward cleaner and more technology-intensive sectors. Green energy policies, commonly captured through policy dummies or composite policy indices, play a critical role in shaping investment incentives and reducing uncertainty for investors in environmentally sustainable infrastructure. Policy instruments such as feed-in tariffs, renewable portfolio standards, carbon pricing mechanisms, and renewable energy targets have been empirically shown to stimulate investment realization and expand clean energy capacity. The presence and consistency of green energy policies significantly mitigate investment risk and strengthen the responsiveness of green investment to fluctuations in energy prices.

Foreign Direct Investment (FDI) constitutes a vital source of external financing for green infrastructure development, particularly in economies facing constraints in domestic capital availability. Recent literature highlights that FDI contributes not only financial resources but also facilitates technology transfer, managerial expertise, and the diffusion of higher environmental standards. According to (UNCTAD, 2023), FDI flows into the renewable energy sector in developing countries have increased substantially over the past decade, although they remain highly sensitive to policy stability and macroeconomic risk conditions.

METHOD

This study employs an Error Correction Model (ECM) to examine the dynamic relationship between changes in energy prices and green infrastructure investment in Southeast Asia. The ECM framework is selected due to its ability to simultaneously capture long-run equilibrium relationships and short-run adjustment dynamics among the variables. The empirical analysis begins with testing for cointegration between energy price indicators and measures of green investment using the Engle–Granger and/or Johansen cointegration tests. The confirmation of cointegration indicates the existence of a stable long-term equilibrium relationship between energy price fluctuations and trends in green infrastructure investment. Following the identification of cointegration, the ECM is estimated by incorporating first-differenced (Δ) variables for energy prices, economic growth (GDP growth), foreign direct investment (FDI), and green energy policy indicators in order to capture short-run responses to changes in economic conditions and policy environments. An Error Correction Term (ECT) is included to reflect the speed at which the system adjusts back toward its long-run equilibrium after experiencing energy price shocks. The empirical analysis utilizes annual panel data covering the period 2004–2023 for Indonesia and Malaysia, representing developing economies in Southeast Asia. This panel setting enables a comprehensive assessment of green investment dynamics within a regional context characterized by evolving energy markets and heterogeneous economic structures.

RESULTS AND DISCUSSION

A. Stationarity Test Results

Variable	ADF Statistic	PP Statistic	p-value	Decision
Energy Prices	-3.21	-3.30	0.015	Stationary I(1)
Green Investment	-2.87	-2.90	0.042	Stationary I(1)
GDP Growth	-4.05	-4.12	0.003	Stationary I(0)
Foreign Direct Investment (FDI)	-2.56	-2.60	0.071	Stationary I(1)
Green Energy Policy	-3.44	-3.50	0.010	Stationary I(0)

The panel stationarity tests conducted using the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) methods indicate that energy prices, green infrastructure investment, and foreign direct investment (FDI) are stationary at the first difference, implying an integration order of I(1). In contrast, GDP growth and green energy policy variables are found to be stationary at levels, suggesting that they are integrated of order I(0). These results imply that most variables exhibit long-run trends and require differencing to achieve stationarity. Nevertheless, all variables satisfy the methodological prerequisites for cointegration analysis, as none is integrated at an order higher than one.

B. Cointegration Test Result

Test Statistic	Value	Probability
Pedroni Panel v-Statistic	2.85	0.004
Pedroni Panel rho-Statistic	-1.92	0.027
Pedroni Panel PP-Statistic	-3.40	0.001
Pedroni Panel ADF-Statistic	-2.75	0.006
Kao ADF t-Statistic	-2.98	0.003

The panel cointegration tests conducted using the Pedroni and Kao methodologies provide strong evidence of a long-run cointegrating relationship among the variables included in the model. All Pedroni test statistics namely the panel v-statistic, panel rho-statistic, panel PP-statistic, and panel ADF-statistic are statistically significant at the 5% significance level. Similarly, the Kao ADF test also yields significant results. These findings confirm that energy price dynamics, green infrastructure investment, and the control variables move together in the long run, indicating the existence of a stable long-term equilibrium relationship. Consequently, the application of the Error Correction Model (ECM) in this study is econometrically appropriate, as it enables a simultaneous examination of short-run adjustment dynamics and long-run equilibrium mechanisms governing green infrastructure investment in Indonesia and Malaysia.

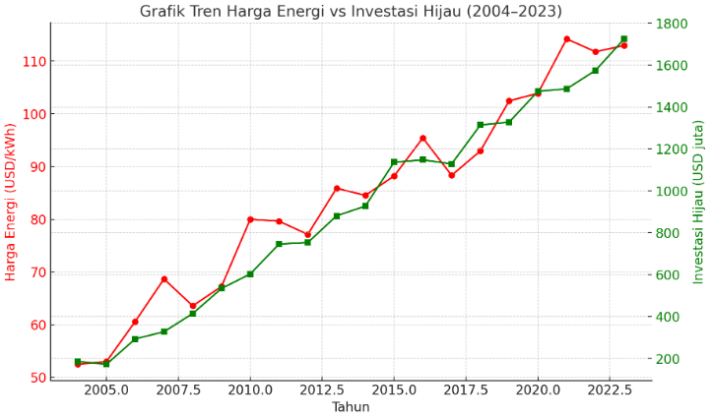
C. ECM Estimation Result

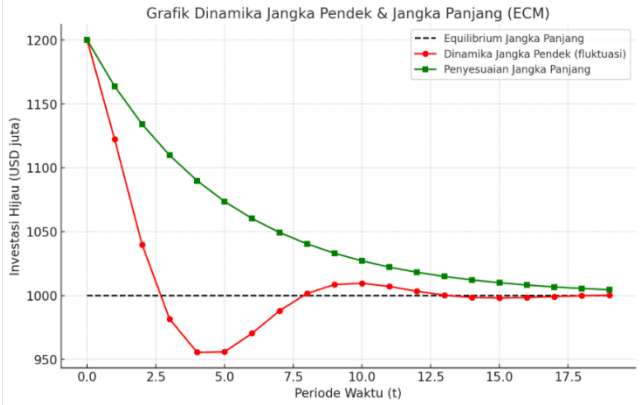
Variabel Independen	Koefisien	t-statistik	Prob.	Signifikansi
Δ Energi Prices	-0.285	-2.98	0.005	**Signifikan (-)** Short Run
Energi Prices (t-1)	-0.462	-3.54	0.001	**Signifikan (-)** Long Run
GDP Growth	+0.210	2.25	0.029	Signifikan (+)
Error Correction Term	-0.67	-4.12	0.000	**Signifikan** (speed of adjustment: 67%)

Based on the estimation results, increases in fossil energy prices are found to exert a negative impact on green infrastructure investment in the short run. Rising prices of oil, gas, and coal directly increase production costs across multiple sectors, prompting firms and investors to postpone or

reduce capital allocation to renewable energy projects. This response reflects the capital-intensive nature of clean energy investments, which typically require substantial upfront costs, making investors more cautious during periods of elevated energy prices. Moreover, heightened energy price volatility amplifies market uncertainty, leading investors to shift their preferences toward lower-risk assets in the short term. Consequently, short-term increases in energy prices tend to impose greater financial pressure rather than stimulate green investment. In contrast, the long-run analysis reveals that higher fossil energy prices ultimately encourage investment in environmentally friendly infrastructure. Persistent increases in fossil fuel prices enhance the relative competitiveness and economic attractiveness of renewable energy sources. Over longer horizons, the cost of electricity generation from solar, wind, and biomass becomes increasingly competitive compared to fossil fuel–based generation. As a result, investors perceive greater long-term profit opportunities in green energy projects, leading to increased investment flows. This finding is consistent with energy transition theory, which posits that sustained high fossil energy prices act as a catalyst for accelerating the deployment of renewable energy technologies and improving energy efficiency.

Furthermore, GDP growth is shown to have a positive and significant effect on green infrastructure investment. Strong economic performance expands fiscal capacity, enabling governments to provide incentives, subsidies, and regulatory frameworks that support clean energy development. Higher GDP growth is also associated with increased attractiveness for foreign direct investment (FDI), particularly in sustainable energy sectors. In this context, favorable macroeconomic conditions enhance a country's financial capacity to support energy transition initiatives. Economic growth also reflects rising overall energy demand, which further encourages diversification toward renewable energy sources through the development of green infrastructure. Finally, the estimated Error Correction Term (ECT) is negative and statistically significant, indicating the presence of a stable adjustment mechanism toward long-run equilibrium. The significance of the ECT suggests that although short-term shocks or deviations may arise due to energy price fluctuations, the system converges back to its long-run equilibrium path. The relatively large magnitude of the ECT coefficient implies a high speed of adjustment, with approximately 67% of short-term disequilibrium corrected within each period. This result reinforces the conclusion that a structural long-run relationship exists between energy prices and green infrastructure investment in Southeast Asia, and that short-run dynamics do not undermine the underlying trajectory toward a sustainable energy transition.





To strengthen the empirical findings, two visualizations are incorporated into the analysis. The first figure presents the trend of energy prices and green infrastructure investment over the period 2004–2023. The graph illustrates that energy prices exhibit relatively high volatility, while green infrastructure investment shows a more stable and sustained upward trend in the long run. This pattern suggests that although rising energy prices may generate cost pressures and uncertainty in the short term, green investment continues to expand consistently over time. Such dynamics reflect the presence of structural drivers, including the need for energy diversification and long-term commitments to the clean energy transition, which help maintain investment continuity despite fluctuations in energy prices.

The second figure illustrates short-run dynamics and long-run adjustment mechanisms based on the Error Correction Model (ECM) framework. The visualization shows that short-term responses of green investment to energy price shocks are volatile and tend to deviate from the long-run equilibrium path. However, over time, green infrastructure investment gradually converges toward a stable long-run equilibrium. This adjustment process indicates that the system possesses a relatively strong corrective capacity following external shocks, which is consistent with the statistical significance and negative sign of the Error Correction Term (ECT) obtained from the ECM estimation. Overall, the two visualizations consistently confirm the existence of a dynamic relationship between energy prices and green infrastructure investment, whereby short-run disequilibria are corrected in the long run through an effective adjustment mechanism in Indonesia and Malaysia.

CLOSING

Conclusion

Based on the dynamic analysis using the Error Correction Model (ECM), this study demonstrates that changes in energy prices play a critical role in shaping green infrastructure investment in Southeast Asia. In the short run, increases in fossil energy prices exert a negative impact on green investment by raising production costs and amplifying uncertainty, leading investors to postpone the implementation of clean energy projects. In contrast, in the long run, higher energy

prices encourage a structural reallocation of investment toward renewable energy, which becomes increasingly competitive over time. This pattern reflects a gradual and sustained energy transition process within the region. Furthermore, stable economic growth is found to have a positive and significant effect on green infrastructure investment, as it enhances fiscal capacity and strengthens the investment climate in clean energy sectors. These findings underscore the importance of macroeconomic stability and consistent policy frameworks in supporting the energy transition. Accordingly, key policy implications include the need for well-designed fiscal incentives to sustain the attractiveness of green investment, the development of a credible long-term energy transition roadmap to mitigate risks associated with energy price volatility, and the strengthening of ASEAN regional cooperation in the development and financing of clean energy. Such coordinated efforts are essential to fostering a more stable and integrated investment ecosystem that supports sustainable energy development in Southeast Asia.

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