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The Impact of Green Finance, and Eco-Innovation on CO2 Emissions: The Pool Mean Group Evidence from ASEAN Countries in the Context of SDGs

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Abstract

This study investigates the influence of green finance, green technology, and eco-innovation on CO2 emissions within ASEAN countries, framed within the context of the Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), and SDG 13 (Climate Action). Utilizing data from 2002 to 2019 and adopting the Pool Mean Group (PMG) methodology, our analysis sheds light on the critical dynamics between sustainable financial practices, technological advancement in green technologies, and eco-innovative approaches towards achieving significant CO2 emissions reduction. Our findings reveal that green finance significantly empowers the deployment of green technologies and eco-innovations, leading to a notable decrease in CO2 emissions across the studied nations. The study highlights the importance of country-specific policy interventions that cater to the unique economic and technological contexts of ASEAN countries to optimize the contribution of green finance and technology to climate action. These insights offer a valuable guide for policymakers, financial institutions, and other stakeholders in harnessing green finance and technology for environmental sustainability, in alignment with the SDGs. This research contributes to the discourse on sustainable development, emphasizing the pivotal role of finance and innovation in environmental stewardship and carbon reduction efforts across ASEAN countries.

Keywords: Green Finance, Green Technology, Eco-Innovation, CO2 Emissions, ASEAN Countries, SDGs, Panel ARDL, Sustainable Development Goals, Climate Action, Environmental Sustainability

INTRODUCTION

The financial sector has played a crucial role in driving human progress since the dawn of the industrial revolution (Machkour & Abriane, 2020). Effectively managing global savings is the primary duty of the worldwide financial industry. Improving people's quality of life is achievable through smart investment strategies. Regrettably, due to the financial crisis, numerous individuals have invested their life savings into environmentally damaging projects, such as real estate bubbles (Waldron,2018). These actions further exacerbate the human-caused effects of climate change. In the past, the banking industry showed little concern for the environment, resulting in the emergence or exacerbation of issues such as pollution, habitat loss, and climate

change. Although financial resources play a crucial role in anthropogenics, which pertains to human impact on the environment, there has been a noticeable absence of substantial efforts to integrate environmental concerns into this field (Nukusheva et al.,2021). Recently, there has been a growing emphasis in the financial sector on green investments and the promotion of sustainable growth. In his work, Falcone, (2020) highlights the potential of utilizing green financial instruments to help achieve a more environmentally sustainable ecosystem. Throughout the course of development, financial intermediaries and markets have introduced a range of financial instruments that prioritize environmental sustainability. These include green bonds, green home mortgages, green loans for commercial buildings, environmental home equity programs, "go green" auto loans, small business administration express loans, and climate credit cards (Meo & Abd Karim, 2022). Australia has introduced a new environmental deposit initiative, utilizing financial instruments with medium-to-long-term durations. These instruments not only provide funding for projects and business activities that prioritize the environment, but also offer direct support for sustainable development and climate-related projects.

Green finance involves the integration of environmentally conscious practices into the fields of finance and business (Falcone, 2020). However, there is a lack of research that has established a link between finance and ecology. A study conducted by Maqbool and Zameer (2018) examined the correlation between the performance and social responsibility of financial institutions. In their study, Zhou et al. (2020) found that environmental finance, also referred to as sustainable finance, is the most effective method for addressing environmental degradation. Investing in green finance supports the funding of innovative technologies and advancements, like renewable energy. Therefore, we are compelled to analyze the ever-changing influence of green finance on the carbon dioxide (CO2) emissions of the five prominent ASEAN countries that endorse it.

According to Aldieri et al. (2019), there is a strong connection between Economic Innovations (EI) and scientific advancements, as they share many common characteristics. As noted by Supramaniam and Singaravelloo (2021) EI has a range of unique features that have important implications for administration and policy. A thorough examination of the factors that drive the development of technology and research and development (R&D) is necessary to understand how to promote the wider use and acceptance of emerging technologies. This understanding can help inform business strategies and public policies aimed at enhancing and guiding the adoption of these technologies. Ecological innovation plays a crucial role in propelling the growth of the green economy, especially given the existing policy framework for promoting green innovation (Fang et al.,2022).

It has been shown that innovation plays a crucial role in reshaping the energy structure of the EU and revolutionizing key practices. One can showcase the effectiveness of eco-innovation through the achievement of a carbon-free and sustainable economy. Researchers have generally found that the environmental impact does not directly affect the improvement of production's eco-performance by reducing toxic emissions. Instead, it has a secondary influence on the enhancement of environmental standards in interconnected sectors through market interactions (Suchek et al.,2021). Due to this, both domestic and international channels are intricately linked to green technologies on a global and local level. Consequently, sectors further downstream are consistently generating environmental performance advantages. The graph illustrates the trend of CO2 emissions over last six decades for

different Southeast Asian countries. Indonesia takes the lead in emissions, with a staggering 619.28 million metric tons in 2021. Following closely behind are Vietnam, Thailand, and Malaysia, with 362.01, 278.5, and 256.05 million metric tons respectively. The Philippines also exhibits notable emissions at 144.26 million metric tons. These figures probably indicate trends in industrial growth and energy consumption. At the lower end, Singapore, despite its developed economy, has relatively moderate emissions. Brunei, Laos, Cambodia, and Myanmar have the lowest figures, which could suggest smaller industrial sectors or different energy policies and usage. The overall trend observed in various countries indicates a growing concern for environmental issues, which in turn has significant implications for climate change policies and regional sustainability initiatives.

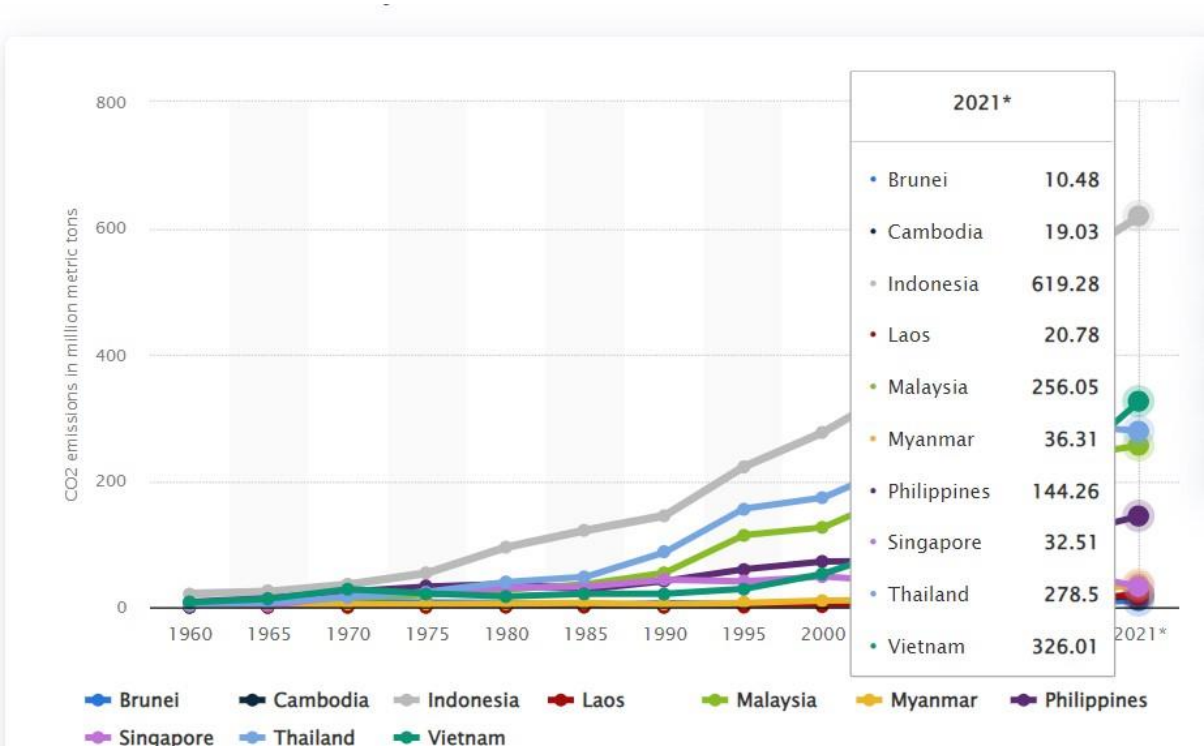

Figure 1.
CO2 emission (million metric tons) in ASEAN countries
Source: WDI

ASEAN countries are facing the pressing challenge of CO2 emissions, as the consequences of rapid industrialization and economic growth become increasingly apparent. In 2021, Indonesia's emissions reached a staggering 600 million metric tons, highlighting its significant dependence on fossil fuels and its position as the largest economy in the region. Vietnam, Thailand, and Malaysia also show similar patterns, with their emissions rising alongside their economic growth and growing energy needs. The Philippines, although ranking lower on the scale, still experiences significant emissions, which can be attributed to its expanding infrastructure and industrial sectors. Singapore's impressive emissions record is a testament to its well-executed urban planning and commitment to green technologies, especially considering its developed economy. In contrast, countries such as Brunei, Laos, Cambodia, and Myanmar have relatively low emissions. This can be attributed to their smaller industrial sectors and, in certain instances, limited access to resources for development. The increase in CO2 emissions throughout ASEAN nations presents notable environmental and health hazards, intensifying the effects of climate change like more frequent

extreme weather events and higher sea levels. These consequences are particularly worrisome for the numerous coastal and island communities in the region. Tackling these emissions presents a multifaceted challenge that necessitates finding a delicate equilibrium between economic ambitions and sustainable practices, as well as fostering regional collaboration to implement effective environmental policies.The contribution of the study is threefold: Firstly, the study examines the pioneering impact of green finance and eco-innovation on the CO2 emissions of Central Asian countries. Secondly, the study has employed one of the robust econometric estimation techniques, The Pool Mean Group (PMG), over a period of 32 years from 1990 to 2021. Lastly, the study has focused on ASEAN countries as they have seen a significant rise in CO2 emission during last three decades. The remaining sections of the study are organized as follows: Section 2 provides an overview and emphasizes the existing literature. Section 3 provides an overview of the data, resources, and methods used in the study. Section 4 presents the statistical results and subsequent discussions. The analysis is concluded in Section 5, which also provides policy recommendations.

LITERATURE REVIEW

One of the most urgent issues facing our planet is the rapid increase in global warming. Contemporary ideas such as sustainable development have their roots in the United Nations' Sustainable Development Goals (SDGs). These goals are designed to tackle environmental degradation and pollution, among other pressing issues. In recent times, financial institutions have shifted their stance on ecological concerns. Previously overlooked, these concerns are now being taken seriously. As a result, new products such as green bonds have been introduced with the goal of protecting the environment. The field of research that explores the intersection of ecology and finance is still in its early stages. According to Sachs et al. (2019), achieving environmental sustainability can be made possible through the development of solar energy financing.

In a study conducted by Haque and Ntim (2018), they reached a similar conclusion, emphasizing that environmental financing is the most effective strategy to mitigate environmental damage. Renewable energy exemplifies how green finance encourages the adoption of state-of-the-art technology. However, previous studies failed to consider the relationship between CO_2 emissions and green bonds, which serve as a proxy for green financing. Green bonds are a form of long-term bond specifically created to finance environmentally beneficial projects or initiatives aimed at reducing pollution. Projects funded by green bonds encompass a range of initiatives such as solar energy, clean water, and clean transportation.

Prior studies have examined the connection between CO_2 emissions and their underlying factors using a range of econometric tests. These include Granger causality, error correction models (ECM), FMOLS, DOLS models, vector error correction models (VECM), bootstrap causality tests, and autoregressive distributed lag models (ARDL). The inherent issue with these approaches is that they exclusively focus on linear relationships. In their 2008 article, Po and Huang highlight the limitations of linear methods in capturing transient fluctuations and unexpected shifts in data series. Pata and Caglar (2021) suggests that linear models may not accurately capture the non-linear nature of macro series in reality. The relationship between green financing and CO_2 emissions is not straightforward, as various factors such as financial crises, sudden policy changes, domestic conflicts, and the intricacies of financial markets can cause regime-switching behavior.

While conducting a thorough analysis of the research on CO2 emissions, it is worth noting that none of the available studies have utilized quantile-on-quantile (QQR) methods to examine the relationship between green finance and CO2 emissions. In this context, this approach is notable due to the potential fluctuation of the relationship between green bonds and carbon dioxide emissions in accordance with the economic cycle and the scale and orientation of green financing. Therefore, we expect that advancements and reductions in green financing will have specific impacts on CO2 emissions. Carbon dioxide emissions typically remain elevated during periods of robust economic growth and decrease during periods of sluggish economic expansion (Mardani et al.,2019). The correlation between CO2 emissions and green finance is subject to fluctuations based on the economic conditions, be it a period of growth or downturn. It is worth noting that CO2 is a complex and multifaceted phenomenon that is influenced by a variety of factors. Thus, it is conceivable that a favorable change in green financing could have a greater impact on reducing CO2 emissions compared to an unfavorable change.

As per Lee (2020), the field of green finance strives to provide assistance to environmentally conscious businesses, foster innovation within these industries, and ultimately enhance environmental quality. It is reasonable to infer that green financing will have a substantial impact on reducing CO2 emissions. In fact, many researchers have proven the hypothesis mentioned earlier. As an expert in the field, it is fascinating to see the research conducted by Zhao et al. (2023) on the relationship between green finance and greenhouse gas emissions in major economies that support green finance. Green financing has been found to have a negative impact on carbon dioxide emissions, as per their research. Studying the relationship between green finance and CO_2 emissions from a national perspective has garnered significant attention. In a recent study, Tran (2021) delves into the relationship between green funding and Vietnam's CO_2 emissions through the application of multivariate time series analysis. Their research reveals a clear and direct link between investments in environmental sustainability and carbon dioxide emissions. In addition, studies have examined the potential correlation between carbon dioxide emissions in a particular industry and the impact of green financing. For instance, Ridzuan et al. (2020) examines the relationship between funding for environmentally friendly initiatives and the levels of CO_2 emissions originating from agricultural activities. Their research reveals that green financing can have a negative impact on agricultural CO_2 emissions. Clayton et al. (2021) delves into the examination of green property financing and the impact of carbon dioxide emissions from the building sector. The findings clearly indicate a negative correlation between the two variables mentioned. Accordingly, we develop our second hypothesis as follows:

H1. Green finance has significant negative impact on CO2 emission.

The term "eco-innovation" describes a method of innovation that combines sustainability with environmental concerns. The term "green innovation," "environmental innovation," or "sustainable innovation" is used frequently by scholars to describe this idea. In order to make certain direct or indirect improvements to the environment, the OECD characterized eco-innovation as the development or improvement of new goods and services, as well as new business procedures and operations (Puertas & Marti, 2021). In order to define and explain environmental innovation, we combine the words "innovation" with "eco," "sustainable," "green," and "environmental.". Concern about the economic and environmental effects of eco-innovation has kept it at the forefront of academic inquiry for the better part of two

decades (Yan et al.,2022). The concerns of climate change, environmental degradation, and global warming have been the center of attention for scholars, business groups, and lawmakers. A more competitive and environmentally friendly economy can be achieved through green innovation, according to studies carried out by international organizations like the UNEP, the EU. He et al. (2018) found that eco-innovation improved both economic and environmental outcomes.

In addition, studies have demonstrated that innovations in organizational structure, behavior, and technology can greatly enhance sustainability. This is especially true when it comes to reducing energy consumption, emissions, and waste. To make up for shifts in the energy mix and other structural changes in developing economies, innovation has been a reliable compensatory mechanism. Few studies have examined innovation, especially its effects on regional and sector-specific emissions performance, due to the novelty of different advancements (Khanna et al.,2023). Innovation, according to previous studies (Kahn, K. B. (2018; Florida et al.,2018), can counteract the increase in emissions brought about by technological advancements and economies of scale.

Researchers have looked into different points of view on eco-innovation. Environmental innovation is defined as the combination of environmentally friendly processes and products. Mat Dahan and Yusof (2020) provided definitions of eco-innovation, eco-product, and eco-process. Elements of the process, product, and organization are deemed important to discuss in the literature. This study takes a different approach than others by looking at eco-innovation through the four lenses of eco-process, eco-product, eco-organization, and eco-marketing. However, the long-ignored question of how eco-innovation contributes to environmental degradation in developing economies needs further investigation. Accordingly, we develop our second hypothesis as follows:

H2: Eco-innovation has significant negative impact on CO2 emission.

MODEL

According to Eriksson (2013), the equation provided below serves as a general representation of carbon emissions:

$$E_{it} = IC_{it} Y_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

In the equation, the total emission from different sectors of the economy is represented by 'TC_{it}', while the proportion of emission produced by an industry is denoted by 'IC_{it}'. This equation shows that the level of emission is dependent on certain factors. If their relationship seems to be negative, emissions will decrease with the use of environmentally friendly technologies. Mathematically, equation 1 can be represented as:

$$TC_{it} = Y_{it} \sum_{i=1}^{n} \partial_{i,t} \, IC_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

In this case, Y_{it} represents the overall output from all industries, while $\partial_{i,t}$ represents the total output from each industry. On differentiating equation 2 concerning the time we get.

$$g^{E} - g^{y} + \sum_{i=1}^{n} \tau_i \, g^{ICi} + \sum_{i=1}^{n} \tau_i \, g^{\partial i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The variables g^{y}, g^{ICi}, and $g^{\partial i}$ are used to analyze the rate of change of emission, specifically in terms of the scale effect, technology effect, and composition effect.

The pollution caused by industry i is quantified by the variable τ_i. Assuming there is no composition effect, it can be inferred that the rate at which total output increases will exceed the rate at which emissions decrease, or vice versa, and the total output expressed as follows:

$g^E \leq 0$ if and only if $g^y \leq -g^{ICi}$

It can also be written as

$g^Y = -g^{ICi} + g^E$.....(4)

Equation 4 shows that when eco-innovation increases, the environment decreases.

Based on the theoretical notion, this study specifies the following function.

$ED_{,it} = f(GDP, ECOIN, GRF)$.....(5)

Based upon the above functions, the econometric models are specified as:

$CO_{2\,it} = \alpha_0 + \alpha_1 ECOIN_{it} + \alpha_2 GDP_{it} + \alpha_3 GRF_{it} + \varepsilon_{it}$.....(6)

DATA AND ESTIMATION TECHNIQUES

Data

In this study, data from ASEAN member states were analyzed from the year 2000 to the year 2020, with a particular emphasis on the impact of green finance, eco-innovation, and economic growth on CO2 emissions.

Table 1.
Variable Description

Variable	Description	Unit of measurement	Data Source
GDP per capita (LGDPC)	Log of GDPC	Constant 2015 US$	World Development Indicators 2021
Green Finance (GRNF)	Green finance development index is built using four indicators such as green credit, green insurance, green securities, and green investment by employing improved entropy method	Green finance index	World Development Indicators 2021
Carbon Dioxide (LCO2)	Log of CO_2 per capita	CO2 metric ton per capita	World Development Indicators 2021,
Eco-innovation (ECON)	Measured by the total patent applications		WIPO

Source: Author's Compilation

PMG Estimation Technique

The Pool Mean Group (PMG) estimator is employed to identify and assess the correlation between the dependent and explanatory variables. The statistical methodology we employ is the pooled mean group (PMG) estimator, which guarantees that all groups possess identical long-term coefficients while permitting variations in short-term coefficients and error variances (Liu et al., 2023). The PMG

method is highly resilient, especially when dealing with small cross-sectional dimensions, when compared to other methods. PMG provides a robust solution to endogeneity concerns by considering both the long and short term, which is an added advantage. According to Saint Akadiri et al. (2019), the PMG estimator demonstrates superior reliability compared to other estimators in the presence of outliers and lag orders.

The PMG model of current study is as follow.

$$\Delta LN2O_{it} = \alpha_0 + \sum_{i=1}^{p} ECOIN_{it-1} + + \sum_{i=1}^{q} LGDP_{it-1} + \sum_{i=1}^{r} LGRF_{it-1} + \pi_1 ECOIN_{it-1} + \pi_2 LGDP_{it-1} + \pi_3 LRGRF_{it-1} + \eta_{it} \quad (31)$$

Within the framework of these models, the lags of the variables that are dependent are assumed to be independent variables. For each and every variable, the logarithmic form becomes applicable.

RESULTS AND DISCUSSIONS

Descriptive Statistics

The summary statistics provided reflect data on CO2 emissions (LCO2), economic innovation (LECOIN), GDP growth (LGDP), and green finance (LGRNF) from 155 observations. The distribution of LCO2 exhibits a high level of symmetry, as evidenced by a skewness value of 0.20, suggesting a moderate right-skewness. The mean is slightly higher than the median, though. The kurtosis value of 2.4 suggests a slightly flatter distribution than what is typically observed. LECOIN exhibits a significant left skew, as evidenced by its unusually high mean in relation to the median, with a skewness value of -5.70. The presence of outliers is evident due to the remarkably high kurtosis value of 51, indicating a distribution that is sharply peaked with heavy tails. This could be attributed to sporadic innovation bursts or potential reporting errors.The statistics of LGRNF exhibit a distribution that closely resembles the normal distribution, with a mean and median that are highly similar and skewness and kurtosis values that closely resemble those of a normal distribution. It appears that there is minimal fluctuation in the level of green financing.

Table 2.
Descriptive Statistics

ariable	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Obs.
LCO2	1.35	1.20	2.80	0.10	0.65	0.20	2.40	155
LECOIN	1.50	1.60	2.15	-4.75	0.70	-5.70	51.00	155
LGDP	4.70	4.75	8.00	1.00	1.25	-0.45	2.90	155
LGRNF	8.60	8.65	9.35	7.35	0.55	-0.40	2.60	155

Source: Author's Computation

RESULTS OF CROSS SECTION DEPENDENCE

By employing cross-section dependence tests such as Saint Akadiri et al. (2019), one can assess the presence of cross-section dependence in the data. The Lagrange multiplier (LM) and Pasaran CD tests are frequently employed in panel data analysis to assess cross-section dependence (CSD). The null hypothesis in these tests posits that the variables lack any cross-sectional dependence, while the alternative hypothesis suggests the presence of such dependence. Table 3 demonstrates that ASEAN

member countries with middle-income and high-income levels display cross-sectional interdependence.

Table 3.
Cross-Section Dependence in residuals

	Model 3 LCO2	
Cross-Section Dependence Tests (d.f =15)	Statistic	P-Value
Breusch-Pegan LM Test	0.00	0.001*
Pasaran scaled LM test	0.00	0.002*
Pasaran CD	0.00	0.000*

Note: *, ** and *** refer to the levels of significance at 1%, 5%and 10%, respectively.

Second Generation Unit Root Test

Once the presence of cross-section dependence is detected, the first-generation unit root test loses its effectiveness. Two econometric tests have been used to investigate this issue. The second-generation unit root tests include the CS-augmented Dickey-Fuller (CADF) test, which was introduced by Ahmad et al. (2023). The results presented in Table 4 offer proof of a blend of integrated orders for the variables analyzed, specifically I(0) and I(1). Despite setting the initial conditions to zero, most of the variables being studied do not remain constant. At time point I(1), there are no changes observed in any of the variables.

Table 4.
Second Generation Panel Unit Root Test

ariable	CIP Level	CIP 1st Diff.	CADF Level	CADF 1st Diff.
LCO2	-1.40	-3.65*	-1.70	-3.90*
LECOIN	-1.60	-4.15*	-2.60	-3.75*
LGDP	-1.70	-3.95*	-2.20	-3.30*
LGRNF	-2.30***	-3.70*	-2.75	-2.87***

Note: *, ** and *** refer to the levels of significance at 1%, 5%and 10%, respectively.

Tests of Cointegration

Gogolin et al. (2018) proposed methodologies that have been used in three separate cointegration tests to investigate long-term relationships between variables. The variables are hypothesized to be non-cointegrated under the null hypothesis and to be cointegrated under the alternative hypothesis over the long term. The results of cointegration tests are shown in Table 5. The results suggest that the variables in high-middle income countries exhibit long-term co-integration in all three models. Long-term integration has also been confirmed in countries with high incomes.

Table 5.
Pedroni Cointegration test

Ho: No Coint.	**Model 2**	
	LCO2	
	Statics.	p-value
Modified variance ratio	-2.21	0.02**
Modified Phillips-Perron	1.69	0.01***
Phillips-Perron	-1.53	0.02***
ADF	-1.78	0.02***

Note: *, ** and *** refer to the levels of significance at 1%, 5% and 10%, respectively

Table 6 displays the outcomes of the cointegration tests performed by Kao (Hatemi, 2020). The results indicate that the variables in all three models for nations with a high-medium income level exhibit evidence of long-term co-integration. Moreover, empirical evidence has demonstrated that affluent nations exhibit enduring integration.

Table 6.
Kao Test of Cointegration

Ho: No Cointg.	**Model 1** **CO2**	
	Statics.	p-value
Modified DF	0.17	0.13
DF	1.81	0.02**
ADF	1.91	0.02**
Unadjusted modified DF	-0.40	0.35
Un-adjusted DF	1.41	0.06***

Note: *, ** and *** refer to the levels of significance at 1%, 5% and 10%, respectively. DF=Dicky Fuller

PMG Estimates

The findings from Model 1 provide valuable insights into the relationship between economic activities and environmental impact, specifically in ASEAN countries. The study examines the effects of economic innovation (LECOIN), economic growth (LGDP), and green finance (LGRNF) on CO2 emissions, shedding light on the connections between these factors. The negative coefficient for LECOIN (-0.50) indicates that there is a correlation between economic innovation and a decrease in CO2 emissions. This suggests that the adoption of cleaner technologies and more efficient processes may be contributing to the reduction in emissions. It is evident that promoting innovation, especially in the realm of sustainable technologies, can serve as a successful approach to addressing environmental degradation. On the other hand, the coefficient for LGDP (1.00) suggests that there is a correlation between economic growth and CO2 emissions. This highlights the typical reliance of economic expansion on energy consumption from carbon-intensive sources. It is evident that there is a strong requirement for policies that prioritize sustainable growth, ensuring that environmental factors are taken into account right from the beginning. Ultimately, the significant negative coefficient for LGRNF (-0.85) underscores the crucial importance of green finance in effectively mitigating emissions. Investments in environmentally friendly projects and technologies through green finance mechanisms have shown great promise in addressing the challenges posed by climate change. These findings highlight the importance of adopting a comprehensive policy approach that promotes economic innovation and green finance. It is crucial to rethink economic growth strategies in order to minimize environmental harm and move towards a more sustainable economic model. This transition is essential for the development trajectory of ASEAN countries and aligns with environmental sustainability goals.

Model 1's short-run results offer a comprehensive analysis of the direct impact of economic variables on CO_2 emissions. These variables include innovation (LECOIN), growth (LGDP), and green finance (LGRNF). The study demonstrates the significant impact of immediate technological advancements and innovative practices on reducing environmental harm. The negative coefficient for LECOIN (-0.20, significant

at 0.005**) indicates that even short-term economic innovation can result in a decrease in CO2 emissions. However, it is worth noting that the positive LGDP coefficient (0.90, highly significant at 0.000***) indicates that in the short term, increased economic growth corresponds to higher emissions. This suggests that rapid economic expansion and activity come with immediate environmental consequences. Investments in sustainable projects with a shorter time horizon have been found to effectively reduce emissions.

Table 7.
Estimates of PMG Regression Analysis

Variable	Model 1 (CO2) Coeff.
Long Run Results	
LECOIN	-0.50 (0.000**)
LGDP	1.00 (0.000***)
LGRNF	-0.85 (0.000**)
Short Run Results	
LECOIN	-0.20 (0.005**)
LGDP	0.90 (0.000***)
LGRNF	-0.10 (0.000***)
C	1.20 (-0.55)
ECM	-0.50 (0.045***)

Note: *, ** and *** refer to the levels of significance at 1%, 5% and 10%, respectively.

This is supported by the significant negative effect of green finance (LGRNF, -0.10, highly significant at 0.000***). The p-value for the constant term is not statistically significant (-0.55), suggesting that there could be other factors at play that have not been accounted for in the reported CO_2 levels. Overall, these findings emphasize the significance of adaptable policy frameworks that can quickly integrate eco-friendly practices and green financing to reduce the negative impact of economic growth on the environment.

CONCLUSION AND POLICY IMPLICATIONS

This study provides a thorough assessment of the role of green financing and eco-innovation in reducing CO2 emissions in ASEAN countries, with a focus on the Sustainable Development Goals (SDGs). Utilizing the panel Autoregressive Distributed Lag (ARDL) methodology, this study demonstrates that targeted financial and technological strategies have the potential to significantly enhance sustainability goals 7 (Affordable and Clean Energy), 9 (Industry, Innovation and Infrastructure), and 13 (Climate Action). Robust policy frameworks that promote and enable green finance systems are crucial, as evidenced by the findings. Strengthening these systems through financial incentives such as subsidies, grants, and tax breaks can greatly encourage investments in eco-friendly projects, aligning with global sustainability targets. Furthermore, the potential for these initiatives to have a wider reach and more significant impact could be realized by implementing standardized green finance products.

This would enhance transparency, attract a larger pool of investors, and so forth.Eco-innovation has become a crucial factor in the development of new technologies aimed at reducing environmental impact. This is made possible through investments in research and development by the government and active involvement of the private sector. Collaboration between academic institutions and research bodies could potentially accelerate the adoption of sustainable solutions, making it a

promising policy measure to foster innovation. In order to ensure that economic growth does not exacerbate environmental degradation, it is crucial to integrate the SDGs into national economic planning and advocate for new growth metrics that consider social and environmental factors. It is crucial to tailor policymaking to the unique economic and environmental conditions of each ASEAN member state. This approach aims to optimize the effectiveness and relevance of interventions across different settings, ensuring their maximum impact. Furthermore, enhancing regional cooperation can greatly enhance these efforts, as the member states of the Association of Southeast Asian Nations (ASEAN) can benefit from exchanging information, adopting standardized practices, and making collaborative investments in eco-friendly infrastructure and technology. In order to drive systemic change, it is crucial to increase awareness and enhance capacities in the field of green technology and financing. To cultivate a knowledgeable and involved community that embraces and reaps the rewards of sustainable practices, it is essential to establish educational programs targeting businesses, lawmakers, and the general public.

Ultimately, through the implementation of these policies, ASEAN nations have the opportunity to harness the benefits of green financing and eco-innovation in order to successfully reach their SDG targets. This will not only bolster their economies, but also enable them to become more responsible stewards of the environment. This comprehensive plan is poised to make significant strides in mitigating the impacts of climate change and achieving sustainable development, serving as a model for other nations in their pursuit of a greener future.

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