The impact of green finance, economic growth and energy usage on CO_2 emission in Vietnam – a multivariate time series analysis

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Abstract

Purpose – This study aims to examine the relationship between green finance, economic growth, renewable energy consumption (energy efficiency), energy import and CO_2 emission in Vietnam using multivariate time series analysis.

Design/methodology/approach – The data were collected from 1986 to 2018 since Vietnam initiated the economic reforms, namely "Doi Moi" in 1986. The concept and methods of cointegration, Granger causality and error correction model (ECM) were employed to establish the relationship between the variables of interest.

Findings – Our results confirmed the existence of cointegration among the variables. The Granger causality test revealed unidirectional causality running from renewable energy consumption to CO_2 emission and green investment to CO_2 emission.

Originality/value – This study results confirm the existence of cointegration among the variables. The results of the study imply that policies on economic development impose a significant impact on pollution in Vietnam. This study has described Vietnam, its economic development, green manufacturing practices, its environmental health and level of carbon dioxide emission which was enhanced due to COVID-19.

Keywords Green finance, Economic growth, GDP, CO_2 emission, Renewable energy, Energy import

Paper type Research paper

1. Introduction

Green finance and energy efficiency have played a vital role in reducing environmental degradation by providing finance and utilizing renewable energy called efficient energy to reduce carbon (CO_2) emissions (Li *et al.*, 2021a; Ehsanullah *et al.*, 2021; Chien *et al.*, 2021a). Economic development is one of the essential goals of every nation. It is a significant factor for all countries to examine their general status of a country. Every year, prestigious organizations inside and outside a country provide reports or synthesized data on economic development to view the country's economy thoroughly. Reports and figures on Vietnam's economic growth can be found in the World Bank or the General Statistics Office of Vietnam (GSO Vietnam). The economic development of a country leads to both positive and negative consequences.

Economic development has brought many positive impacts on a country, such as creating more jobs for workers, increasing gross domestic product (GDP) for the country and increasing incomes for people. However, many serious issues need attention and resolution because of the negative impacts that economic development has caused. One of the top issues is environmental pollution. Economic development is accompanied by a fast-growing number of companies, factories and enterprises, leading to a concentrated workforce living in these areas. Thus, resulting in CO_2 emissions from human activities and causing negative impacts on human habitats and natural ecosystems. For these reasons, this study aimed to analyze the relationship between economic development (measured by GDP), green finance, energy usage and CO_2 emissions to understand whether a causal relationship exists between

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economic development and environmental pollution in Vietnam. If so, what the relationship is like in particular (Chakraborty and Maity, 2020).

One of the major problems of the 21st century is global change. Despite the attempts in recent decades to preserve nature, humans have only been willing to take few measures forward but not to a commendable degree. The environment and energy usage are associated with each other, and efficient energy and green finance could improve the condition of the environment. As a result of globalization, the world's environment was already at stake (Zambrano-Monserrate *et al.*, 2020). The world's glaciers are melting at a rapid speed. The international environment-related community is worried about drastic negative changes in the world environment. As a result of COVID-19, the environment of the world has become more polluted. The world is already in the process of controlling the world environment by applying the green finance concept. This enhancement in pollution also results in an enhancement in CO_2 emission.

Energy usage always remains a core issue for the world. The use of energy decides the world environment's future whether it will get more polluted or clean. The environment is getting more polluted, resulting in less energy usage, whether renewable or nonrenewable (SanJuan-Reyes *et al.*, 2021; Chien *et al.*, 2021b; Li *et al.*, 2021b). Energy usage is distributed in multiple ways, i.e. residential, commercial, transportation and industrial. When people quarantine themselves, this act affects all the sectors of energy usage. Once people get themselves quarantined in their homes, this means that all the energy usage phases get affected. For instance, when there is no movement, this means nil transportation usage; and when the country's institution is locked, this means no use energy usage commercially and industrially. This less energy usage also results in less usage of renewable energy. All this increases the demand to increase the need to use renewable energy (Cheval *et al.*, 2020; Hsu *et al.*, 2021; Li *et al.*, 2021c).

Another factor in controlling environmental pollution is the concept of green financing. The importance of green finance literature is increasing at a rapid pace. The world has realized that to control the world's increasing temperature, the best remedy is to invest in green finance projects. The demand for green finance is enhanced due to the less energy usage (Espejo *et al.*, 2020). The more investments in green finance projects, there will be lesser pollution in the world environment. A global financial structure produces, values and transacts capital assets such that real resources can fulfill the long-term needs of an equitable and sustainable community. Green finance then applies to all financial tools that are earmarked for programs and interventions for renewable growth, agricultural goods and policies with the sole aim to facilitate a green economic transition to reduce the increasing CO_2 emission while improving the sustainable and equitable pathways (Wang and Su, 2020; Chien *et al.*, 2021c; Li *et al.*, 2021c). Green finance's two primary objectives are to control the growing threats of the environment and to reduce risk expectations. Promoting broad and economically feasible green financing helps to favor green initiatives over business-as-usual investments that preserve unsustainable development trends. Green finance facilitates openness and long-term investment which will flow toward environmental priorities and contains many of the requirements for sustainable growth defined under the UN sustainable development goals (SDGs) (Madurai Elavarasan and Pugazhendhi, 2020).

Green finance offers investment funding for all financial sectors and assets that incorporate environmental, social and governance-ESG requirements into investment decisions; therefore integrating sustainability into risk management to promote sustainable economic growth. Various participants in the investment value chain increasingly use environmental, social and governance-ESG knowledge in their reporting processes. As the reporting of environmental, social and governance-ESG moves from niche to mainstream and continues to have consequences for the balances, investors ask tough questions about assessing, managing and reporting environmental, social and governance-

ESG results. Environmental, social and governance-ESG's risk estimates of insurers' three-fold asset and responsibility are critical: physical risk, transfer risk and liability risk. For banks, environmental, social and governance-ESG threats affect the creditworthiness of banks. Banks will also include sustainable loans and provide environmental effects in risk analyses and price assessments. In order to recognize challenges and rewards, institutional investors should combine environmental, social and governance-ESG portfolio selection and management considerations (Barcelo, 2020).

Most studies focus on the green finance and environmental degradation such as Zhou *et al.* (2020) and Hafeez *et al.* (2018). But the role of green finance along with energy efficiency and economic growth on the CO_2 emission in Vietnam is one of the first attempts. A study conducted by Shove (2018) on energy efficiency and carbon emission recommended that future studies could examine the impact of energy efficiency along with green finance on the CO_2 emission. Therefore, current study answers the gap mentioned above and investigates the impact of green finance, economic development and energy usage on CO_2 emission. The research is valuable for the policymakers while developing the policies related to the green finance and energy efficiency role on carbon emission. This study is also beneficial for the environment protection authorities of Vietnam to control the high environmental degradation in the country. Thus, the current research aims to investigate the relationship between green finance, economic development, energy usage and CO_2 emission. The objective of the study includes:

(1) To examine the effects of green finance on CO_2 emission in Vietnam.

(2) To investigate the impact of energy efficiency on the CO_2 emission in Vietnam.

(3) To explore the relations of economic development and environmental degradation.

Based on the above objectives of the study, the current study has the following research questions that need to be answered:

RQ1. Does green finance affect environmental degradation in Vietnam?

RQ2. Does energy efficiency affect CO_2 emission in Vietnam?

RQ3. What is the relationship between economic development and CO_2 emission in Vietnam?

In Vietnam, there were few studies conducted on the relationship between economic growth, green finance, renewable energy consumption and CO_2 emission; where most of the results found two-way causalities between CO_2 emissions and income using integration and Granger causality tests (Klemeš *et al.*, 2020). In addition, most research were based on the environmental Kuznets curve (EKC) approach, which assumed an inverted U-shaped relationship between income and pollution, deals with the relationship between economic growth and pollution that resulted in controversial outcomes. For example, the study supported the EKC hypothesis, which assumed an inverted U-shaped relationship between CO_2 emissions and economic growth in Vietnam from 1976 to 2009 (Jiang *et al.*, 2021). However, the empirical results did not support the EKC theory in Vietnam from 1980 to 2010. There was also another study that investigated the existence of the EKC hypothesis in Vietnam between 1981 and 2011 (Chen *et al.*, 2020). Using the autoregressive distributed lag (ARDL) method, they found that the EKC hypothesis did not exist because the relationship between GDP and pollution was positive in both the short and long run. More recently, the 1974–2016 annual data of Vietnam showed that the EKC did not exist in the short run but only in the long run and that the N-shape described the long run income-pollution relationship better (Fell *et al.*, 2020). The current investigation investigates the relationship between green finance, economic development, energy usage and CO_2 emission. Furthermore, the current investigation is all about Vietnam.

2. Literature review

This study is supported by the green economy theory that highlighted the links between the people and the environment. The individual should improve the environment by using green growth, green finance and green and efficient energy (Bondarenko *et al.*, 2020). The green economy theory forces individuals to use green finance and efficient energy to improve green economic development and to not affect the environment (Ivlev and Ivleva, 2018; Chien *et al.*, 2021a). Thus, the current study also investigates the impact of green finance, economic development and energy usage on the CO_2 emission in Vietnam.

GDP measures the total income of a nation, which means the total income of everyone in the economy. GDP is the most closely watched economic statistic because it is thought to be the single best measure of a society's economic well-being. Therefore, GDP is an important indicator used to track the health of a nation's economy, such as economic growth. One of the negative consequences of economic development is CO_2 emission because it has been reported to be significantly linked to air pollution and climate change which has seriously damaged our environment and life (Jiang *et al.*, 2021; SanJuan-Reyes *et al.*, 2021; Nguyen *et al.*, 2021; Othman *et al.*, 2020). The relationship between green finance, GDP, energy usage and CO_2 emission has been found in many countries and they are controversial. It could be a nonsignificant, unidirectional or bidirectional causality relationship between them, either in the long- or short-run (Smith and Mennis, 2020). For instance, there was a significant long- and short-term causal relationship between CO_2 emissions and economic growth in Pakistan (Hosseini, 2020). Additionally, the bidirectional causal relationship was also investigated between CO_2 emissions and growth (Nawaz *et al.*, 2020a, b).

Another factor that plays a vital role toward CO_2 emission reduction is the investment in the green finance project (Nawaz *et al.*, 2020a, b; Anh Tu *et al.*, 2021). A green financing facility is a combination of the related facilities. The credit facility is one of the core factors of green financing. Credit facility in the world has provided numerous opportunities for businesses to enhance their operational capabilities, which further lessen the environmental threat by reducing the CO_2 emission, which improved as a result of COVID-19 (Chakraborty and Maity, 2020). Green finance could enhance the green economic growth that does not affect the environment and reduce CO_2 emissions (Zhang *et al.*, 2021). In addition, the green credit grantee scheme that is also a part of the green finance could improve the environment and reduce CO_2 emissions (Taghizadeh-Hesary and Yoshino, 2019). Moreover, low CO_2 emission in the country can be achieved using green finance and efficient energy that reduces environmental degradation (Mohsin *et al.*, 2020). A study by Yoshino *et al.* (2021) reported that sustainable environmental goals can be achieved using green finance and efficient energy.

This facility has also eluded the restrictions of business expansions which were prevalent on environmental control. Therefore, green credit inducement in the current world has emerged with numerous policies that provide ease of business facilities in terms of environmental control (Naderipour *et al.*, 2020). The facilities of credit loans to companies have mitigated the environmental impact in organizations. This induction has also provided the facilities for companies to enhance their poor environmental performance. While reining the credit loans to organizations, the policy of green credit implementation has gained much importance at both provincial and national levels. It is the significant mode of achieving standards and lack of environmental problems that are prominent in the organization (Paez *et al.*, 2020; Vaka *et al.*, 2020).

The integration of policy with global influence has attained practical importance that has enhanced the performance rating system. This is a positive approach in many countries where the green credit system has been established to control the environmental threats which are getting worse (Eroğlu, 2020). The enhanced policy of green credit has also eliminated the vague policies, which were harmful for organizational growth and the betterment of the environment. It also asserted its positive contribution toward economic growth by the outlined improvement

in the world's environment. Some remarkable achievements have emerged in the global world, which are dominant in the industries. These achievements are positive endurance of the green credit which induced its prominent importance among the elements of organizations and governments. Green credit policy is the paradox among optimization of industrial structure, emission reduction and energy saving. Numerous gaps also existed among the local governments and enterprises with the illustration of expectations and realities with the policy execution of green credit (Leach *et al.*, 2021).

Investment in the organizations is a positive contributor of growth toward the world's environmental health, which gets badly affected by COVID-19. This contribution is usually based on investors' perception, which is more about the economic and environmental conditions. The exclusionary impact of ethical investments also influences corporate behavior. Therefore, green investments asserted a significant role among the costs of a firm's capital. This influence and role are presented by the equilibrium behaviors of green investments, which are reluctant due to effective policies toward projects. Various reforms have been made in the organizations due to reluctant behaviors of green investment (Ataguba, 2020). This is an incentive toward the firms which are indulged in the parameters of environmental pollution. Therefore, some reasonable measures are required in the organizations to avail the ultimate benefits of green investment, which uplifts the environmental conditions. This is upon the trends of green investments, which extends the benefits that boost the performance of organizations (in terms of environment control support operations) and economies.

With the emergence of economic conditions in most countries, the value of green investment has also been enhanced (Gopalan and Misra, 2020). This enhancement induces sound financial systems that refer to the low interest rate with high fuel prices. Some intervention of green investment policies drives the support toward organizations that are closely associated with investing elements. The cash flows are also associated with the financial elements of green investment, which states societal benefits, i.e. betterment of the air and other related pollution, carbon emission etc. Energy imports have a prominent role in the increment of energy resources. This prominence also induces a significant impact on the carbon emission of energy systems. Therefore, the reduction in energy imports could cause a substantial impact on energy security, imported fuels, diversification of energy resources and primary energy supply. This diversification of energy resources is eminent with the two-fold impact of reducing energy resources while cumulating renewable energy. Although the results are eminently inducing a positive role due to the reduction, the role of resilience also prevails.

The prevalence of resilience in energy import develops the investigations over output and input of energy imports (Chakraborty and Maity, 2020; Madurai Elavarasan and Pugazhendhi, 2020). It could enumerate the levels of energy import that can endure the sacrificing demands of domestic companies. These levels are a significant enumeration of assumed portfolios developed with dependencies in the improvement of energy resilience. This development confronts the influence of political leadership, which expands the diversification of energy imports. It not only impacts the economic conditions but also enumerates the drawbacks as well. Some beneficial alternatives have been described with specific circumstances which enhance the importance of energy import and its influence on strategic decision making. Many countries have placed the procedure of scrutiny over energy imports that are important for the development of future to tackle challenges. Some prominence of geographical locations has widely stated the ambiance in regions where the energy import benefits. These benefits are taken mainly by large organizations, contributing to the significant portion of energy import. The emergence of energy imports is also linked with the development of international tourism with rich cultures (Gautam and Hens, 2020; Tisdell, 2020). Energy imports will play a vital role in the improvement of environmental health.

Renewable energy consumption, environment and economic growth are significantly linked with each other. The driving demand for renewable energy consumption has created

numerous opportunities for emerging economies. It is only due to the high usage of renewable energy that is dominant for income generation, but focusing more on environmental betterment in many countries (Jin, 2020; Tsao *et al.*, 2021). Some positive impacts have also been ascertained in many economies where the variation of energy consumption is usually based on the geographical structures of organizations. The relationship between renewable energy consumption, environmental and economic conditions is prevalent in the long-run equilibrium. This linkage significantly exists among the labor force factors, capital formation, renewable energy consumption and real GDP. This dominates the economic conditions, which are closely associated with a variety of macroeconomic factors. Although macroeconomic elements indicate its long-run and short-run impact, the enhancement in renewable energy usage is the urgent need to minimize the COVID-19 threat in terms of the environment (Aktar *et al.*, 2021; Rizou *et al.*, 2020). This impact is also enumerated by the positive relationship between economic growth and renewable energy consumption.

The functions of augmented and classical production make a comparison among the renewable energy consumption. This comparison states the series of functional elements for the development of betterment in disturbed environmental conditions. The factors associated with renewable energy consumption have positively contributed to reducing CO_2 emission (Atalan, 2020; Wilcox *et al.*, 2003). Although some impacts are dominant in many countries, effective policies of developing renewable energy through the bulk of wastage cover huge costs. This relevance of cost is also considered a massive barrier toward the development of better economies. Therefore, many countries have benefited from their environmental and economic conditions through the effective usage of renewable energy.

2.1 Theoretical background

The past literature such as Zhang *et al.* (2021), Taghizadeh-Hesary and Yoshino (2019) and Yoshino *et al.* (2021) have reported that green finance has a positive and significant influence on the environment and reduce the CO_2 emission of the country. In addition, past studies such as Awodumi and Adewuyi (2020), Shuai *et al.* (2019) and Khan *et al.* (2020) indicated that economic growth could reduce the CO_2 emission in the country and has a positive and significant influence on the environment. Moreover, the studies of Nguyen and Kakinaka (2019), Emir and Bekun (2019) and Acheampong *et al.* (2019) have shown that effective renewable energy consumption has a positive and significant influence on the environment and reduce CO_2 emission. Based on the above-mentioned studies, the current study has developed the theoretical framework that shows green finance such as green credit and green investment along with economic growth, renewable energy consumption and energy import have a significant association with CO_2 emission and environmental performance.

3. Data and research method

This study investigated the nexus among green investment, green credit, economic growth, renewable energy consumption, energy import and CO_2 emission of Vietnam. The data includes observations collected for GDP, renewable energy consumption, energy import, green credit, green investment and CO_2 emissions since Vietnam implemented the "Doi Moi" policy to date, specifically for the period of 1986–2019. The estimation equation is as follow:

$$CO_{2t} = \alpha_0 + \beta_1 GC_t + \beta_2 GINV_t + \beta_3 EG_t + \beta_4 REC_t + \beta_5 EI_t + e_t \quad (1)$$

where;

CO_2 = Carbon emission

t = Time period

GC = Green credit

GINV = Green investment

EG = Economic growth

REC = Renewable energy consumption

EI = Energy import

Green finance was measured by using green investment and green credit. In particular, the data for GDP was calculated in GDP per capita growth (annual percentage) and CO_2 was the emissions from residential buildings, commercial services and public services (percent of total fuel burning) and was calculated as a percentage, denoted by CO_2 in the data processing. In contrast, green investment was measured as the ratio of investment in environmental protection projects to GDP and green credit was measured as the ratio of green loans to total loans. In addition, renewable energy consumption was measured as the percentage of total energy consumption and energy import was measured as the energy import to total energy usage. The measurements are shown in Table 1.

To analyze the relationship between the two-time series, the commonly used statistical model is VAR (vector autoregressive) or VEC (Vector Error Correction) model. The usual procedure is to first unit test for two-time series. If it is found to be stationary, then the Granger causality test and estimation of the VAR model are applied; otherwise, if the two-time series is not stationary, then we test the cointegration. If cointegration exists, then we estimate the VEC model to examine the causal relationship.

3.1 Unit root test

This test was conducted to see if the time series is stationary or otherwise. A stationary time series process is one whose probability distributions are stable over time in the following sense: if we take any collection of random variables in the sequence and then shift that sequence ahead in a fixed time period, the joint probability distribution must remain unchanged. If time series are non-stationary, there may be a spurious regression between the two series. Even though they are independent of each other, a strongly significant relationship can be given when we conduct regression analysis for these time series. The commonly used unit root test include the Dickey–Fuller tests. The estimation equations for the unit root test are as follow:

$$d(Y_t) = \alpha_0 + \beta t + \gamma Y_{t-1} + d(Y_t(-1)) + \varepsilon_t \quad (2)$$

S#	Variables	Measurement	Sources
01	Carbon emission	Emissions from residential buildings, commercial services and public services (percent of total fuel burning)	World bank database
02	Green credit	The ratio of green loans to total loans	Central bank of Vietnam
03	Green investment	The ratio of investment in environmental protection projects to GDP	Central bank of Vietnam
04	Economic growth	GDP per capita growth (annual percentage)	World bank database
05	Renewable energy consumption	Renewable energy consumption (percentage of total energy usage)	World bank database
06	Energy import	Energy import (percentage of total energy usage)	World bank database

Table 1.
Variables with measurements

Thus, for the individual construct, stationarity was examined separately, and estimation models of each construct are given below:

$$d(\mathrm{CO}_{2t}) = \alpha_0 + \beta t + \gamma \mathrm{CO}_{2t-1} + d(\mathrm{CO}_{2t}(-1)) + \varepsilon_t \quad (3)$$

$$d(\mathrm{GLC}_t) = \alpha_0 + \beta t + \gamma \mathrm{GC}_{t-1} + d(\mathrm{GC}_t(-1)) + \varepsilon_t \quad (4)$$

$$d(\mathrm{GINV}_t) = \alpha_0 + \beta t + \gamma \mathrm{GINV}_{t-1} + d(\mathrm{GINV}_t(-1)) + \varepsilon_t \quad (5)$$

$$d(\mathrm{EG}_t) = \alpha_0 + \beta t + \gamma \mathrm{EG}_{t-1} + d(\mathrm{EG}_t(-1)) + \varepsilon_t \quad (6)$$

$$d(\mathrm{REC}_t) = \alpha_0 + \beta t + \gamma \mathrm{REC}_{t-1} + d(\mathrm{REC}_t(-1)) + \varepsilon_t \quad (7)$$

$$d(\mathrm{EI}_t) = \alpha_0 + \beta t + \gamma \mathrm{EI}_{t-1} + d(\mathrm{EI}_t(-1)) + \varepsilon_t \quad (8)$$

3.2 Granger causality test

Correlation does not imply causality because correlation or covariance is asymmetric, bivariate relationship: $\mathrm{cov}(x, y) = \mathrm{cov}(y, x)$. However, Granger causality, defined by Granger (1969), can infer possible causality between pairs of variables. The x is said to "Granger cause" y when past values of x aid in the prediction of y_t, conditional on having already accounted for the effects on y_t of past values of y, i.e. $x \geq y$.

To perform the Granger causality test, time series must be stationary. Therefore, we first need to conduct a unit root test for time series to determine whether they are stationary or non-stationary. If at least one of these series is non-stationary, then we might find other ways, such as getting the first difference to make the series stationary to test the Granger causality later. However, differencing variables limits the scope of the questions that we can answer. Thus, we might apply other methods suitable for non-stationary series, such as the ARDL model (Pesaran *et al.*, 2001).

3.3 Test for cointegration

The notion of cointegration, which was given a formal treatment, makes regressions involving I (1) variables potentially meaningful. Time series are said to be integrated of order zero, or I (0), which means that nothing needs to be done to such series before using them in regression analysis; averages of such sequences already satisfy the standard limit theorems. I (0) therefore also mean that the series is stationary. The issue of cointegration applies when two series are I (1), but a linear combination of them is I (0); in this case, the regression of one on the other is not spurious but instead tells us something about the long-run relationship between them. Cointegration between two series also implies a particular kind of model, called an error correction model (ECM), for the short-term dynamics. So, if the series x and y are non-stationary and cointegrated, then the Granger causality test will no longer be suitable and a more suitable way of causality test will be considered, such as Johansen's likelihood ratio test for cointegration, based on the ECM.

3.4 The error correction model (ECM)

In the analysis of vector autoregressions, we assume that the variables of the model are stationary. Individually non-stationary variables may be cointegrated: two (or more) variables may have common underlying stochastic trends along which they move together on a non-stationary path. An ECM is the appropriate econometric specification for the simple case of two variables and one cointegrating relationship. In this model, the equation is differenced and an error-correction term was measuring the previous period's deviation from long-run equilibrium.

$$\Delta y_t = \beta_{y0} + \beta_{yy1}\Delta y_{t-1} + \beta_{yx1}\Delta x_{t-1} + \lambda_y(y_{t-1} - \alpha_0 - \alpha_1 x_{t-1}) + v_t^y \quad (9)$$

$$\Delta x_t = \beta_{x0} + \beta_{xy1}\Delta y_{t-1} + \beta_{xx1}\Delta x_{t-1} + \lambda_x(y_{t-1} - \alpha_0 - \alpha_1 x_{t-1}) + v_t^x \quad (10)$$

All the terms in the above equations are I (0) if the variables are cointegrated with cointegrating vector (1, $-\alpha_0$, $-\alpha_1$), which means if ($y_{t-1}-\alpha_0-\alpha_1 x_{t-1}$) term is stationary. The λ coefficients are the error-correction coefficients, measuring the response of each variable to the degree of deviation from long-run equilibrium in the previous period. Since $\partial\Delta y_t/\partial y_{t-1} = \lambda_y$, we expect λ_y to be negative for the reason that: if y_{t-1} is above its long-run value in relation to x_{t-1} then the error-correction term in parentheses is positive and this should lead other things constant, to downward movement in y in period t. The coefficient λ, which we expect to be negative, represents the amount of correction of this period (t–1) disequilibrium that happens in period t. For example, if λ_y is −0.25, then 25% of the gap between y_{t-1} and its equilibrium value would tend to be reversed in period t because the sign is negative.

The expected sign of λ_x depends on the sign of α_1 because $\partial\Delta x_t/\partial x_{t-1} = -\lambda_x\alpha_1$ and we expect $-\lambda_x\alpha_1 < 0$ for the reason that if x_{t-1} is above its long-run relation to y, then we expect Δx_t to be negative, other things constant. x is said to cause a Granger effect on y if in the equation of Δy_t the coefficients of the lag variables of x, which represent the long-term relationship, or the coefficient of the error correction component, which represents the short-term relationship, is statistically significant. A similar approach adapts to the equation of Δx_t when considering y causes Granger effect on x.

4. Results

The results section shows the descriptive statistics and the unit root test, ECM and Granger causality tests. These analyses are given below in subsections.

4.1 Descriptive statistics

Table 2 below shows the variables' descriptive statistics, including economic growth, renewable energy consumption, green investment, green credit, energy import and CO_2. These results showed the mean values along with standard deviation and minimum and maximum values.

4.2 Test for stationary

The unit root tests by Dickey–Fuller were employed to test for stationary. The null hypothesis of these tests was that the series is not stationary. The results revealed that both, EG, REC, GINV, GC, EI and CO_2 time series are non-stationary at a level. However, the first difference of EG, REC, GINV, GC, EI and CO_2 were stationary. This implies a potential cointegration between the two series. These values are highlighted in Table 3.

4.3 Johansen test for cointegration

Johansen test was applied only for series with the same integration I (q) where $q > 0$. Here we used the Johansen test with the trend since we identified a significant trend in each series previously in the descriptive statistics section. The null hypothesis (Ho) was that the series are not cointegrated. We reject Ho if the value of the statistic is greater than the critical value. The results showed both trace statistic and max statistic were larger than a critical value, confirming that CO_2, REC, GINV, GC, EI and EG are cointegrated and they have one cointegration vector; therefore, they have a long-run relationship, which means that the two series go together in the long run. These values are highlighted in Table 4.

4.4 Error correction model (ECM)

The ECM outputs showed a short-run causality from GDP, GINV, GC, REC and EI to CO_2. The error correction term was −1.085095, indicating the speed of adjustment toward equilibrium, which means 80.51% of the gap between $CO_{2(t-1)}$ and its equilibrium value would tend to be reversed in period t because the sign was negative. These values are mentioned in Table 5.

The Granger casualty test was also examined by the researchers to check the both sided nexus among the variables. The outcomes showed no causality among CO_2 and economic growth, CO_2 and EI, and CO_2 and GC while a unidirectional causality between CO_2 and GINV, CO_2 and REC. These are shown in Table 6.

5. Discussions

Vietnam is a developing country with an emerging economy and green financing system. This study describes the impact of green financing options on the overall CO_2 emission in Vietnam. The results have indicated that green finance has a negative association with CO_2 emission in Vietnam and these outcomes are in line with the results of Li *et al.* (2021a), who also exposed that green investment reduces CO_2 emission in the country. The results of the proposed experimental techniques summarized the overall development of an eco-friendly atmosphere. These findings were directly correlated with the research-based studies (Tien *et al.*, 2020). The results also exposed the renewable energy consumption or energy efficiency

Variable	Obs	Mean	Std. Dev	Min	Max
CO_2	33	5.144	4.192	1.634	13.288
GINV	33	0.265	0.383	0.309	0.435
GC	33	0.166	0.188	0.102	0.416
EG	33	4.678	1.243	3.610	8.720
REC	33	0.212	0.655	0.171	0.437
EI	33	0.248	0.632	0.156	0.448

Table 2. Descriptive statistics

Augmented Dickey–Fuller test (ADF)	Level	*t*-statistics	*p*-values
CO_2	I (1)	−6.953	0.0000
GINV	I (1)	−8.022	0.0000
GC	I (1)	−5.604	0.0001
RG	I (1)	−4.908	0.0004
REC	I (1)	−6.127	0.0000
EI	I (1)	−4.315	0.0019

Table 3. Unit root test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical value	Prob**
None*	0.781049	145.9112	102.8473	0.0000
At most 1*	0.554039	80.15370	75.97277	0.0131
At most 2	0.412731	45.28521	53.07904	0.1056
At most 3	0.257036	22.20847	34.19275	0.4145
At most 4	0.127680	9.16080	19.26184	0.5240
At most 5	0.079530	2.939375	8.164546	0.3212

Note(s): * denotes rejection of the hypothesis at the 0.05 level; ** MacKinnon *et al.* (1999) *p*-values

Table 4. Unrestricted cointegration rank test (trace)

Table 5.
Error correction model

Variable	Coefficient	Std. Error	*t*-statistic	Prob
D(GINV)	−1.450432	0.169265	−8.569001	0.0000
D(GC)	−0.352896	0.141657	−2.491201	0.0090
D(EG)	1.436952	0.320123	4.488749	0.0000
D(REC)	−0.155515	0.064106	−2.425904	0.0102
D(EI)	0.556290	0.073828	7.534946	0.0000
ECT(−1)	−0.805095	0.123059	−6.542349	0.0000
C	0.824283	0.329373	2.502582	0.0101
R^2	0.731111	Mean dependent var		−0.160743
Adjusted R^2	0.712963	S.D. Dependent var		3.572583

Table 6.
Granger causality test

Null hypothesis	Obs	*F*-statistic	Prob	Decision
EG does not Granger cause CO_2	33	0.79595	0.4169	NO
CO_2 does not Granger cause EG		1.12913	0.3673	
GINV does not Granger cause CO_2	33	0.25232	0.7054	
CO_2 does not Granger cause GINV		4.26581	0.0234	Unidirectional
GC does not Granger cause CO_2	33	2.17743	0.1396	
CO_2 does not Granger cause GC		0.44486	0.7106	NO
REC does not Granger cause CO_2	33	1.26213	0.2687	
CO_2 does not Granger cause REC		3.21612	0.0612	Unidirectional
EI does not Granger cause CO_2	33	1.73375	0.1740	
CO_2 does not Granger cause EI		2.26709	0.1078	NO

to reduce the CO_2 emission, and this result matched with the findings of Shove (2018), who also indicated that the energy efficacy reduces environmental degradation. The modern industries have successfully been implemented in Vietnam and the results were quite drastic in previous years. These results also exposed that economic growth has a positive linkage with CO_2 emission and were similar to the results of Shuai *et al.* (2019), who also found that a positive association with economic development and environmental degradation.

This study explains the impact of CO_2 emissions on global warming and the ozone layer depletion crisis on Vietnam's economy and environmental health (Le *et al.*, 2020). Green financing is another way to improvise the environmental condition of Vietnam and this research paper proved that green financing affects the enhancement in CO_2 emission. Specifically, the evidence from Vietnam showed in this research paper matches the research findings of the research group in Chinese universities (Anser *et al.*, 2020). Globalization is the new and improvised trend of modern societies. Green investments are the emerging notion of a modernized world. This trend is essential for the economic and social well-being and the environmental betterment of the nations. Sustainable development and protection of natural habitats are also vital, and this paper showed that Vietnam is making rapid progress in environmental improvisation (Ridzuan *et al.*, 2020). The pace of success is quite fast in terms of economic growth and environmental advancement in Vietnam (Jelínek *et al.*, 2021).

The technological advancements are numerous and the current study describes the impact of energy usage and globalization on CO_2 emission in Vietnam. Modern societies are the hub of technological advancement. Energy usage is imperative for the business firms to work properly with the intention to recover from the COVID-19 pandemic after effects. The trend of the establishing improvised and techno-smart firms in Vietnam is a major cause of environmental pollution. The research findings are in coordination with the research findings of previous researchers (Wang *et al.*, 2020). Economic growth and development are the most

integral part of national growth and are associated with CO_2 emission. The emergence of new and innovative technological advancements has provided a safe hub for developing green projects. This study shows the association between economic growth and CO_2 emission in Vietnam. Modern machinery and green manufacturing practices have helped Vietnam to cope with the havoc caused by the COVID-19 pandemic. These findings are in line with the research of the researcher.

The CO_2 emission index is a trend to improve the environmental health of the community. The trading and transfer of information with other nations worldwide are essential for economic stability, but the cost of the nation's health is not suitable. Vietnam has improved a lot in these years, and this study described and correlated the impacts of economic growth on the modernized societies and safe green manufacturing practices of Vietnam. The most important thing is that the government of Vietnam should take radical steps to improve environmental health and economic development simultaneously. The research findings aligned with the research work of Abdul-Latif *et al.* (2020).

5.1 Conclusion

The results indicated that renewable energy consumption and green finance have a significant impact in reducing pollution in Vietnam. Effective renewable energy consumption and the valuable investment in green finance could reduce CO_2 emission and improve the environmental condition in Vietnam. This current study also deduced that the economic development, green manufacturing practices, environmental health and social, technological and economic corporate social responsibility of Vietnam had shown the seriousness of the nation toward the environmental conditions of the country. Additionally, the investment in green projects is fruitful in terms of the enhanced ecological and environmental performance of Vietnam. Therefore, the correct and effective usage of renewable energy is essential to provide new endeavors for psychological and ecological sustainability. The current study supports the process of green financing and biologically sound practices. The study suggests that the modernized nations with more technological advancements are prospering in the world by virtue of their eco-friendly products.

5.2 Study implications

The current study has theoretical and practical implications that are mentioned under the subsection given below:

5.2.1 Theoretical implications. This study has some theoretical implications, such as it provides theoretical support to the literature related to green finance, renewable energy consumption, economic growth and CO_2 emission. In addition, the study also provides theoretical support to the literature related to the relationships among renewable energy consumption and CO_2 emission, green finance and CO_2 emission, and economic growth and CO_2 emission. Finally, this study also provides theoretical support to the literature regarding joint relationships among green finance, renewable energy consumption, economic growth and CO_2 emission.

5.2.2 Practical implications. The economy of a large population like Vietnam and the human capital burden is thriving to achieve environmental betterment. The current study provides the help to develop effective policies that reduce CO_2 emission. The research is valuable for the policymakers while developing the policies related to the green finance and energy efficiency role on CO_2 emission. This study is also beneficial for the environment protection authorities of Vietnam to control the high environmental degradation in the country by using green finance and efficient energy. Further, this study provides the guidelines to the industry sector in Vietnam that they should reduce their CO_2 emission that affects the environment badly by using green finance and effective energy usage. Finally, the

current study provides guidance to the new studies that want to examine the green finance and efficient energy impact on environmental degradation.

5.3 Limitations and future directions

All the research works have some flaws in them that are due to the research-based shortcomings. The current study also has some crucial issues. These limitations of the current study are the way of hope and innovation for future researchers and their research works. This study is based on research-based evidence from a single country which is one of the developing and economies of the Asia–Pacific. So, the researchers have faced a lot of hurdles in data collection and overall analysis. Generalizability is scarce in these data which is the main limitation. Cross-verification of the research-based evidence is necessary in this regard. This research-based study suggested that if the industries are capable of maintaining the environmental safety precautions vide investment in green projects and business systematic simultaneously, then environmental as well as economic performance becomes marvelous in a very short length of time. The current study examines the impact of economic growth, energy usage and green financing on CO_2 emission rates in Vietnam, specifically. More independent and dependent variables are necessary for getting better results in future studies. Future researchers must find new data sets from different nations and communities of the modernized world to have a wide view and differentiate versions. The comparative analysis will provide additional information about different problems in adopting economic growth and CO_2 emission. Future researchers are suggested to use more independent variables in terms of GDP and safe environmental practices.

Highlights

(1) Currently, carbon emission has become a global issue that has adverse effects on the environment.

(2) The investment in renewable energy could reduce carbon emissions and environmental degradation.

(3) Green finance has been considered the foremost solution for environmental degradation and reduces carbon emission in the environment.

(4) The regulators should enhance their focus on green finance that controls environmental degradation and low investment in renewable energy.

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