Heliyon 10 (2024) e30149

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Spillover impacts of financial development and globalization on environmental quality in ASEAN countries

Bui Hoang Ngoc [a,*], Nguyen Huynh Mai Tram [b]

[a] The FEMRG Research Group, Ho Chi Minh City Open University, Ho Chi Minh City, Viet Nam
[b] Ho Chi Minh City Open University, Ho Chi Minh City, Viet Nam

ARTICLE INFO

JEL classification:
C23
F43
Q56
Q57

Keywords:
Financial development
Ecological footprints
Economic growth
Globalization
ASEAN countries

ABSTRACT

In the globalization era, the economic policy of a specific country might be influenced by the development of neighboring countries. Thus, this study aims to probe the direct and spillover effects of financial development, economic growth, and globalization on environmental sustainability in ASEAN countries during the period of 1992-2021. By applying three spatial regression models, the results are summarized: (1) There are positive spillover effects of financial development in neighboring countries on ecological footprint in a particular country; (2) Economic growth has a positive impact on ecological deficits in both the host country and neighboring countries in the short-run; (3) The expansion of globalization in neighboring countries has a negative spillover effect on the ecological footprint in a particular country and vice versa. Based on these findings, the study recommends that when a country formulates its economic policies, it is necessary to calculate the impact of that policy on neighboring countries and vice versa. Encouraging economic growth and expanding the money supply ought to go hand in hand with fostering greater integration. This integration is essential to counterbalance the potential adverse effects of these macroeconomic variables on environmental quality and ecological balance.

1. Introduction

Economic development associated with environmental protection has never been a simple problem for most governments, especially without harming natural ecosystems. According to Asongu [1], the choices of developing countries are not diverse because the pressure to improve per capita income is always high. Even if it does not enhance people's living standards, it can lead to societal instability. However, economic theory and empirical research show that it is impossible to promote economic growth without affecting the natural environment [2,3]. This statement implies a trade-off (perhaps in the short term) between promoting economic growth and reducing habitat quality or depleting ecological assets such as timber in forests, fish in the ocean, green space in urban areas, etc. Therefore, policymakers and economists worldwide always welcome and seek economic policies that cause little or no harm to environmental quality. In this context, good experiences from developed countries such as the OECD community and the United States in issuing environmental regulations are necessary for emerging countries, especially ASEAN nations.

Financial development is the government's primary solution to promote economic growth, as "injecting more money" into the economy will help economic activities become more diversified and liquid [4,5]. If inflation is ignored, financial development will affect all industries through the money multiplier effect, resulting in the implementation of many manufacturing or construction projects, creating new jobs

* Corresponding author. 97 Vo Van Tan Street, District 3, Ho Chi Minh City, 70000, Viet Nam
E-mail addresses: ngoc.bh@ou.edu.vn (B.H. Ngoc), tramnhm.20ae@ou.edu.vn (N.H.M. Tram).

https://doi.org/10.1016/j.heliyon.2024.e30149
Received 29 November 2023; Received in revised form 5 April 2024; Accepted 21 April 2024
Available online 25 April 2024

and contributing to increasing income. Admittedly, the notion "*more money, more growth*" was supported by several governments worldwide. However, this means that the economy will need more inputs for the production process, such as raw materials, energy, means of transport, etc., for which most of these factors are required based on natural exploitation [6,7]. Thus, the relationship between financial development and ecological assets is formed. Many previous studies found that financial development might damage the environment [8–12]. However, Muhammad, Kousar and Makhdum [13], Pata and Yilanci [14] argue that financial development helps increase income and environmental protection awareness for individuals, benefiting the environment. In three decades, many ASEAN members implemented expanded monetary policy to achieve economic growth goals, so investigating the impact of these policies on environmental quality in the host country and neighboring countries plays a vital role in issuing common policies for this community.

Analyzing the impact of financial development and globalization on environmental quality is essential for ASEAN countries because eight members, including Brunei, Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam, have fallen into the ecological deficit [15]. Parker [16] and Hung, Anh [17] noted that the ASEAN community faces numerous and severe environmental problems. If such as deforestation, green gas emissions, soil erosion, and biodiversity loss are not well-controlled, ASEAN countries may confront a scarcity of natural resources before achieving developed status. Therefore, gaining a comprehensive understanding of the direct and spillover effects of financial development, economic growth, and globalization on ecological deficits enriches economic theory and provides empirical evidence for ASEAN governments in drafting and promulgating common economic policies for the entire bloc, focusing on financial development, economic growth and environmental protection.

In terms of empirical studies, previous research on the relationship between financial development, economic growth, and globalization to ecological footprint has yielded inconsistent conclusions. Some studies found that financial development increases the ecological footprint [18,19], while Uddin, Salahuddin [20] argued that financial development reduces the ecological footprint. Moreover, the study by Omoke, Nwani [21] concluded that a decrease in the financial sector enhances the ecological footprint in the study context of Nigeria from 1971 to 2014. Hoang Ngoc [22] employed the panel non-linear autoregressive distributed lag approach and concluded that globalization negatively influences ecological footprint in 15 RCEP countries. Despite these dissimilarities, previous studies have also failed to answer some questions about the natural relationship between financial development and ecological footprint. Two questions arise: (*i*) Is there spatial spillover between financial development or ecological footprint between countries in a specific geographic area? (*ii*) If the spillover effect exists, how will an increase in a host country's financial development affect the ecological footprint of neighboring countries, and vice versa?

This study was conducted to address the two aforementioned questions in the context of 10 countries belonging to the Association of South-East Asian Nations (ASEAN) between 1992 and 2021. In addition to filling these research gaps, the contributions of this study can be summarized as follows:

Firstly, prior studies on ASEAN countries, such as those by Hung, Anh [17], Ahmed, Wang [2], and Kongbuamai, Zafar [23], have predominantly focused on the impact of financial development and globalization on the ecological footprint in specific countries. The spatial influence of the ecological footprint is rarely discussed in the earlier literature. This study applied three spatial econometric techniques to assess how financial development, globalization, and ecological footprint vary and are distributed across ASEAN members. The findings help identify the factors driving environmental problems in local countries and uncover interconnectedness among regions.

Secondly, spatial regression models can accommodate parameter variations across regions, accounting for differences in coefficients between neighboring countries, which other econometric methods might fail to adequately capture [24]. Therefore, the findings of this study provide a foundation for devising collaborative strategies and cross-border initiatives to collectively address environmental challenges in the ASEAN economic community. It also helps to develop effective strategies and interventions to reduce harmful environmental effects and unveils the interconnectedness and interdependencies among various members.

The study is divided into five sections. Following the introduction, Section 2 will review theories on the impact of economic activities on the environment. Section 3 presents the research model, data, and estimation methods. The empirical results are then discussed in Section 4, and the conclusions and policy implications are summarized in Section 5.

2. Literature review

2.1. Theoretical background

Economic theory recognized some models to explain the impact of economic activities on the natural environment, such as the hypothesis of the environmental Kuznets curve (EKC) proposed by Kuznets [25], or the POET (population, organization, environment, technology) model presented by Duncan [26]. However, the most widely used model is the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) proposed by Dietz and Rosa [27]. Accordingly, the impact of economic activities on environmental quality is expressed through the equation:

$$I_t = a.P_t^{\alpha}.A_t^{\beta}.T_t^{\gamma}.e_t$$

where, I (environmental impacts) represents the impact of economic activities on the quality of the environment, P (population) denotes the population size, A (affluence) represents wealth or the impact of economic growth, and T (technology) illustrates the impact of technologies. Parameters α, β, γ indicate the proportion of the impact of each factor on environmental quality, and a shows the impact of other elements, such as institutional quality, human capital, etc., in environmental protection. Thus, the STIRPAT model is open, allowing the researcher to include more country-specific variables (shown in parameter a) and the three main pillars P, A, and T that affect environmental quality.

2.2. Review of empirical studies

Undoubtedly, since the idea of the relationship between economic growth and environmental quality was proposed by Kuznets, attention to environmental quality has been raised by governments, businesses, and individuals. Numerous empirical studies have been conducted to confirm this relationship, such as those by Ang [28], Acheampong [29], Sarkar, Al-Amin [30], Altıntaş and Kassouri [31]. In most early studies, air pollution (measured by CO_2 emissions) served as a proxy for environmental quality. For instance, Shahbaz, Hye [32] explored the effects of economic growth, energy consumption, financial development, and trade openness on CO_2 emissions in Indonesia from the first quarter of 1975 to the fourth quarter of 1975. Empirical results using the vector error correction model showed that while economic growth and energy consumption increase air pollution, financial development and trade openness reduce CO_2 emissions. Using panel vector autoregression, Mahdi Ziaei [33] discovered a bidirectional causality relationship between financial development (measured by the ratio of private sector credit to GDP) and CO_2 emissions in European, East Asian, and Oceania countries. Interestingly, Bekhet, Matar and Yasmin [34] found no link between financial development and CO_2 emissions in all six countries, including KSA, UAE, Oman, Kuwait, Qatar, and Bahrain, in the long term.

However, Footprintnetwork.org (2021) states that the ecological footprint is the most holistic and comprehensive indicator because it measures supply and demand. On the demand side, it measures the ecological assets that a given population or product requires to produce the natural resources it consumes (including plant-based food and fiber products, livestock and fish products, timber, and other forest products, space for urban infrastructure) and to absorb its waste, especially carbon emissions. On the supply side, this index is also built on five components: (1) cropland, (2) grazing land, (3) forest land, (4) fishing grounds, and (5) built-up land, to measure the biocapacity of a particular government or locality to provide ecological assets. Therefore, in recent years, many researchers have turned to ecological footprint indicators to analyze the effectiveness of policies in promoting economic growth and environmental quality.

For example, by using the augmented mean group approach, Nathaniel and Khan [35] showed that economic growth, trade openness, and non-renewable energy consumption exacerbated the ecological deficit in six ASEAN countries, including Indonesia, Malaysia, Philippines, Thailand, and Vietnam, from 1990 to 2016. Regarding the impact of financial development on the ecological footprint, Charfeddine [36] found a positive effect of both economic growth and financial development on the ecological footprint in Qatar's economy. Justifying these results, he argued that monetary expansion facilitates economic growth and improves people's living standards. As the standard of living improves, the demand for housing and household appliances such as televisions, cars, air conditioners, and nutritious food also increases. Therefore, the demand for timber for building houses, fishing in the ocean, and the high rate of urbanization adversely affect the ecological capacity of Qatar in the context that natural conditions and advances in science and technology cannot keep up.

In Japan, considered to have no abundance of natural resources, Ahmed, Zhang and Cary [37] used symmetric and asymmetrical analysis methods to understand the relationship between economic growth, financial development, globalization, and ecological footprint between 1971 and 2016. After rigorous testing of estimation techniques, they found that an increase in financial development substantially impacts the ecological footprint more than a decrease in financial development. Along with that, both globalization expansion and contraction reduce the ecological footprint. Finally, an inverted U effect exists in the relationship between economic growth and the ecological footprint in Japan. Recently, Khanday, Wani and Tarique [38] employed the ARDL approach to explore the role of financial development in ecological sustainability in India from 1980 to 2019. Their outcomes revealed that financial development and institutional quality are beneficial for the long-run environmental sustainability of India, while economic growth is detrimental to the environment. Likewise, by applying the novel dynamic ARDL simulation techniques, Nathaniel, Ahmed [39] found that both financial development and globalization significantly reduce the ecological footprint by 0.08 % and 0.25 % in Bangladesh. The spatial impact of the ecological footprint has recently attracted more attention in developed countries. For example, Chen, Madni and Shahzad [24] used the spatial Dubin model to identify the determinants of ecological footprint in BRI countries. Their findings revealed that neighboring economies significantly affect the ecological footprint of an economy. More precisely, both globalization and the development of financial sector lead to an increase in environmental problems in these countries. Before that, Lv and Li [10] also found that a country's CO_2 emissions could be influenced by the financial development of its neighbors in the panel data of 97 countries. A summary of other empirical studies on the relationship between financial development, economic growth, globalization, and environmental pollution is illustrated in detail in Table 1.

The above reviews do not fully capture the breadth of existing research on the relationship between financial development, economic growth, globalization, and environmental pollution. Nevertheless, they also indicate that the spatial effects seem to be of little concern. According to international trade theories, if a specific government injects more money into the economy, it will directly affect the competitiveness of that country's goods with those of neighboring countries (through exchange rate effects), thus indirectly affecting the economic growth of neighboring countries. Additionally, people living in countries without forests or not adjacent to the sea still need wood to make houses, cabinets, tables, chairs, or seafood from the ocean, leading them to tend towards "ecological import" from other countries. All these are signals that spillovers may exist between countries in the same region or that there are constraints on foreign trade or financial conditions with each other. Therefore, the study aims to fill this gap in the ASEAN economic community, a dynamic economic region with many signed trade and investment agreements.

Table 1
Summary of empirical results of some previous studies.

Author(s)	Method(s)	Area and time interval	Results
Salari, Javid and Noghanibehambari [40]	GMM	USA, 1997–2016	GDP => CO_2 (inverted U shape)
Abbasi, Parveen [41]	VECM	8 ASEAN countries, 1982–2017	GDP => CO_2 (+)
Sun, Samuel [42]	AMG	OECD countries, 1992–2015	GDP => CO_2 (+)
Bekun, Alola and Sarkodie [43]	PMG-ARDL	16 EU countries, 1996–2014	GDP &#x0004; CO_2 (+)
Muhammad [44]	SUR, GMM	68 countries, 2001–2017	GDP => CO_2 (+)
Hashmi, Fan [45]	FMOLS, DOLS	South, South-east, and East Asian countries, 1971–2014	GDP => CO_2 (+)
Dogan, Ulucak [46]	DCC-MG DCC-PMG	BRICS, 1980–2014	GDP => EF (U)
Ahmed, Zafar and Mansoor [47]	ARDL	Pakistan, 1971–2016	GDP => EF (U)
Godil, Sharif [19]	QARDL	Turkey, 1986–2018	FD => EF (+) Global => EF (+)
Ahmed, Zhang and Cary [37]	ARDL, NARDL	Japan, 1971–2016	FD => EF (+) Global => EF (+)
Shahbaz, Solarin [48]	ARDL, VECM	Malaysia, 1971–2011	FD &#x0004; CO_2
Ekwueme and Zoaka [49]	FMOLS, DOLS	10 MENA countries, 1970–2017	FD => CO_2 (−)
Shujah Ur, Chen [50]	ARDL	Pakistan, 1970–2016	FD => CO_2 (−)
Nasir, Duc Huynh and Xuan Tram [51]	FMOLS, DOLS	5 ASEAN countries, 1982–2014	FD => CO_2 (+)
Yurtkuran [52]	ARDL	Turkey, 1970–2017	Global => CO_2 (+)
Pata [53]	Fourier ARDL	BRICS, 1971–2016	Global => CO_2 (+)
Langnel and Amegavi [54]	ARDL	Ghana, 1971–2016	Global => CO_2 (−)

Note: GDP is economic growth; CO_2 is CO_2 emissions; Global represents globalization; EF represents ecological footprint. (+) is the positive effect; (−) is the negative effect.

3. Research model, data, and econometric strategy

3.1. Model and data

The study aims to explore the spillover effects of financial development, economic growth, and globalization on the ecological footprint in 10 ASEAN countries between 1992 and 2021. Therefore, the study applies the spatial regression method proposed by Anselin [55], utilizing the following general model:

$$EF_{it} = \alpha + \rho . \sum_{j=1}^{n} w_{ij} . EF_{jt} + \sum_{k=1}^{K} X_{itk} . \beta_k + \sum_{k=1}^{K} \sum_{j=1}^{n} w_{ij} . X_{jtk} . \theta_k + \mu_i + \vartheta_t + \upsilon_{it} \quad \text{(Equation 1)}$$

$\upsilon_{it} = \lambda \sum_{j=1}^{n} w_{ij} . \upsilon_{jt} + \varepsilon_{it}$ and $i = 1, \ldots, n$ $t = 1, \ldots, T$

where, EF_{it} illustrates a vector of the ecological footprint (N x 1) for spatial unit i at time t, and X is a (N x 3) vector of three independent variables, including financial development (labeled *FD*), economic growth (labeled *GDP*), and globalization (labeled *Global*). i represents the units (i = 1,2,..,10, corresponding to Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam). t is the time, ρ illustrates the spatial lag parameter, and λ is the spatial autocorrelation coefficient. w_{ij} shows the ith and jth elements of a spatial weights matrix by countries and times, and $W = (w_{ij})$ is the row-standardized (N x N) spatial weights.

The database of EF variable (unit: gha per capita) was collected from Footprintnetwork.org [56]. This study uses the financial development index (unit: percentage) as a proxy for financial development collected from the International Monetary Fund (IMF). Economic growth is illustrated by the GDP per capita (unit: U.S. dollars, at 2010 fixed prices) provided by the World Bank. Finally, the globalization variable is represented by the KOF globalization index (unit: points) calculated and published by the Swiss Economics Institute. The data begins in 1992, as this is the earliest publication of the financial development index for Vietnam, and ends in 2021 because the financial development data after 2021 has not been released. In our proposed model, GDP denotes the affluence factor, and financial development proxies the technology factor, while EF represents environmental impacts in the STIRPAT model.

3.2. Econometric strategy

In order to achieve the research objective, the analysis sequence was carried out through the following steps.

Step 1: Analyze descriptive statistics and test the stationarity of the variables
Step 2: Check for cross-sectional dependence.
Step 3: Test slope heterogeneity.
Step 4: Calculate the Moran's I index.
Step 5: Estimate research results using the Spatial Error Model (SEM), Spatial Autoregressive Model (SAR), and Spatial Dubin Model (SDM). Then, we will test to choose the most suitable model and analyze the direct and spillover effects.
Step 6: Investigate the Granger non-causality.

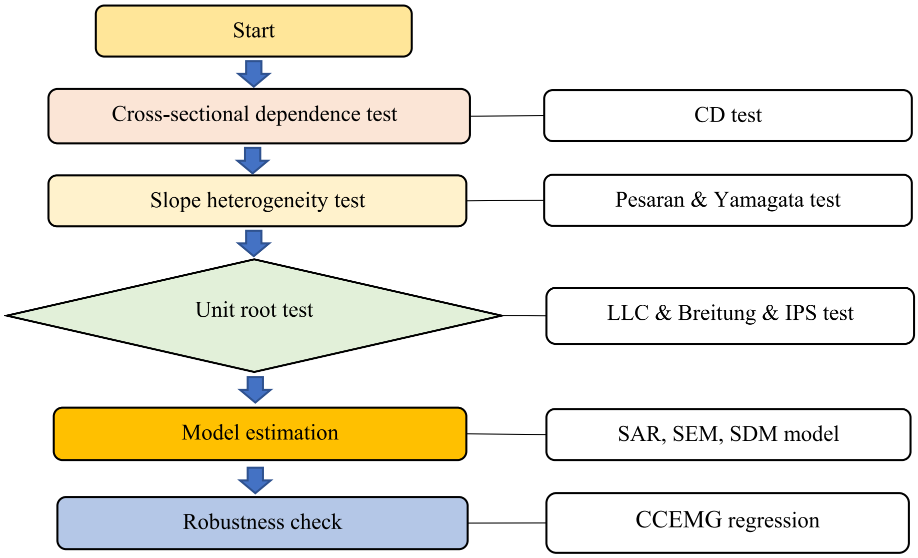


Fig. 1. Methodology flow diagram by authors.

The diagram illustrating the methodology flow can be found in Fig. 1.

There are three common spatial econometric models, including the Spatial Autoregressive (SAR) model, Spatial Error Model (SEM), and Spatial Dubin Model (SDM). According to Elhorst [57], the SAR model is employed if the dependent variable (EF) is spatially correlated, while the SEM model is used when the residuals are spatially correlated. The SDM is applied when spatial correlation is present in both the dependent and independent variables. To choose the most suitable spatial model, this article uses the null hypothesis $H_{0,1}$: $\theta = 0$ and the alternative hypothesis $H_{1,1}$: $\theta \neq 0$ to compare the SDM model and the SAR model. If the Lagrange multiplier test results yield a p-value <0.05, it is evidence to reject the null hypothesis, implying that the SDM model is better than the SAR model. Similarly, the null hypothesis $H_{0,2}$: $\rho = 0$ and $\theta = 0$, and the alternative hypothesis $H_{1,2}$: $\rho \neq 0$, and $\theta \neq 0$ are used to compare the SDM model with the SEM model. If $H_{0,2}$ is rejected, it implies that the spatial Dubin model best describes the data [58].

According to Elhorst [59], determining the spatial weight matrix (W) is essential for the spatial regression method. Ghemawat [60] proposed four ways to determine the spatial weights matrix by using: (1) cultural distance, (2) economic distance, (3) geographical distance, (4) administrative distance. Considering the context of the 10 ASEAN countries and avoiding further debates about measuring cultural or administrative distance accuracy, this study uses geographic distance to construct the spatial weights matrix. Two basic methods are employed for constructing a spatially weighted element from geographic distance:

Method 1: Encode the distance in binary, where $w_{ij} = \begin{cases} 1, \\ 0, \end{cases}$ (=1 if country i and country j share a land border, = 0 otherwise).

Method 2: Using the actual distance, where $w_{ij} = \begin{cases} d_{ij} \\ 0 \end{cases}$, d_{ij} is the actual distance by air between the capital of country i to the capital of country j.

Since the borders between ASEAN countries are both at sea and on the continent, and Indonesia is wholly isolated from the other nine countries, this study decided to use the actual distances between the capitals to construct the original spatial weights element, with actual data provided by the Google Earth software. According to international trade theory, the farther the actual distance between two countries, the higher the transportation costs, leading to less bilateral trade volume. Hence, the article uses the inverse distance ($1/|d_{ij}|$) in the final spatial weight matrix to construct spatially weighted elements.

4. Results and discussions

4.1. Descriptive statistics

According to a report by Footprintnetwork.org [56], the ecological deficit of the entire ASEAN region is a matter of concern. Specifically, while only Myanmar and Laos have not yet fallen into deficit, the remaining eight countries are in a state of alarm. For example, the demand for ecological assets from businesses and individuals has exceeded Singapore's ecological capacity by 10,300 %, making Singapore the country with the highest ecological deficit in the world. However, it is important to note that Singapore is a developed country. Consequently, the ecological deficit situation is anticipated to be even more challenging in other countries, including Cambodia, Indonesia, Malaysia, Philippines, Thailand, and Vietnam, as these countries are currently classified as developing. Descriptive statistics for the variables are presented in Table 2.

Table 2
Descriptive statistics of variables.

Variables	Mean	Std	Min	Max
EF	2.631	2.111	0.602	8.347
logGDP	3.424	0.684	2.063	4.824
FD	0.354	0.215	0.010	0.831
Global	55.964	16.061	20.018	83.721

Table 3
Result of panel unit root tests.

Variables	LLC test		Breitung test		IPS test	
	Level	First diff	Level	First diff	Level	First diff
EF	−0.217	−0.101	1.579	−3.802***	−0.042	−6.401***
logGDP	0.204	0.679	2.142	−2.892***	3.263	−3.899***
FD	1.510	1.602	1.252	−2.804***	0.478	−7.234***
Global	1.321	−1.437*	1.147	−2.445***	−2.532***	−2.654***

Note. Three tests are chosen based on the Akaike Information Criterion with intercept and trend. *, and *** respectively denote significance levels of 10 %, and 1 %.

To avoid spurious regression results, a stationarity test is crucial for the variables. In this study, the article applies three standard tests for panel data: the LLC test by Levin, Lin and James Chu [61], the Breitung test by Breitung [62], and the IPS test proposed by Im, Pesaran and Shin [63]. As indicated in Table 3, all three tests confirm that four variables are stationary at the first difference I(1). Thus, the spatial regression method can be applied [58].

4.2. Panel unit root tests

.

4.3. Cross-sectional dependence test

Subsequently, the study uses the CD test proposed by Pesaran [64] to assess cross-sectional dependence, defined by the following formula:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\rho}_{ij}\right)$$

where, N is the number of cross-sectional observations, T is the number of observations in time, and $\widehat{\rho}_{\text{ij}}$ represents the correlation coefficient between the residuals of the *i*th and the *j*th unit. Table 4 shows the CD test results.

The results in Table 4 show that all cross-sectional dependence tests are statistically significant at the 1 % level. According to Pesaran [64], when panel data exhibits cross-sectional dependence, the results estimated by ordinary least square (OLS) are unreliable.

4.4. Slope heterogeneity tests

Another critical problem for panel data analysis is the slope heterogeneity test (HS test). This test addresses the phenomenon where the slopes in the regression function of each subject are not the same, likely due to variations in the size of economies and levels of development across countries in a panel dataset. Pesaran and Yamagata [65] proposed the HS test formula to check slope homogeneity as follows:

$$\widetilde{\Delta}_{adj.HS} = \sqrt{N}.\left(\frac{2k(T-k-1)}{T+1}\right)^{-\frac{1}{2}}\left(\frac{1}{N}\widetilde{S} - 2k\right)$$

However, according to Blomquist and Westerlund [66], the HS test is not applicable in the practically relevant case of heteroskedastic and serially correlated errors. Blomquist and Westerlund [66] suggested the following formula:

$$\Delta_{HAC} = \sqrt{N}\left(\frac{N^{-1}S_{HAC} - k}{\sqrt{2k}}\right)$$

where $S_{HAC} = \sum_{i=1}^{N} T(\widehat{\beta}_i - \widehat{\beta})'(\widehat{Q}_{i,T}\widehat{V}_{i,T}^{-1}\widehat{Q}_{i,T})(\widehat{\beta}_i - \widehat{\beta})$, $\widehat{\beta} = \left(\sum_{i=1}^{N} T\widehat{Q}_{i,T}\widehat{V}_{i,T}^{-1}\widehat{Q}_{i,T}\right)^{-1}\sum_{i=1}^{N}\widehat{Q}_{i,T}\widehat{V}_{i,T}^{-1}X_i' M_\tau y_i$.

where, $\widehat{\beta}_i$ is the result of OLS estimation for object *i*. In this study, the author applies both testing methods to enhance reliability, and the empirical results are shown in Table 5.

Table 4
The cross-sectional dependence test results.

Variable	EF	FD	logGDP	Global
Value of CD test	16.64***	16.43***	34.27***	34.04***

Note. *** represents the significant level of 1 %.

Table 5
Result of slope heterogeneity tests.

Pesaran & Yamagata test		Blomquist & Westerlund test	
Delta	Adjusted Delta	Delta	Adjusted Delta
−1.132	−1.277	1.398	1.577

The results in Table 5 show that the two tests by Pesaran and Yamagata [65], and Blomquist and Westerlund [66] are not statistically significant. This finding provide evidence to conclude that the slope of each unit is homogeneous and that the application of spatial regression is satisfied.

4.5. Calculation of spatial correlation coefficient (Moran's I index)

Table 4 provides evidence of a cross-sectional dependence among the subjects. Therefore, the subsequent analysis aims to determine the spatial correlation coefficient using Moran's I index to confirm whether spatial spillover effects exist among ASEAN countries. Moran's I index is calculated according to the following formula:

$$I=\frac{n\sum_{i=1}^{n}\sum_{j=1}^{n}\left[w_{ij}(X_i-\overline{X})(X_j-\overline{X})\right]}{\left(\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}\right)\sum_{i=1}^{n}(X_i-\overline{X})^2}$$

where, w_{ij} is the spatial weight between object i and j, and X_i is the actual value of variable X of the ith object and $\overline{X}$ is the mean value of variable X.

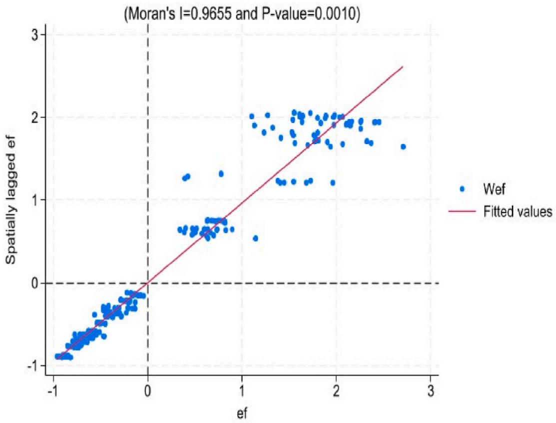
Moran's I index was presented in Fig. 2(a,b,c,d), and Table 6. Accordingly, the Moran's I coefficient for *EF, FD, logGDP, and Global* variables are 0.965, 0.966, 0.974, and 0.968, respectively. All tests are significant, implying a positive spatial correlation among the ten ASEAN countries. The results suggest that applying the OLS regression alone will not fully explain the relationship between financial development, economic growth, globalization, and ecological footprint in the ASEAN community, as it may provide biased parameters [58].

4.6. Estimation results by spatial regression methods

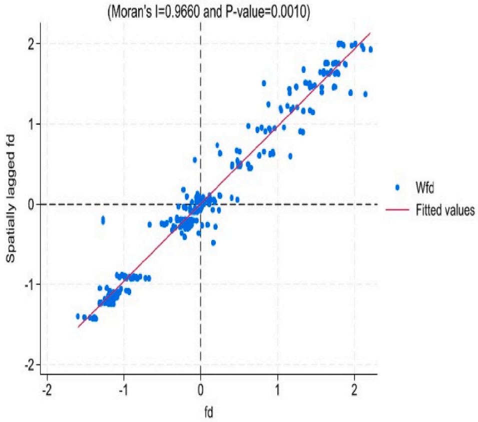
Before applying the spatial regression, the work utilized the Lagrange and robust Lagrange multiplier to select the best model. Table 7 indicates that the null hypotheses $H_{0,1}$ and $H_{0,2}$ are rejected, implying that the spatial Dubin model is the most suitable to describe the data [58]. Therefore, the spatial Dubin model should be adopted to estimate the direct and spillover effects of financial development, economic growth, and globalization on the ecological footprint in ASEAN countries. More precisely, the results in Table 8 show that economic growth has a positive effect ($\beta = 0.207$) and is statistically significant at 1 %, while the impact of globalization reduces the ecological footprint ($\beta = -0.112$, $p\text{-}value = 0.000$). Simultaneously, the study finds evidence of a link between financial development ($\beta = 0.010$, $p\text{-}value = 0.000$) and ecological footprint when considering impacts within a country.

However, the primary focus of this study is to analyze spillover effects. Table 8 shows that the coefficient of the variable (*W.FD*) is 0.666 ($p\text{-}value = 0.000$), which implies that an increase in financial development in neighboring countries leads to an increase in the ecological footprint in country *i*, and vice versa. Similarly, the coefficient of the variable (*W.logGDP*) is 0.899 ($p\text{-}value = 0.000$), indicating that as economic growth in neighboring countries improves, the demand for ecological assets in country *i* also increases, and vice versa. Alternatively, the ecological supply capacity in country *i* increases so that the economic growth of neighboring countries is supported [59]. On the contrary, an increase in the degree of globalization in neighboring countries leads to a decrease in EF in country *i*, and vice versa ((*W.Global* $= -0.514$, $p\text{-}value = 0.000$). These findings will be discussed in the following discussion section.

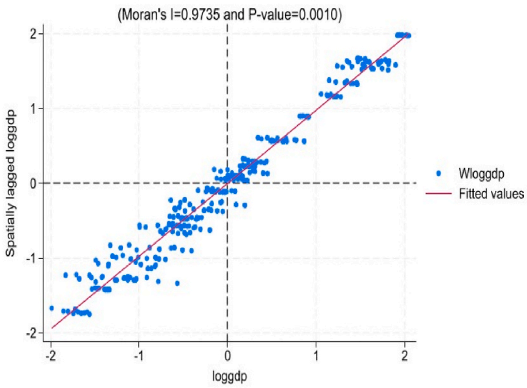
In the next step, the work investigates the direct and spillover effects of financial development, economic growth, and globalization on ecological footprint, presenting the outcomes in Table 9. Accordingly, the study finds that financial development positively drives EF both in the short and long term. Specifically, financial development may not have a significant impact on EF in the host country in the short run, but positively drives ecological demand in both the host and neighboring nations in the long run. Similarly, the study identifies the spillover effect of economic growth on EF in both the short and long term. An interesting finding is that the development of neighboring income per capita is not beneficial for the ecological footprint in a particular country in the short run, but it becomes beneficial in the long run ($\beta = -0.175$, $p\text{-}value = 0.019$). On the flip side, the outcome also reveals that enhancing the degree of



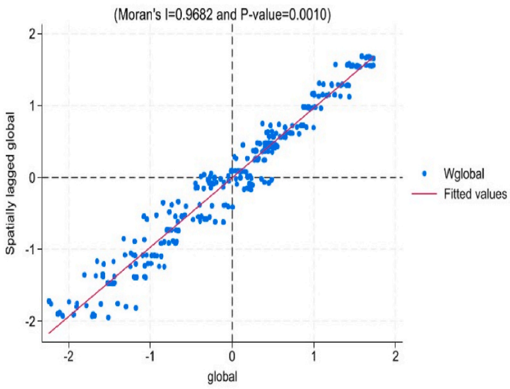
a. Moran's I index for the variable EF



b. Moran's I index for the variable FD



c. Moran's I index for the variable logGDP



d. Moran's I index for the variable Global

Fig. 2a. Moran's I index for the variable EF Fig. 2b. Moran's I index for the variable FD Fig. 2c. Moran's I index for the variable logGDP Fig. 2d. Moran's I index for the variable Global.

Table 6
The Moran's I result.

Statistics	EF	FD	logGDP	Global
Moran's I	0.965	0.966	0.974	0.968
Mean	−0.003	−0.003	−0.003	−0.003
Std deviation	0.029	0.029	0.029	0.029
Z-score	33.41	33.43	33.69	33.51
p-value	0.000	0.000	0.000	0.000

globalization plays an important role in reducing environmental deterioration in ASEAN nations in both the short term ($\beta = -0.178$) and long term ($\beta = -0.148$).

4.7. Robustness check

All suggested policies must be based on realistic and reliable findings. So, in the subsequent step, the study employs the Common Correlated Effects Mean Group estimator (CCEMG) proposed by Pesaran [67] to evaluate the validity of estimated coefficients by the SDM model, and the outcome is presented in Table 10. Accordingly, regarding direct influences, the results in Table 10 showed that financial development and economic growth positively impact ecological footprint, while globalization reveals an inverted influence. However, the outcome also reveals that the cross-sectional averaged coefficients of financial development and economic growth

Table 7
Lagrange multiplier test results.

Test	Statistics	p-value
Spatial Error:		
Moran's I	22.26	0.000
Lagrange multiplier	430.34	0.000
Robust Lagrange multiplier	96.66	0.000
Spatial lag:		
Lagrange multiplier	377.52	0.000
Robust Lagrange multiplier	43.84	0.000

Table 8
Estimation result by spatial regression methods.

Variables	SAR model		SEM model		SDM model	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
W.EF(-1)	−0.794	0.000			−0.767	0.000
FD	0.537	0.000	0.537	0.000	0.019	0.000
logGDP	0.770	0.000	0.425	0.000	0.207	0.000
Global	−0.014	0.000	−0.056	0.000	−0.112	0.000
W.FD					0.666	0.000
W.logGDP					0.899	0.000
W.Global					−0.514	0.000

Table 9
Direct- and spillover effects analysis.

Variables	Total effect	Direct-effects	Spillover effects
Short-run effect			
FD	0.154***	−0.049	0.203***
logGDP	0.558***	−0.305	0.863***
Global	−0.178***	−0.045*	−0.133***
Long-run effect			
FD	0.472***	0.082***	0.390***
logGDP	0.672***	0.847	−0.175**
Global	−0.148***	−0.126***	−0.022***

Note: ***, **, * denote significance levels of 1 %; 5 % and 10 %, respectively.

Table 10
Result of the CCEMG estimator.

Variables	Coefficient	p-value
FD	0.031	0.023
logGDP	0.912	0.086
Global	−0.038	0.024
MG_EF	0.965	0.000
MG_FD	−0.024	0.880
MG_logGDP	−0.867	0.177
MG_Global	−0.039	0.031
Intercept	−0.238	0.849

Note: The MG_EF, MG_FD, MG_logGDP, and MG_Global variables refer to cross-sectional averaged coefficients of EF, FD, logGDP, and Global variables, respectively.

variables are not significant, while globalization has a negative and significant influence. These results align with the findings of the spatial Dubin model, which allows us to conclude that the findings of this study are reliable and could be used to predict and suggest policy implications. Finally, the test proposed by Juodis, Karavias and Sarafidis [68] is employed to examine the causality relationship between each pair of variables in the initial model. The results presented in Table 11 and Fig. 3 show a bi-directional causality between ecological footprint and globalization, as well as economic growth and globalization. An uni-directional causality runs from financial development to ecological footprint, from ecological footprint to economic growth, and other findings are depicted in Fig. 3. These findings reinforce the results obtained from the spatial econometric analysis.

Table 11
Result of the Granger non-causality test.

Null hypothesis: No causality	Wald test	p-value
FD does not Granger cause EF	14.062	0.001
EF does not Granger cause FD	4.968	0.083
logGDP does not Granger cause EF	4.367	0.113
EF does not Granger cause logGDP	22.77	0.000
Global does not Granger cause EF	16.774	0.000
EF does not Granger cause Global	105.864	0.000
logGDP does not Granger cause FD	2.885	0.236
FD does not Granger cause logGDP	7.282	0.026
Global does not Granger cause FD	14.924	0.000
FD does not Granger cause Global	3.861	0.145
Global does not Granger cause logGDP	242.943	0.000
logGDP does not Granger cause Global	91.739	0.000

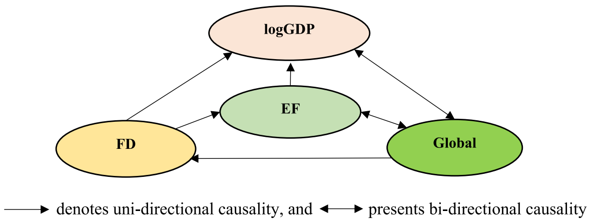


Fig. 3. The plot of Granger non-causality tests.

5. Discussion

The findings of this study shed light on the spatial spillover effects of financial development, economic growth, and globalization on ecological footprints in ASEAN from 1992 to 2021. Firstly, the results indicate that financial development in neighboring countries has a significant spatial spillover effect on the ecological footprint in country *i*, and vice versa. This finding is consistent with the notion that the economic activities in one country can impact the ecological conditions of its neighbors. The result suggests that countries with higher financial development tend to have a larger ecological footprint than neighboring countries. This conclusion aligns with previous studies in different contexts, such as Kongbuamai, Bui [69] or Nathaniel and Khan [35], but differs from Bekhet, Matar and Yasmin [34]. This finding also highlights the importance of regional cooperation and coordination in addressing environmental challenges.

Moreover, the study indicates a positive spatial spillover effect between economic growth and ecological footprint. This implies that economic growth in a particular country not only increases the ecological footprint in the host country but also affects the ecological footprint in its neighboring countries. This result is similar to studies by Alola, Bekun and Sarkodie [70] for 16 EU countries in the period 1997–2014, Ahmed, Zafar [71] for G7 countries from 1971 to 2014, or Nathaniel, Anyanwu and Shah [72] for the countries of the MENA region. This suggests that economic growth can have positive effects beyond national borders and contribute to sustainable development in the region. However, policymakers should be mindful of the potential negative environmental impacts of economic growth and ensure that environmental concerns are integrated into economic policies. According to Chen and Chang [73], economic growth can distort the natural environment in many ways, such as natural resource exploitation and energy consumption. However, it can be improved when people know how to increase their ecological capacity through a sense of protection, new planting, regeneration of crops, and using fuel with higher economic efficiency.

In contrast to the positive spillover effect of economic growth on ecological footprints, the study found a spatial negative spillover effect between globalization and ecological footprints. This implies that increasing globalization can contribute more positively to decreasing environmental degradation and maintaining ecological balance in the region. This finding is consistent with the notion that globalization can lead to the dissemination of knowledge and technology that can help mitigate the negative impact of economic activities on the environment, as seen in Tahir, Luni [11], Majeed, Wang [74], and Lv and Xu [75]. According to the authors, this result may be reasonable because, after several significant environmental disasters in the region, such as consecutive forest fires in Indonesia in 2003, 2015, and 2019, the environmental protection awareness of both the government and civilians in ASEAN has changed. For example, Singapore believes it's time for ASEAN to act together and has encouraged businesses to apply green technologies in the production process. Expanding economic integration and access to developed countries is also an opportunity for developing countries to self-reflect, and change production technology, thereby reducing environmental pollution.

The findings of the article underscore the reciprocal influence among ASEAN member nations and emphasize the critical role of collaboration. This is not unexpected, given that the Association of Southeast Asian Nations has genuinely articulated its ambitions to attain heightened regional integration and cooperation, somewhat resembling the European Union (EU) [76,77]. Recently, ASEAN has been working on developing a regional taxonomy for sustainable finance [78,79]. Sustainable finance taxonomies are frameworks that define and classify environmentally sustainable economic activities. They help investors, businesses, and policymakers identify and support environmentally friendly projects and investments. The ASEAN Taxonomy for Sustainable Finance is expected to align with international standards, particularly the European Union's Taxonomy Regulation, which sets criteria for environmentally sustainable economic activities [80]. The goal is to create a common language and set of standards for sustainable finance across the ASEAN region. The development of the ASEAN Taxonomy involves collaboration between various financial market participants, including governments, regulators, financial institutions, providers of capital, and rating agencies [81]. These entities are required to disclose the extent to which their investments align with the taxonomy. It aims to promote transparency, consistency, and comparability in sustainable finance across the region. For example, the stakeholder engagement undertaken during the development of the ASEAN Sustainable Capital Markets Roadmap revealed a lack of transparency in information and quality data [82]. Exchanges in six ASEAN member states (Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam) require sustainability reporting according to national guidelines [83–85]. Companies falling within the scope of the regulation are required to disclose information on how and to what extent their activities align with the taxonomy.

Besides, the demand for classification has been identified as the primary motivation to expand comprehensive market participation and accessibility. It also contributes to the ASEAN's broader goal of achieving a sustainable and green transition. The taxonomy focuses on six environmental objectives: climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, and protection and restoration of biodiversity and ecosystems. The ASEAN Taxonomy Regulation is part of a broader set of sustainable finance initiatives in the ASEAN. Other related regulations, including the ASEAN Green Bond Standards in 2017, followed by the ASEAN Social Bond Standards and the ASEAN Sustainability Bond Standards in 2018, were introduced by the ASEAN Capital Markets Forum (ACMF).

However, many challenges exist that could hinder ASEAN's progress toward achieving environmentally sustainable levels of financial development, economic growth, and globalization. The 'one-size-fits-all' taxonomy system is not considered the optimal solution for ASEAN. Firstly, ASEAN encompasses ten member states characterized by varied political systems, economic structures, cultural backgrounds, and developmental levels [86,87]. These distinctions present challenges in identifying common ground and nurturing a shared vision for regional integration. Secondly, substantial economic disparities exist among ASEAN member states, with countries like Singapore and Malaysia exhibiting higher development levels than some newer members. Addressing these economic gaps and promoting inclusive growth constitutes a complex undertaking. Thirdly, ASEAN operates on the principle of non-interference in each other's internal affairs and relies on consensus-based decision-making. While this principle fosters diplomatic cooperation, it can impede decision-making, posing challenges in reaching agreements on intricate issues. Fourthly, connectivity among ASEAN member states-physical infrastructure and digital networks - is not as advanced as within the EU [87]. Strengthening these connections is vital for facilitating trade, investment, and interpersonal interactions. Although ASEAN has made headway in establishing legal frameworks for regional cooperation, these may not be as comprehensive or enforceable as those within the EU. Enhancing these legal frameworks is indispensable for effectively implementing and enforcing regional agreements.

To cater to diversity among the member states, the ASEAN Taxonomy adopts a multi-tiered approach that allows ASEAN countries to use the ASEAN Taxonomy based on their own economic development, financial sector, infrastructure maturity and transition paths. Implementing a multi-tiered strategy involves two key components: (1) a Foundation Framework utilizing principles-based guiding questions and a decision tree for evaluating and categorizing sustainable activities; and (2) a Plus Standard, an advanced assessment approach employing both threshold-based (quantitative) and process-based or practice-based (qualitative) technical screening criteria for the assessment and classification of sustainable activities [88]. The establishment of an ASEAN Taxonomy is expected to draw increased capital inflow into the region, facilitating the transition of ASEAN member states and their stakeholders toward a low-carbon economy and the accomplishment of climate change objectives.

6. Conclusion and policy implications

This article draws the following main conclusions by applying three spatial regression models to the context of ten ASEAN countries in the period from 1992 to 2021: (*i*) There is sufficient evidence to conclude that financial development in neighboring countries has spatial spillovers on ecological footprints in country *i*, and vice versa; (*ii*) there is a spatial spillover between economic growth and ecological footprint. Accordingly, an expansion of economic growth not only increases the ecological footprint in the host country but also positively affects ecological footprint in neighboring countries; (*iii*) there is a spatial negative spillover effect between globalization and ecological footprint. In a sense, increasing globalization will contribute more positively to maintaining the ecological balance in the region.

Based on these findings, the article offers some policy implications as follows:

On the one hand, the spatial correlation coefficient between ASEAN countries is positive. Therefore, when a country develops its economic policies, it is necessary to calculate the effect of that policy on neighboring countries and vice versa. Promoting economic growth and expanding monetary supply should be accompanied by the expansion of integration to neutralize the impact of these two macroeconomic variables on environmental quality or ecological balance.

On the other hand, within the broader framework of the ASEAN Taxonomy for the sustainable development of finance in the region, member nations should focus on certain policy implications that arise due to existing limitations. *First,* if each ASEAN member state interprets and implements the taxonomy differently, it can lead to inconsistencies and hinder cross-border collaboration and investment. Fostering collaboration and coordination among ASEAN member countries to align interpretations and implementations is vital. The alliance should develop standardized reporting frameworks and guidelines to ensure a harmonized approach across jurisdictions. *Second,* a highly detailed taxonomy can be complex and increase the administrative burden on businesses and financial institutions. Compliance may become challenging, especially for smaller enterprises with limited resources. Governments should simplify and streamline the taxonomy where possible by establishing clear guidelines and providing support mechanisms for businesses to navigate and comply with the taxonomy. Besides, regulators might offer training and resources to help them understand and implement sustainable finance practices. *Third,* the taxonomy may inadvertently exclude certain sectors or activities that could contribute to sustainability but do not fit neatly into predefined categories. It may be challenging to accurately measure the real impact of sustainable finance activities and investments on environmental and social goals. ASEAN countries should develop robust impact measurement methodologies and reporting standards, including mechanisms for regular reviews and updates to expand the taxonomy to encompass a broader range of sustainable activities. In particular, governments might encourage feedback from industry experts, non-governmental organizations, and other stakeholders to ensure inclusivity. Businesses are encouraged to disclose their compliance with the taxonomy and the tangible outcomes of their sustainable initiatives. This could involve creating standardized metrics and reporting frameworks. *Finally*, the complexity of the taxonomy may result in limited public awareness, making it challenging for consumers and investors to make informed decisions based on sustainable finance criteria. ASEAN member states should implement public awareness campaigns to educate consumers, investors, and businesses about the taxonomy and its implications. Moreover, each nation can create user-friendly guides and resources to enhance understanding. It is essential to guarantee that the ASEAN Taxonomy is in accordance with globally recognized international standards. Governments also collaborate with global organizations to harmonize frameworks, making it easier for businesses and investors to operate across borders.

During 1992–2021, the ASEAN economy suffered two Asian economic crises in 1997 and the world economic crisis in 2008, which implies that structural breaks may appear in the data. However, the authors cannot perform this test for panel data within our limits. Besides, the globalization index used in the study is a composite index, so the study does not show that economic integration, policy integration, or social integration will reduce the ecological footprint. In addition, the study concludes that country i affects neighboring countries, not specifying which of the ten ASEAN countries. The authors acknowledge some limitations of the study and consider these as suggestions for further studies on the same topic./.

Data availability statement

Data will be made available on request.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

CRediT authorship contribution statement

Bui Hoang Ngoc: Writing – review & editing, Supervision, Project administration, Methodology, Formal analysis. **Nguyen Huynh Mai Tram:** Writing – original draft, Visualization, Project administration, Investigation, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We thank the Editor-in-Chief, Senior Editor, and anonymous reviewers for their very useful comments and suggestions. All errors are ours.

References

[1] S.A. Asongu, CO2 emission thresholds for inclusive human development in sub-Saharan Africa, Environ. Sci. Pollut. Control Ser. 25 (26) (2018) 26005–26019.
[2] Z. Ahmed, et al., Does globalization increase the ecological footprint? Empirical evidence from Malaysia, Environ. Sci. Pollut. Control Ser. 26 (18) (2019) 18565–18582.
[3] F. Zagonari, Religious and secular ethics offer complementary strategies to achieve environmental sustainability, Humanit. Soc. Sci. Commun. 8 (1) (2021).
[4] S.-J. Hsueh, Y.-H. Hu, C.-H. Tu, Economic growth and financial development in Asian countries: a bootstrap panel Granger causality analysis, Econ. Modell. 32 (2013) 294–301.
[5] O. Adeniyi, et al., Financial development and economic growth in Nigeria: evidence from threshold modelling, Econ. Anal. Pol. 47 (2015) 11–21.
[6] N.M. Ha, B.H. Ngoc, M. McAleer, Financial integration, energy consumption and economic growth in Vietnam, Ann. Fin. Econ. 15 (3) (2020) 2050010.
[7] M. Sarfraz, et al., Toward a new understanding of environmental and financial performance through corporate social responsibility, green innovation, and sustainable development, Humanit. Soc. Sci. Commun. 10 (1) (2023).
[8] N.T. Long, B.H. Ngoc, Is financial development good for ecological footprint A Bayesian multilevel mixed-effects analysis in ASEAN countries, Int. J. Environ. Sustain Dev. 22 (4) (2023) 409–424.
[9] Z. Ahmed, B. Zhang, M. Cary, Linking economic globalization, economic growth, financial development, and ecological footprint: evidence from symmetric and asymmetric ARDL, Ecol. Indicat. 121 (2021) 107060.
[10] Z. Lv, S. Li, How financial development affects CO2 emissions: a spatial econometric analysis, J. Environ. Manag. (2021) 277.
[11] T. Tahir, et al., The impact of financial development and globalization on environmental quality: evidence from South Asian economies, Environ. Sci. Pollut. Control Ser. 28 (7) (2021) 8088–8101.

[12] M. Ahmad, et al., Does financial development and foreign direct investment improve environmental quality? Evidence from belt and road countries, Environ. Sci. Pollut. Res. Int. 27 (19) (2020) 23586–23601.
[13] U. Muhammad, R. Kousar, M.S.A. Makhdum, The role of financial development, tourism, and energy utilization in environmental deficit: evidence from 20 highest emitting economies, Environ. Sci. Pollut. Control Ser. 27 (34) (2020) 42980–42995.
[14] U.K. Pata, V. Yilanci, Financial development, globalization and ecological footprint in G7: further evidence from threshold cointegration and fractional frequency causality tests, Environ. Ecol. Stat. 27 (4) (2020) 803–825.
[15] Y. Shang, et al., Eco-tourism, climate change, and environmental policies: empirical evidence from developing economies, Humanit Soc Sci Commun 10 (1) (2023) 275.
[16] L. Parker, Environmentalism and education for sustainability in Indonesia, Indones. Malay World 46 (136) (2018) 235–240.
[17] T.V. Hung, et al., Asymmetric effects of foreign direct investment and globalization on ecological footprint in Indonesia, PLoS One 19 (1) (2024) e0297046.
[18] M.A. Destek, S.A. Sarkodie, Investigation of environmental Kuznets curve for ecological footprint: the role of energy and financial development, Sci. Total Environ. 650 (Pt 2) (2019) 2483–2489.
[19] D.I. Godil, et al., The asymmetric effect of tourism, financial development, and globalization on ecological footprint in Turkey, Environ. Sci. Pollut. Control Ser. 27 (32) (2020) 40109–40120.
[20] G.A. Uddin, et al., Ecological footprint and real income: panel data evidence from the 27 highest emitting countries, Ecol. Indicat. 77 (2017) 166–175.
[21] P.C. Omoke, et al., The impact of financial development on carbon, non-carbon, and total ecological footprint in Nigeria: new evidence from asymmetric dynamic analysis, Environ. Sci. Pollut. Control Ser. 27 (17) (2020) 21628–21646.
[22] B. Hoang Ngoc, Do tourism development and globalization reinforce ecological footprint? Evidence from RCEP countries, Sage Open 12 (4) (2022).
[23] N. Kongbuamai, et al., Determinants of the ecological footprint in Thailand: the influences of tourism, trade openness, and population density, Environ. Sci. Pollut. Control Ser. 27 (32) (2020) 40171–40186.
[24] Q. Chen, G.R. Madni, A.A. Shahzad, The usage of spatial econometric approach to explore the determinants of ecological footprint in BRI countries, PLoS One 18 (10) (2023) e0288683.
[25] S. Kuznets, Economic growth and income inequality, Am. Econ. Rev. 45 (1) (1955) 1–28.
[26] O.D. Duncan, Human ecology and population studies, The Study of Population (1959) 678–716.
[27] T. Dietz, E.A. Rosa, Rethinking the environmental impacts of population, affluence and technology, Hum. Ecol. Rev. 1 (1994) 277–300.
[28] J.B. Ang, CO2 emissions, energy consumption, and output in France, Energy Pol. 35 (10) (2007) 4772–4778.
[29] A.O. Acheampong, Economic growth, CO2 emissions and energy consumption: what causes what and where? Energy Econ. 74 (2018) 677–692.
[30] M.S.K. Sarkar, et al., Energy consumption, CO2 emission and economic growth: empirical evidence for Malaysia, Int. J. Environ. Sustain Dev. 18 (3) (2019) 318–334.
[31] H. Altıntaş, Y. Kassouri, Is the environmental Kuznets Curve in Europe related to the per-capita ecological footprint or CO2 emissions? Ecol. Indicat. 113 (2020).
[32] M. Shahbaz, et al., Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia, Renew. Sustain. Energy Rev. 25 (C) (2013) 109–121.
[33] S. Mahdi Ziaei, Effects of financial development indicators on energy consumption and CO2 emission of European, East Asian and Oceania countries, Renew. Sustain. Energy Rev. 42 (2015) 752–759.
[34] H.A. Bekhet, A. Matar, T. Yasmin, CO 2 emissions, energy consumption, economic growth, and financial development in GCC countries: dynamic simultaneous equation models, Renew. Sustain. Energy Rev. 70 (2017) 117–132.
[35] S. Nathaniel, S.A.R. Khan, The nexus between urbanization, renewable energy, trade, and ecological footprint in ASEAN countries, J. Clean. Prod. 272 (2020).
[36] L. Charfeddine, The impact of energy consumption and economic development on ecological footprint and CO2 emissions: evidence from a markov switching equilibrium correction model, Energy Econ. 65 (2017) 355–374.
[37] Z. Ahmed, B. Zhang, M. Cary, Linking economic globalization, economic growth, financial development, and ecological footprint: evidence from symmetric and asymmetric ARDL, Ecol. Indicat. (2021) 121.
[38] I.N. Khanday, I.U. Wani, M. Tarique, Do financial development and institutional quality matter for ecological sustainability in the long run? Evidence from India, Manag. Environ. Qual. Int. J. 34 (6) (2023) 1668–1689.
[39] S.P. Nathaniel, et al., Linking clean energy consumption, globalization, and financial development to the ecological footprint in a developing country: insights from the novel dynamic ARDL simulation techniques, Heliyon 10 (5) (2024) e27095.
[40] M. Salari, R.J. Javid, H. Noghanibehambari, The nexus between CO2 emissions, energy consumption, and economic growth in the U.S, Econ. Anal. Pol. 69 (2021) 182–194.
[41] M.A. Abbasi, et al., Urbanization and energy consumption effects on carbon dioxide emissions: evidence from Asian-8 countries using panel data analysis, Environ. Sci. Pollut. Res. Int. 27 (15) (2020) 18029–18043.
[42] H. Sun, et al., Non-linear nexus between CO2 emissions and economic growth: a comparison of OECD and B&R countries, Energy 212 (2020) 118637.
[43] F.V. Bekun, A.A. Alola, S.A. Sarkodie, Toward a sustainable environment: nexus between CO(2) emissions, resource rent, renewable and nonrenewable energy in 16-EU countries, Sci. Total Environ. 657 (2019) 1023–1029.
[44] B. Muhammad, Energy consumption, CO2 emissions and economic growth in developed, emerging and Middle East and North Africa countries, Energy 179 (2019) 232–245.
[45] S.H. Hashmi, et al., Non-linear relationship between urbanization paths and CO2 emissions: a case of South, South-East and East Asian economies, Urban Clim. 37 (2021) 100814.
[46] E. Dogan, et al., The use of ecological footprint in estimating the Environmental Kuznets Curve hypothesis for BRICST by considering cross-section dependence and heterogeneity, Sci. Total Environ. 723 (2020) 138063.
[47] Z. Ahmed, M.W. Zafar, S. Mansoor, Analyzing the linkage between military spending, economic growth, and ecological footprint in Pakistan: evidence from cointegration and bootstrap causality, Environ. Sci. Pollut. Control Ser. 27 (33) (2020) 41551–41567.
[48] M. Shahbaz, et al., Does financial development reduce CO2 emissions in Malaysian economy? A time series analysis, Econ. Modell. 35 (2013) 145–152.
[49] D.C. Ekwueme, J.D. Zoaka, Effusions of carbon dioxide in MENA countries: inference of financial development, trade receptivity, and energy utilization, Environ. Sci. Pollut. Res. Int. 27 (11) (2020) 12449–12460.
[50] R. Shujah Ur, et al., Financial development and its moderating role in environmental Kuznets curve: evidence from Pakistan, Environ. Sci. Pollut. Res. Int. 26 (19) (2019) 19305–19319.
[51] M.A. Nasir, T.L. Duc Huynh, H.T. Xuan Tram, Role of financial development, economic growth & foreign direct investment in driving climate change: a case of emerging ASEAN, J. Environ. Manag. 242 (2019) 131–141.
[52] S. Yurtkuran, The effect of agriculture, renewable energy production, and globalization on CO2 emissions in Turkey: a bootstrap ARDL approach, Renew. Energy 171 (2021) 1236–1245.
[53] U.K. Pata, Linking renewable energy, globalization, agriculture, CO2 emissions and ecological footprint in BRIC countries: a sustainability perspective, Renew. Energy 173 (2021) 197–208.
[54] Z. Langnel, G.B. Amegavi, Globalization, electricity consumption and ecological footprint: an autoregressive distributive lag (ARDL) approach, Sustain. Cities Soc. 63 (2020).
[55] L. Anselin, in: T.C. Mills, K. Patterson (Eds.), *Spatial Econometrics*. Palgrave Handbook of Econometrics, vol. 1, Palgrave MacMillan, New York, 2007.
[56] Footprintnetwork.org, Ecological deficit/reserve (2021). Available from: https://data.footprintnetwork.org/.
[57] J.P. Elhorst, The dynamic general nesting spatial econometric model for spatial panels with common factors: further raising the bar, Rev. Reg. Res. 42 (2021) 249–267.
[58] J.P. Elhorst, Applied spatial econometrics: raising the bar, Spatial Econ. Anal. 5 (1) (2010) 9–28.
[59] J.P. Elhorst, Specification and estimation of spatial panel data models, Int. Reg. Sci. Rev. 26 (3) (2016) 244–268.

[60] P. Ghemawat, Distance still matters. The hard reality of global expansion, Harv. Bus. Rev. 79 (8) (2001) 137–147.
[61] A. Levin, C.-F. Lin, C.-S. James Chu, Unit root tests in panel data: asymptotic and finite-sample properties, J. Econom. 108 (1) (2002) 1–24.
[62] J. Breitung, Nonparametric tests for unit roots and cointegration, J. Econom. 108 (2) (2002) 343–363.
[63] K.S. Im, M.H. Pesaran, Y. Shin, Testing for unit roots in heterogeneous panels, J. Econom. 115 (1) (2003) 53–74.
[64] M.H. Pesaran, General diagnostic tests for cross-sectional dependence in panels, Empir. Econ. 60 (1) (2020) 13–50.
[65] M.H. Pesaran, T. Yamagata, Testing slope homogeneity in large panels, J. Econom. 142 (1) (2008) 50–93.
[66] J. Blomquist, J. Westerlund, Testing slope homogeneity in large panels with serial correlation, Econ. Lett. 121 (3) (2013) 374–378.
[67] M.H. Pesaran, Estimation and inference in large heterogeneous panels with a multifactor error structure, Econometrica 74 (4) (2006) 967–1012.
[68] A. Juodis, Y. Karavias, V. Sarafidis, A homogeneous approach to testing for Granger non-causality in heterogeneous panels, Empir. Econ. 60 (1) (2020) 93–112.
[69] N. Kongbuamai, et al., The impact of tourism and natural resources on the ecological footprint: a case study of ASEAN countries, Environ. Sci. Pollut. Control Ser. 27 (16) (2020) 19251–19264.
[70] A.A. Alola, F.V. Bekun, S.A. Sarkodie, Dynamic impact of trade policy, economic growth, fertility rate, renewable and non-renewable energy consumption on ecological footprint in Europe, Sci. Total Environ. 685 (2019) 702–709.
[71] Z. Ahmed, et al., Linking urbanization, human capital, and the ecological footprint in G7 countries: an empirical analysis, Sustain. Cities Soc. 55 (2020).
[72] S. Nathaniel, O. Anyanwu, M. Shah, Renewable energy, urbanization, and ecological footprint in the Middle East and North Africa region, Environ. Sci. Pollut. Control Ser. 27 (13) (2020) 14601–14613.
[73] S.-T. Chen, H.-T. Chang, Factors that affect the ecological footprint depending on the different income levels, AIMS Energy 4 (2016) 557–573.
[74] A. Majeed, et al., Modeling the dynamic links among natural resources, economic globalization, disaggregated energy consumption, and environmental quality: fresh evidence from GCC economies, Resour. Pol. 73 (2021) 102204.
[75] Z. Lv, T. Xu, Is economic globalization good or bad for the environmental quality? New evidence from dynamic heterogeneous panel models, Technol. Forecast. Soc. Change 137 (2018) 340–343.
[76] L. Jones, Explaining the failure of the ASEAN economic community: the primacy of domestic political economy, Pac. Rev. 29 (5) (2016) 647–670.
[77] D.B.H. Anh, N.H. Tien, Comparative analysis of the process of economic integration of EU and ASEAN, International Journal of Commerce and Management Research 5 (3) (2019) 96–99.
[78] U. Volz, Institutional mechanisms for scaling up finance for the SDGs in ASEAN: lessons from the European union, in: V. Anbumozhi, K. Kalirajan, F. Kimura (Eds.), Sustainable Development Goals and Pandemic Planning: Role of Efficiency Based Regional Approaches, Springer Nature Singapore, Singapore, 2022, pp. 601–625.
[79] ASEAN Taxonomy Board, Overview of the ASEAN Taxonomy for Sustainable Finance, 2022. Presentation by the ASEAN Taxonomy Board.
[80] A. Tripathy, L.W. Mok, K. House, Defining climate-aligned investment: an analysis of sustainable finance taxonomy development, The J. Environ. Invest. 10 (1) (2020).
[81] A. Durrani, M. Rosmin, U. Volz, The role of central banks in scaling up sustainable finance – what do monetary authorities in the Asia-Pacific region think? J. Sustain. Fin. Invest. 10 (2) (2020) 92–112.
[82] H. Tian, Role of capital market to accelerate the transition to low-carbon energy system, in: V. Anbumozhi, K. Kalirajan, F. Kimura (Eds.), Financing for Low-Carbon Energy Transition: Unlocking the Potential of Private Capital, Springer Singapore, Singapore, 2018, pp. 211–238.
[83] M. Tran, E. Beddewela, Does context matter for sustainability disclosure? Institutional factors in Southeast Asia, Bus. Ethics Eur. Rev. 29 (2) (2020) 282–302.
[84] T.K. Sari, F.R. Cahaya, C. Joseph, Coercive pressures and anti-corruption reporting: the case of ASEAN countries, J. Bus. Ethics 171 (3) (2021) 495–511.
[85] C. Arena, R. Liong, P. Vourvachis, Carrot or stick: CSR disclosures by Southeast Asian companies, Sustain. Account. Manag. Policy J. 9 (4) (2018) 422–454.
[86] J. Rüland, Democratic backsliding, regional governance and foreign policymaking in Southeast Asia: ASEAN, Indonesia and the Philippines, Democratization 28 (1) (2021) 237–257.
[87] L.M. Mueller, Challenges to ASEAN centrality and hedging in connectivity governance—regional and national pressure points, Pac. Rev. 34 (5) (2021) 747–777.
[88] ASEAN Taxonomy Board (ATB), ASEAN Taxonomy for Sustainable Finance (Version 2), 2023.