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Environmental impact of financial technology across quantiles: the importance of natural resources in ASEAN countries

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Abstract

Purpose – This study examines the environmental impacts of financial technology (Fintech) development and elucidates the mediating role of natural resources in the relationship between Fintech and the environment. The study adopts a multidimensional environmental perspective by simultaneously considering environmental degradation and environmental quality.

Design/methodology/approach – The study employs panel data from 10 Association of Southeast Asian Nations (ASEAN) countries over the period 2000–2021. Environmental degradation is measured using the ecological footprint (ecf), while environmental quality is proxied by the ecological efficiency (sdi). The analysis applies panel-corrected standard error and method of moments quantile regression to address heteroskedasticity, autocorrelation, non-normality and potential endogeneity.

Findings – Fintech exerts a positive environmental impact in ASEAN countries. Specifically, Fintech significantly reduces environmental degradation across all quantiles and improves environmental quality from the 30th to the 90th quantiles. The study also identifies a transmission channel through natural resources, whereby Fintech contributes to environmental improvement by reducing natural resource rents. The magnitude of the mediating effect ranges from 20.802% to 49.726% for environmental degradation, while for environmental quality, it increases from 39.437% to 64.706% across quantiles.

Originality/value – This study provides empirical evidence on the heterogeneous, quantile-based effects of Fintech on environmental outcomes and clarifies the underlying mediating mechanism through natural resources. Based on these findings, the study proposes policy implications emphasizing the strengthening of market-based instruments and intelligent technological solutions in the financial and banking sectors to enhance the economic value of natural resources and contribute to the achievement of SDG 13.

Keywords Fintech, Environmental degradation, Environmental quality, Natural resources, MM-QR, Intermediary channel

Paper type Research article

1. Introduction

The Association of Southeast Asian Nations (ASEAN) plays a pivotal role in the dynamics of the global economy. ASEAN countries make substantial contributions to economic growth, promote trade, attract investment capital and serve as critical links in the global value chain network (Wang *et al.*, 2024a, b). However, accompanying this economic expansion is an environmental trade-off, as suggested by the Environmental Kuznets Curve (EKC) hypothesis (Grossman and Krueger, 1995). In recent years, ASEAN have experienced a significant increase in natural disasters and extreme weather events and is among the most affected by the adverse environmental consequences of global warming (Ding and Beh, 2022).

JEL Classification — Q56, O44, G23, Q32

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According to the ASEAN SDG Snapshot Report [1], ASEAN is considered one of the most vulnerable regions to climate-related disasters and weather variability. Statistics show that, on average, 2,546.8 individuals per 100,000 population were reported dead, missing, or directly affected by climate-related disasters, an alarming increase compared to 554 cases per 100,000 in 2016. Based on data from the SDG Score [2], ASEAN countries have made notable progress in achieving several United Nations Sustainable Development Goals (SDGs), particularly in poverty reduction and human capital development (Tang *et al.*, 2024). However, performance on environmental goals, specifically SDG 13 (Climate action) and SDG 12 (Responsible consumption and production), remains relatively weak. Most ASEAN countries, except for Singapore, are still in the industrialization phase and rely heavily on finite natural resources (including coal, oil, forest land and natural gas), following a predominantly linear economic model (Murshed and Rahman, 2024). These countries have yet to implement effective interventions to address the depletion of natural resources, minerals and fossil fuels driven by excessive economic exploitation (Tang *et al.*, 2022; Le *et al.*, 2026).

Concurrently, Fintech, the intersection of technology and finance, has garnered significant attention from public sector policymakers as well as being a catalyst for engagement among the business community and academic researchers (Dong *et al.*, 2024; Okere *et al.*, 2025a). Fintech has revolutionized the operations of financial, banking and monetary systems through digital transformation over the past decade, contributing to the streamlining of business processes and the expansion of capital mobilization. The automation and digitization of financial services through Fintech have had widespread impacts across various sectors and dimensions. Smart technological solutions such as mobile payments, e-banking, blockchain technology, mobile money, the Internet of Things (IoT) and peer-to-peer (P2P) lending are encompassed within the scope of Fintech. Moreover, Fintech represents a wide range of financial activities, including payments, financial advisory, project financing, deposits, lending and insurance services (Stulz, 2019).

In the ASEAN context, Fintech has effectively contributed to economic growth and financial inclusion. It has presented both opportunities and challenges for traditional financial institutions through digital transformation via technologies such as artificial intelligence (AI), blockchains and cryptocurrencies (Barroso and Laborda, 2022; Okere *et al.*, 2024). The digitalization of payment and remittance services has streamlined processes, reduced costs, and enhanced efficiency for businesses as well as financial and banking institutions (Scardovi, 2017). Fintech has also gained recognition for its potential to democratize financial services and promote financial inclusion, while mitigating negative environmental impacts through increased savings derived from technological efficiency (Thomas and Hedrick-Wong, 2019). Empirical studies indicate that the adoption of advanced technologies, particularly in the financial and banking sector, holds the potential to reduce CO_2 emissions in the financial industry by enabling online transactions, optimizing traditional processes and conserving resources and materials (Zhang and Liu, 2022). As a result, Fintech is regarded as a transformative tool that not only sustains economic growth and productivity but also has the capacity to address environmental concerns (Tamasiga *et al.*, 2022; Okere *et al.*, 2024, 2026).

Given the urgency stated, this study aims to investigate the environmental impacts of Fintech as well as the significance of natural resources. Despite a growing body of literature, several important empirical gaps remain. First, existing studies predominantly focus on the direct relationship between Fintech and environmental outcomes, often overlooking the underlying transmission mechanisms (particularly the role of natural resource utilization), thereby risking omitted variable bias. Second, while evidence on the Fintech–environment nexus is gradually emerging, there is a notable scarcity of research within the ASEAN context, where structural characteristics, institutional quality, and resource dependence may lead to markedly different dynamics. Moreover, prior works tend to rely on single proxies such as CO_2 emissions, which may not fully capture the multidimensional nature of environmental sustainability. To address these limitations, this study provides a more comprehensive empirical framework by incorporating both environmental degradation and environmental quality indicators, while explicitly modeling the mediating channel of natural resources. Furthermore, Fintech has the potential to reduce information asymmetry and transaction costs, thereby improving the allocation of financial resources in economic activity. This study will revisit the EKC hypothesis to revisit the environmental aspects of the country-level development cycle when being controlled by Fintech. In these realms, the study seeks to answer these research questions:

RQ1. How does financial technology (Fintech) affect the environment (including environmental degradation and environmental quality) in ASEAN countries?

RQ2. What role do natural resources play in shaping the environmental impact of Fintech in ASEAN countries?

RQ3. Does the Environmental Kuznets Curve (EKC) hypothesis hold within the context of Fintech development of ASEAN countries?

The academic contributions of this research are manifold. Firstly, instead of focusing solely on environmental degradation (proxied by CO2 emissions) as previous studies have (Muganyi *et al.*, 2021; Tao *et al.*, 2022; Udeagha and Muchapondwa, 2023), this study evaluates the impact of Fintech on both environmental degradation (proxied by the ecological footprint) and environmental quality (proxied by the Sustainable Development Index of Hickel (2020) in measuring the ecological efficiency of human development). This dual approach allows for a more comprehensive and multidimensional assessment and enables testing for the consistency of Fintech's environmental effects. Moreover, using these dependent variables provides a better foundation to explain the role of natural resources in moderating Fintech's environmental impact. Secondly, this is the first study to investigate the mediating role of natural resources in the pathway through which Fintech influences the environment. The most recent study by Dong *et al.* (2024) found that Fintech contributes to reducing CO_2 emissions and enhances resource rent (i.e. the value of natural resource extraction). However, no existing research has empirically examined the mechanism and extent to which natural resources mediate the environmental effects of Fintech. Thirdly, the study seeks to test the EKC hypothesis within the context of ASEAN countries by incorporating the presence and development of Fintech, using panel data from 2000 to 2021. Additionally, the study applies the robust Method of Moments Quantile Regression (MM-QR) estimation of Machado and Santos Silva (2019), which allows for the estimation of heterogeneous effects of Fintech across the conditional distribution of environmental indicators. MM-QR is particularly suitable for addressing issues of non-normality, autocorrelation and heteroskedasticity.

The remaining article is structured as follows. Section 2 provides a review of the relevant literature and hypothesis development of the Fintech-environment nexus. Section 3 outlines the research methodology and data. Section 4 presents the empirical results and discussion. Section 5 concludes with key findings and policy implications.

2. Literature review and hypothesis development

2.1 Nexus of Fintech and the environment

The financial and banking sector is currently undergoing a significant transformation in a positive direction, largely driven by the explosive growth of Fintech (Chen *et al.*, 2021; Okere *et al.*, 2025a). The term Fintech refers to technological advancements and intelligent solutions within the financial sector aimed at enhancing access to financial services and products (Puschmann, 2017; Mention, 2019). Fintech holds substantial potential in promoting environmentally friendly investment opportunities and mitigating the adverse impacts of climate change (Muganyi *et al.*, 2021). For instance, blockchain and smart contracts, two foundational technologies of Fintech, offer promising capabilities for ensuring transparent monitoring and evaluation of environmental impacts (Parmentola *et al.*, 2021; Macchiavello and Siri, 2022). These solutions contribute to expanding the accessibility of financial markets and facilitate the acceleration of investment decision-making processes for both enterprises and investors (Alt *et al.*, 2018). Fintech plays a pivotal role in redirecting capital flows toward sustainable projects, thereby encouraging the use of renewable energy and enhancing resource productivity and the effectiveness of existing initiatives. Technological advancements in the financial and banking sector also help to reduce market barriers through digital transformation, thereby accelerating the implementation of sustainable finance and investment projects (Bian *et al.*, 2023; Samour *et al.*, 2024).

Recent studies have provided empirical evidence supporting the relationship between Fintech and environmental outcomes. Fintech has been shown to enhance the efficiency of financial operations and even influence consumption behavior across multiple levels, including the macro level (i.e. public procurement and policymaking) and the micro level (i.e. enterprises, investors and households) (Karim *et al.*, 2022). Muganyi *et al.* (2021) found that Fintech contributes to a reduction in commercial carbon emissions in China. Using the difference-in-differences (DID) methodology, Sreenu (2022) demonstrated that Fintech solutions and green finance initiatives in India have the potential to mitigate carbon emissions. Similarly, through a comprehensive systematic review, Chueca Vergara and Ferruz Agudo (2021) concluded that Fintech facilitates environmentally friendly investment practices, thereby indirectly contributing to improvements in environmental quality. Tao *et al.* (2022) further explored the nexus between Fintech development and greenhouse gas (GHG) emissions, particularly carbon dioxide (CO_2), and concluded that the advancement of Fintech plays a positive role in accelerating the transition toward a global low-carbon economy.

Using the generalized method of moments (GMMs) and two-stage least squares regression techniques, Croutzet and Dabbous (2021) concluded that the economies of the Organisation for Economic Co-operation and Development (OECD) are progressively transitioning toward sustainable energy use in parallel with the development of Fintech strategies. The authors also observed that OECD countries possess significant potential to leverage Fintech in ensuring energy security amid geopolitical shocks. These findings align with those of Lobato *et al.* (2021), who asserted that investment, savings, and expenditure through Fintech mechanisms in the clean energy sector can contribute to improving environmental quality. Within the European context, Muhammad *et al.* (2022), employing Method of Moments Quantile Regression (MM-QR) and Instrumental Variables-GMM (IV-GMM), found that the Fintech industry, emerging as part of the Fourth Industrial Revolution, has a positive and enhancing effect on environmental performance.

Recently, Qin *et al.* (2023) found that Fintech and its various dimensions, including financial outreach, financial depth and financial digitalization, have a positive impact on environmental outcomes in China. In the Chinese context over the 2000–2020 period, Liu *et al.* (2024), using the quantile autoregressive distributed lag model, revealed that Fintech contributes to achieving green growth targets, while the continued exploitation of natural resources exerts adverse effects on ecological balance. A similar pattern has been observed in BRICS countries, where Udeagha and Muchapondwa (2023) demonstrated that Fintech exerts a favorable impact on environmental quality, whereas natural resource rents have a detrimental effect. Within the top six global manufacturing economies, Li *et al.* (2024), employing the GMM-panel vector autoregressive (GMM-PVAR) method, discovered that improvements in financial efficiency can reduce carbon emissions.

At the global level, Mertzanis (2023) provided evidence that Fintech has a positive, albeit modest, influence on both environmental and social performance. Notably, the effects of Fintech do not exhibit a nonlinear trend but instead show a lagged effect, meaning that investments in Fintech tend to yield more substantial environmental benefits over the long term. Further support for Fintech's role as a crucial tool in minimizing CO_2 emissions and achieving carbon neutrality has been found in various empirical studies, including Zhang *et al.*

(2024) in Asian countries, Udeagha and Ngepah (2023) in BRICS economies, and Uddin *et al.* (2024) in the G20 context. In the ASEAN region during the 1990–2021 period, Tang *et al.* (2024) affirmed that Fintech can serve as a catalyst for promoting green investments and the development of sustainable projects. However, the continued reliance on and exploitation of natural resources may pose significant environmental threats to ASEAN countries. Based on the aforementioned literature review, this study proposes the following research hypotheses H1a and H1b:

H1a. Fintech has an inverse relationship with the ecological footprint (environmental degradation) in ASEAN countries.

H1b. Fintech has a proportional relationship with ecological efficiency (environmental quality) in ASEAN countries.

2.2 Nexus of natural resources and the environment

The growing concern over ecological sustainability has rendered resource consumption a critical global issue (Ahakwa *et al.*, 2023; Nwani *et al.*, 2024; Okere *et al.*, 2025b) and rapid economic expansion relies heavily on excessive exploitation of natural resources, significantly contributing to the imbalance between biodiversity and ecological footprint, and thereby undermining environmental sustainability. Both researchers and policymakers are currently striving to increase the availability of financial capital while ensuring a country's economic growth remains unaffected (Saqib and Shahzad, 2024). Natural resources rents refer to the intrinsic value of natural resources and represent the difference between actual revenue and the cost incurred from resource extraction used in the production process to generate income (Okere *et al.*, 2024, 2026). In other words, resource rent is the monetary value paid for the use of a unit of natural resource and an excessive increase in the value of resource rent implies intensive exploitation of natural resources.

Danish *et al.* (2023) conducted a study in the United States using the ARDL method and found that natural resources rents act as an adverse factor in achieving sustainability as the financial attractiveness associated with resource exploitation leads to the over-extraction of fossil fuels, ultimately resulting in a significant increase in CO_2 emissions. Similar results were observed in South Africa, where Joshua and Bekun (2020) identified natural resource rents as one of the root causes of CO_2 emissions in the country. Mahmood and Furqan (2020) examined the relationship between resource extraction and GHG emissions in the Gulf Cooperation Council region using a spatial Durbin model, concluding that natural resource exploitation contributes to increased pollution levels in the area. Hassan *et al.* (2018) stated that both economic growth and natural resource exploitation have negative effects, increasing CO_2 emissions in Pakistan. According to Sun *et al.* (2020), excessive increases in resource rents lead to higher energy consumption, which ultimately causes pollution. These authors proposed the use of renewable energy to achieve environmental sustainability goals, while Dong *et al.* (2024), in a study of Asian countries, pointed out that Fintech can reduce CO_2 emissions and natural resource rent (i.e. reduce resource exploitation).

The literature suggests that an increase in resource rents may either be a barrier to carbon neutrality goals or potentially an opportunity for sustainable development when resource extraction is maintained at a moderate level. Notably, no research has yet deeply examined, within the ASEAN countries, the mechanism and the extent of the mediating effect of Fintech on the environment through either increasing or decreasing the actual exploitation of natural resources. Therefore, this study proposes Hypotheses H2 and H3:

H2. Natural resources rents have a significant impact on the ecological footprint and ecological efficiency in ASEAN countries.

H3. Natural resources mediate the environmental impact of Fintech in ASEAN countries.

2.3 Nonlinear nexus of economic growth and the environment

Numerous studies have demonstrated that economic growth is a primary cause of environmental degradation (Stern *et al.*, 1996; Alvarado and Toledo, 2016; Nuţă *et al.*, 2024) as the trade-off between environmental quality and economic growth objectives is inevitable, especially in countries undergoing industrialization processes, such as ASEAN nations. However, the EKC hypothesis proposed by Grossman and Krueger (1995) suggests that the impact of economic growth follows an inverted U-shaped relationship, and that, specifically during the early stages of economic development, increasing economic activities lead to higher levels of environmental pollution. Nevertheless, once the economy reaches a certain threshold of growth, environmental pollution begins to decline, as the economy then places greater emphasis on sustainability aspects, welfare and cleaner production processes.

Numerous studies within ASEAN countries have confirmed the EKC hypothesis regarding the inverted U-shaped relationship between economic growth and environmental degradation (Amin *et al.*, 2022; Kostakis, 2024; Adha *et al.*, 2024; Yusma *et al.*, 2024). Moreover, contemporary researchers have increasingly sought to validate the EKC hypothesis in various contexts, such as circular economy (Nguyen *et al.*, 2024), globalization (Shahbaz *et al.*, 2016), economic policy uncertainty (Udeagha and Muchapondwa, 2022) and digital transformation (Ullah *et al.*, 2024). Through a comprehensive literature review, this study observes that prior EKC validation efforts predominantly focus on the environmental degradation aspect but pay limited attention to environmental sustainability. Specifically, economic growth tends to deteriorate environmental quality until a certain turning point, after which further economic growth contributes to environmental improvement. Furthermore, the potential nonlinear relationship between economic growth and the environment in the context of Fintech development remains underexplored. Therefore, the study proposes the following hypotheses H4a and H4b. Figure 1 visualizes the research framework employed in this study.

H4a. An inverted U-shaped Environmental Kuznets Curve (EKC) exists between economic growth and ecological footprint in the context of Fintech development in ASEAN countries.

H4b. A U-shaped Environmental Kuznets Curve (EKC) exists between economic growth and ecological efficiency in the context of Fintech development in ASEAN countries.

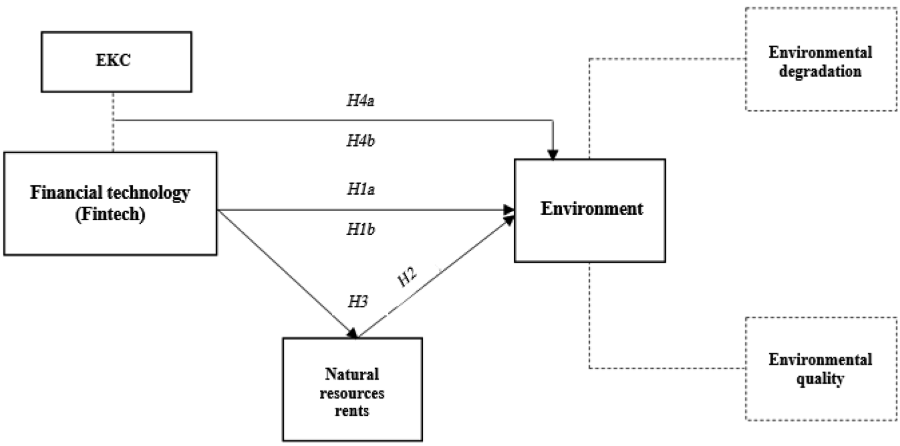

Figure 1. Research framework

3. Methodology

3.1 Empirical model

An appropriate model is crucial for accurately assessing the environmental impact of Fintech and preventing estimation bias caused by omitted variables. Therefore, this study employs the foundational Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model developed by Dietz and Rosa (1997) and York *et al.* (2003), as represented in Equation (1). Recent studies, such as Shu *et al.* (2024), have also applied the STIRPAT framework to investigate the environmental effects of Fintech.

$$I = P \times A \times T \tag{1}$$

The article employs the ecological footprint (ecf) index to represent the environmental degradation, instead of CO_2 emissions or GHG emissions (Tang *et al.*, 2024; Shu *et al.*, 2024) with the ecological footprint providing a more comprehensive and holistic view of human impact on the environment. While CO_2 emissions only measure the amount of carbon released and mainly focus on climate change issues, the ecological footprint accounts for the total natural resources required to sustain human activities, including arable land, water, energy, and waste assimilation. This allows for a fuller reflection of environmental degradation across multiple dimensions, from resource consumption to the depletion of marine life, forests and ecosystems. On the other hand, the study utilizes Hickel's (2020) Sustainable Development Index (sdi) to represent the environmental quality to measure the ecological efficiency of human development. In essence, the research model includes two variables, namely the ecological footprint (ecf) and sustainable development index (sdi), to represent the environmental factor (I) in the STIRPAT model.

The main explanatory variable is Fintech, capturing the technology (*T*) aspect, in addition to renewable energy (rne) (Shu *et al.*, 2024). For the population (P) factors, we employ urbanization (urb) and unemployment rate (une) as representative variables (Ortiz *et al.*, 2022; Nuţă *et al.*, 2024), while affluence (A) is commonly represented by gross domestic product (GDP) (Ullah *et al.*, 2024). Due to the extensibility of the STIRPAT model, this research incorporates natural resources rents (nrr), which is considered a novel addition as current studies tend to include more factors to better clarify the determinants of the environment (Gani, 2021). Drawn from the EKC, the study introduces the squared term of GDP to examine the nonlinear mechanism in the economic–environment relationship under the Fintech development context, as defined by Equations (2) and (3).

$$ecf_{it} = \beta_0 + \beta_1 fin_{it} + \beta_2 nrr_{it} + \beta_3 lngdp_{it} + \beta_4 lngdp_{it}^2 + \beta_5 une_{it} + \beta_6 urb_{it} + \beta_7 rne_{it} + \varepsilon_{it} \tag{2}$$

$$sdi_{it} = \beta_0 + \beta_1 fin_{it} + \beta_2 nrr_{it} + \beta_3 lngdp_{it} + \beta_4 lngdp_{it}^2 + \beta_5 une_{it} + \beta_6 urb_{it} + \beta_7 rne_{it} + \varepsilon_{it} \tag{3}$$

In which i = 1, 2, 3, . . ., *N* denotes the observations for country i in year t = 2000, 2001, 2002, . . . 2021. β denotes the regression coefficients estimated using linear regression methods. ε is the stochastic error term (constant) in the research model.

3.2 Data

The study uses a sample of ten ASEAN countries (including Brunei, Cambodia, Laos, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam) for the period from 2000 to 2021 with the secondary research data collected from official databases. Table 1 summarizes information (name, symbol and measurement) of the investigated variables with natural logarithm transformation applied to variables with original units measured outside of index and percentages. The purpose of this transformation is to ensure that the interpretation of the results reflects how a 1% increase in the independent variable leads to a percentage change

Table 1. Summary of variables

	Symbol	Calculation	Unit	Source
Dependent variables	ecf	Ecological footprint index	gha	Global Footprint Network
	sdi	Ecological efficiency of human development	index	Hickel (2020)
Independent variables	fin	Composite index of financial development index, share of Internet users and mobile cellular subscriptions, measured by principal component analysis	index	IMF and World Bank
	nrr	Total natural resources rents	% GDP	World Bank
Control variables	une	Share of unemployed population	%	World Bank
	urb	Share of urban population	%	World Bank
	gdp	Logarithm of GDP per capita	USD	World Bank
	rne	Share of renewable energy consumption	%	World Bank

in the dependent variable. Specifically, the variable converted to a natural logarithm scale is GDP, which is measured in USD. The remaining variables, measured by indexes or percentages, will not be logarithmically transformed.

The dependent variables include the ecological footprint (ecf) and the ecological efficiency (sdi). These two variables represent different environmental aspects, namely, environmental degradation and environmental quality and, therefore, the expected effects of independent variables on these two dependent variables are expected to be opposite. The variable ecf data is collected from the Global Footprint Network, while sdi is aggregated from Hickel's Sustainable Development Index (sdi) (2020).

The main independent variable is Fintech. Currently, most studies measure the Fintech variable using a composite index constructed by principal component analysis from financial development indicators of the International Monetary Fund, Internet usage and mobile phone subscriptions from the World Bank data. Figure 2 illustrates the distribution of Fintech development levels across ASEAN countries. It can be observed that Singapore, Thailand, Malaysia and Vietnam have higher levels of Fintech development compared to other countries in the region.

The second independent variable is natural resources rents, measured as a percentage of GDP from total rental values of natural resources (including oil, gas, coal, minerals and forests). The data on natural resource variables are collected from the World Bank database and other variables serve as control variables in the research model, including unemployment rate (percentage of total labor force), urbanization rate (percentage of urban population over total population), GDP (USD at current exchange rates) and renewable energy (percentage of total energy use). Data for all control variables are sourced from the World Bank.

3.3 Quantitative estimation

Based on discussions from previous studies, this research hypothesizes that Fintech has a positive impact on the ASEAN environment through its intermediary effect on reducing or enhancing the exploitation of natural resources. To test this hypothesis (H3 as proposed), the study applies Baron and Kenny's (1986) mediation testing procedure, as denoted by Equations (4)–(6):

$$Y = \alpha X + \varepsilon_1 \tag{4}$$

$$M = \beta X + \varepsilon_2 \tag{5}$$

Figure 2. Fintech development in ASEAN (average of the 2000–2021 period)

$$Y = \alpha' X + \gamma M + \varepsilon_3 \quad (6)$$

Where in, natural resources rents (nrr) serve as the mediating variable M in the causal pathway from the independent variable X – Fintech to the dependent variables Y – ecological footprint (ecf) and ecological efficiency (sdi). First and foremost, we estimate the total effect of Fintech on environmental degradation and environmental quality, Equation (4). Subsequently, we estimate the effect of Fintech on natural resources rents as in Equation (5). Ultimately, as Equation (6), we regress Fintech on the environment, controlling for the presence of natural resources to examine changes in Fintech's environmental impact due to mediation through the enhancement or depletion of resource rents.

Before regression, the article performs various diagnostic tests to check for potential model deficiencies, including non-normal distribution, heteroskedasticity and autocorrelation. If the research data exhibit heteroskedasticity and autocorrelation, the panel-corrected standard error (PCSE) estimator is deployed to address these issues in the model. The rationale for using PCSE is that the dataset has a panel structure where the cross-sectional dimension N (number of countries) is smaller than the time dimension T (number of years). In addition, we explicitly account for potential endogeneity between Fintech and environmental outcomes. Such endogeneity may arise from reverse causality (i.e. environmental degradation or stricter environmental regulations may stimulate the adoption of Fintech solutions), omitted variable bias (i.e. institutional quality, technological readiness, or financial development affecting both Fintech and environmental performance), and measurement-related issues. When the data also exhibit non-normal distribution, heterogeneity and endogeneity, we further adopt the Method of Moments Quantile Regression (MM-QR) of Machado and Santos Silva (2019). The method is currently regarded as the most efficient approach, combining quantile regression with the GMM to simultaneously correct for non-normal distribution and endogeneity. Additionally, this estimator provides insightful findings on the magnitude of Fintech's environmental impact across quantiles.

4. Empirical results

4.1 Descriptive statistics

Table 2 presents the descriptive statistics, consisting of 220 observations, covering 10 ASEAN countries from 2000 to 2021. The first dependent variable, ecological footprint (ecf), captures the environmental degradation dimension and the mean value of ecf is 2.7774 (measured in global hectares per capita), with a standard deviation of 2.1720, indicating significant variation in environmental degradation levels across countries. The minimum value is 0.8410 and the maximum is 8.8258. The skewness is 1.1515, suggesting a right-skewed distribution, while the kurtosis is 2.5629, indicating a distribution moderately close to normal.

The second dependent variable, ecological efficiency (sdi), represents the environmental quality dimension. The variable sdi averages 0.5922 with a standard deviation of 0.1873, showing less variation, and the values range from 0.1210 to 0.8130. The skewness of −1.2171 indicates a left-skewed distribution, while the kurtosis of 3.4356 suggests a slightly higher and sharper peak compared to a normal distribution. The main explanatory variable is Fintech development (fin) and the variable has a mean close to zero (3.53e−10) and a standard deviation of 1.5157, with values ranging from −2.4953 to 2.9469. The skewness is 0.0804, which is very close to zero, indicating a relatively symmetric distribution and the kurtosis is 1.9534, which is lower than 3, implying a flatter and more spread-out distribution than the normal distribution.

4.2 Preliminary tests

Before conducting multivariate regression, the research employs several diagnostic tests to examine the presence of potential econometric issues in the model and dataset across ASEAN countries. Table 3 presents the results of normality and endogeneity tests for the research variables. The Jarque–Bera test is used to assess the normality of the data distribution and the results reveal that none of the variables follows a normal distribution, indicating a serious issue that must be addressed. This is because conventional estimation methods typically rely on the assumption that the variables are normally distributed and use the mean to estimate regression coefficients. When the data deviates from normality and contains outliers, traditional regression results may be biased and unreliable. Figure 3 illustrates the data distributions of the two dependent variables, ecf and sdi. The data points for both variables do not align along a straight line, further confirming non-normality.

Table 2. Descriptive statistics

	Obs	Mean	Std. dev.	Min	Max	Skewness	Kurtosis
ecf	220	2.7774	2.1720	0.8410	8.8258	1.1515	2.5629
sdi	220	0.5922	0.1873	0.1210	0.8130	−1.2171	3.4356
fin	220	3.53e−10	1.5157	−2.4953	2.9469	0.0804	1.9534
nrr	220	7.5468	8.2275	0.0001	45.3351	1.8338	6.5766
urb	220	50.0455	24.0517	18.5860	100	0.7399	2.4695
une	220	2.9260	2.0591	0.12	9.3160	0.7416	2.8700
gdp	220	8.1468	1.5015	4.9472	11.3900	0.3111	2.3740
rne	220	33.0396	27.2474	0	85.8	0.3666	1.9073

Table 3. Preliminary tests

	Jarque-bera		Durbin Wu-Hausman		Slope heterogeneity		Woolridge		Breusch-Pagan	
	Adj $\chi^2(2)$	Prob > χ^2	Eq. (2)	Eq. (3)	Eq. (2)	Eq. (3)	Eq. (2)	Eq. (3)	Eq.(2)	Eq. (3)
ecf	29.82	0.0000								
sdi	33.50	0.0000								
fin	40.84	0.0000	0.0136	0.0021						
nrr	71.26	0.0000	0.0413	*3.8238**						
urb	19.21	0.0001	0.7561	*8.5730****						
une	15.99	0.0003	*6.2245***	0.1483						
gdp	10.13	0.0063	*3.0241**	0.2025						
rne	54.11	0.0000	0.4753	1.4867						
Δ					2.805***	7.903***	4.652*	7.844**	77.01 ***	30.48 ***
Adj Δ					3.548***	9.997***				

Note(s): ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

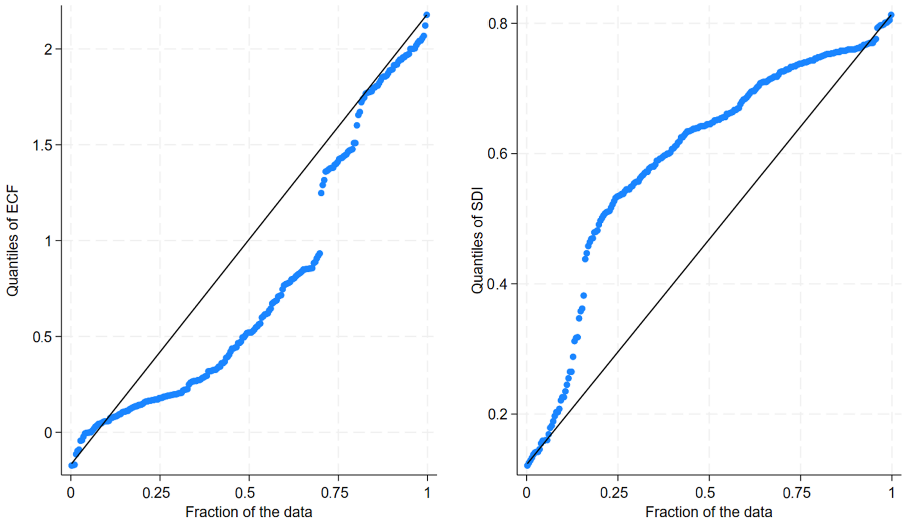

Figure 3. Data fraction of dependent variables (ecf and sdi)

In addition, we present the results of diagnostic tests for other econometric issues, including slope heterogeneity based on the test proposed by Pesaran and Yamagata (2008), heteroskedasticity using the Breusch–Pagan test, and autocorrelation using the Wooldridge test. The results indicate that both research models suffer from significant econometric problems, including slope heterogeneity (due to non-normal distribution), heteroskedasticity and autocorrelation.

To address these issues, the author initially applies the PCSE estimation technique to correct for heteroskedasticity and autocorrelation. The PCSE estimator is preferred because it is suitable for panel datasets where the number of cross-sectional units (N) is smaller than the number of time periods (T). To complement the PCSE results, the article employs the method of moments quantile regression (MMQR) proposed by Machado and Santos Silva (2019) as this approach combines quantile regression to handle non-normality and slope heterogeneity with GMM techniques to address potential endogeneity. Additionally, MMQR yields more robust estimates when the dataset exhibits heteroskedasticity and autocorrelation.

4.3 Direct environmental effects of Fintech

Tables 4 and 5, respectively, present the direct effects of Fintech on ecological footprint (ecf) and ecological efficiency (sdi) of ASEAN countries, using the PCSE and MM-QR estimation methods. The direct effect refers to the impact without the mediation of natural resource rents (nrr).

Table 9 reveals that Fintech (fin) exerts an inverse effect on ecological footprint (a proxy for environmental degradation) under both estimation methods. Specifically, a 1% increase in the level of Fintech development in ASEAN countries leads to a 0.4411% reduction in environmental degradation (using the PCSE estimator), and a reduction ranging from 0.4264% to 0.4569% (using the MM-QR estimator), all statistically significant at the 1% level. An interesting finding is that the coefficients under the MM-QR method decline gradually from the tenth to the 90th quantile, suggesting that the environmental mitigation effect of Fintech is stronger in countries with lower levels of pollution. A plausible explanation is that in less polluted countries, the adoption of Fintech may facilitate more efficient resource utilization, improve operational effectiveness, and reduce pollution-generating activities (Hopalı *et al.*,

Table 4. Direct effect of Fintech on environmental degradation (ecological footprint – ecf)

		Low quantiles			Middle quantiles			High quantiles		
	PCSE	q10	q20	q30	q40	q50	q60	q70	q80	q90
fin	−0.4411***	−0.4569***	−0.4520***	−0.4463***	−0.4423***	−0.4397***	−0.4358***	−0.4337***	−0.4308***	−0.4264***
	(0.0643)	(0.0777)	(0.0674)	(0.0607)	(0.0608)	(0.0630)	(0.0691)	(0.0736)	(0.0807)	(0.0931)
urb	0.0165**	0.0120	0.0134*	0.0150**	0.0162**	0.0169**	0.0181**	0.0187*	0.0195*	0.0208*
	(0.0076)	(0.0078)	(0.0071)	(0.0071)	(0.0076)	(0.0081)	(0.0091)	(0.0097)	(0.0106)	(0.0122)
une	−0.0827**	−0.1085***	−0.1005***	−0.0911***	−0.0848**	−0.0805**	−0.0741*	−0.0706	−0.0659	−0.0587
	(0.0375)	(0.0398)	(0.0355)	(0.0333)	(0.0344)	(0.0362)	(0.0402)	(0.0430)	(0.0470)	(0.0537)
lngdp	−2.3094***	−2.2296***	−2.2544***	−2.2833***	−2.3029***	−2.3162***	−2.3360***	−2.3468***	−2.3613***	−2.3836***
	(0.3455)	(0.7215)	(0.6098)	(0.4941)	(0.4314)	(0.3999)	(0.3756)	(0.3750)	(0.3886)	(0.4371)
$lngdp^2$	0.2096***	0.1966***	0.2006***	0.2053***	0.2085***	0.2107***	0.2139***	0.2156***	0.2180***	0.2216***
	(0.0236)	(0.0487)	(0.0414)	(0.0339)	(0.0298)	(0.0278)	(0.0263)	(0.0263)	(0.0272)	(0.0302)
rne	−0.0169***	−0.0157***	−0.0161***	−0.0165***	−0.0168***	−0.0170***	−0.0173***	−0.0175***	−0.0177***	−0.0180***
	(0.0034)	(0.0043)	(0.0037)	(0.0032)	(0.0031)	(0.0034)	(0.0032)	(0.0033)	(0.0035)	(0.0040)
_cons	7.1849***	6.8615**	6.9620***	7.0792***	7.1586***	7.2126***	7.2925***	7.3364***	7.3954***	7.4856***
	(1.4855)	(2.8208)	(2.3878)	(1.9612)	(1.7533)	(1.6654)	(1.6319)	(1.6645)	(1.7609)	(2.0035)
R-squared	0.9106									
Obs	220	220	220	220	220	220	220	220	220	220

Note(s): Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 5. Direct effect of Fintech on environmental quality (ecological efficiency – sdi)

	Low quantiles				Middle quantiles			High quantiles		
	PCSE	q10	q20	q30	q40	q50	q60	q70	q80	q90
fin	0.0152**	0.0055	0.0098	0.0120*	0.0142**	0.0161***	0.0177***	0.0193***	0.0211***	0.0238***
	(0.0068)	(0.0100)	(0.0081)	(0.0072)	(0.0065)	(0.0062)	(0.0060)	(0.0061)	(0.0063)	(0.0070)
urb	−0.0038***	−0.0016	−0.0029**	−0.0031***	−0.0035***	−0.0040***	−0.0043***	−0.0047***	−0.0051***	−0.0056***
	(0.0007)	(0.0016)	(0.0013)	(0.0011)	(0.0009)	(0.0008)	(0.0007)	(0.0006)	(0.0006)	(0.0006)
une	−0.0021	−0.0061	−0.0044	−0.0035	−0.0025	−0.0018	−0.0011	−0.0005	0.0003	0.0013
	(0.0036)	(0.0068)	(0.0054)	(0.0047)	(0.0040)	(0.0035)	(0.0032)	(0.0029)	(0.0027)	(0.0027)
lngdp	0.5346***	0.6322***	0.5892***	0.5671***	0.5446***	0.5260***	0.5097***	0.4932***	0.4750***	0.4480***
	(0.0324)	(0.0560)	(0.0459)	(0.0407)	(0.0376)	(0.0365)	(0.0369)	(0.0386)	(0.0411)	(0.0480)
$lngdp^2$	−0.0379***	−0.0455***	−0.0421***	−0.0404***	−0.0387***	−0.0372***	−0.0359***	−0.0346***	−0.0332***	−0.0311***
	(0.0021)	(0.0039)	(0.0032)	(0.0028)	(0.0025)	(0.0023)	(0.0023)	(0.0023)	(0.0024)	(0.0028)
rne	−0.0050***	−0.0044***	−0.0047***	−0.0048***	−0.0049***	−0.0050***	−0.0051***	−0.0052***	−0.0053***	−0.0055***
	(0.0034)	(0.0006)	(0.0005)	(0.0004)	(0.0004)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0004)
_cons	−0.8052***	−1.2714***	−1.0660***	−0.9600***	−0.8531***	−0.7645***	−0.6864***	−0.6076***	−0.5208***	−0.3919*
	(0.1459)	(0.2632)	(0.2145)	(0.1899)	(0.1752)	(0.1699)	(0.1720)	(0.1801)	(0.1933)	(0.2257)
R-squared	0.8976									
Obs	220	220	220	220	220	220	220	220	220	220

Note(s): Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

2022). In contrast, in more polluted countries, the impact of Fintech may be constrained by structural factors such as the dominance of polluting industries, economic systems or outdated infrastructure (Sunanda and Joseph, 2023).

Similarly, Table 10 indicates that Fintech has a proportional effect on improving ecological efficiency (a measure of environmental quality) for both estimators. This finding aligns with expectations, as the effects of Fintech (fin) are expected to be opposite in the cases of environmental degradation and environmental sustainability. Specifically, in ASEAN countries, a 1% increase in Fintech development leads to a 0.0152% improvement in environmental quality under the PCSE method, and an increase ranging from 0.0142% to 0.0238% across the 30th to 90th quantiles under the MM-QR method. A noteworthy point is that the regression coefficients in the MM-QR method increase gradually from the 30th to the 90th quantile, implying that the beneficial effect of Fintech on environmental quality becomes more pronounced and significant in countries with higher environmental quality. This can be attributed to the fact that these countries likely possess more supportive infrastructure and policy frameworks for the implementation of Fintech, thereby enhancing the effectiveness of Fintech in contributing to sustainable solutions (Almansour, 2023; Le *et al.*, 2026).

Conversely, in countries with very low environmental quality (i.e. 10th and 20th quantiles), Fintech appears to have no significant impact on environmental quality. One plausible explanation is that these countries face more severe and structurally complex environmental challenges, where the marginal contribution of Fintech alone is insufficient to generate measurable improvements. In such contexts, governments may need to complement Fintech initiatives with additional policy measures, such as enhancing environmental regulatory frameworks or investing in green technologies, to achieve more meaningful environmental outcomes. These findings highlight the conditional nature of Fintech's environmental impact and imply that policy effectiveness depends on the broader socio-economic and institutional context. They are also consistent with the results of Saqib and Shahzad (2024), who employed the load capacity factor as a proxy for environmental quality. Therefore, the evidence provides partial support for Hypothesis H1b, particularly in middle- and higher-quantile contexts rather than universally across all countries.

4.4 Does Fintech raise or reduce natural resources rents?

Subsequently, to examine the mediating role of natural resource rents (nrr) in the environmental impact of Fintech, the study has to assess the effect of Fintech on natural resource rents and ensure that the coefficient of Fintech is statistically significant. The results in Table 6 indicate that Fintech has the potential to reduce natural resource rents in ASEAN countries. Specifically, at the 1% level of statistical significance, a 1% increase in Fintech development leads to an average reduction of approximately 3.4351% in natural resource rents under the PCSE method, and a reduction ranging from 1.7024% to 5.4273% across the tenth to 90th percentiles under the MM-QR. Figure 4 depicts the quantile distribution effects of variables on natural resources.

These findings imply that the impact of Fintech in reducing natural resource exploitation is more pronounced in countries with higher levels of resource rents. ASEAN countries that heavily rely on natural resource exploitation are likely to experience more substantial benefits from Fintech in terms of reducing dependence on resource rents. The digital transformation and promotion of technological solutions in the financial and banking sector can contribute to lowering resource exploitation by improving resource-use efficiency and fostering the development of sustainable business models (Delina, 2023). Fintech can accelerate the implementation of environmentally friendly solutions such as green finance, sustainable investment, and digital financial services that enhance the capacity to manage and utilize resources more efficiently. This finding may encourage the sustainable use of natural resources and reduce reliance on extractive activities (Dong *et al.*, 2024).

Table 6. Fintech and natural resources rents (dependent variable: nrr)

	Low quantiles				Middle quantiles			High quantiles		
	PCSE	q10	q20	q30	q40	q50	q60	q70	q80	q90
fin	−3.4351***	−1.7024***	−2.0586***	−2.2283***	−2.4321***	−2.9450***	−3.8072***	−4.4389***	−4.9735***	−5.4273***
	(0.7173)	(0.5401)	(0.5370)	(0.5391)	(0.5645)	(0.6500)	(0.7845)	(0.8942)	(0.9923)	(1.0864)
urb	−0.3200***	−0.3859***	−0.3724***	−0.3659***	−0.3581***	−0.3386***	−0.3058***	−0.2818***	−0.2615***	−0.2442**
	(0.0684)	(0.0491)	(0.0471)	(0.0470)	(0.0477)	(0.0521)	(0.0658)	(0.0788)	(0.0910)	(0.1014)
une	1.3054***	1.9881***	1.8477***	1.7809***	1.7006***	1.4985***	1.1588***	0.9099**	0.6993*	0.5205
	(0.3610)	(0.2373)	(0.2227)	(0.2196)	(0.2258)	(0.2514)	(0.3037)	(0.3537)	(0.4028)	(0.4452)
lngdp	−11.805***	−1.9955	−4.0125	−4.9730	−6.1267*	−9.0305**	−13.912***	−17.488***	−20.5145***	−23.084***
	(4.1755)	(3.3480)	(3.3662)	(3.4248)	(3.5809)	(4.0606)	(4.9350)	(5.6762)	(6.3102)	(7.1307)
$lngdp^2$	1.0072***	0.4148**	0.5366***	0.5946***	0.6643***	0.8396***	1.1344***	1.3503***	1.5331***	1.6882***
	(0.2496)	(0.1983)	(0.1984)	(0.2015)	(0.2108)	(0.2391)	(0.2912)	(0.3358)	(0.3742)	(0.4254)
rne	−0.1433***	−0.0566	−0.0745	−0.0830*	−0.0931**	−0.1188**	−0.1619***	−0.1935***	−0.2203***	−0.2430***
	(0.0450)	(0.0485)	(0.0460)	(0.0450)	(0.0448)	(0.0464)	(0.0520)	(0.0586)	(0.0652)	(0.0716)
_cons	51.543***	4.084	13.842	18.489	24.071	38.120**	61.735***	79.037***	93.680***	106.11***
	(19.735)	(16.169)	(16.067)	(16.230)	(16.869)	(19.025)	(23.073)	(26.584)	(29.619)	(33.413)
Turning point	350,831	n/a	n/a	n/a	100,624	216,558	460,299	649,107	804,748	931,567
R-squared	0.3913									
Obs	220	220	220	220	220	220	220	220	220	220

Note(s): Standard errors in parentheses. ****p* < 0.01, ***p* < 0.05, **p* < 0.1. n/a is nonapplicable

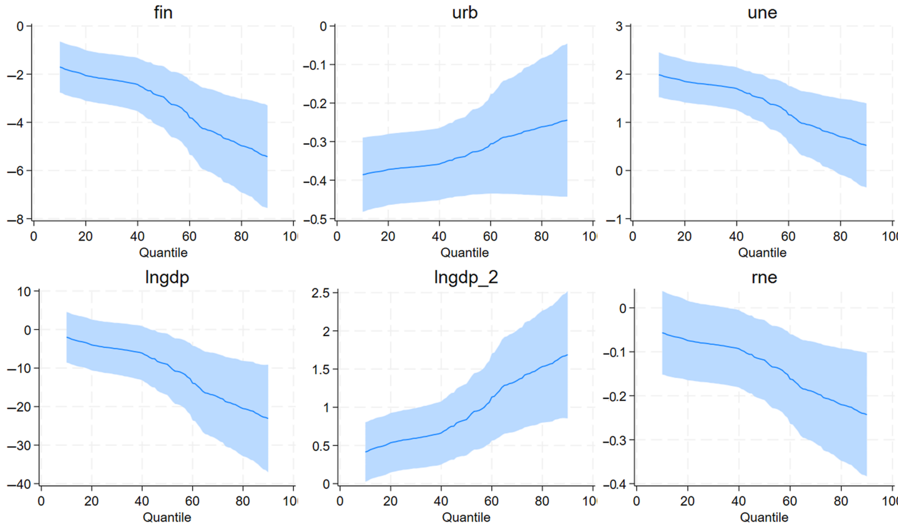

Figure 4. Quantile distributional effect on natural resources rents (nrr)

Moreover, the study identifies both linear (from the tenth to the 30th percentiles) and nonlinear (from the 40th to the 90th percentiles) effects of economic growth on natural resource rents. For countries with low levels of resource extraction, economic growth positively impacts the value of natural resource rents. This can be explained by the fact that initial economic development often relies heavily on natural resource exploitation to drive production and GDP growth. At this stage, resource extraction plays a crucial role in supplying raw materials and energy inputs necessary for the industrial and economic development of the country. Therefore, as countries begin to experience economic growth, the demand for natural resources rises, leading to increased resource extraction. For ASEAN countries with moderate to high levels of resource extraction, the effect of economic growth on natural resource rents is initially positive, meaning economic growth tends to increase the level of resource exploitation. However, when the GDP per capita reaches a certain turning point, economic growth starts to have a negative impact, reducing natural resource extraction. This turning point is estimated to fall within the range of GDP per capita between USD 100,624 and USD 931,567.

The MM-QR regression results indicate that the more a country depends on natural resources, the higher the GDP threshold required to reach the turning point where economic growth begins to reduce resource extraction. This implies that countries with a high level of resource dependency will take longer to achieve a stage of sustainable and resource-friendly development. In other words, ASEAN countries with intensive natural resource use must undergo a longer and more challenging transition to shift toward a resource-efficient economy, as they have historically relied on natural resources as a key driver of economic growth. This delay may pose long-term environmental and sustainability challenges if appropriate policies and strategies are not implemented to facilitate the transition toward less resource-dependent economic sectors.

4.5 Environmental effects of Fintech: mediated by natural resources rents

Ultimately, the study carried out a regression analysis, incorporating the natural resources rents (nrr) to clarify the impact path on the environmental impact of Fintech development. Table 7 presents the mediating role of natural resources in the nexus between Fintech and ecological

Table 7. Indirect effect of Fintech on environmental degradation (ecological footprint – ecf), mediated by nrr

	Low quantiles				Middle quantiles			High quantiles		
	PCSE	q10	q20	q30	q40	q50	q60	q70	q80	q90
fin	−0.2861***	−0.2297***	−0.2494***	−0.2616***	−0.2731***	−0.2886***	−0.2997***	−0.3091***	−0.3241***	−0.3377***
	(0.0525)	(0.0615)	(0.0545)	(0.0539)	(0.0557)	(0.0616)	(0.0678)	(0.0739)	(0.0852)	(0.0962)
nrr	0.0451***	0.0564***	0.0525***	0.0500***	0.0477***	0.0446***	0.0424***	0.0405***	0.0375***	0.0347***
	(0.0066)	(0.0094)	(0.0082)	(0.0076)	(0.0073)	(0.0072)	(0.0074)	(0.0077)	(0.0084)	(0.0092)
urb	0.0310***	0.0295***	0.0300***	0.0303***	0.0306***	0.0310***	0.0313***	0.0316***	0.0320***	0.0324***
	(0.0061)	(0.0076)	(0.0068)	(0.0068)	(0.0071)	(0.0079)	(0.0088)	(0.0096)	(0.0110)	(0.0124)
une	−0.1416***	−0.1530***	−0.1490***	−0.1466***	−0.1442***	−0.1411***	−0.1388***	−0.1369***	−0.1338***	−0.1312**
	(0.3510)	(0.0335)	(0.0294)	(0.0290)	(0.0304)	(0.0345)	(0.0386)	(0.0427)	(0.0498)	(0.0567)
lngdp	−1.7769***	−1.1850*	−1.3919**	−1.5193***	−1.6402***	−1.8030***	−1.9197***	−2.0186***	−2.1758***	−2.3184***
	(0.3510)	(0.6435)	(0.5541)	(0.4978)	(0.4560)	(0.4186)	(0.4059)	(0.4057)	(0.4251)	(0.4584)
lngdp^2	0.1641***	0.1157***	0.1326***	0.1431***	0.1529***	0.1663***	0.1758***	0.1839***	0.1968***	0.2084***
	(0.0231)	(0.0435)	(0.0375)	(0.0336)	(0.0306)	(0.0279)	(0.0269)	(0.0267)	(0.0277)	(0.0297)
rne	−0.0104***	−0.0126***	−0.0118***	−0.0114***	−0.0109***	−0.0103***	−0.0099***	−0.0096***	−0.0090***	−0.0085**
	(0.0029)	(0.0032)	(0.0028)	(0.0026)	(0.0024)	(0.0024)	(0.0025)	(0.0027)	(0.0030)	(0.0034)
_cons	4.8597***	2.6940	3.4509	3.9171*	4.3600**	4.9553***	5.3825***	5.7445***	6.3200***	6.8413***
	(1.5353)	(2.6268)	(2.2693)	(2.0593)	(1.9168)	(1.8150)	(1.8084)	(1.8480)	(1.9873)	(2.1757)
R-squared	0.9284									
Obs	220	220	220	220	220	220	220	220	220	220

Note(s): Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

footprint. It is evident that the natural resource rents (nrr) have a positive effect, meaning they increase the ecological footprint in ASEAN countries, which implies that, as the natural resource rents rise, the level of environmental degradation also worsens. Holding other factors constant, a 1% increase in natural resource rents (relative to GDP) corresponds to an increase in environmental degradation ranging from 0.0347% to 0.0564%. This clearly indicates that natural resource extraction in ASEAN countries contributes to increasing environmental pressures, leading to ecosystem degradation.

Table 7 and Figure 5 illustrate that the negative impact of natural resources rents diminishes in countries with higher levels of environmental pollution. This can be explained by the fact that countries with higher pollution levels have likely undergone phases of excessive resource exploitation, and the marginal negative effect of additional resource extraction may be less pronounced compared to countries with lower pollution levels. Another plausible reason is that countries with higher pollution levels often face international community pressure, environmental regulations or have reached a saturation point in resource extraction, making further impacts from resource exploitation less significant. The findings are consistent with Ullah *et al.* (2021) and Alvarado *et al.* (2021).

Moreover, in Table 7, the coefficients of Fintech indicate an inverse effect, meaning that Fintech contributes to reducing environmental degradation. However, the magnitude of this effect changes when the mediating role of natural resources is introduced, specifically the extent of the mediation effect that has been calculated and presented in Table 8. Fintech exerts an inverse impact on environmental degradation by positively reducing the resource rent value. In other words, the development of Fintech effectively mitigates the ecological footprint (ecf) in ASEAN countries through mechanisms that enhance resource use efficiency and conserve resource capital, thereby reducing the exploitation of natural resources. Fintech not only plays a role in improving financial efficiency but also supports more sustainable use and management of natural resources. As ASEAN countries adopt and develop Fintech, resource management becomes more effective, leading to a reduction in unnecessary resource extraction and consumption. Another point to note is that the mediating effect of natural resources decreases (from 49.726% to 20.802%) as the level of environmental pollution in a country increases. This can be explained by the fact that countries with higher pollution levels have often already exploited their natural resources to the maximum extent or have undergone

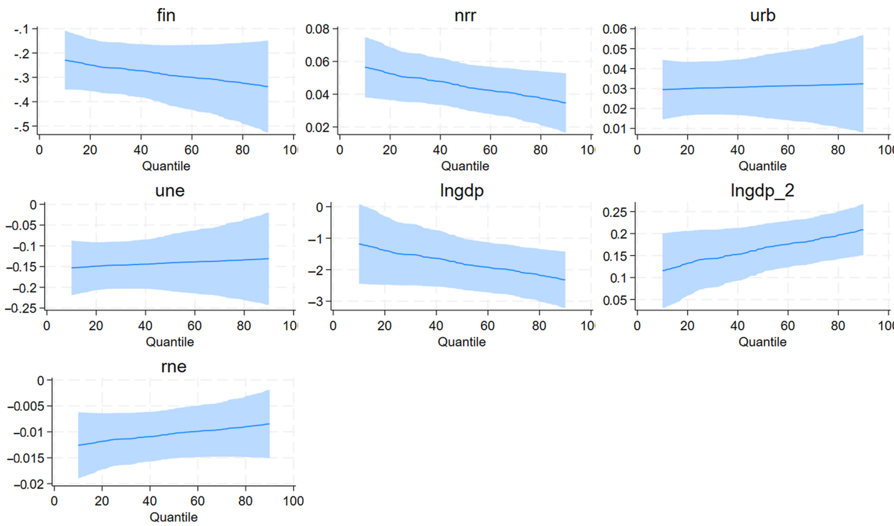

Figure 5. Quantile distributional effect on ecological footprint (ecf)

Table 8. Calculation of mediation and turning point (ecf)

	Low quantiles				Middle quantiles			High quantiles		
	PCSE	q10	q20	q30	q40	q50	q60	q70	q80	q90
% Mediation	35.139%	49.726%	44.826%	41.385%	38.255%	34.364%	31.230%	28.730%	24.768%	20.802%
Turning point (USD)	224,545	167,503	190,279	202,052	213,500	226,088	235,073	241,848	251.627	260.442

Table 9. Indirect effect of Fintech on environmental quality (ecological efficiency – sdi), mediated by nrr

	Low quantiles				Middle quantiles			High quantiles		
	PCSE	q10	q20	q30	q40	q50	q60	q70	q80	q90
fin	*0.0212****	0.0012	0.0092	0.0138	*0.0198****	*0.0226****	*0.0271****	*0.0303****	*0.0342****	*0.0392****
	(0.0065)	(0.0118)	(0.0097)	(0.0084)	(0.0069)	(0.0063)	(0.0056)	(0.0054)	(0.0054)	(0.0061)
nrr	*0.0017***	0.0006	0.0011	0.0013	*0.0017**	*0.0018***	*0.0021****	*0.0023****	*0.0025****	*0.0028****
	(0.0007)	(0.0017)	(0.0014)	(0.0012)	(0.0010)	(0.0009)	(0.0007)	(0.0007)	(0.0006)	(0.0008)
urb	−0.0032***	−0.0013	−0.0021*	−0.0025**	−0.0031***	−0.0033***	−0.0038***	−0.0041***	−0.0044***	−0.0049***
	(0.0006)	(0.0015)	(0.0012)	(0.0010)	(0.0008)	(0.0008)	(0.0006)	(0.0005)	(0.0005)	(0.0005)
une	−0.0044	−0.0099	−0.0077	−0.0065	−0.00482	−0.0040	−0.0028	−0.0019	−0.0008	0.0005
	(0.0036)	(0.0064)	(0.0053)	(0.0046)	(0.0039)	(0.0035)	(0.0031)	(0.0029)	(0.0028)	(0.0029)
lngdp	*0.5552****	*0.6255****	*0.5975****	*0.5813****	*0.5603****	*0.5502****	*0.5345****	*0.5233****	*0.5096****	*0.4921****
	(0.0.0326)	(0.0521)	(0.0435)	(0.0390)	(0.0348)	(0.0337)	(0.0333)	(0.0341)	(0.0363)	(0.0403)
$lngdp^2$	*−0.0397****	*−0.0454****	*−0.0431****	*−0.0418****	*−0.0401****	*−0.0392****	*−0.0379****	*−0.0370****	*−0.0359****	*−0.0344****
	(0.0022)	(0.0036)	(0.0030)	(0.0026)	(0.0023)	(0.0022)	(0.0021)	(0.0021)	(0.0022)	(0.0024)
rne	−0.0047***	−0.0048***	−0.0048***	−0.0048***	−0.0047***	−0.0047***	−0.0047***	−0.0047***	−0.0046***	−0.0046***
	(0.0003)	(0.0006)	(0.0004)	(0.0004)	(0.0003)	(0.0003)	(0.0002)	(0.0003)	(0.0003)	(0.0003)
_cons	−0.8953***	−1.2107***	−1.0853***	−1.0126***	−0.9182***	−0.8730***	−0.8025***	−0.7522***	−0.6906***	−0.6121***
	(0.1458)	(0.2465)	(0.2037)	(0.1811)	(0.1597)	(0.1536)	(0.1510)	(0.1541)	(0.1643)	(0.1835)
R-squared	0.9012									
Obs	220	220	220	220	220	220	220	220	220	220

Note(s): Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 10. Calculation of mediation and turning point (sdi)

	Low quantiles				Middle quantiles			High quantiles		
	PCSE	q10	q20	q30	q40	q50	q60	q70	q80	q90
% Mediation	39.474%	n/a	n/a	n/a	39.437%	40.373%	53.107%	56.995%	62.085%	64.706%
Turning point (USD)	1,088,377	981,190	1024,08	1046,65	1,081,695	1,116,392	1,154,533	1,178,057	1,208,933	1,277,444

Note(s): Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. n/a is nonapplicable significant resource degradation, making the impact of Fintech through the mechanism of reducing resource extraction less effective. Therefore, the study validates Hypothesis H3.

The study continues to test H3 concerning the environmental quality dimension, with the dependent variable being ecological efficiency (sdi). The mediating role of natural resources in the impact of Fintech on environmental quality is presented in Table 9 and Figure 6. Specifically, an increase in the natural resources rents has a positive effect on environmental quality, although the estimated coefficients range only between 0.0017 and 0.0028 (from the median to higher quantiles), which indicates that the increase in natural resource extraction significantly affects only countries with moderate to high environmental quality. The reason may lie in the fact that these countries possess better infrastructure and environmental management systems, allowing them to utilize natural resource inputs more efficiently. The development of Fintech can act as a facilitating factor, helping to optimize the extraction and management processes of natural resources, thereby contributing to the improvement of environmental quality. Conversely, in countries with low environmental quality, the impact of natural resource extraction is not clearly evident, which suggests these countries may lack effective environmental management policies or the capacity to utilize Fintech appropriately to optimize resource value. Moreover, resource extraction without adequate consideration of environmental quality may lead to adverse consequences, such as environmental pollution and biodiversity loss (Niu *et al.*, 2024). Therefore, this study further confirms Hypothesis H2. While increased natural resource extraction or growing resource scarcity may exacerbate environmental degradation, it may also simultaneously contribute to improvements in ecological efficiency.

Table 10 presents the extent of the mediating effect of natural resources in the relationship between Fintech and environmental quality (ecological efficiency). The mediating role of natural resources in the impact of Fintech on environmental quality occurs only in countries with medium to high ecological quality (from the 40th to the 90th percentile). This finding suggests that, in countries with better environmental quality, Fintech can be applied more effectively, leading to optimized natural resource management and improvements in environmental quality. For example, when natural resources are well managed through Fintech technologies and services, they can promote sustainable behaviors, thereby generating positive environmental outcomes.

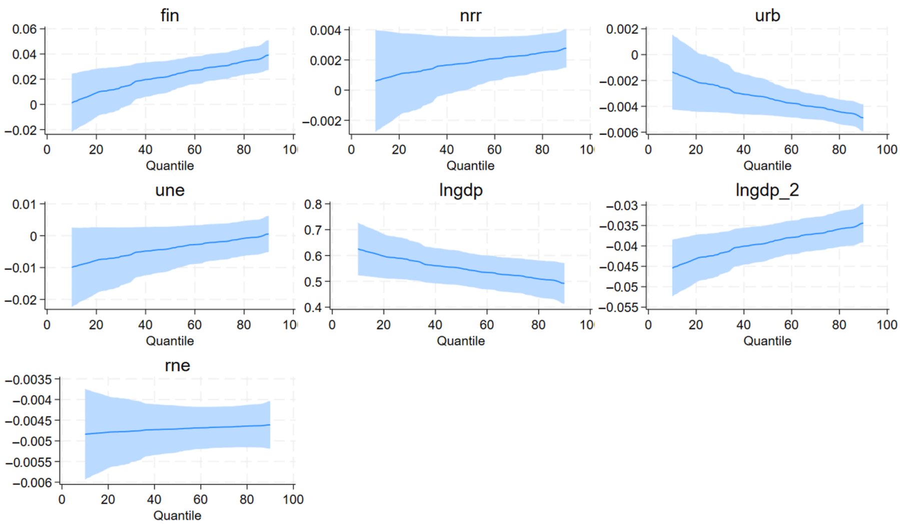

Figure 6. Quantile distributional effect on ecological efficiency (sdi)

Moreover, the magnitude of the mediating effect gradually increases from 39.437% to 64.706% across the quantiles, providing strong evidence that natural resources act as a key transmission channel through which Fintech influences environmental quality and this pattern indicates that the impact of Fintech is not only direct but also operates indirectly by shaping how natural resources are utilized. Specifically, Fintech enhances the efficiency of resource allocation by reducing information asymmetry and transaction costs, thereby facilitating investment flows into activities related to resource extraction, processing, and energy use (Okere *et al.*, 2025b). Through this mechanism, natural resources become an important conduit linking Fintech development to environmental outcomes. When resource use is directed toward cleaner production processes, the indirect effect of Fintech contributes to environmental improvement. The increasing magnitude of the mediating effect across quantiles suggests that, as environmental quality improves, the role of natural resources in transmitting the benefits of Fintech becomes more pronounced. In such contexts, resource utilization is more aligned with sustainability-oriented activities, allowing Fintech to amplify its positive environmental impact through this channel. Conversely, in lower quantiles where environmental quality is weaker, the mediating role of natural resources is less effective. In these cases, Fintech-driven financial flows may not sufficiently redirect resource use toward environmentally friendly activities, limiting their indirect contribution to environmental quality. Accordingly, the results provide robust empirical support for the mediating role of natural resources and strongly validate Hypothesis H3.

4.6 Does the Environmental Kuznets Curve (EKC) exist?

Concerning the EKC hypothesis in ASEAN countries, the study observes that the traditional inverted U-shaped EKC does not appear to hold in the context of Fintech development. The MM-QR and PCSE estimation, when using ecological footprint (ecf) as the dependent variable (in Table 7), reveal that GDP and the square of GDP have statistically significant negative and positive effects, respectively, across all percentiles. This finding suggests that, under the influence of Fintech, the EKC hypothesis may undergo a structural shift. Specifically, economic growth initially reduces ecological degradation; however, beyond a certain threshold of GDP per capita, further growth tends to intensify environmental degradation and pollution. The turning points are calculated and presented in Table 8, ranging from USD 167,503 to USD 260,442 – levels below the average GDP per capita in the research sample. Many ASEAN countries still have the potential to achieve economic growth without triggering excessive environmental degradation and, furthermore, the threshold at which GDP growth begins to worsen environmental conditions increases in countries with more severe environmental degradation and where the role of natural resources diminishes. Fintech can offer numerous opportunities for investment in green and sustainable solutions; however, it may also increase environmental pressure if economic activities are expanded without adequate environmental safeguards. Therefore, Fintech must be accompanied by robust environmental policies to ensure that economic growth does not come at the expense of environmental quality. As a result, the study rejects Hypothesis H4a regarding the conventional inverted U-shaped EKC and concludes that, in the context of Fintech, the EKC follows a U-shape, with a turning point at a relatively low level of GDP per capita.

When ecological efficiency (sdi) is used as the dependent variable (in Table 9), the linear relationship between economic growth and environmental quality under Fintech development contradicts the traditional EKC hypothesis. Specifically, GDP exerts a positive impact on environmental quality, while the squared term of GDP has a negative effect, and this indicates that in initial stages, GDP growth may enhance environmental quality through the adoption of sustainable Fintech such as digital payments, accessible online lending and investments in renewable energy. However, once a certain GDP threshold is reached, the positive impact diminishes, leading to a decline in environmental quality and this result reflects that unsustainable development may occur when economic growth exceeds the environmental management capacity of countries. Table 10 shows that the threshold at which GDP growth transitions from positively to negatively affecting environmental quality ranges from USD 981,190 to USD 1,277,444. A key insight is that countries with higher environmental quality can sustain the environmentally benign phase of Fintech development longer than countries with lower environmental quality, which highlights that effective environmental policies, in tandem with sustainable Fintech development, can enable countries to maintain economic progress without harming the environment. As a result, we reject Hypothesis H4b as the EKC for ecological efficiency follows an inverted U-shape.

5. Concluding remarks

This study provides a fresh examination of the interrelationship between Fintech, economic growth and the environment (including environmental degradation and environmental quality) across ASEAN countries during the 2000–2021 period. By employing advanced quantitative methodologies such as PCSE and MM-QR, the study offers robust empirical evidence on the role of Fintech in influencing environmental outcomes. Initially, Fintech exerts a significantly advantageous impact on the environment, notably through the reduction of ecological footprints and the enhancement of eco-efficiency. These results underscore the potential contribution of Fintech to sustainable development objectives, particularly when accompanied by effective natural resource management policies. Moreover, the mediating role of natural resources in the Fintech–environment nexus is empirically validated, suggesting that efficient governance and utilization of natural capital are essential for amplifying the environmental benefits of digital financial development. Specifically, the mediating effects range from a decrease of 20.802% to 49.726% for environmental degradation and an increase from 39.437% to 64.706% for environmental quality across different quantiles. Importantly, the empirical results deviate from the traditional EKC hypothesis, indicating a nonlinear U-shaped curve with ecological footprint and an inverted U-shaped curve with ecological efficiency. While economic growth initially contributes to environmental improvement, surpassing a certain GDP level reverses this trend, exacerbating ecological deterioration. For instance, ecological footprints decline with early-stage GDP growth but subsequently increase after crossing a critical income threshold. However, in contrast, eco-efficiency initially rises with GDP but diminishes beyond a relatively low GDP level. These dynamics suggest that digital transformation through Fintech necessitates nuanced and adaptive policy responses to ensure a sustainable balance between economic expansion and environmental preservation.

Generally, the study sheds light on the complex interactions between Fintech, natural resources and environmental sustainability in the ASEAN context. The findings highlight the imperative of designing forward-looking, integrated policy strategies that align digital financial innovation with environmental stewardship. Firstly, ASEAN policymakers should foster a supportive legal and institutional framework to encourage Fintech development as a tool for achieving environmental and sustainability goals. This includes integrating Fintech into natural resource management, enhancing transparency in environmental monitoring and incentivizing green Fintech projects through regional cooperation and knowledge sharing. Secondly, to amplify the environmental benefits of Fintech, policymakers must pair Fintech advancement with effective natural resource governance, which involves clear regulatory frameworks, tax incentives, infrastructure support and the use of digital technologies for real-time monitoring and sustainable resource utilization. Finally, given the nonlinear relationship between economic growth and environmental quality, ASEAN countries should strategically deploy Fintech to boost eco-efficiency in early growth stages, while implementing targeted fiscal, credit, and green investment policies beyond certain GDP thresholds to mitigate environmental degradation and ensure sustainable development.

This study is not without limitations. Firstly, this study primarily focuses on the impact of Fintech on environmental quality, without fully accounting for other influential factors such as environmental policies, green technology investment or broader macroeconomic variables.

Secondly, future research could extend the analysis to a global scale to examine the potential convergence of Fintech development. This direction may uncover mechanisms for optimizing economic–environmental policies based on convergence patterns and cooperation among countries with similar Fintech maturity levels. Finally, beyond natural resources, various mediating factors such as government regulation, technological infrastructure, the development of the digital economy and public environmental awareness may also shape the relationship between Fintech and environmental quality and warrant deeper investigation.

Notes

1. https://asean.org/wp-content/uploads/2021/10/ASCCR-e-publication-Correction_8-June.pdf
2. https://dashboards.sdgindex.org/map

References

Adha, R., Hong, C., Yang, S. and Muzayyanah, S. (2024), "Re-Unveiling the energy efficiency impact: paving the way for sustainable growth in ASEAN countries", *Sustainable Development*, Vol. 32 No. 5, pp. 5812-5824, doi: 10.1002/sd.3005.

Ahakwa, I., Xu, Y., Tackie, E.A. and Mangudhla, T. (2023), "How crucial are natural resources in descending environmental degradation in Ghana? A novel dynamic ARDL simulation approach", *Journal of Cleaner Production*, Vol. 420, 138427, doi: 10.1016/j.jclepro.2023.138427.

Almansour, M. (2023), "Artificial intelligence and resource optimization: a study of Fintech start-ups", *Resources Policy*, Vol. 80, 103250, doi: 10.1016/j.resourpol.2022.103250.

Alt, R., Beck, R. and Smits, M.T. (2018), "FinTech and the transformation of the financial industry", *Electronic Markets*, Vol. 28 No. 3, pp. 235-243, doi: 10.1007/s12525-018-0310-9.

Alvarado, R. and Toledo, E. (2016), "Environmental degradation and economic growth: evidence for a developing country", *Environment, Development and Sustainability*, Vol. 19 No. 4, pp. 1205-1218, doi: 10.1007/s10668-016-9790-y.

Alvarado, R., Tillaguango, B., Dagar, V., Ahmad, M., Işık, C., Méndez, P. and Toledo, E. (2021), "Ecological footprint, economic complexity and natural resources rents in Latin America: empirical evidence using quantile regressions", *Journal of Cleaner Production*, Vol. 318, 128585, doi: 10.1016/j.jclepro.2021.128585.

Amin, N., Shabbir, M.S., Song, H. and Abbass, K. (2022), "Renewable energy consumption and its impact on environmental quality: a pathway for achieving sustainable development goals in ASEAN countries", *Energy and Environment*, Vol. 35 No. 2, p. 662, doi: 10.1177/0958305x221134113.

Baron, R.M. and Kenny, D.A. (1986), "The moderator–mediator variable distinction in social psychological research: conceptual, strategic and statistical considerations", *Journal of Personality and Social Psychology*, Vol. 51 No. 6, pp. 1173-1182, doi: 10.1037/0022-3514.51.6.1173.

Barroso, M. and Laborda, J. (2022), "Digital transformation and the emergence of the Fintech sector: systematic literature review", *Digital Business*, Vol. 2 No. 2, 100028, doi: 10.1016/j.digbus.2022.100028.

Bian, W., Ge, T., Ji, Y. and Wang, X. (2023), "How is Fintech reshaping the traditional financial markets? New evidence from insurtech and insurance sectors in China", *China Economic Review*, Vol. 80, 102004, doi: 10.1016/j.chieco.2023.102004.

Chen, X., You, X. and Chang, V. (2021), "FinTech and commercial banks' performance in China: a leap forward or survival of the fittest?", *Technological Forecasting and Social Change*, Vol. 166 No. 166, 120645, doi: 10.1016/j.techfore.2021.120645.

Chueca Vergara, C. and Ferruz Agudo, L. (2021), "Fintech and sustainability: do they affect each other?", *Sustainability*, Vol. 13 No. 13, 7012, doi: 10.3390/su13137012.

Croutzet, A. and Dabbous, A. (2021), "Do Fintech trigger renewable energy use? Evidence from OECD countries", *Renewable Energy*, Vol. 179, pp. 1608-1617, doi: 10.1016/j.renene.2021.07.144.

Danish, Ulucak, R. and Baloch, M.A. (2023), "An empirical approach to the nexus between natural resources and environmental pollution: do economic policy and environmental-related technologies make any difference?", *Resources Policy*, Vol. 81, 103361, doi: 10.1016/j.resourpol.2023.103361.

Delina, L.L. (2023), "Fintech RE in a global finance centre: expert perceptions of the benefits of and challenges to digital financing of distributed and decentralised renewables in Hong Kong", *Energy Research and Social Science*, Vol. 97, 102997, doi: 10.1016/j.erss.2023.102997.

Dietz, T. and Rosa, E.A. (1997), "Effects of population and affluence on CO2 emissions", *Proceedings of the National Academy of Sciences*, Vol. 94 No. 1, pp. 175-179, doi: 10.1073/pnas.94.1.175.

Ding, D.K. and Beh, S.E. (2022), "Climate change and sustainability in ASEAN countries", *Sustainability*, Vol. 14 No. 2, 999, doi: 10.3390/su14020999.

Dong, Z., Zhou, Z., Ananzeh, M., Hoang, K.N., Shamansurova, Z. and Luong, T.A. (2024), "Exploring the asymmetric association between fintech, clean energy, climate policy, natural resource conservations and environmental quality. A post-COVID perspective from Asian countries", *Resources Policy*, Vol. 88, 104489, doi: 10.1016/j.resourpol.2023.104489.

Gani, A. (2021), "Fossil fuel energy and environmental performance in an extended STIRPAT model", *Journal of Cleaner Production*, Vol. 297, 126526, doi: 10.1016/j.jclepro.2021.126526.

Grossman, G.M. and Krueger, A.B. (1995), "Economic growth and the environment", *Quarterly Journal of Economics*, Vol. 110 No. 2, pp. 353-377, doi: 10.2307/2118443.

Hassan, S.T., Xia, E., Khan, N.H. and Shah, S.M.A. (2018), "Economic growth, natural resources, and ecological footprints: evidence from Pakistan", *Environmental Science and Pollution Research*, Vol. 26 No. 3, pp. 2929-2938, doi: 10.1007/s11356-018-3803-3.

Hickel, J. (2020), "The sustainable development index: measuring the ecological efficiency of human development in the anthropocene", *Ecological Economics*, Vol. 167, 106331, doi: 10.1016/j.ecolecon.2019.05.011.

Hopalı, E., Vayvay, Ö., Kalender, Z.T., Turhan, D. and Aysuna, C. (2022), "How do mobile wallets improve sustainability in payment services? A comprehensive literature review", *Sustainability*, Vol. 14 No. 24, 16541, doi: 10.3390/su142416541.

Joshua, U. and Bekun, F.V. (2020), "The path to achieving environmental sustainability in South Africa: the role of coal consumption, economic expansion, pollutant emission and total natural resources rent", *Environmental Science and Pollution Research*, Vol. 27 No. 9, pp. 9435-9443, doi: 10.1007/s11356-019-07546-0.

Karim, S., Naeem, M.A., Mirza, N. and Paule-Vianez, J. (2022), "Quantifying the hedge and safe-haven properties of bond markets for cryptocurrency indices", *The Journal of Risk Finance*, Vol. 23 No. 2, pp. 191-205, doi: 10.1108/jrf-09-2021-0158.

Kostakis, I. (2024), "An empirical investigation of the nexus among renewable energy, financial openness, economic growth and environmental degradation in selected ASEAN economies", *Journal of Environmental Management*, Vol. 354, 120398, doi: 10.1016/j.jenvman.2024.120398.

Le, H.N., Dang, M.N., Ho, P.U., Tran, N.H.N., Tran, T.A.V., Nguyen, P.H. and Trinh, M.Q. (2026), "The more, the merrier? Innovation-Led sustainable development", *Sustainable Development*, Vol. 34 No. 1, pp. 808-836, doi: 10.1002/sd.70292.

Li, B., Wang, J. and Wang, M. (2024), "Pursuit of sustainable environment; quantifying the role of Fintech, natural resources and energy efficiency in carbon neutrality in top six manufacturing nations", *Resources Policy*, Vol. 97, 105247, doi: 10.1016/j.resourpol.2024.105247.

Liu, L., Chen, Z., Al-Hiyari, A. and Nassani, A. (2024), "Sustainable growth in mineral rich BRI countries: linking institutional performance, Fintech and green finance to environmental impact", *Resources Policy*, Vol. 96, 105159, doi: 10.1016/j.resourpol.2024.105159.

Lobato, M., Rodríguez, J. and Romero, H. (2021), “A volatility-match approach to measure performance: the case of socially responsible exchange traded funds (ETFs)”, *The Journal of Risk Finance*, Vol. 22 No. 1, pp. 34-43, doi: 10.1108/jrf-04-2020-0066.

Macchiavello, E. and Siri, M. (2022), “Sustainable finance and Fintech: can technology contribute to achieving environmental goals? A preliminary assessment of ‘green Fintech’ and ‘sustainable digital finance’”, *European Company and Financial Law Review*, Vol. 19 No. 1, pp. 128-174, doi: 10.1515/ecfr-2022-0005.

Machado, J.A.F. and Santos Silva, J.M.C. (2019), “Quantiles via moments”, *Journal of Econometrics*, Vol. 213 No. 1, pp. 145-173, doi: 10.1016/j.jeconom.2019.04.009.

Mahmood, H. and Furqan, M. (2020), “Oil rents and greenhouse gas emissions: spatial analysis of gulf cooperation council countries”, *Environment, Development and Sustainability*, Vol. 23 No. 4, pp. 6215-6233, doi: 10.1007/s10668-020-00869-w.

Mention, A.-L. (2019), “The future of Fintech”, *Research-Technology Management*, Vol. 62 No. 4, pp. 59-63, doi: 10.1080/08956308.2019.1613123.

Mertzanis, C. (2023), “FinTech finance and social-environmental performance around the world”, *Finance Research Letters*, Vol. 56, 104107, doi: 10.1016/j.frl.2023.104107.

Muganyi, T., Yan, L. and Sun, H. (2021), “Green finance, fintech and environmental protection: evidence from China”, *Environmental Science and Ecotechnology*, Vol. 7, 100107, doi: 10.1016/j.ese.2021.100107.

Muhammad, S., Pan, Y., Magazzino, C., Luo, Y. and Waqas, M. (2022), “The fourth industrial revolution and environmental efficiency: the role of Fintech industry”, *Journal of Cleaner Production*, Vol. 381, 135196, doi: 10.1016/j.jclepro.2022.135196.

Murshed, M. and Rahman, A.K.M.A. (2024), “The importance of settling geopolitical disputes in neutralizing the carbon curse of natural resources: evidence from South and Southeast Asia”, *Mineral Economics*, Vol. 38 No. 1, pp. 143-158, doi: 10.1007/s13563-024-00465-8.

Nguyen, P.H., Le, T.N., Pham, M.T. and Trinh, M.Q. (2024), “Circular economy, economic growth and e-waste generation in EU27 countries: further evidence from the novel circular economy index and threshold effect”, *Environmental Science and Pollution Research*, Vol. 31, pp. 55361-55387, doi: 10.1007/s11356-024-34855-w.

Niu, J., He, J. and He, Y. (2024), “Harnessing Fintech for sustainable mineral development with innovative financing strategies in China”, *Resources Policy*, Vol. 90, 104697, doi: 10.1016/j.resourpol.2024.104697.

Nuţă, F.M., Sharafat, A., Abban, O.J., Khan, I., Irfan, M., Nuţă, A.C., Dankyi, A.B. and Asghar, M. (2024), “The relationship among urbanization, economic growth, renewable energy consumption and environmental degradation: a comparative view of European and Asian emerging economies”, *Gondwana Research*, Vol. 128, pp. 325-339, doi: 10.1016/j.gr.2023.10.023.

Nwani, C., Okere, K.I., Dimnwobi, S.K., Uche, E. and Iorember, P.T. (2024), “From non-renewables to renewables and high-tech production: the impact of natural wealth and technology on ecological load capacity in Sub-Saharan Africa”, *Review of Development Economics*, Vol. 29 No. 2, pp. 1170-1194, doi: 10.1111/rode.13161.

Okere, K.I., Dimnwobi, S.K. and Fasanya, I.O. (2024), “Do Fintech, natural resources and globalization matter during ecological crises? A step towards ecological sustainability”, *Journal of Open Innovation Technology Market and Complexity*, Vol. 10 No. 3, 100371, doi: 10.1016/j.joitmc.2024.100371.

Okere, K.I., Dimnwobi, S.K. and Fasanya, I.O. (2025a), “Pathways to environmental sustainability: exploring the role of Fintech, natural resources and globalization in North Africa”, *International Journal of Sustainable Development and World Ecology*, Vol. 32 No. 4, pp. 446-464, doi: 10.1080/13504509.2025.2481222.

Okere, K.I., Fasanya, I.O. and Dimnwobi, S.K. (2025b), “Environmental impacts of natural resource and FinTech in oil-rich economies: the role of Fintech in mitigating the carbon curse”, *Natural Resources Forum*, Vol. ahead-of-print No. ahead-of-print, doi: 10.1111/1477-8947.70021.

Okere, K.I., Dimnwobi, S.K., Fasanya, I.O. and Umeajaghaku, O.L. (2026), "Innovation meets nature: investigating the environmental impact of Fintech, technological innovation and natural resource wealth in North Africa", *Environmental Modeling and Assessment*, Vol. ahead-of-print No. ahead-of-print, doi: 10.1007/s10666-025-10093-3.

Ortiz, C., Alvarado, R., Méndez, P. and Flores-Chamba, J. (2022), "Environmental impact of the shadow economy, globalisation and human capital: capturing spillovers effects using spatial panel data approach", *Journal of Environmental Management*, Vol. 308, 114663, doi: 10.1016/j.jenvman.2022.114663.

Parmentola, A., Petrillo, A., Tutore, I. and De Felice, F. (2021), "Is blockchain able to enhance environmental sustainability? A systematic review and research agenda from the perspective of sustainable development goals (SDGs)", *Business Strategy and the Environment*, Vol. 31 No. 1, pp. 194-217, doi: 10.1002/bse.2882.

Pesaran, M.H. and Yamagata, T. (2008), "Testing slope homogeneity in large panels", *Journal of Econometrics*, Vol. 142 No. 1, pp. 50-93, doi: 10.1016/j.jeconom.2007.05.010.

Puschmann, T. (2017), "Fintech", *Business and Information Systems Engineering*, Vol. 59 No. 1, pp. 69-76, doi: 10.1007/s12599-017-0464-6.

Qin, L., Aziz, G., Hussan, M.W., Qadeer, A. and Sarwar, S. (2023), "Empirical evidence of Fintech and green environment: using the green finance as a mediating variable", *International Review of Economics and Finance*, Vol. 89, pp. 33-49, doi: 10.1016/j.iref.2023.07.056.

Samour, A., Radmehr, R., Ali, E.B., Shayanmehr, S., Ofori, E.K., Porhajašová, J.I., Babošová, M., Kačániová, M. and Dimnwobi, S.K. (2024), "The role of financial inclusion and technological innovation in stimulating environmental sustainability in the European countries: a new perspective based on load capacity factor", *Heliyon*, Vol. 10 No. 22, e39970, doi: 10.1016/j.heliyon.2024.e39970.

Saqib, N. and Shahzad, U. (2024), "Pathways to sustainability: evaluating the impact of green energy, natural resources, Fintech, and environmental policies in resource-abundant countries", *Resources Policy*, Vol. 97, 105264, doi: 10.1016/j.resourpol.2024.105264.

Scardovi, C. (2017), *Digital Transformation in Financial Services'*, Springer International Publishing, doi: 10.1007/978-3-319-66945-8.

Shahbaz, M., Solarin, S.A. and Ozturk, I. (2016), "Environmental Kuznets curve hypothesis and the role of globalization in selected African countries", *Ecological Indicators*, Vol. 67, pp. 623-636, doi: 10.1016/j.ecolind.2016.03.024.

Shu, X., Usman, M., Ahmad, P. and Irfan, M. (2024), "Analyzing the asymmetric Fintech services under natural resources and renewable energy in the future environmental performance: new insights from STIRPAT model framework", *Resources Policy*, Vol. 92, 104984, doi: 10.1016/j.resourpol.2024.104984.

Sreenu, D.N. (2022), "Impact of Fintech and green finance on environmental quality protection in India: by applying the semi-parametric difference-in-differences (SDID)", *Renewable Energy*, Vol. 193, pp. 913-919, doi: 10.1016/j.renene.2022.05.020.

Stern, D.I., Common, M.S. and Barbier, E.B. (1996), "Economic growth and environmental degradation: the environmental Kuznets curve and sustainable development", *World Development*, Vol. 24 No. 7, pp. 1151-1160, doi: 10.1016/0305-750x(96)00032-0.

Stulz, R.M. (2019), "Fintech, bigtech and the future of banks", *Journal of Applied Corporate Finance*, Vol. 31 No. 4, pp. 86-97, doi: 10.1111/jacf.12378.

Sun, X., Chenggang, Y., Khan, A., Hussain, J. and Bano, S. (2020), "The role of tourism and natural resources in the energy-pollution-growth nexus: an analysis of belt and road initiative countries", *Journal of Environmental Planning and Management*, Vol. 64 No. 6, pp. 999-1020, doi: 10.1080/09640568.2020.1796607.

Sunanda, V.J. and Joseph, V.K. (2023), "Green finance and Fintech: toward a more sustainable financial system", in *Sustainable Finance*, pp. 283-300, doi: 10.1007/978-3-031-29031-2_12.

Tamasiga, P., Onyeaka, H. and Ouassou, E.H. (2022), “Unlocking the green economy in African countries: an integrated framework of Fintech as an enabler of the transition to sustainability”, *Energies*, Vol. 15 No. 22, 8658, doi: 10.3390/en15228658.

Tang, C., Irfan, M., Razzaq, A. and Dagar, V. (2022), “Natural resources and financial development: role of business regulations in testing the resource-curse hypothesis in ASEAN countries”, *Resources Policy*, Vol. 76, 102612, doi: 10.1016/j.resourpol.2022.102612.

Tang, P., Ma, H., Sun, Y. and Xu, X. (2024), “Exploring the role of Fintech, green finance and natural resources towards environmental sustainability: a study on ASEAN economies”, *Resources Policy*, Vol. 94, 105115, doi: 10.1016/j.resourpol.2024.105115.

Tao, R., Su, C.-W., Naqvi, B. and Rizvi, S.K.A. (2022), “Can Fintech development pave the way for a transition towards low-carbon economy: a global perspective”, *Technological Forecasting and Social Change*, Vol. 174, 121278, doi: 10.1016/j.techfore.2021.121278.

Thomas, H. and Hedrick-Wong, Y. (2019), *How Digital Finance and Fintech Can Improve Financial Inclusion*, Inclusive Growth, pp. 27-41, doi: 10.1108/978-1-78973-779-020191004.

Uddin, M., Siddik, A.B., Yuhuan, Z. and Naeem, M.K. (2024), “Fintech and environmental efficiency: the dual role of foreign direct investment in G20 nations”, *Journal of Environmental Management*, Vol. 360, 121211, doi: 10.1016/j.jenvman.2024.121211.

Udeagha, M.C. and Muchapondwa, E. (2022), “Investigating the moderating role of economic policy uncertainty in environmental Kuznets curve for South Africa: evidence from the novel dynamic ARDL simulations approach”, *Environmental Science and Pollution Research*, Vol. 29 No. 51, pp. 77199-77237, doi: 10.1007/s11356-022-21107-y.

Udeagha, M.C. and Muchapondwa, E. (2023), “Green finance, Fintech and environmental sustainability: fresh policy insights from the BRICS nations”, *International Journal of Sustainable Development and World Ecology*, Vol. 30 No. 6, pp. 1-17, doi: 10.1080/13504509.2023.2183526.

Udeagha, M.C. and Ngepah, N. (2023), “The drivers of environmental sustainability in BRICS economies: do green finance and Fintech matter?”, *World Development Sustainability*, Vol. 3, 100096, doi: 10.1016/j.wds.2023.100096.

Ullah, A., Ahmed, M., Raza, S.A. and Ali, S. (2021), “A threshold approach to sustainable development: nonlinear relationship between renewable energy consumption, natural resource rent and ecological footprint”, *Journal of Environmental Management*, Vol. 295, 113073, doi: 10.1016/j.jenvman.2021.113073.

Ullah, A., Dogan, M., Pervaiz, A., Ather, A., Akkus, H.T. and Dogan, H. (2024), “The impact of digitalization, technological and financial innovation on environmental quality in OECD countries: investigation of N-shaped EKC hypothesis”, *Technology in Society*, Vol. 77, 102484, doi: 10.1016/j.techsoc.2024.102484.

Wang, C.-N., Nhieu, N.-L. and Liu, W.-L. (2024a), “Unveiling the landscape of Fintech in ASEAN: assessing development, regulations, and economic implications by decision-making approach”, *Humanities and Social Sciences Communications*, Vol. 11 No. 1, pp. 1-16, doi: 10.1057/s41599-023-02581-2.

Wang, X., Yang, J., Ahmad, M. and Ahmed, Z. (2024b), “Green energy transition, economic complexity, green finance, and ecological footprint: shaping the SDGs in the presence of geopolitical risk”, *Natural Resources Forum*, Vol. 49 No. 4, pp. 3893-3910, doi: 10.1111/1477-8947.12556.

York, R., Rosa, E.A. and Dietz, T. (2003), “STIRPAT, IPAT and impact: analytic tools for unpacking the driving forces of environmental impacts”, *Ecological Economics*, Vol. 46 No. 3, pp. 351-365, doi: 10.1016/s0921-8009(03)00188-5.

Yusma, N., Aris, H., Hafizuddin, W., Khusyairi, A., Yurnaidi, Z., Safrina, R., Utama, N.A. and Rosalia, S.A. (2024), “The driving forces behind renewable energy consumption: a comprehensive analysis of key determinants and environmental concerns in ASEAN countries”, *Environmental Science and Pollution Research*, Vol. 31 No. 35, pp. 48388-48405, doi: 10.1007/s11356-024-34358-8.

Zhang, M. and Liu, Y. (2022), “Influence of digital finance and green technology innovation on China’s carbon emission efficiency: empirical analysis based on spatial metrology”, *Science of the Total Environment*, Vol. 838, 156463, doi: 10.1016/j.scitotenv.2022.156463.

Zhang, L., Wong, W.-K., Liu, L., Al Shraah, A., Albasher, B. and Shamansurova, Z. (2024), “Balancing environmental sustainability through Fintech, green finance natural resource, and economic growth in Asian economies – a Cup-FM and Cup-BC study”, *Resources Policy*, Vol. 98, 105294, doi: 10.1016/j.resourpol.2024.105294.

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