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The Dynamic Impact of Financial Technology and Energy Consumption on Environmental Sustainability

Mohd Afjal [1], Chinnadurai Kathiravan [1,*], Leo Paul Dana [2] and Chitra Devi Nagarajan [1]

[1] VIT Business School, Vellore Institute of Technology, Vellore 632014, India
[2] Faculty of Management, Dalhousie University, Halifax, NS B3H 4R2, Canada
* Correspondence: kathiravan.c@vit.ac.in

Abstract: This research investigates the dynamic interplay between financial technology, information and communication technology, energy consumption, and economic growth on environmental sustainability within Emerging and Growth-Leading Economies (EAGLEs) from 2005 to 2020. Utilizing advanced econometric techniques, such as Fully Modified Least Squares (FMOLS) and Vector Autoregressive Error Correction Model (VECM), the investigation scrutinizes the hypothesized relationships among these variables. Panel unit root tests were deployed to assess stationarity, while panel least squares methodology was employed to determine the presence of co-integration among the variables under study. The analysis reveals that internet usage, GDP, and renewable energy consumption exhibit a notable influence in diminishing CO_2 emissions within EAGLE economies. Additionally, the findings substantiate the existence of long-term causality originating from these variables and impacting CO_2 emissions. Conversely, the role of ATM networks in CO_2 emissions remains ambiguous, implying that financial technology's influence on environmental sustainability is inconclusive. Consequently, the research posits that environmental sustainability in EAGLE economies is chiefly determined by factors such as internet usage, economic expansion, and renewable energy consumption, with financial technology demonstrating no discernable impact. In light of these findings, the study advocates for the reevaluation and adaptation of existing policies and strategies to account for shifting climatic conditions. By doing so, decision-makers can better align their efforts with the pursuit of environmental sustainability in the context of rapidly evolving economies.

Keywords: environmental sustainability; financial technology; energy consumption; economic growth; EAGLE economies

JEL Classification: Q01; Q42; O33; O47

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1. Introduction

Human well-being is closely tied to the health of the environment. The World Health Organization notes that a small percentage of mortality worldwide is attributed to avoidable environmental factors [1]. Clean air, water, and soil are critical for human health, and environmental change impacts not only our daily lives but also the future of all species globally [2]. For businesses, environmental sustainability policies have become increasingly important goals. NASA reports that human activity, such as industry, is a significant contributor to climate change due to its reliance on resources like land, fossil fuels, and continuous production and consumption [3].

Environmental sustainability refers to the use of resources in a manner that can be maintained indefinitely while minimizing environmental impact. The ultimate goal of environmental sustainability is to facilitate economic development while also ensuring the sustainability of resources. Sustainable development ensures resources are used fairly without negatively impacting economic growth. Environmental limits must be considered to achieve this goal. These limits establish the maximum amount of resource degradation that can occur before resources are severely compromised [4].

Environmental regulations exist to prevent natural resources from being damaged. International agreements like the Paris Agreement of 2015 aim to promote the use of renewable energy sources and reduce climate change while protecting the planet's health and ensuring economic development [5]. The focus on environmental concerns, such as air, water, and soil pollution, excessive mining, deforestation, etc., has increased as events that affect human life worldwide have become more frequent, primarily due to human activities. Climate change presents a significant challenge to democracy, economic growth, and overall sustainability. In terms of environmental economics and related sociologies, research has shown that climate change, resource depletion, and ecological deterioration cannot be adequately addressed in conditions of continuous economic growth and technology development [6]. It is critical to implement sustainable practices to ensure a healthy environment and a sustainable future for all.

Despite the lack of evidence supporting the outright decoupling of gross domestic product growth, consumption of materials, and emissions of greenhouse gases, most policy approaches do not question the need for environmentally sustainable economic growth [7] accounting for CO_2 emissions. A significant portion of global greenhouse gas emissions is a result of the extraction and processing of materials, fuels, and food. Economic growth is generally associated with augmented manufacture of goods and services, and on its account, this is associated with source manipulation and environmental effects, and become a threat to the world [8]. Since GDP, carbon dioxide emissions, and resource consumption have all grown rapidly over time and significantly correlate with one another, growth has not yet been isolated from these issues on a global scale. Therefore, financial development, economic expansion, and technical improvement should result in sustained economic growth. In this study, we have applied FMOLS and Panel VECM in EAGLE economies to study the impact of fintech, internet usage, GDP and renewable energy consumption on CO_2 emissions. According to Banco Bilbao Vizcaya Argentaria (BBVA) research [9], Emerging and growth leading economies (EAGLEs) are a gathering of crucial developing markets, which are estimated to be 10 leading growth countries in the world. The EAGLE economies are supposed to lead worldwide development in the following 10 years and to give significant open doors to investors. The reason for choosing EAGLE economies for the analysis is that they provide two significant pathways for developing nations to achieve environmental sustainability. First and foremost, the possible financial and social effects of environmental degradation are especially significant for emerging nations. They are the most vulnerable to environmental change and will quite often be more reliant than developed economies on the exploitation of natural resources for economic growth. Furthermore, many developing nations face extreme financial, social and environmental risks from energy, and food inadequacy to environmental change and outrageous climate gambles. These factors sabotage their economic growth. In addition, in the present scenario even though developing nations contribute only a minor portion to greenhouse gas (GHG) emissions in comparison to the developed nations, soon they will increment their CHG emissions. Since environmental circumstances and financial and social frameworks contrast from one country to another, there is no single outline for how sustainability practices are to be done. Every nation needs to chip away at its substantial arrangement to guarantee that sustainable advancement is followed as a worldwide goal. The remainder of the paper is structured as follows: Section 2 describes the theoretical foundations of the investigation, Section 3 gives data and econometric methodology, Section 4 presents empirical results, and Section 5 explains the conclusion.

Table 1 delineates the variables and their respective indicators or measurements. The initial variable, Financial Technology, is characterized by the Automated Teller Machine Network (ATMN), gauged as per 100,000 adults. ATMN constitutes a system of devices enabling users to execute banking transactions without accessing a physical branch. The subsequent variable, Information and Communication Technology, is exemplified by Internet Use (IU), appraised as a percentage of the population. IU quantifies the proportion of individuals utilizing the internet within the past year. The third variable, Energy Consumption, is signified by Renewable Energy Consumption (REC), measured as a percentage of total final energy. REC evaluates the share of energy consumption originating from renewable sources. The fourth variable, Economic Growth, is embodied by Gross Domestic Product (GDP), calculated as per capita (current US$). GDP represents the aggregate value of goods and services generated by a nation or region over a specific timeframe. The fifth variable, Environmental Sustainability, is epitomized by Carbon Dioxide Emissions (CO_2) in metric tons per capita. CO_2 assesses the volume of carbon dioxide emissions generated by human endeavors, a critical factor in climate change.

Table 1. Variable Description.

Variables	Indicators	Abbreviation
Financial Technology	Automated Teller Machine Network	ATMN
Information and Communication Technology	Internet Use	IU
Energy Consumption	Renewable Energy Consumption	REC
Economic Growth	Gross Domestic Products	GDP
Environmental Sustainability	Carbon Dioxide Emissions	CO_2

This study's novelty resides in examining the dynamic repercussions of Financial Technology, Information and Communication Technology, Energy Consumption, and Economic Growth on Environmental Sustainability within EAGLEs, employing Fully Modified Least Squares (FMOLS) and Vector Autoregressive Error Correction Model (VECM) for the 2005–2020 period. The research enhances the scholarly literature by scrutinizing these variables' influence on CO_2 emissions in the EAGLEs' milieu and dissecting the long-term causality extending from internet usage, GDP, and renewable energy consumption to CO_2 emissions. Furthermore, the study offers valuable insights into the negligible effect of ATM networks on CO_2 emissions, underscoring the necessity of considering a nation or region's unique context when devising policies to foster environmental sustainability.

2. Theoretical Framework

Financial technology, commonly known as FinTech, represents the confluence of innovative financial services and state-of-the-art technological advancements. This interdisciplinary field encompasses a diverse array of applications, from mobile banking and peer-to-peer lending to cryptocurrencies and robo-advisory services. As a growing force within the global financial landscape, FinTech has not only redefined traditional banking systems, but also facilitated the democratization of financial access, promoting economic growth and financial inclusion. However, the rapid expansion of FinTech has sparked concerns about its energy consumption and ensuing implications for environmental sustainability. As a result, gaining a nuanced comprehension of the intricate relationship between financial technology, energy utilization, and ecological conservation is crucial to maximizing the benefits of FinTech while simultaneously mitigating its environmental impact.

In recent years, FinTech has surfaced as a formidable disruptor, contesting conventional financial paradigms and driving a paradigm shift toward nimble, customer-focused solutions. By harnessing advanced technologies such as artificial intelligence, machine learning, and blockchain, FinTech has given rise to a plethora of innovative financial instruments, payment gateways, and alternative lending platforms, revolutionizing the worldwide economic landscape. As FinTech thrives, its unparalleled growth has elicited critical questions about the industry's energy consumption patterns and their subsequent effect on environmental sustainability. Specifically, energy-intensive activities like cryptocurrency mining, data center operations, and algorithmic trading have faced scrutiny for their sizable carbon footprint, intensifying global climate change concerns.

To address these urgent issues, a thorough and integrative analysis of the complex interconnection between FinTech innovation, energy consumption, and environmental conservation is required. By investigating this multifaceted relationship, researchers and policymakers can more effectively pinpoint strategies to encourage sustainable development within the FinTech sector, achieving a delicate balance between technological advancement and ecological accountability. Ultimately, this informed approach can foster a more sustainable and resilient financial ecosystem that curtails environmental degradation while capitalizing on the transformative potential of financial technology.

Extensive research has focused on the global factors influencing climate change, examining the interplay between energy consumption and trade openness, as well as the integration of these connections within a single framework. Additionally, the link between economic growth, renewable energy utilization, and CO_2 emissions has been exhaustively explored. However, few studies have delved into the relationship between FinTech, internet usage, renewable energy consumption, GDP, and environmental sustainability, highlighting the need for further investigation in this area.

2.1. Impact of Fintech on Environmental Sustainability

There is general agreement in the field of academia that fintech can affect economic growth [10]. Although FinTech is associated with communication and data handling, it has not been demonstrated whether it promotes or obliges economic growth. The improvement of financial activity and administration processes can significantly improve the efficiency of economic governance [11,12]. The potential risks arising because of the improvement of FinTech can't be disregarded [13]. The application of FinTech technology with respect to environmental concerns is able to speed up the positioning of assets for energy and climate projects, advance the development of renewable power and environmental foundations, and contribute to the improvement of natural and ecological systems by providing adequate funding [14]. In the context of a circular economy, one important area in which digital technology may prove valuable is financing, especially for new ventures that often struggle to access capital [15]. The convergence of digitalization and sustainability offers businesses new chances to use cutting-edge technology to plan their impact on the environment and gauge how the environment affects their business [16,17], however, believes that neither ineffective FinTech nor ineffective regulations are beneficial for economic growth. Silva, L. [18] also found that fintech developments may influence monetary policy and macroprudential measures, which in turn can stimulate economic growth by taming the economic cycle and enhancing macroprudential measures. It has been demonstrated that fintech has a significant positive impact on the environment [19]. However, Afjal, M. et al. [20] found that there does not seem to be a significant association between cryptocurrencies and the energy markets over a long period of time. Sachse, S. et al. [21] and Haddad, C. et al. [22] have found evidence that FinTech's principal benefit is its capacity to develop an all the more and impartial society. A relative examination of the business models of FinTechs versus conventional banks are studied by Anand, D. et al. [23]. Other than revitalizing social and economic objectives of sustainability, FinTech developments are sustaining the natural quality and easing back down climate change [24]. Bitcoin may be used as a verge against the risk of swings in the stock markets, based on the findings of [25]. FinTech was examined by SSubanidja, M. et al. [26] to see whether it complements or competes with quantitative examination methods in the financial and banking sectors. The outcomes uncover that FinTech can possibly work together with the financial and banking industry. Digitalization promises to convey significant worth to organizations participating in sustainable practices. Owing to the high energy-consuming blockchain, technology isn't normally connected with environmental policies. Regardless, the FinTech developments with people-to-people payments present congruity and intelligibility with the environmental, social and governance world that captures an all the more ecofriendly, ESG versatile, and uncertain financial framework to help environmental events [27].

Fin-tech refers to the integration of technology in financial services, aimed at providing more efficient, faster, and better services. This can include a range of technologies such as mobile payments, blockchain, robo-advisors, and peer-to-peer lending [28,29]. To measure the impact of fin-tech on energy consumption and sustainability, various quantitative measures can be employed. One possible measure is the number of online or mobile transactions, which could indicate a shift away from traditional, paper-based processes [30]. Other measures could include the adoption of renewable energy sources by fin-tech companies, the use of energy-efficient technologies, and the development of products and services that promote sustainability. Additionally, surveys and interviews with consumers and businesses can be conducted to measure the adoption and impact of fin-tech on energy consumption and sustainability practices. In this study, Financial Technology is represented by the Automated Teller Machine Network (ATMN) measured as per 100,000 adults. The ATMN is a network of machines that allows customers to perform banking transactions without visiting a physical branch. Based on this, we formulated the hypotheses that adoption of fintech in financial services leads to a reduction in paper-based transactions or energy, resulting in a decrease in energy consumption and improved sustainability outcomes.

2.2. Impact of ICT on Environmental Sustainability

Over the last decades a significant amount of study has been conducted to analyze the efficiency of internet usage/information and communication technology (ICT). But limited attention has been given to the sustainability impact of ICT. Thus, the connection among ICT and environmental sustainability is as yet uncertain. Since, environmental sustainability is a significant issue, in this way, this study leads a similar investigation to comprehend the connection among ICT and CO_2 emissions. Some investigations discovered that quick development of ICT has decidedly impacted climate by moderating carbon dioxide (CO_2) emissions. It is contended that while ICT insurgency has prompted another time of financial development among nations, in any case, it has added to the present notable peculiarity of a worldwide temperature alteration brought about by higher CO_2 discharges. Lee et al. [31] demonstrated the link between ICT and CO_2 that for a group of ASEAN nations (ASEAN). The review demonstrated that, for the chosen sample, ICT effectively led to an increase in CO_2 emissions from 1991 to 2009. However, Al-Mulali et al. [32] found that only developed countries were significantly impacted by internet retailing when they studied the effect of online shopping on CO_2 emissions for 77 different countries. ICT industry accepts a possible part in plummeting carbon dioxide productions, according to Zhang and Liu [33] who utilised the STIRPAT model to examine the links between ICT and carbon dioxide discharges in China at the public and local levels between 2000 and 2010. In advance, Wang, Q. et al. [34] and Wang, Y. [35] demonstrated how ICTs reduce CO_2 discharges caused by road freight transport. Profaizer, P et al. [36] showed how ICT has the ability to play a role in improving energy performance and found that a 20% increase in energy investment funds might be achieved through the use of a variety of ICT arrangements. Shabani, Z.D. et al. [37] argued that ICT development contrarily influences CO_2 emissions in the developed nations, while the inverse is valid for the developing nations. Shabani, Z.D et al. [38] utilized the GMM approach to study how ICT impact CO_2 discharges to trigger comprehensive human development in SSA. They found that ICT and CO_2 emissions complement one another. As the economy grows, the demand for and supply of ICT products puts more strain on the world's energy resources. The fact that ICT can adversely affect environmental quality due to the creation of gadgets, ICT-related devices, and the repurposing of electronic trash is demonstrated by [37]. According to May, G. et al. [39], internet use automates the production cycle, increasing production efficiency and lowering energy use.

Danish et al. [40] analyzed the ICT-CO_2 emissions nexus in a developing economy. In consonance with most of the past examinations, ICT adds to CO_2 emissions. Still for SSA, [14] found that ICT doesn't affect CO_2 emissions. Haldar et al. [41] examine the impact of ICT, electricity consumption, innovation, and renewable power generation on economic growth in emerging economies. Their findings emphasize the importance of tailored policies for sustainable development, offering valuable insights for policymakers and industry professionals. Majeed, M.T. [42] utilizes a panel data index comprising of 48 developed and 84 developing nations to address the heterogenous outcomes of ICTs for the climate. The discoveries of the study propose that ICTs are fundamental for environmental sustainability in developed nations. Using panel data of BRICS economies from 1994 to 2014, Haseeb, A. et al. [43] discovered that internet use and mobile phone subscriptions have a negative impact on CO_2 emissions in the BRICS economies. Tsaurai, K. et al. [44], as well as Ozcan, B. et al. [45], argued that the growth of ICT aids in the decrease of air pollution in developing nations. As ICT advances production processes, further develops energy efficiency, diminishes CO_2 emissions, and creates transportation frameworks and creates more urban areas [46]. It proposes positive role of ICT foundation while prompting financial development [47,48].

Amri, F. et al. [49] explored how ICT and total factor productivity on CO_2 emissions in Tunisia from 1975 to 2014. They found that ICT doesn't essentially affect CO emissions in Tunisia. Shahnazi, R. et al. [50] focused on the impacts of ICT on CO_2 emissions in five sectors of the Iranian economy. The significant results were that ICT increases CO_2 emissions in the farming and industrial sector, while it decreases in transport and service sector. Avom, D. et al. [51] investigated the role of ICT on CO_2 emissions in 21 SSA nations from 1996 to 2014. From their discoveries, it shows that ICT has an indirect relationship with CO_2 emissions. Nguyen, T.T. et al. [52] utilized the FMOLS and quantile approach to investigate the impact of ICT on CO_2 emissions in thirteen G20 nations from 2000–2014. Their discoveries uncovered that the exported and imported ICT products increases CO_2 emissions. Sahoo, M. et al. [53] analyzed the positive effect of cell phones and the internet in mitigating carbon emissions in India during the period of 1990 and 2018. They found that ICT has a negative impact on the environment.

2.3. Impact of Energy Consumption and Economic Growth on Environmental Sustainability

The interplay between energy consumption, economic growth, and environmental sustainability has been the subject of extensive research, with numerous empirical studies exploring the associations among these factors. NASA [3] established a causal connection among economic growth, CO_2 emissions, and energy consumption in Italy, while other studies have investigated the Environmental Kuznets Curve (EKC) and its N-shaped relationship [54,55]. In accordance with these findings, Allard, A. [56] examined the link between CO_2 emissions and GDP per capita, uncovering an N-shaped EKC for 74 countries between 1994 and 2012. Furthermore, Fernández-Amador, O. et al. [57] identified a bidirectional relationship between CO_2 emissions and economic growth.

In terms of energy efficiency, Afjal, M. et al. [58] reported no significant energy efficiency for 42 countries. Ito, K. [59] discovered a robust and positive correlation between CO_2 emissions and a country's economic growth. Similarly, Shahbaz, M. et al. [60] found an N-shaped connection among GDP, net FDI, and CO_2 emissions in the MENA region. In contrast, Turkey's economy does not exhibit an N-shaped relationship between GDP and CO_2 emissions, unlike most other world regions [61]. Odugbesan, J.A. et al. [62] observed a strong association between economic growth, energy use, and CO_2 emissions in MINT countries, with unidirectional causality for energy use in Nigeria and Indonesia and bidirectional causality for Mexico and Turkey. A long-term linkage among economic growth, energy use, CO_2 emissions, and urbanization is also evident in all MINT nations.

Prior research has illuminated the significance of environmental sustainability and renewable energy consumption (EC). Afjal, M. et al. [63] underscored the urgency for policymakers to promptly select suitable scale sizes and eradicate managerial inefficiencies.

Ocal, O. et al. [64] delved into the economic evolution of renewable energy consumption, while Arouri, M.E.H. et al. [65] examined the relationship between real GDP, energy use, and ozone-depleting emissions in a panel of 12 Middle Eastern and North African countries. Qi, T. et al. [66] found that renewable energy consumption reduces environmental pollution in China between 1990 and 2011. Sebri, M. et al. [67] identified a feedback causation between CO_2 emissions and renewable energy in the BRICS economies using VECM. Aydoğan, B.et al. [68] noted that renewable energy decreases CO_2 emissions but exacerbates air pollution, while Charfeddine, L. [69] demonstrated that renewable energy usage ameliorates the climate quality for 24 African countries, and Ikram, M. [70] emphasized the importance of employing renewable energy sources to curtail air pollution.

This study distinguishes itself from preceding research in multiple ways: by utilizing the EAGLE economy as a framework; employing advanced methodologies to explore the cross-sectional associations among the variables; and investigating the dynamic impact of Financial Technology, Information and Communication Technology, Energy Consumption, and Economic Growth on Environmental Sustainability in EAGLEs using Fully Modified Least Squares (FMOLS) and Vector Autoregressive Error Correction Model (VECM). Moreover, it examines the effects of these variables on CO_2 emissions within the context of EAGLEs, as well as the long-term causality emanating from fintech, internet usage, GDP, and renewable energy consumption, ultimately affecting CO_2 emissions.

3. Data and Methodology

This investigation delves into the associations among Financial Technology, Information and Communication Technology, Energy Consumption, Economic Growth, and Environmental Sustainability within 15 Emerging and Growth-Leading Economies (EAGLEs) spanning from 2005 to 2020. Utilizing secondary data sourced from the World Bank database, the study employs a desk research approach to gather information from official reports and statistics published by the World Bank. To address the research inquiries, the study incorporates three categories of data: (1) Financial Technology data, including Automated Teller Machine Network (ATMN) and Internet Use (IU), (2) sustainability-related data, such as Carbon Dioxide Emissions (CO_2) and Renewable Energy Consumption (REC), and (3) Economic Growth data, represented by Gross Domestic Product (GDP). Various econometric methodologies, such as Fully Modified Least Squares (FMOLS), Vector Autoregressive Error Correction Model (VECM), panel unit root tests, and Impulse Response Functions (IRFs), are employed to scrutinize the amassed data and evaluate the hypotheses. These techniques are widely applied in econometric research to analyze time-series data.

Given the objectives of the study, the following hypotheses are proposed:

Hypothesis 1. *Financial technology has a significant impact on environmental sustainability in the 15 Emerging and Growth-Leading Economies (EAGLEs).*

Hypothesis 2. *Information and Communication Technology (ICT) has a significant impact on environmental sustainability in the 15 Emerging and Growth-Leading Economies (EAGLEs).*

Hypothesis 3. *Energy consumption has a significant impact on environmental sustainability in the 15 Emerging and Growth-Leading Economies (EAGLEs).*

Hypothesis 4. *Economic growth has a significant impact on environmental sustainability in the 15 Emerging and Growth-Leading Economies (EAGLEs).*

Hypothesis 5. *There is a significant interaction effect between financial technology, ICT, energy consumption, and economic growth on environmental sustainability in the 15 Emerging and Growth-Leading Economies (EAGLEs).*

3.1. Descriptive Statistics

Table 2 presents descriptive statistics encompassing five variables: CO_2, ATMN, IU, GDP, and REC. CO_2 denotes carbon dioxide emissions, ATMN signifies ATM networks, IU represents internet usage, GDP corresponds to gross domestic product, and REC refers to renewable energy consumption. For each variable, the table provides mean values, medians, minimum and maximum values, standard deviations, skewness, kurtosis, Jarque-Bera statistics, probabilities, as well as sums of values and squared deviations.

Table 2. Descriptive Statistics.

	CO_2	ATMN	IU	GDP	REC
Mean	3.562096	40.80422	34.29727	5111.871	26.22669
Median	2.298114	24.18912	29.2	3355.627	23.73085
Maximum	11.63994	185.4067	89.55501	15974.64	88.7493
Minimum	0.235264	0.201629	0.241637	499.4619	0.7021
Std. Dev.	3.106056	40.26857	23.96087	3933.126	22.26527
Skewness	1.026614	1.423439	0.432376	0.640347	0.94822
Kurtosis	2.976775	4.588436	1.955232	2.065634	3.49636
Jarque-Bera	42.16286	106.2785	18.39338	25.13217	38.42856
Probability	0.0000	0.0000	0.0001	0.0000	0.0000
Sum	854.9031	9793.012	8231.344	1,226,849	6294.405
Sum Sq. Dev.	2305.773	387,552.3	137,215.5	3.70×10^9	118,482.4

From Table 2, it is evident that the average CO_2 emissions value stands at 3.56, ranging from a minimum of 0.24 to a maximum of 11.64. The mean value for ATMN (ATM networks) is 40.80, with values spanning from 0.20 to 185.41. The average value for IU (internet usage) is 34.30, with the minimum and maximum values being 0.24 and 89.56, respectively. The GDP mean value amounts to 5111.87, with its range extending from 499.46 to 15,974.64. The average REC (renewable energy consumption) value is 26.23, with a minimum of 0.70 and a maximum of 88.75.

Moreover, the skewness values indicate that some variables exhibit positive skewness, suggesting a right-skewed distribution, while others display negative skewness, implying a left-skewed distribution. The kurtosis values reveal that all variables possess leptokurtic distributions, characterized by heavier tails and a higher prevalence of outliers compared to a normal distribution. Lastly, the Jarque-Bera statistics and probabilities imply that none of the variables exhibit normal distributions.

The analytical methodology employed in this study encompasses five stages. The initial stage involves utilizing the Levin-Lin-Chu (LLC), Philips Perron (PP), and ADF-Fisher panel unit root tests to determine the stationarity of each variable. If all variables exhibit stationarity at the first difference, the second stage proceeds with examining cross-dependency among the variables using the panel least square method. Subsequently, the Kao, C. [71] cointegration tests are applied in the third stage to investigate the presence of a cointegrating relationship between variables in bivariate models. In the fourth stage, the cointegrating regression equation is assessed using Fully Modified Ordinary Least Squares (FMOLS) to evaluate the bidirectional long-run elasticity coefficients in bivariate models. The fifth stage involves determining the causal relationships between components using the Vector Error Correction Model (VECM), based on the cointegrating connection between elements in each bivariate model. Lastly, an impulse response function is employed to analyze the dependent variable's response to the independent variable's shocks.

3.2. Panel Unit Root Tests

The stationary nature of the variable series is one of the fundamental prerequisites for regression analysis because non-stationary serios yields spurious regression results. Therefore, the panel unit root test is applied to examine the stationarity of CO_2, ATMN, IU, GDP, and REC. The panel unit roots consist of common root test and individual root test depending on whether or not each cross-sectional unit has a similar unit root. Wang, Y. et al. [72] conducted research in this area by applying the LLC (Levin, Lin, and Chu) panel unit test for normal root and ADF-Fisher test for individual root analysis. The following is how the LLC test can be explained [50].

$$\Delta\, Y_{it} = \rho\, Y_{it-1} + \sum_{j=1}^{\rho i} b_{ij}\, \Delta\, Y_{it-1} + M_{it}^{i}\, \theta + \mu_{it} \tag{1}$$

The Equation (1) represents a dynamic panel data model that analyzes the change in variable Y (ΔY_{it}) for an individual i at time period t. It considers the influence of Y's lagged value (Y_{it-1}), lagged changes in Y (ΔY_{it-1}), and a matrix of covariates (M^{i}_{it}) on the change in Y. The model incorporates individual-specific and time-varying effects, as well as coefficients (ρ, b_{ij}, and θ) to measure the impact of these factors on the change in Y. Lastly, an error term (μ_{it}) accounts for unexplained variation in the change of Y not captured by the other variables. This model is useful for studying the behavior of variables over time in econometrics and social sciences. The null hypothesis, $H0 : = 0$, suggests the presence of a unit root, while the alternative hypothesis, $H1 : \rho < 0$, implies no unit root. The ADF-Fisher test was developed which can be expressed using Equations (1) and (2).

$$ADF - Fisher\ I = -2 \sum_{i=1}^{N} \log(\rho_i)\ \rightarrow\ X^2_{2N} \tag{2}$$

$$ADF - Choi\ Z = \frac{1}{\sqrt{N_{i=1}}} \sum_{i=1}^{N} \psi^{-1}(\rho_i)\ \rightarrow\ N(0,\, 1) \tag{3}$$

The given equations represent two panel unit root test statistics, namely the ADF-Fisher and ADF-Choi tests. These tests are used to examine the presence of unit roots in panel data, which can help determine if the variables in the dataset are stationary or non-stationary. Equation (2) describes the ADF-Fisher test statistic, which is calculated by taking the sum of the logarithms of individual test statistics (ρ_i) for each unit i, then multiplying by -2. This sum converges to a chi-squared distribution with 2N degrees of freedom (X^2_{2N}) as the sample size increases, where N is the number of units in the panel. Equation (3) presents the ADF-Choi test statistic, which is based on the inverse standard normal cumulative distribution function (ψ^{-1}). The test statistic is calculated by summing the $\psi^{-1}(\rho_i)$ values for each unit i and dividing by the square root of the total number of units (N). This statistic converges to a standard normal distribution (N(0,1)) as the sample size increases. Both ADF-Fisher and ADF-Choi tests are used to determine the presence of unit roots in panel data and are essential for understanding the time series properties of the variables in the dataset.

3.3. Cross-Sectional Dependence

Using panel data analysis, macroeconomic factors taken into consideration for the study might show the issue of heterogeneity and cross-sectional dependence. Thus, it is crucial to test stationarity and cross-sectional dependence when examining economic variables. When cross-sectional dependence exists, the results are biased and unreliable. To take into consideration the cross-sectional dependence and heterogeneity difficulties, cutting-edge econometric techniques must be used. To ascertain whether cross-sectional reliance exists in the data during the first phase of the investigation, this study applies Pesaran, M.H. et al. [73] and Pesaran, M.H. [74] cross-sectional dependence test.

3.4. Co-Integration Test

The result of stationary test reveals that all the variables are stationary at first different, we have applied Kao C. [71] cointegration test to check for a cointegrating link between the variables. To establish cointegration, this test allows for a variety of cross-sectional dependencies as well as other various individual effects. The first test statistic is based on pooling residuals inside the panel's dimension. The following is an expression for the regression formula:

$$y_{it} = \alpha_i + \delta_{it} + \beta_{1i}x_{1i.t} + \ \beta_{2i}x_{2i.t} + \ldots + \beta_{Ni}X_{Ni.t} \ + \varepsilon_{it} \tag{4}$$

where N refers to the number of exogenous variables, y_{it} is the dependent variable for individual i at time t, α_i is the individual fixed effect or intercept, δ_{it} is the time fixed effect, $x_{1i.t}$, $x_{2i.t} \ldots x_{Ni.t}$ are the independent variables for individual i at time t. β_{1i}, $\beta_{2i} \ldots \beta_{Ni}$ are the coefficients of the independent variables, and ε_{it} is the error term for individual i at time t. This model accounts for both individual and time fixed effects and allows for the estimation of coefficients for each independent variable for each individual over time.

3.5. Panel FMOLS

Panel Fully Modified Ordinary Least Squares (FMOLS) is an econometric technique employed to estimate long-term relationships among variables in a panel data context. This method extends the FMOLS estimator, typically used for time series data, to panel data applications. Panel FMOLS addresses potential endogeneity and heterogeneity concerns arising in panel data analyses by adopting an instrumental variable approach, utilizing lagged levels of the dependent variable and its first difference as instruments for the levels and first difference of the independent variable, respectively.

This study employs the panel FMOLS model developed by Pedroni, P. [75] to further quantify the bidirectional long-term elasticity between variables in bivariate models, including CO_2 and ATMN, CO_2 and IU, CO_2 and GDP, and CO_2 and REC. The asymptotically efficient estimation in panel series has been adopted from Christopoulos, D.K. [76], utilizing the Fully Modified Least Squares approach, which accounts for non-exogeneity, serial correlation, and heterogeneity. As all explanatory variables are cointegrated with the temporal pattern, the panel unit root tests (LLC, IPS, Fisher ADF, and PP) and panel cointegration tests indicate the existence of a long-term equilibrium relationship among the variables. The FMOLS method not only enables accurate and valuable cointegration vector evaluation but also addresses the issues of simultaneous biases and nonstationary regressors in heterogeneous cointegrated panels.

Panel FMOLS offers several advantages over other panel data estimation methodologies, such as fixed effects and random effects models. It enables the estimation of long-term relationships among variables while controlling for the potential presence of unit-specific effects and serial correlation. Moreover, it can accommodate various error structures, including heteroscedasticity and cross-sectional dependence. Equation (5) represents the between-dimensional FMOLS notation, which can be applied independently to assess the minor, moderate, and significant effects;

$$\Psi^*{}_{NT} = N^{-1} \ \sum_{i=1}^{N} \left[\sum_{i=1}^{T} (\mu_{it} - \mu_i)^2 \ \right]^{-1} \left[\sum_{i=1}^{T} (\mu_{it} - \mu_i) Y_t^* - T_{ti} \ \right] \tag{5}$$

where the necessary assessment is made, assuming that the related t-statistic is normally distributed. This equation represents the estimator for the matrix Ψ*, which is used in the analysis of panel data. In this equation, N is the number of units or individuals in the panel, T is the number of time periods observed, μ_{it} is the average of the i-th individual across time periods, μ_i is the grand mean of the i-th individual across all units, y_t * is the mean of the dependent variable across all units at time t, and T_{ti} i is the mean of the i-th individual's value at time t. The equation involves taking the sum of squared differences between the individual means and grand mean, and then inverting that quantity to weight the sum of differences between the individual means and the mean of the dependent variable. The resulting estimator is used in the analysis of the efficiency of the panel data estimators.

3.6. Panel VECM (Vector Error Correction Model)

The panel VECM test is used to examine the meanings of causation for the variables in the subsequent stage. The panel VECM test documentation [24,43]. The panel VECM test notations, which were examined independently for mild, moderate, and severe effect [59,77], are provided in Equation (6);

$$\Delta(\Psi) = \theta_1 + \sum_{k=1}^{m+1} \beta_{1i}\Delta\Psi_{it-j} + \sum_{k=1}^{m+1} \gamma_{1j}\mu_{it-j} + \partial_1 ECT_{it-1} + \Delta\varepsilon_{1it} \quad (6)$$

where:

- $\Delta(\Psi)$ is the first-difference operator of the endogenous variables vector Ψ
- θ_1 is the intercept
- β_{1i} is the coefficient matrix of lagged differences of the endogenous variables
- $\Delta(\Psi)_{it-j}$ is the lagged first-differences of the endogenous variables
- $\gamma_{1j}\gamma$ is the coefficient matrix of lagged first-differences of the exogenous variables
- μ_{it-j} is the lagged first-differences of the exogenous variables
- ∂_1 is the coefficient of the error correction term (ECT)
- ECT_{it-1} is the lagged error correction term
- $\Delta\varepsilon_{1it}$ is the first-differences of the error term.

3.7. Impulse Response Function

This section utilizes impulse response functions to investigate the unique features of the projected VECM for the OECD over a ten-year period. The study employs the orthogonalized methods developed by [45,78] to analyze impulse responses, as shocks to one variable may have an impact on fluctuations in other variables. This technique allows for the tracking of the effects of various shocks on the variables over time. Sims, C.A. [79], Sims, C.A. [80] and Bernanke, B.S. [81] seminal works provide an overall understanding of this process, which is widely available in the literature.

4. Empirical Results

4.1. Panel Unit Root Test

In this study, we examined the effects of financial technology, information and communication technology, energy consumption, and economic growth on environmental sustainability using the FMOLS and Panel VECM models. To analyze the time series properties of the variables, we employed Levin, A. et al. [78], Im-Pesaran-Shin [45], and Dickey, D.A. et al. [82] tests, as developed by Maddala, G.S. et al. [83]. Multiple tests, each with different null and alternative hypotheses, were utilized to assess the robustness of the results. The null hypothesis for each of these panel unit root tests consistently considers the non-stationarity of the data. The IPS test amalgamates data from both cross-sectional and time series dimensions, thus requiring fewer time observations for the test to achieve statistical significance.

Table 3 presents the results of the panel unit root test. Based on the findings, the null hypothesis can be rejected, as all first differences of the variables were stationary at the 1% significance level. Since all the variables are stationary at first difference and integrated of order one for series, the cointegration test is employed to analyze the long-term relationship among the variables in the EAGLE economies.

Table 3. Panel Unit Root Test Results.

At Level				
Panel Unit Root Tests Results (Individual Intercept)				
	Levin. Lin and Chu	Im. Pesaran Shin	ADF-Fisher Chi square	PP-Fisher Chi square
CO_2	−11.6865 ***	−9.62081 ***	134.835 ***	189.247 ***
ATMN	0.85451 n0	3.24811 n0	20.4084 n0	19.6896 n0
IU	4.12021 n0	9.23448 n0	3.04971 n0	3.22656 n0
GDP	0.47295 n0	0.32372 n0	33.754 n0	46.8797 **
REC	−2.19145 **	−1.42861 *	51.2533 ***	43.1494 **
At First Difference				
Panel Unit Root Tests Results (Individual Intercept)				
	Levin. Lin and Chu	Im. Pesaran Shin	ADF-Fisher Chi square	PP-Fisher Chi square
CO_2	−11.6865 ***	−9.62081***	134.835 ***	189.247 ***
ATMN	−3.85251 ***	−3.42484 ***	56.6626 ***	62.6063 ***
IU	−6.92631 ***	−7.02099 ***	110.087 ***	117.796 ***
GDP	−8.20829 ***	−5.56635 ***	81.6053 ***	79.3696 ***
REC	−11.2298 ***	−9.22451 ***	131.003 ***	191.471 ***

(*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1% and (n0) Not Significant. Lag Length based on SIC.

4.2. Cross-Sectional Dependence Test

Table 4 showcases the outcomes of the cross-sectional dependence analysis among the variables. The findings from the CD test indicate that all elements are stationary, leading to the rejection of the null hypothesis. The results of this examination highlight the interdependence among the investigated variables. The subsequent phase of the analysis entails validating the cointegration between CO_2 emissions, financial technology, internet usage, GDP, and renewable energy consumption.

Table 4. Cross-Section dependence test results.

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
ATMN	0.024724	0.005102	4.845873	0.0000
IU	−0.01054	0.007114	−1.48153	0.0398
GDP	0.000176	5.12×10^{-5}	3.440213	0.0007
REC	−0.0747	0.006141	−12.163	0.0000
C	3.973632	0.347984	11.41899	0.0000

4.3. Co-Integration Test

Tests developed by Kao and Pedroni [71] have been used to analyze the cointegration of variables and to obtain reliable results. These tests are advantageous for time series cointegration analysis because they increase cross sections and hence increase test size. Pedroni offered seven different types of tests that establish a mechanism to ensure that a panel has time impact and variable heterogeneity. The Kao test allows homogenous panels, and the cross section is person-independent. Kao and Pedroni's null hypothesis are that there is no co-integration between the variables, whereas their alternative hypothesis is that there is co-integration. Table 5 demonstrates that four Pedroni tests reject the null hypothesis of no cointegration at the 1% and 5% level of significance, confirming the long-term relationship between variables. The Kao test also rejects the null hypothesis that there is no cointegration and it is concluded from the analysis that variables have a long-term relationship.

Table 5. Co-integration Test Results.

Kao Residual Cointegration Test	t-Statistic	
ADF	−2.425542 ***	
Residual variance	0.023458	
HAC variance	0.030915	
Pedroni Residual Cointegration Test		
Within Dimension		
	Statistic	Weighted Statistic
Panel v-Statistic	0.306543	−2.020047
Panel rho-Statistic	2.731632	2.985455
Panel PP-Statistic	−1.102877 **	−3.572292 ***
Panel ADF-Statistic	−4.3373 ***	−5.464094 ***
Between Dimension		
	Statistic	
Group rho-Statistic	4.593576	
Group PP-Statistic	−5.899324 ***	
Group ADF-Statistic	−5.479755 ***	

Note: *** and ** indicate 1% and 5% level of significance.

4.4. Fully Modified OLS (FMOLS)

The study uses FMOLS to extract coefficient values. The problem of serial correlation and endogeneity can be eliminated using a variety of techniques. A few of them include the panel ordinary least squares, the generalised method of moments, random effects, fixed effects, completely modified OLS (FMOLS), and the dynamic ordinary OLS (DOLS).

Table 6 represents the information of the Panel FMOLS (Fully Modified Ordinary Least Squares) regression analysis. The table includes the independent variables—ATMN, IU, GDP, and REC—along with their coefficients, standard errors, and t-statistics. The t-statistics indicate the significance level of the coefficients, with ***, **, and * indicating 1%, 5%, and 10% levels of significance, respectively.

Table 6. Panel FMOLS results.

Independent Variable	**Coefficient**	**Std. Error**	**t-Statistic**
ATMN	0.008861	0.008942	0.99087
IU	0.043059	0.011219	3.83811 ***
GDP	0.000315	$8.25 \times 10^{-0.5}$	3.820378 ***
REC	−0.02092	0.00683	−3.06311 ***

Note: *** indicate 1% level of significance.

From the results of FMOLS represented in Table 6, it is visible that all the variables except ATM networks are significant meaning that, ATM networks cannot explain a change in CO_2 emissions. The result is conflicting with Zhang, C. [33].

The coefficient for IU is significant at the 1% level, suggesting that a one-unit increment in internet usage will lead to a 0.043059 unit rise in CO_2 emissions, while keeping all other variables constant. The elasticities of CO_2 emissions in relation to ICTs are both positive and significant, insinuating that ICT may have an adverse impact on environmental quality.

The reason for ICT's negative impact could be due to the high energy utilization from the utilization of countless ICT hardware that isn't energy efficient and the utilization of materials for the production and utilization in day-to-day life increases e-waste. Strategy measures ought to take for the progression of the ICT industry which prompts energy efficiency and diminishing CO_2 emissions. Similarly, the coefficient for GDP is significant at the 1% level, suggesting that a one-unit increase in GDP will lead to a 0.000315 unit increase in CO_2 emissions, holding all other variables constant. The outcomes confirm that rising economic growth policies have a solid effect on reducing environmental quality. Ang, J.B. [84] expressed that economic growth positively impacts CO_2 emissions and environmental degradation is caused by economic growth. Arouri et al. [65] also argued that GDP development is the essential driver of environmental degradation in MENA nations. Economic growth practices in developing nations additionally cause environmental degradation because these nations are consuming non-renewable energy resources for economic activities which ultimately increases CO_2 emissions. The coefficient for REC is likewise significant at the 1% level, signifying that a one-unit augmentation in renewable energy consumption will lead to a 0.02092 unit reduction in CO_2 emissions, while maintaining all other variables constant. Results indicate that renewable energy is environmentally friendly and can help with environmental pollution. Zhang, S. et al. [85] have observed that a one per cent increment in renewable energy diminishes CO_2 emissions by 0.15%. The coefficient for ATMN is not significant, meaning that changes in ATM networks do not have a statistically significant impact on CO_2 emissions. EAGLE economies can contribute to reducing worldwide CO_2 emissions by enhancing their consumption of renewable energy. Energy efficiency will not only contribute to reducing environmental pollution and increasing economic growth but also increase the quality of life. Energy is a significant element of production, and it ought to be clean and helpful in the reduction of environmental degradation and contamination decrease and renewable energy is the ideal solution for the EAGLE economies.

4.5. Panel VECM

To scrutinize the short- and long-term dynamic interconnections among financial technology, information and communication technology, energy consumption, economic growth, and CO_2 emissions, this research employed a two-stage method advocated by Engle, R.F. et al. [86]. In the initial step, the long-run model depicted in Equation (1) must be assessed, while in the subsequent stage, the lagged residual procured must be designated as the error correction term (ECT).

Table 7 showcases the outcomes of the Panel Vector Error Correction Model (VECM) analysis, a statistical approach employed to examine long-run relationships among variables in a panel dataset. The table displays the coefficients, standard errors, t-statistics, and *p*-values for the five variables incorporated in the model, along with the constant term (C). The t-statistic denotes the number of standard errors that the estimated coefficient is distant from zero. The *p*-value signifies the likelihood of observing a t-statistic as extreme as the one estimated, assuming the null hypothesis (the coefficient equals zero) is true. If the *p*-value is below the selected significance level (typically 0.05), the null hypothesis is rejected, and it is concluded that the estimated coefficient is statistically significant at that level.

Table 7. Panel VECM Results.

Long Run Equilibrium				
	Coefficient	**Std. Error**	**t-Statistic**	***p*-Value**
C(2)	0.037082	0.088052	0.421139	0.6738
C(14)	−2.89399	1.764737	−1.6399	0.1014
C(26)	2.566308	1.968153	1.303917	0.1934
C(38)	−536.545	410.8998	−1.30578	0.1926
C(50)	0.59024	0.657066	0.898296	0.3693
Wald Test for Short Run Equilibrium				
Variables	Test Statistic	Value	df	*p*-Value
CO_2	Chi-square	0.040587	1	0.8403
ATM	Chi-square	1.417392	1	0.2338
IU	Chi-square	0.121152	1	0.7278
GDP	Chi-square	0.070832	1	0.7901
REC	Chi-square	0.253035	1	0.6149

The Error Correction Term (ECT) coefficients and their respective *p*-values show the long-run relationships between the variables. The most significant long-run relationship is between REC and CO_2 emissions (C(12) coefficient: 0.05966, *p*-value: 0.0116). This implies that an increase in renewable energy consumption leads to an increase in CO_2 emissions in the long run, holding other factors constant. This result seems counterintuitive, as renewable energy is typically associated with lower CO_2 emissions. A possible explanation for this finding could be the rebound effect, where increased renewable energy consumption leads to more overall energy consumption, offsetting the environmental benefits [87]. The other independent variables, ATMN, IU, and GDP, do not have significant long-run relationships with CO_2 emissions, as their *p*-values are higher than 0.05. This suggests that these factors may not have a direct impact on CO_2 emissions in the long run. However, the nonsignificant relationships could be due to other factors or confounders not accounted for in the model.

The Wald test results provide insight into the short-run causality between the independent variables and CO_2 emissions. None of the independent variables have a significant short-run impact on CO_2 emissions, as all *p*-values are higher than 0.05. This indicates that changes in ATMN, IU, GDP, and REC may not have immediate effects on CO_2 emissions. This could be due to the time it takes for changes in these variables to manifest in CO_2 emissions or the presence of other factors that buffer their short-term impact.

The Panel VECM results suggest that only renewable energy consumption has a significant long-run relationship with CO_2 emissions, while the other independent variables do not have significant long- or short-run effects. This highlights the complexity of the relationships between CO_2 emissions and various economic, technological, and environmental factors, and the need for a more comprehensive understanding of these relationships. Our findings demonstrate a clear alignment with specific segments of the existing literature, while simultaneously diverging from others. For instance, the study by Pao, H. T et al. [88] corroborates the positive correlation between renewable energy consumption and the reduction of CO_2 emissions through their analysis of a panel of BRIC countries. Their research reveals evidence of Granger causality between the variables, suggesting that policies targeting renewable energy can effectively mitigate CO_2 emissions.

Wang, Q. et al. [34] and Wang, Y. et al. [35] determined that the escalation of internet usage in China led to increased indirect CO_2 emissions from household consumption, primarily attributable to the energy-intensive nature of internet infrastructure. This conclusion contradicts the nonsignificant relationship between IU and CO_2 emissions discovered in the Panel VECM results. Nevertheless, it is crucial to recognize the differing scope and context of their study, which concentrates on indirect CO_2 emissions and one specific country.

Regarding the relationship between ATMN and CO_2 emissions, no direct literature exists to investigate this connection. A potential link may arise through heightened energy consumption due to the operation and maintenance of ATM networks. However, in the absence of extensive evidence, it remains challenging to draw definitive conclusions about the association between ATMN and CO_2 emissions. York, R. [89] ascertained that renewable energy sources failed to supplant fossil fuel energy sources on a one-to-one basis, thereby supporting the counterintuitive finding of a positive relationship between REC and CO_2 emissions within the Panel VECM results. Such a phenomenon could stem from the rebound effect or energy market dynamics that preclude a comprehensive substitution of renewable energy for fossil fuels.

4.6. Impulse Response Function

The associations among the variables throughout the sample period were examined using impulse response functions (IRFs). IRFs trace the consequences of a one standard deviation shock on the current and future values of numerous endogenous variables; however, they do not reveal the magnitude of the impact. The IRFs devised by Love, I. et al. [90] rely on the Cholesky decomposition of the variance-covariance matrix of residuals to ensure the orthogonalization of shocks. Primarily, the analysis concentrates on the relationships between CO_2 emissions and ATMN, CO_2 emissions and IU, CO_2 emissions and GDP, as well as CO_2 emissions and REC.

Figure 1 illustrates that the response of CO_2 to its shock is positive in the long run and maintains stability up to year 10. Regarding ATM networks, the response of CO_2 emissions to ATM networks is negative from the outset and continues until year 10. The results indicate that the response of CO_2 emissions to internet usage is positive from the beginning and intensifies in the long run. For the GDP equation, the response of CO_2 emissions to GDP is negative from year 1 to year 10. Lastly, concerning renewable energy consumption, the results demonstrate that the response of CO_2 emissions to REC is initially weak and positive but then dissipates entirely between years 3 and 10. This outcome aligns with previous literature, which has verified the significant impact of renewable energy and GDP on reducing CO_2 emissions. The findings of this study are consistent with other accurate results that have posited that an increase in renewable energy consumption improves environmental sustainability [69]. The relationship between economic growth and the environment is intricate, with various factors at play, including the scale and composition of the economy—particularly the proportion of services in GDP as opposed to primary industries—and technological changes that can mitigate the environmental impacts of production and consumption choices in EAGLE economies.

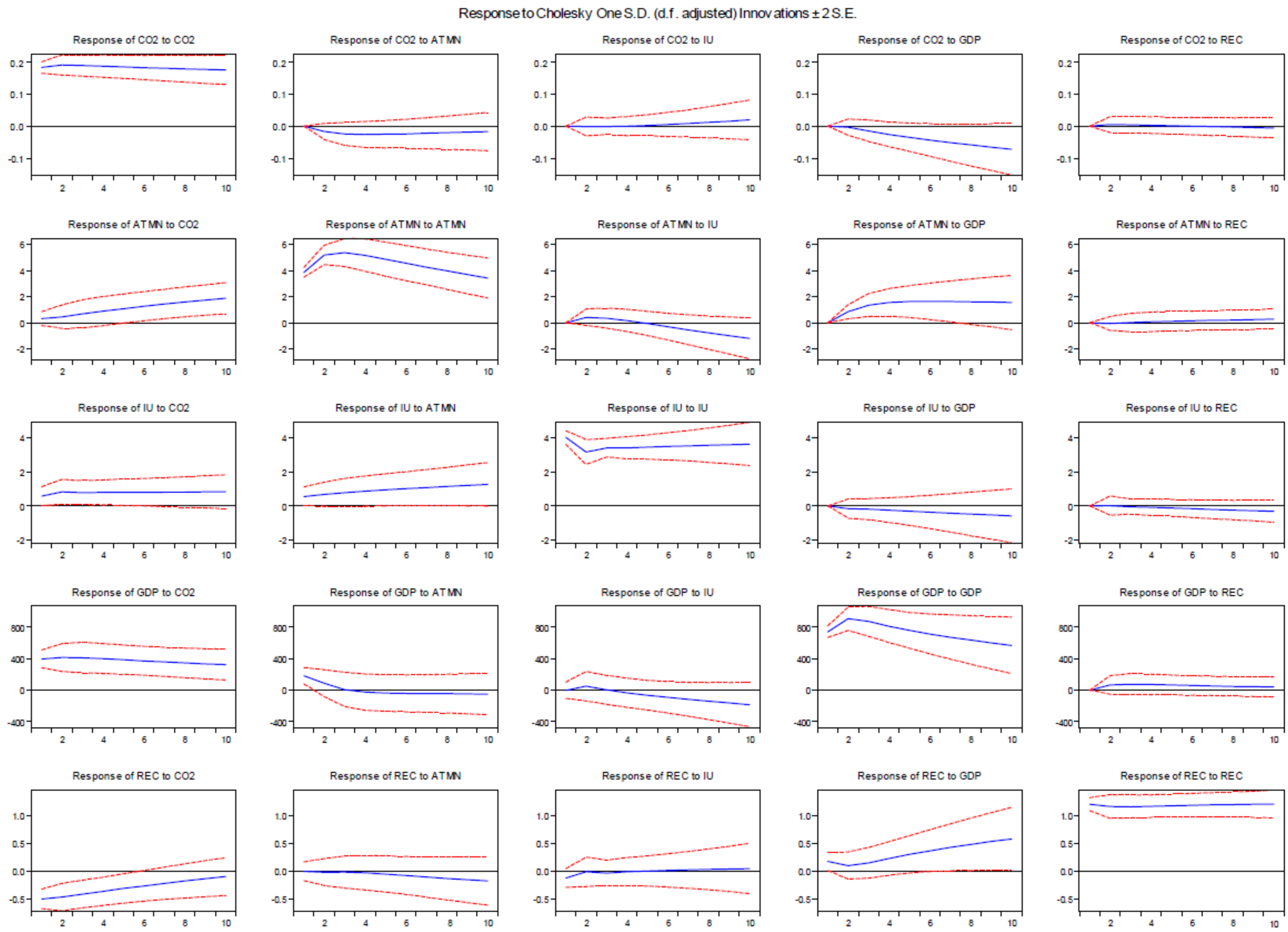

Figure 1. Impulse-response graphs. The graph presents the impulse response functions (IRFs) used to examine the associations among variables throughout the sample period. IRFs illustrate the system's response to a one standard deviation shock and its effect on the current and future values of multiple endogenous variables.

5. Conclusions and Policy Implications

The study looked at how FinTech, economic growth and the use of renewable energy affect environmental sustainability. The variables are suggested to be stationary at the first difference level by the results of the panel unit root test. The Kao and Pedroni tests demonstrate that there is a co-integration between the variables. FMOLS and Panel VECM were employed in the study to examine the relationships between the variables. Since ATM networks cannot account for a change in CO_2 emissions, according to the results of FMOLS experiments, fintech cannot be said to have either a positive or negative impact on CO_2 emissions. This finding was confirmed by the panel VECM, which also demonstrates that there are no immediate or long-term side effects linking ATM networks to CO_2 emissions. Consumption of renewable energy and Internet use both contribute significantly to lower carbon dioxide emissions. Our rationale for the potential of internet use to reduce CO_2 emissions lies in its ability to substitute for more carbon-intensive activities. For instance, teleconferencing and online shopping can replace travel and brick-and-mortar shopping, respectively, thereby reducing the carbon footprint associated with these activities. However, we acknowledge that more research is needed to establish a causal link between internet use and reduced CO_2 emissions.

The Panel VECM results suggest a complex relationship between CO_2 emissions and the independent variables, with only renewable energy consumption showing a significant long-run impact. The findings highlight the need for further research to better understand the relationships between CO_2 emissions and various economic, technological, and environmental factors. The findings of the impulse response functions corroborate that the use of renewable energy and economic growth both contribute to a reduction in CO_2 emissions, while the long-term impact of internet usage remains inconclusive. To sum up, internet usage, economic expansion, and renewable energy consumption significantly affect the environmental sustainability of EAGLE economies in a negative manner, while fintech has no adverse effects. The adoption of renewable energy sources, such as biomass, geothermal, hydropower, solar, and wind, instead of non-renewable ones, such as coal, oil, and gas, can ensure environmental sustainability. Policymakers and legislators should encourage foreign investors to invest in renewable energy and develop business practices that are environmentally friendly. The government must establish stringent environmental regulations to ensure sustainability. The first paragraph of Section 5 is well-written, while the second paragraph could be improved.

Developing a global architecture which is helpful for environmental sustainability will require further reinforcement of courses of action for keeping up with the nature of worldwide public goods, expanded co-activity in the area of science and innovation, and provision of finance to help activity by developing and emerging economies, and working with the dissemination of clean technologies. Expanded endeavors to support worldwide exchange and speculation streams would likewise serve to support supported development. Simultaneously, there is a requirement for expanding vigilance around the potential spillover impact of EAGLE economic policy measures on developing nations. It will make it easier to avail finance, innovations and technology. Moreover, a worldwide empowering climate for environmental sustainability will work with the international exchange of information about environmental sustainability issues.

Future research directions for this study could involve exploring the relationship between internet use and CO_2 emissions in more detail to establish a more definitive causal link. Examining the impact of other factors on CO_2 emissions, such as transportation and agriculture, could provide further insight into the overall environmental sustainability of EAGLE economies. A shortcoming of this study is the potential for omitted variable bias. While the study examined several key factors that contribute to environmental sustainability, there may be other factors that were not included in the analysis that could have an impact on CO_2 emissions. Additionally, the study was limited to EAGLE economies, and the findings may not be generalizable to other regions or countries. Finally, the study relied on secondary data sources, which may have limitations and inaccuracies that could affect the results.

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