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Revolutionizing Finance for the Environment: An Empirical Examination of the Role of Financial Technology in Shaping Environmental Sustainability

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Abstract

A while back, the general populace has been aware of environmentalists' worries about excessive power consumption, notably in cryptocurrency mining. Regarding this, regulators and stakeholders have been reassessing the costs and advantages of technological advancement in general, along with Fintech, concentrating their efforts on environmental restoration. Considering that technology has customarily been seen as having both positive and negative effects on the environment, now would be a good moment to evaluate its actual contribution to environmental improvement—or, conversely, environmental destruction. Therefore, this study attempts to empirically explore the relationship between fintech and environmental sustainability in the presence of GDP and fossil fuel consumption as control variables in the Indian context. The data utilized in this research have been collected for the period of 2001-2021. By employing the Johansen cointegration test and Vector Error Correction Model, the summary of the findings of this study suggests that fintech, GDP, fossil fuel consumption, and carbon emission have short-term as well as long-term relationship, where fintech and GDP have detrimental effects on carbon emission whereas fossil fuel consumption positively affects the same. Necessary policy ramifications have also been provided so as to contend with the demanding situations.

Keywords Fintech, Technological Advancement, Environmental Sustainability, Economic Growth, Fossil Fuel Consumption

1. Introduction

Technological know-how has prolonged been criticized for having a negative impact on the environment. Technological advancement is frequently cited as a driving element behind environmental deterioration. However, experts and academics believe that technical breakthroughs hold the key to addressing a wide range of environmental concerns. Despite the paradox of technology being a two-edged sword, modern technological advancements have profoundly altered the landscape of our planet. The finance industry is not an exception owing to the fact that it is going through an unrivaled change in its functioning mechanism due to disruptive innovation and technologies. Fintech has changed the entire landscape of the finance industry. In this regard, this new dilemma has triggered researchers and academicians to investigate the nexus between Financial Technology and Environmental Sustainability. Financial technologies are acknowledged for their ability to combat climate change by encouraging clean energy trading, lowering carbon emissions, and increasing climate financing flows **(Green, 2018**; **UNFCCC, 2017)**. They are, however, criticized for consuming a lot of power and hastening the loss of extremely scarce natural resources **(Dupont, 2019; Truby, 2018)**. Hereinafter, various national and international organizations, government bodies, regulatory bodies, and policymakers are arguing, and contemplating the cost and benefits of the fintech ecosystem, in the context of economic growth and environmental protection **(Jiao et al., 2021**; **Su et al., 2020**).

The 2015 Paris Agreement made clear that the fast rate of climate change throughout the world triggered the need to create and execute policies, ideas, and technologies that are both economically and environmentally sustainable **(Umar et al.,**

2020a, 2021). The growing knowledge of climate change and its consequences on people's well-being has influenced consumer behavior, resulting in a greater demand for eco-friendly and sustainable products that promote a more sustainable lifestyle **(Checa Vergada and Agudo, 2021)**. Blockchain, artificial intelligence (AI), machine learning (ML), and big data are among the technologies that are significantly changing business operations nowadays **(Atayah and Alshater, 2021)**. The financial services industry is presently dealing with fresh difficulties, mostly as a result of consumers' growing demands for environmentally friendly and sustainable practices in the goods and services they purchase and consume **(Checa Vergada and Agudo, 2021)**. For the underlying improvements in productivity and the requirements of the people, technological innovation is regarded as a vital force. However, on the downside, as per the World Economic Forum 2021, there exists a 1.6 million tons of e-waste during the past few years which was just 8 lakh tons in the year 2012 **(Central Pollution Control Board, 2012)**. Previous notable research has found that financial technologies such as cryptocurrency and blockchain are leading to an increase in power consumption **(Dittmar and Praktiknjo, 2019; Schinckus et al., 2020)**. Consequently, cognizance is forcing and pushing economies to rely on a wide variety of fossil fuels for energy production, thus inducing rapid climate change and other environmental risks. Given the paradoxical nature of financial technology, it is critical to understand how FinTech innovations may successfully solve issues like climate change, global warming, pollution, carbon emissions, and other environmental disasters. Evaluating this quandary is critical for providing important information for policymakers in both the technology and environmental sectors, allowing them to coordinate their efforts toward sustainability while still supporting the expansion of the FinTech ecosystem.

FinTech, GDP, the use of fossil fuels, and environmental sustainability all have intricate and multifaceted relationships with one another. FinTech solutions are frequently adopted more widely in nations with higher GDP levels because these nations typically have more developed financial systems and technological infrastructure **(Fidan et al., 2023)**. However, depending on variables like energy consumption, resource efficiency, and the type of FinTech applications used, the environmental effects of FinTech adoption may differ **(Singh et al., 2020)**. Further, growing economies and greater uptake of FinTech services can lead to increased consumption of fossil fuels **(Vo et al., 2023)**, which can have serious negative effects on the environment, such as greenhouse gas emissions, water and air pollution, and habitat destruction. Emissions from the burning of fossil fuels put ecosystems, human health, and natural resources at risk and are a primary cause of climate change and environmental deterioration **(Perera, 2018)**. However, several variables, including energy efficiency, legal frameworks, and the accessibility of alternative energy sources, influence how much environmental damage is caused by the use of fossil fuels. In conclusion, the adoption of FinTech and its impact on environmental sustainability can be influenced by GDP and fossil fuel usage, but the link itself is dependent on a number of factors, including governmental frameworks, societal priorities, and technology design.

Thus, the current study aimed to investigate the association between FinTech and Environmental Sustainability by using GDP and consumption of fossil fuel as control variables for India for the time period of 2001-2021. The study, by employing the econometric methodologies, proved that Fintech affects environmental sustainability positively. Stated alternatively, it is found that the use of fintech leads to environmental betterment. The contribution of this paper is as follows: First, the government organizations and legislators in charge of creating environmental laws and regulations can benefit greatly from the insights this study can offer. Policymakers can create focused regulations that support green finance, encourage sustainable investments, and reduce environmental risks related to financial activity by knowing how FinTech innovations affect environmental sustainability. Second, the best practices and guidelines for incorporating environmental factors into financial decision-making processes can be developed with the help of this study which further can assist investors, regulators, and financial institutions in adopting eco-conscious strategies by identifying efficient FinTech solutions for sustainable finance. Third, the research can also increase understanding of the role that FinTech plays in promoting environmental sustainability among stakeholders, including investors, companies, civil society organizations, and the general public. Fourth, this paper highlights how FinTech facilitates the flow of green finance in environmentally sustainable projects and thereby ensures a sustainable environment. Fifth and last, the findings of this research can assist international efforts to address urgent environmental challenges and promote sustainable development globally by illustrating how FinTech can help to achieve these goals.

Further, the study has been organized in the following manner: **Section 2** of the study provides a detailed overview of previous works in a similar field. **Section 3** gives a holistic view of the data and methodologies used in this study along with empirical modeling. **Section 4** dealt with the empirical results and discussion and at last **Section 5** included the conclusive statement of this study.

2. Background Information

2.1 Fintech

In the last few years, FinTech arose as a means of addressing the financial challenges and leading towards the financial goals. It is a combination of "financial" and "technology" which refers to any technology that enables people to digitally access, manage, and gain insight into their financial affairs. FinTech is broadly used to describe the embryonic advancements in technology within the financial services sector, with ever-increasing reliance on information technology **(Reserve Bank of India, 2020)**. The **Financial Stability Board (FSB, 2019)** defined FinTech as technological innovation in financial services, which may lead to the development of new business models, applications, procedures, or products that have a significant impact on how financial services are provided. The FinTech ecosystem is built on four characteristics: (i) availability of technical, financial services, and entrepreneurial skills; (ii) availability of financial resources for start-ups and scale-ups; (iii): government policy beyond regulation; (iv) demand: consumers, firms and financial institutions (**EY, 2019,** as cited in **Merello et al., 2021). Lee and Shin, 2018** identify five different players in any FinTech ecosystem, namely: (i) FinTech startups; (ii) Technology developers; (iii) Government (financial regulators); (iv) Financial customers; (iv) Traditional financial institutions. **Arner et al., 2015** described the development of FinTech as a continuing process "during which finance and technology have evolved together" and which paved the way for a plethora of incremental and disruptive technologies, including online banking, crowdfunding, peer-to-peer lending, Robo-Advisory, online identification, mobile payments, etc. One of the benefits of FinTech is financial inclusion, which makes financial services more accessible and affordable to consumers **(Merello et al., 2021)**. In order to ensure the industry's long-term viability, users' confidence and security are crucial, and this is mostly achieved through regulation **(Senyo and Osabutey, 2020)**. Because of its innovativeness and ability to cause disruptions in the financial services sector **(Ferreira et al., 2015)**, FinTech is claimed to possess a comprehensive and lasting impact on the entire sector **(Heap and Pollari, 2015)**.

2.2 Environmental Sustainability

The term environmental sustainability is the blend of two words: "Environment" + "Sustainability". It can be characterized as the idea of utilizing natural resources in such a way that can be fruitful to satisfy the needs of present as well as future generations. It is based on the concept of intra and inter-generational equity. To promote environmental sustainability, addressing climate change is the best option **(IPCC, 2021)**.

There subsists a dire need to contribute to the quality of the environment as sustainable development is a major concern today (**Nasim et al., 2022a; Nisar et al., 2022**). First of all, the World Bank, 1992 coined the term environmental sustainability as environmentally responsible development, which subsequently changed to 'environmentally sustainable development' **(Serageldin and Streeter, 1993)**. Finally, the concept of environmental sustainability was developed **(Goodland, 1995)**. According to Goodland, "Environmental Sustainability looks for succoring the life support system perpetually". He defined environmental sustainability as the 'maintenance of natural capital'. **John Morelli, 2011** defines environmental sustainability as a state of balance, resilience, and interconnectedness that permits human culture to fulfill its requirements while not surpassing the limit of its supporting ecosystems to keep on regenerating the resources important to address those needs. Since the quality of life is influenced by the environment, the environment must be preserved for future generations **(Khan et al., 2022)**.

2.3 Fintech and Environmental Sustainability

Financial technology, commonly known as FinTech, signifies the use of technologies in improving and automating the remittance of financial services. As India's fintech ecosystem is expanding continuously, it is supposed to be a major player in ensuring the sustainability of the environment. **Alsadi & Nobanee, 2021** argue that fintech has green attributes in itself which is a pre-requisite for environmental sustainability. This is attributable to the fact that digital connectivity has grown to be an essential component of productivity and sustainability (**Alaryani & Nobanee, 2022**).
The integration of financial technology (FinTech) into the financial services sector has been recognized as a transformative force, not only revolutionizing traditional banking practices but also ushering in a new era of environmental sustainability. **Cen & He (2018)** assert that FinTech has the potential to reshape financial services into a green, low-carbon, and time-saving industry, thereby contributing to global sustainability efforts. This notion of "Green FinTech " seeks to embed

financial sustainability principles into core institutional frameworks, utilizing finance and the economy as catalysts for fostering a more sustainable planet **(Alshamsi & Nobanee, 2021)**. Empirical studies, such as those conducted by **Wen & Siddik (2022)**, have explored the relationship between FinTech adoption and environmental performance, revealing significant impacts on sustainability outcomes. Furthermore, digital finance and FinTech play pivotal roles in advancing the Sustainable Development Goals (SDGs) by optimizing financial resources, expanding financial system accessibility, and directly contributing to SDG achievement **(Buckley et al., 2019)**. **Tao et al. (2021)** corroborate these findings, demonstrating that FinTech development can drive economies towards lower carbon emissions when accompanied by critical control variables. However, **Deng et al. (2019)** suggest a nuanced relationship, proposing a U-shaped curve between FinTech and sustainable development, indicating complexities in the fintech-sustainability nexus. While the literature on green fintech remains limited, **Puschmann (2020)** underscores its potential in greening the global economy, echoing the sentiment shared by **Feroz et al. (2021)**, who emphasize the need for deeper exploration into the environmental impacts of digital transformation. **Vergara & Agudo (2021)** highlight the synergies between sustainable finance and fintech, positing that fintech can catalyze green finance initiatives, thus bolstering overall financial sustainability. **Rahim et al. (2022)** and **Yan et al. (2022)** further underscore the significant influence of fintech on economic, social, and environmental sustainability, emphasizing its role in shaping the sustainability performance of banking institutions. Nonetheless, **Varga (2018)** cautions against the absence of a robust framework for evaluating the triple-bottom-line impact of fintech. Consequently, this study seeks to fill this gap by examining the impact of fintech on environmental sustainability within the Indian context, aiming to provide comprehensive insights into this pivotal alliance and inform sustainable development strategies for the future.

3. Methodological Framework

3.1 Theoretical Framework

Many previous researchers have looked into the relationship between technological advancement and consumption-based carbon emissions in a variety of ways. In this study, however, we are primarily interested in determining how income and fossil fuel consumption, which are significant determinants of environmental conditions, influence the impact of FinTech on carbon emissions. Therefore, in order to understand this link pertaining to a single equation model, we have primarily relied upon the work of **(Tao et al., 2021; Ozturk, 2022).** The incorporation of gross domestic product in the base model is heavily supported by **(Hasanov et al., 2018; Knight and Schor, 2014; Shahbaz et al., 2018; Wang et al., 2020).** However, the novelty of this study lies in the fact that the current study has utilized fossil fuel consumption as an important determinant of carbon emission, which is untouched till now in the arena of analyzing the relationship between fintech and environmental sustainability.

3.2 Empirical Modelling

The structure of this study depends on the thought of evaluation of a positive or negative role of Fintech on the environment on the basis of time series data in the Indian context. This has been done to see if the fintech actually helps economies move toward a lower level of carbon emission and other greenhouse gases. On the one hand, FinTech solutions can reduce environmental impacts and carbon emissions by automating tasks, digitizing processes, and streamlining operations. They also facilitate the transition to a low-carbon economy and expand green finance markets, positively impacting environmental sustainability. However, some FinTech applications may have unanticipated negative effects or trade-offs with the environment, such as increased energy consumption and carbon emissions from data centers, digital infrastructure, and electrical equipment if not managed well. Overall, while FinTech generally has a positive impact on environmental sustainability, it is crucial to consider potential trade-offs and potential negative impacts. As a result, the framework can be conceptually represented as:

Carbon emission = f (Fintech) **(1)**

After taking into consideration the control variables, i.e., GDP and fossil fuel consumption, the framework can be conceptualized as:

Carbon emission = f (Fintech, GDP, FFC) **(2)**

The pictorial presentation of the suggested model is given in **Figure 1**.

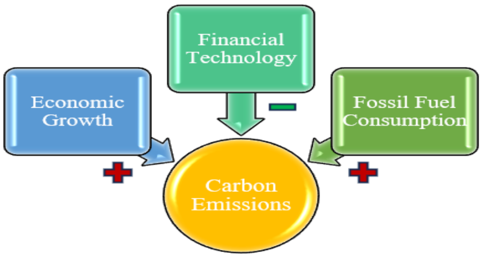

Figure 1 Proposed Model
Source Authors' Creation

The conceptual model can then be turned into a regression model in the given scenario, defining carbon emissions as our dependent variable, the fintech as our independent variable, and economic growth and fossil fuel consumption as our control variables.

The non-linear observations taken in this study suggest that a log-log model should be used to describe the model because the log transformation of observations generates the desired linearity in parameters. The estimated coefficients are actually the elasticities in the log-log or log-linear specifications. Because of the one percent change in the independent variable, this can be directly interpreted as the percentage change in the dependent variable **(Tao et al., 2021)**. The model can be framed as follows:

$$(CE_i) = \beta_0 + \beta_1(Fin_i) + \beta_2(GDP_i) + \beta_3(FFC_i) + \varepsilon_i \quad (3)$$

In **Eq. (3)** above, (CE_i) represents the carbon emissions, which is the country-level data pertaining to the carbon emissions from all the sources that are usually taken into consideration (GHG). Then, Fin_i is the proxy of the Fintech Development of the country that has been included in our sample, and GDP_i and FFC_i, are the vector of macroeconomic control variables, representing the Gross Domestic Product (GDP) and fossil fuel consumption respectively. Once the observations have been transformed into a log structure; it can be written as follows:

$$(\ln CE_i) = \beta_0 + \beta_1(\ln Fin_i) + \beta_2(\ln GDP_i) + \beta_3(\ln FFC_i) + \varepsilon_i \quad (4)$$

In the above formula 'ln' has been used to represent the natural log where the natural log of carbon emission, fintech, GDP, and fossil fuel is represented by $\ln CE_i$, $\ln Fin_i$, $\ln GDP_i$, and $\ln FFC_i$ respectively.

3.3. Data description

This study is based on the time series data collected from the World Bank and Statista for the period of 2001-2021. The periods and indicators used in this analysis were chosen based on the data availability. In the current study, the dependent variable 'environmental sustainability' is represented by CO_2 emissions (metric tons per capita), the independent variable 'FinTech' is measured by expenditure on R&D (% of GDP), and the control variables, i.e., GDP and fossil fuel consumption is depicted by GDP per capita (current US$) and Fossil Fuel Consumption (terawatt-hours) respectively. Spending on research and development (R&D) is frequently used as a stand-in for innovation in an economy. Being a quickly developing industry, fintech greatly depends on technological, product, and service innovation. Businesses and organizations in the fintech ecosystem can create new platforms, technologies, and business models that propel the industry's expansion by investing in research and development. Fintech is a broad term that includes many different technologies, such as blockchain, big data analytics, cybersecurity, and artificial intelligence. Research and development (R&D) investments support the growth and development of these technologies, which are essential to the operation of fintech solutions. Consequently, increased R&D spending might be a sign of more technological innovation potential in the fintech industry.

Table 1 shows a brief discussion of the definitions and abbreviations of variables as well as the data sources.

Variables	Data Source	Description
Carbon Emission (CO2)	World Bank	CO2 emissions (metric tons per capita)
Fintech	Reserve Bank of India	Expenditure on R&D (% of GDP)
Economic Growth	World Bank	GDP per capita (current US$)
Fossil Fuel Consumption	World Bank	Fossil Fuel Consumption (terawatt-hours)

Table 1
Source Authors' Calculation

3.4 Econometric Methodology

3.4.1. Unit Root Test

In order to select the appropriate econometrics models for the analysis, the first step for the empirical analysis is to determine the order of integration of the series. In this study, Augmented Dicky Fuller (ADF) Test has been used for this purpose. The augmented Dickey-Fuller (ADF) test is frequently thought to be superior to the KPSS (Kwiatkowski-Phillips-Schmidt-Shin) or PP (Phillips-Perron) tests for assessing the smoothness of time series data **(Gujarati et al., 2017)** because it can handle both stationary and non-stationary processes within a single framework and is able to detect possible serial correlation in the data. ADF Test assumes the null hypothesis of non-stationarity against the alternative hypothesis of stationarity of the series. Here, the series is said to be level stationary if it is integrated at its level or I (0). But, in case, if series is non-stationary at its level, then it becomes stationary at their first (I (1)) or second difference (I (2)), whatever the case may be. The time series under consideration may not be stationary, based on the non-rejection of the null hypothesis. Akaike Information Criterion (AIC) has been used to select the optimal lag length. Mathematically, the model for the ADF test can be framed as:

$$(1)\ \Delta Y_t = \gamma\ Y_{t-1} + \sum_{j-1}^{p} (\delta_j \Delta Y_{t-j}) + \epsilon_t$$

$$(2)\ \Delta Y_t = \alpha + \gamma\ Y_{t-1} + \sum_{j-1}^{p} (\delta_j \Delta Y_{t-j}) + \epsilon_t$$

$$(3)\ \Delta Y_t = \alpha + \beta t + \gamma\ Y_{t-1} + \sum_{j-1}^{p} (\delta_j \Delta Y_{t-j}) + \epsilon_t$$

where,

- t is the time index,
- α is an intercept constant called a drift,
- β is the coefficient on a time trend,
- γ is the coefficient presenting process root, i.e., the focus of testing,
- p is the lag order of the first-differences autoregressive process,
- e_t is an independent identically distributed residual term.
- The coefficient of Y_{t-1} is zero.

3.4.2. Cointegration Test

Johansen cointegration test has been used for determining whether three or more time series are cointegrated. All the more explicitly, it evaluates the validity of a cointegrating relationship, utilizing a Maximum Likelihood Estimates (MLE) approach. It can also be used to estimate the relationships between the variables and find out how many connections exist between them **(Wee & Tan, 1997)**. The test is better suited than Engle-Granger for multivariate analysis and can identify many cointegrating vectors. The fact that Johansen's test treats each test variable as an endogenous variable is another advantageous characteristic **(Wassell & Saunders, 2008)**.

3.4.3. VECM Model

A unique application of Vector Autoregressive (VAR) Models is the Vector Error Correction Model (VECM). The specification of the VECM model entails the addition of an error term to the VAR models. If the variables in the system have a long-term interaction and if they are cointegrated in the long run, the VECM approach is employed. To accommodate for short-run behavior, the VECM was respecified in differences. Along with the short-run, the VECM model includes error correction components and co-integrating equations to account for short-run modifications and long-run cointegrating relationships. A VECM's overall shape may be described as follows:

$$\Delta x_t = \Pi x_{t-1} + \sum_{l=1}^{p-1} \Gamma_l \Delta x_{t-l} + Cd_t + \epsilon_t$$

Where Δx is the initial difference of the variables of vector x; P_i is the coefficient of the cointegrating relationship; Γ is the lags of the variables of x; d is the vector of the deterministic terms; C is the corresponding coefficient matrix; p is the lag order in VAR form of the model; ε is the error term with a mean of 0 and a variance-covariance matrix of Σ.

4. Empirical Results and Discussions

Table 2 and **Table 3** respectively present the results of descriptive statistics for all the variables and their correlation matrix. **Table 2** of descriptive statistics shows that CO_2 and FFC are slightly skewed to the left but it is almost symmetrical while FIN and GDP are positively skewed to the right of its peak than on the left side. And all the series are leptokurtic which implies that it has a larger peak and heavier tails than a normal distribution. In contrast to a normal distribution, it contains more data points grouped around the mean and more extreme values in the tails.

Further, by analyzing the table it can also be interpreted that all the series in the dataset are normally distributed as the probability values for the Jarque Bera test is more than 0.05 for all. A similar result can also be observed by looking at the values of mean and median for all the series as both the values are almost close to each other.

Variables	LNCO2	LNFIN	LNGDP	LNFFC
Mean	1.423333	0.75714	1696.848	6085.857
Median	1.410000	0.80000	1823.05	6067.000
Minimum	0.920000	0.700000	493.930	3466.000
Maximum	1.930000	0.9000	3150.310	8815.000
Std. Dev.	0.360837	0.059761	829.6051	1788.246
Skewness	-0.051279	0.440908	0.076757	-0.015387
Kurtosis	1.50548	2.292	1.805407	1.624438
Jarque-Bera	1.963595	1.119006	1.269292	1.656477
Probability	0.374637	0.571493	0.530123	0.436818
Sum	29.89000	15.9000	35633.8	127803.00
Observations	21	21	21	21

Table 2
Source Authors' Calculation

The result of the correlation matrix in **Table 3** represents that there is a positive and high correlation between CO_2 and GDP and CO_2 and FFC whereas a negative and low correlation exists between CO_2 and FIN. This signifies that with an increase in the economic growth level and fossil fuel consumption, carbon emissions will increase while the development of FinTech exerts a negative impact on carbon emissions.

	CO2	FIN	GDP	FFC
CO2	1			
FIN	-0.1785371	1		
GDP	0.9818493	-0.0621179	1	
FFC	0.9972513	-0.1221732	0.9919447	1

Table 3
Source Authors' Calculation

4.1. Unit Root Test

Table 4 presents the result of the ADF test and indicates that all the variables are stationary at their first difference, i.e., I(1). The optimal lag value for the ADF test has been selected on the basis of the Akaike Information Criteria. The first-order differencing signifies that after removing any trend or deterministic components through differencing, the time series data exhibit stationary behavior that will produce more trustworthy parameter estimates and forecasts.

Critical Value						
Variables	**Test Statistic**	**1%**	**5%**	**10%**	**p-value**	**Decision**
CO2	-4.98449	-3.831511	-3.02997	-2.655194	0.0009	I(1)
LNFIN	-5.117537	-3.886751	-3.052169	-2.655194	0.0007	I(1)
GDP	-3.954074	-4.582648	-3.320969	-2.666593	0.0088	I(1)
FFC	-3.839869	-3.857386	-3.040391	-2.660551	0.0104	I(1)

Table 4
Source Authors' Calculation

4.2. Cointegration Test

Once, the series becomes stationary, performing a cointegration test is vital to establish the long-term correlation between the variables. The cointegration among the variables has been examined using the Johansen Cointegration Test considering that every variable is integrated in the first order. The outcome of this test has been presented in **Table 5 (a & b)**, which shows that each of the variables is cointegrated in the long run as one of the trace statistics is greater than the critical values and its probability value is also less than 0.05, i.e., 0.0032. The same result can also be seen by observing the Max Eigen Value, which also exceeds its critical values, and the probability value for the same is 0.0267 (less than 0.05). Since the variables are cointegrated, it implies the fact that the series are related and can be combined in a linear function. That is, even if there are short-run shocks that affect movement in individual series, they will converge over time (in the long run).

Hypothesized no. of CE (s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Probability****
None*	0.790071	59.03708	47.85631	0.0032
At most 1	0.620036	29.37835	29.79707	0.0558
At most 2	0.423768	10.99246	15.49471	0.212
At most 3	0.026936	0.518806	3.841465	0.4714

Table 5 (a)
Source Authors' Calculation

Hypothesized no. of CE (s)	**Eigenvalue**	**Max-Eigen Statistics**	**0.05 Critical Value**	**Probability****
None*	0.790071	29.65873	27.58434	0.0267
At most 1	0.620036	18.38588	21.13162	0.1161
At most 2	0.423768	10.47366	14.26460	0.1826
At most 3	0.026936	0.518806	3.841465	0.4714

Table 5 (b)
Source Authors' Calculation

Notes *Rejection of hypothesis at the 5 percent significance level; **Mackinnon-Haug-Michelis (1999) p-values; *denotes rejection of the hypothesis at 0.05 percent level.

4.3. Vector Error Correction Model

Following the result of the cointegration test that reflects the long-term relationship among the variables, the short-run and long-run model needs to be estimated. In this study, the VECM model has been used to predict the short-run and long-run model among the variables as a fundamental tenet of VECM models is stationarity of data at its first-order differencing, i.e. I(1). Stated differently, the variables must be stationary in their first differences in order to estimate a VECM. The presence of cointegration is suggested when variables are smooth after first-order differencing, which validates the use of a VECM to examine their dynamic relationships. Therefore, the smoothness of the data series at first-order differencing confirms that VECM is a suitable model for representing the dynamic relationships between variables in a time series setting.

Establish the Model's Ideal Lag

Choosing the appropriate lag for the model is a critical step in the VAR process **(Table 6)**.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-204.947	NA	13953.85	20.89469	21.09383	20.93356
1	-145.369	89.36675*	186.5494*	16.53690*	17.53263*	16.73128*

Table 6 VECM lag order selection
Source Authors' Calculation

Note FPE: Final prediction error **AIC:** Akaike information criterion **SC:** Schwarz information criterion **HQ:** Hannan-Quinn information criterion

A star (*) denotes the greatest value for each information criterion. The result for the optimal lag selection is given in **Table 6**, indicating that the optimum lag determined by the AIC, FPE, HQIC, LR, and SBIC selection criteria is at lag 2. In order to prepare for further testing, we used 2 lags and one co-integration. The VECM model may be employed with a view to see whether the fitted model is adequate.

The error correction coefficient in the VECM model indicates how quickly the model will re-establish its equilibrium after any disturbances. The long-run model equation can be represented as follows:

$$\mathbf{ECT_{t-1}} = 1.000CO_{2t-1} + 0.2768FIN_{t-1} + 0.0002GDP_{t-1} - 0.0003FFC_{t-1} – 0.2256$$

The test result shows that in the long run, for the Fintech variable, one unit change in fintech will decrease 27.68% of CO_2 which is positively significant for environmental sustainability in the long run; for the GDP variable, one unit change in GDP will decrease carbon emission by 0.02%. This proportion is not so big but may prove beneficial in the long-term for the betterment of the environment as it signifies that in addition to the growth, the economy is also paying due attention towards environmental sustainability by allocating a major portion of the funds for green and eco-friendly projects. And last, for the variable fossil fuel consumption, one unit change in consumption of fossil fuel will increase the emission of carbon dioxide by 0.03% which shows that fossil fuel will continue to contribute towards carbon emission in the long run but the intensity of its contribution is not much significant. The explanation for this outcome could be the substitution of fossil fuels for renewable energies in the long period that aims at facilitating a smooth and healthy ecosystem. Thus, overall, it is possible to deduce that FinTech and GDP will have adverse effects while fossil fuel consumption has a positive effect on carbon emissions in the long run.

Error Correction	Coefficients	Standard Errors	t-statistics
CointEq1	-4.105457	1.72605	2.37853
D(CO2(-1))	-3.778573	2.37698	-1.58965
D(FIN(-1))	-0.949480	0.43098	-2.20308
D(GDP(-1))	-0.000462	0.00028	-1.66946
D(FFC(-1))	0.000853	0.00062	1.36974

C	0.073950	0.02548	2.90281
R-squared	0.430618		
Adj. R-squared	0.211625		
F-statistic	1.966354		

Table 7 VECM Estimation Results and Tests
Source Authors' Calculation

As per the result of the VECM short-run model, it can be inferred that the disequilibrium of previous years can be corrected in the present year at the rate of -4.11 percent. In other words, the coefficient value of ECT_{t-1} is -4.11. This indicates that the deviation from the long-run relationship is corrected at the rate of 4.11% in the present since the value of the error correction term is negative and significant. Further, from the equation, it can be construed that a percent increase in carbon emission itself leads to a decrease in carbon emission by 3.78%. It may be due to awareness among the people about the negative effects of carbon emissions. Because, once the emission of carbon dioxide increases in the atmosphere, it creates a lot of problems for the environment as well as for the health of the people, which makes them aware of the environmental issues and prompts them to take steps to reduce the carbon emission and improves the quality of its ecosystem. In the same way, a percent increase in FinTech and GDP leads to a 0.95% and 0.0005% decrease in carbon emission respectively. This result is in line with **Tao et al., 2021, Muganyi et al., 2021, Toumi et al., 2022, Meiling et al., 2021, Hoang et al., 2022, Wen & Siddik, 2022, Vergara & Agudo, 2021, Okaily et al., 2021, Rahim et al., 2022, Yan et al., 2022, Coffie et al., 2022;** who poses that fintech positively affects the environmental sustainability; in contrast with **Lisha et al., 2022, Deng et al., 2019, Feroz et al., 2021** who poses that fintech negatively impacts environment sustainability or positively contributes towards carbon emission. The findings of this study can be observed in **Figure 2** also. The reason for the positive effect of Fintech on environmental sustainability may be the increased investment by Fintech in facilitating green finance and environmental technologies, which may have a curbing effect on carbon emissions. Through its ability to connect investors with ecologically friendly investment options, fintech platforms can facilitate the financing of green projects and activities. These include peer-to-peer lending networks, online investment platforms, and crowdfunding sites that help finance energy-related projects, conservation efforts, sustainable infrastructure, and energy efficiency programs. Blockchain technology is one example of a FinTech innovation that can improve accessibility, efficiency, and transparency in the issuing and trading of green bonds. Blockchain can minimize transaction costs, and administrative constraints, and boost trust in green finance instruments by offering transparent and safe platforms for transactions. This will draw more issuers and investors to the green bond market. By guaranteeing that funds are distributed and used in line with environmental goals, this can enhance the efficacy, accountability, and transparency of green finance projects. By facilitating investments in sectors like affordable housing, sustainable infrastructure, clean energy, and climate resilience, fintech technologies can help accomplish the Sustainable Development Goals (SDGs). FinTech platforms have the potential to support several SDGs, such as those pertaining to poverty alleviation, climate action, renewable energy, and sustainable cities and communities, by allocating funding to projects that tackle critical sustainability concerns. Thus, FinTech can expedite the transition to a more sustainable and resilient future, increase transparency and accountability, and open up new avenues for sustainable investment by utilizing cutting-edge technologies, data analytics, and digital platforms.

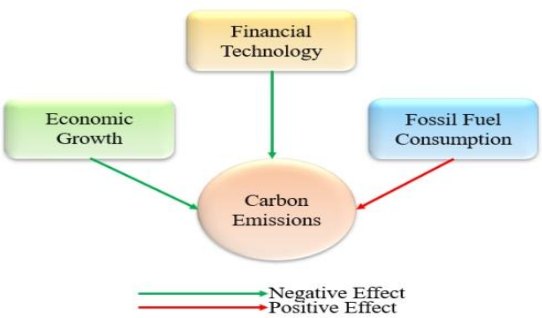

Figure 2 Pictorial Results of the study **Source** Authors' Creation

At the same time, a percent change in FFC leads to an increase in carbon emission by 0.0009% which is also in line with the study undertaken by **Mulali et al., 2014.** In the long run, Technological breakthroughs and modifications to the energy infrastructure may eventually cause a shift away from fossil fuels with higher carbon contents, like coal, toward greener options, like natural gas or renewable energy sources like solar and wind. Less carbon emissions per unit of energy produced can be achieved by increasing the energy efficiency of fossil fuel use through technological advancements and efficiency measures. Lower carbon emissions can be achieved, for instance, by using less fossil fuel to produce the same level of energy services through the use of more fuel-efficient appliances, industrial processes, and automobiles. At last, C (5) is constant or intercept. By taking CO_2 as the dependent variable, the equation can be formed as follows:

$$\mathbf{D(CO_2) =} -4.11ECT_{t-1} - 3.78CO2_{t-1} - 0.95FIN_{t-1} - 0.0005GDP_{t-1} + 0.0009FFC_{t-1} + 0.0739$$

5. Conclusion and Policy Implications

During the last few decades, the growth of financial technologies has transformed the entire landscape of the global financial system. Various concrete evidence featured in fintech literature offers various efficiencies and better risk management capabilities. However, the study of the link between fintech and environmental sustainability has taken a very narrow perspective. Therefore, from the perspective of the local economy, there is still a large gap to be filled. Consequently, it is necessary to analyze such technologies while keeping in mind the horizon of sustainable development with a view to explaining their productive or destructive function. This investigation has addressed this vacuum by focusing on FinTech as one of the leading factors of environmental sustainability in India by keeping GDP and consumption of fossil fuels as constant. In order to achieve this, data for the time spanning from 2001-2021 has been utilized. By employing the Johansen cointegration test and VECM model, this paper concluded that fintech and GDP lead to the decline in CO_2 emissions, while FFC leads to the increase in carbon emission both in the short and long term. It means it can be asserted that financial technologies can prove as a good means of ensuring environmental sustainability. In the lamp of the results following policy recommendations can be provided:

First, to accomplish sustainable development goals, the government in India should combine its technological policies with its environmental policies. Simultaneously, employing renewable energy sources may assist in minimizing dependency on energy from fossil fuels; hence, immediate sustainable benefits may be created. Second, giving incentives to businesses and community organizations to invest exclusively in sustainable fintech is another option. Third, the government should issue a notice regarding the use of a percent of GDP towards environmental protection once it reaches its desired limit. Fourth, the government should emphasize the use of renewable energies instead of fossil fuels in order to curb carbon emissions. Policy frameworks that are clear and encouraging and give priority to sustainable fintech investments and renewable energy can be developed by governments. This could entail establishing performance targets for renewable energy, putting carbon pricing mechanisms in place, and advocating for regulatory sandboxes that encourage fintech innovation. To encourage investment in sustainable fintech and renewable energy, regulatory certainty is essential. Governments have the power to create stable, open regulatory frameworks, expedite the approval process, and guarantee regulatory uniformity amongst jurisdictions. Financial incentives can be offered by governments to encourage investments in sustainable fintech and renewable energy. Subsidies, grants, tax breaks, and low-interest loans for green fintech startups and renewable energy projects may fall under this category.

Finally, at last, it is important to recognize research limits as well as future directions. This study examined the influence of fintech on environmental sustainability taking into consideration just CO_2 while ignoring other indicators such as SO_2, NO_2, ecological footprint, etc. Further, other indicators like industrialization, urbanization, and other factors also impose considerable effects on carbon emission, which have not been taken into consideration in this study. Similarly, this study is just confined to India. As the future scope, this study can be extended to other countries like ASEAN countries or BRICS countries by incorporating the other variables utilizing the panel data. Besides this, more attention should be given towards the formulation of environmental policies so as to protect the environment.

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