# RETRACTED: Linking Financial Development and Environment in Developed Nation Using Frequency Domain Causality Techniques: The Role of Globalization and Renewable Energy Consumption

*Sara Mosleh*[1], *Souha Al-Geitany*[1], *Okechukwu Lawrence Emeagwali*[1], *Mehmet Altuntaş*[2], *Ephraim Bonah Agyekum*[3], *Salah Kamel*[4], *Mohamed F. El-Naggar*[5,6]* and *Ebenezer Agbozo*[7]

[1]Department of Business, Girne American University, Girne, Northern Cyprus, [2]Department of Economics, Faculty of Economics, Administrative and Social Sciences, Nisantasi University, Nisantasi, Turkey, [3]Department of Nuclear and Renewable Energy, Ural Federal University Named after the First President of Russia Boris Yeltsin, Ekaterinburg, Russia, [4]Electrical Engineering Department, Faculty of Engineering, Aswan University, Aswan, Egypt, [5]Department of Electrical Engineering, College of Engineering, Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia, [6]Department of Electrical Power and Machines Engineering, Faculty of Engineering, Helwan University, Helwan, Egypt, [7]Department of Big Data Analytics and Methods of Video analysis, Ural Federal University, Ekaterinburg, Russia



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***Correspondence:**
*Mohamed F. El-Naggar*
*mfelnaggar@yahoo.com*

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The topic of whether globalization, energy consumption and financial development can substantially reduce emissions during the globalization era remains unanswered. In this context, this research highlights empirical indications supporting this theoretical discord; assessing the effect of globalization, energy consumption and financial development on the $CO_2$ emissions in Japan (utilizing a dataset that spans between 1990 and 2019). The study employed the Autoregressive Distributed Lag (ARDL) technique and frequency domain causality to probe these relationships. Unlike other conventional causality tests, the frequency domain causality test can capture causality at different frequencies. The findings from the ARDL analysis disclosed that globalization and renewable energy contribute to the mitigation of $CO_2$ emissions while fossil fuel, economic growth and financial development caused an upsurge in $CO_2$ in Japan. Furthermore, the frequency domain demonstrated that all the exogenous variables can forecast $CO_2$ mostly in the long-term which implies that any policy initiated based on the exogenous variables will impact emissions of $CO_2$. Based on the results obtained, Japan has to improve its financial systems and increase its use of renewable energy. Furthermore, Japan needs to restructure its policy regarding globalization owing to the fact that it contributes to the degradation of the environment. Since globalization is a major driver of economic growth, the government should concentrate on luring and licensing investors that use environmentally beneficial (net-zero) technology.

**Keywords: financial development, globalization, renewable energy consumption, $CO_2$ emissions, Japan**

## 1 INTRODUCTION

Climate alteration and global warming are key sources of the issue in many narratives as a fundamental threat, notably in this globalized age of reduced geographical heterogeneity and the eradication of national borders (Awosusi, Adebayo, et al., 2022; Adebayo, 2022b). The Kyoto Protocol was implemented to mitigate the level of greenhouse gases (GHGs) that have a major contribution to atmospheric change in response to global warming, which was recognized as a calamity (crisis). $CO_2$ emissions contribute roughly 58.8% to climatic variability and global warming (Kyoto Protocol, 1997). Furthermore, the Paris Agreement, which aims at limiting GHG emissions, was signed in 2016, and it follows in the footsteps of the Kyoto Protocol in combating global warming and climate change. To attain these goals, all partner states (member nations) decided to sign this pact, demonstrating their understanding and commitment to curbing the threat of climate change and global warming. Nonetheless, all of these accords point to a minor bright light, with 2016 being recorded as the world's warmest year (NASA, 2020). Chlorofluorocarbons (CFCs), methane ($CH_4$), water vapor ($H_2O$), $CO_2$ and nitrous oxide ($N_2O$) are among the scientifically (empirically) recognized gases that contribute to climate change and global warming (NASA, 2020). $CO_2$ makes up around 81% of all these GHGs. Globalization, Financial development, and fossil fuel energy have also been identified as key contributors to rising $CO_2$ emissions (Shahzad, 2020; Ikram et al., 2021; AbdulKareem et al., 2022; Gyamfi, Adebayo, et al., 2022).

The financial sector's competency is boosted by an economy's thriving ability and serves as a function in supporting economic development. Lowering investment hurdles and putting less pressure on financial resources, helps to boost investors' and consumers' confidence in a company's development. However, obtaining such wealth through an established financial business is not without cost (Baloch et al., 2019). Energy consumption can be utilized more effectively with improved technical services, and ecological security requirements may be supported with minimal cost and maximum returns, thanks to a strengthened financial sector (Acheampong et al., 2020; Ahmad et al., 2021; Sadiq-Bamgbopa et al., 2022; Tony Odu et al., 2022). There is a large body of recent work that has identified and studied the significant relationship between a robust financial sector and ecological deficit (Abbasi & Riaz, 2016; Anwar et al., 2021).

Nonetheless, empirical study findings have yielded a wide range of outcomes for both poor and advanced nations. Against the backdrop of an uncertain (insignificant) link between financial development (FD) and environmental deterioration, a few research have produced perplexing results (Demetriades & Hussein, 1996; Bekhet et al., 2017; Baloch et al., 2019; Fakher et al., 2021). For example, a thriving finance sector is capable of supporting businesses overcome planning constraints and achieve economies of scale in the manufacturing sector; ensuing in reduced contamination generation (Taiwo Onifade et al., 2021; Erdoğan et al., 2022; Onifade, 2022). Another viewpoint contends that the financial sector may facilitate the establishment of new conventional, polluting, traditional, and unproductive sectors that pose a menace to ecological quality. As a consequence, the available literature results are extremely diverse, necessitating further empirical investigation in order to provide a more accurate image of reality (Awosusi et al., 2022; Gyamfi, Bekun, et al., 2022).

Another focus of our work is to re-assess the contaminant degradation function and evaluate the ecological quality of Japan by using the globalization index, renewable and fossil fuel. Moreover, (Koengkan et al., 2020) on the other hand, defined globalization as the connectivity, growth, and interdependence of many areas of society. Globalization, on the other hand, is defined by Leal & Marques (2021a) and Rahman (2020) as a broad and multifaceted phenomenon that encompasses cross-national social, economic, technical, environmental, and cultural, linkages. It brings nations together to trade which eventually results in foreign direct investment (FDI) to speed up economic activity, financial development, and energy consumption, as well as their degree of openness (Leal & Marques, 2021b; Wani & Mir, 2021). Apart from these possible reasons, economic deprivation and worldwide economic integration raise the level of environmental repercussions owing to elevated human stress on the environmental ecosystem (Shittu et al., 2020; Lyulyov et al., 2021; Ngoc et al., 2021; Wani & Mir, 2021; Yameogo et al., 2021). Clearly, it contributes to the well-being of our planet, but there are significant variable approaches as to how these changes can be implemented.

Energy sources have an important influence in determining ecological integrity. Currently, empirical analysis is performed by separating energy usage into two categories: non-renewable and renewable energy usage, in order to truly comprehend the impact of these separating types of energy usage on $CO_2$ and, as a result, to make more effective specific proposals. It is critical to evaluate the significant influence of renewable and fossil fuel on ecological responsibility in order to accomplish additional advantages to the existing structure of economic growth and accomplish the Sustainable Development Goals (SDGs) targets. Another vacuum in the empirical studies remains unresolved without taking into account the differential impacts of these two types of energy sources. As a result, the current work contributes to the empirical studies of finance, environmental and energy economics by offering models and establishing policies.

In our study, three important research issues will be examined based on the three qualities described above. To begin, how do Japan's established financial sectors contribute to improved environmental protection? Secondly, can Japan's economic expansion withstand the country's ecological pressures? Thirdly, in the globalization era, which type of energy has a greater capacity to reduce environmental damage, renewable or non-renewable?

This current study differs from previous research in five ways: Most importantly, the current study examines the connections between FD and $CO_2$, including fossil fuel renewable energy, throughout the globalization mode. According to the best of the researchers' knowledge, this is the first study to highlight a link between the abovementioned factors in the context of Japan. (ii) The financial development index provided by the International Monetary Fund (IMF) was considered in this research to integrate many aspects of financial development, including relative nation rankings based on access, efficiency and depth. (iii) This research introduces a novel technique for investigating the causal influence of FD, globalization, renewable energy, and fossil fuels on $CO_2$. Investigating the vague interrelationships between globalization, financial development and renewable energy usage provide Japan's pivotal bodies and decision-makers with a central database for formulating policies related to financial development and renewable energy usage during the globalization mode. The investigators utilized the frequency domain causality test which is capable of detecting short, medium and long-term causality between time series variables. This will help policymakers understand new aspects of ecological sustainability. (v) Lastly, Japan is a leader in the implementation of SDG-related goals. To maintain environmental brilliance throughout this pursuit, it is critical to understand how Japan uses its financial and energy mix resources. In light of these goals, the essential results of this research emphasize the importance of efficient and eco-friendly initiatives for new comprehensive economic and financial advancement, as well as sustainable energy-efficient investment that does not pose a threat to Japan's atmosphere.

The remainder of the study is as follows: **Section 2** presents the current state of the art, **Section 3** presents the data and methods, **Section 4** presents findings and **Section 5** presents the conclusion and policy directions.

## 2 LITERATURE REVIEW

Over the years, studies have been undertaken regarding the factors driving environmental degradation. As a result, several scholars have used different proxy of environmental degradation such as $CO_2$ emissions, ecological footprint and load factor etc to assess these interrelationship. For instance, Ali & Kirikkaleli (2021) investigated the connection between economic growth, financial development and trade openness in Turkey. The findings from the study using the FMOLS and DOLS reported that economic growth and trade openness stimulate environmental degradation. Similarly, He et al. (2021) using the BRICS nations as a case study examined the drivers of $CO_2$ emissions using the panel regression. The study outcomes reveal that economic growth and energy use contribute to the degradation of the environment while renewable energy and globalization curb environmental degradation. Similarly, Usman & Makhdum (2021) in their study on the determinants of environmental degradation in United States using the ARDL approach and the study findings disclosed that economic growth and financial development lessens environmental degradation while energy consumption increase environmental degradation.

Moreover, Saidi & Hammami (2015) examined the relationship regarding energy consumption, renewable energy and ecological pollution in 58 nations employing a 1990–2012 dataset. The authors employed the panel methodology and discovered that energy consumption increase CO2 while renewable energy renewable energy consumption. This means that increasing energy consumption degrades the ecological efficiency. Furthermore, Leal & Marques (2021a) examined the relationship between $CO_2$ pollution and energy (renewable energy and nonrenewable), economic progress in the MINT countries utilizing a dataset spanning 1980–2018 and recently established econometric panel methods The empirical evidence indicates that energy usage and economic growth has effect on $CO_2$ pollution while renewable energy decreases emissions. With respect Mexico, Acheampong and Boateng (2019) investigated the effect of trade openness, energy consumption and trade openness on $CO_2$ pollution employing wavelet coherence and ARDL techniques. The empirical findings indicate that energy consumption and trade openness impact $CO_2$ pollution positively, implying that energy consumption degrades the atmosphere while renewable energy use enhances the quality of the environment. Additionally, Shan et al. (2021) examined the connection between $CO_2$ pollution, globalization, financial development, and energy usage utilizing data from 1990 to 2012. The authors established this connection using ARDL, output signal, and Granger causality tests. The ARDL long-run analysis showed that energy consumption and globalization impact $CO_2$ emissions while renewable energy decrease emissions. However, (Dogan & Inglesi-Lotz, 2020) examined the relationship between trade openness, financial development, energy consumption and ecological degradation in 17 African nations using non-parametric quantile causal link. Their results reveal a causal correlation regarding financial development, energy use and environmental degradation in both directions.

Furthermore, Farhani et al. (2014) observed that by including urbanization in their framework and focusing on eleven (11) Middle East and North Africa (MENA) nations, their results enhanced and reduction in $CO_2$ levels. Gao & Zhang (2021), in an analysis of 8 Asia-Pacific countries established a long-run connection between trade openness; while Awosusi et al. (2022) explored this on the level of energy usage, economic development, as well as $CO_2$. Begum et al. (2015) on the other hand used Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) to investigate the complex impact of energy usage population expansion and GDP advancement on CO2 pollution over the duration 1970–2009. The study observed that there is a long-run cointegration relationship among GDP expansion, CO2 emissions, population increase, and energy utilization in Malaysia The environmental Kuznets curve (EKC) is not accurate, as shown by empirical evidence. Additionally, energy consumption and GDP have a long-term beneficial impact on CO2, whereas population increase has no noticeable impact on CO2 emissions. Moreover, Ayobamiji and Kalmaz (2020), on the other hand, used the wavelet approach to obtain the frequency domain dependence of $CO_2$ as well as potential income, which affirms the findings of (Samour et al., 2022).

## 3 DATA AND METHODS

### 3.1 Data

Using Japan as a case study the current paper, out study probes into the drivers of $CO_2$ emissions (namely globalization,

**TABLE 1** | Variable description.

| Indicators | Symbol | Measurement | Sources |
|---|---|---|---|
| $CO_2$ emissions | $CO_2$ | Per capita emission | BP |
| Globalization | GLO | Globalization Index | KOF |
| Economic growth | GDP | GDP per constant 2010 | WDI |
| Fossil fuel | FF | Addition of gas, coal and oil energy consumption | BP |
| Renewable energy | REC | Addition of nuclear, geothermal, wind, and solar energy consumption | BP |
| Financial development | FD | Financial development index | IMF |

economic growth, fossil fuel, and financial development). The dependent variable is $CO_2$ while the regressors are globalization, economic growth, fossil fuel, and financial development. The dataset used in this study spans between 1990 and 2019 (30 observations). The data sources and measurements are presented in **Table 1**.

The current investigation function presented by **Eq. 1** as follows:

$$CO_{2t} = f\,(GDP_t, GLO_t, REC_t,\ FF_t, FD_t) \tag{1}$$

Where; FF depicts fossil fuel, GLO represents globalization, REC denotes renewable energy, FD means financial development, $CO_2$ represents carbon emissions, and GDP denotes economic growth.

## 3.2 Models Construction

Given that the Japanese economy is one of the world's leading emitters of $CO_2$ emissions, the world's third-largest economy, and operates as an open market, this investigation is essential. Based on the economic function above, we construct economic model which is depicted by **Eq. 2** as follows:

$$CO_{2t} = \vartheta_0 + \vartheta_1 GDP_t + \vartheta_2 GLO_t + \vartheta_3 REC_t + \vartheta_4 FF_t + \vartheta_5 FD_t + \varepsilon_t \tag{2}$$

Where; FF is representative of fossil fuel, GLO represents globalization, REC denotes renewable energy, FD means financial development, $CO_2$ represents carbon emissions, and GDP denotes economic growth. $\vartheta_1 \ldots\ldots \vartheta_5$ represents the coefficient of the exogenous variables and $\varepsilon_t$ denotes the error term.

## 3.3 Econometric Methods

The stationarity feature of time series data determines the trustworthiness of empirical outcomes. As a result, we employed both Phillips–Perron (PP) and Augmented Dickey-Fuller Test (ADF) test stationarity to catch the variable's stationarity properties.

The current empirical analysis utilized the ARDL to investigate the interrelationship between $CO_2$ and the exogenous variables. It addresses the endogeneity and serial correlation issue among the variables through a suitable selection of lag and robust estimates, allowing for the use of relatively small sample sizes to signal both short and long-run interrelationships. In contrast to Johansen's cointegration approach, the ARDL model permits all variables to be integrated in a different order. The equations for the three models are illustrated as follows:

$$\begin{aligned}\Delta CO_{2t} = \beta_0 &+ \sum_{k=1}^{p}\theta_{1k}\Delta CO2_{t-k} + \sum_{k=0}^{p}\theta_{2k}\Delta GDP_{t-k} + \sum_{k=0}^{p}\theta_{3k}\Delta GLO_{t-k}\\ &+ \sum_{k=0}^{p}\theta_{4k}\Delta REC_{t-k} + \sum_{k=0}^{p}\theta_{5k}\Delta FF_{t-k} + \sum_{k=0}^{p}\theta_{6k}\Delta FD_{t-k}\\ &+ \varphi_1 GDP_{t-1} + \varphi_2 GLO_{t-1} + \varphi_3 REC_{t-1} + \varphi_4 FF_{t-1}\\ &+ \varphi_5 FD_{t-1} + \xi ECM_{t-1} + \varepsilon_t\end{aligned} \tag{3}$$

Subsequently, to gather the causal relationship between ecological footprint and the exogenous variables we utilized the (Breitung & Candelon, 2006) causality test to identify (a) whether REC, GLO, FD, FF and GDP granger cause $CO_2$, and (b) at which frequency does this causality occur. The test has advantages over typical time-domain techniques because it provides more degrees of variation than standard time-domain tests, which only provide variation over a set timeframe. As a result, the frequency domain method is more resistant to seasonality variations. Moreover, the approach is consistent in nonlinear topography, and causality cycles occur at higher or lower frequencies.

# 4 FINDINGS AND DISCUSSION

**Table 2** presents brief information regarding the variables used. The GDP(43519.16) is the highest and it ranges from 38074.46 to 49187.83. This is followed by FF(4840.137) which ranges from 4355.192 to 5198.311, REC(866.5147) which ranges from 333.0990 to 1198.267, GLO(69.13010) which ranges between 55.91589 and 79.53600, $CO_2$(9.661274) which ranges from 8.723510 to 10.24598 and FD(0.748023) which ranges from 0.568429 to 0.876659. With the exemption of GDP, all the variables (GLO, FF, REC, FD, and $CO_2$) are negatively skewed. Furthermore, the values of all variables are less than 3 which implies that the series are platykurtic. The value of the JB also disclosed evidence of normality of variables of investigation.

Next, we probe the stationarity attribute of the variables using the conventional PP and ADF tests which are presented in **Table 3**. At level, all the variables are nonstationarity with GLO exemption; however, at the first difference, REC, GLO, $CO_2$, FD, FF and GDP are stationary. This implies that our series are I(1) and I(0) variables. Therefore using the ARDL approach is permitted based on these outcomes.

**TABLE 2 |** Descriptive statistics.

| | GDP | GLO | FF | FD | $CO_2$ | REC |
|---|---|---|---|---|---|---|
| Mean | 43519.16 | 69.13010 | 4840.137 | 0.748023 | 9.661274 | 866.5147 |
| Median | 43207.85 | 68.84033 | 4881.384 | 0.788227 | 9.771878 | 954.8144 |
| Maximum | 49187.83 | 79.53600 | 5198.311 | 0.876659 | 10.24598 | 1198.267 |
| Minimum | 38074.46 | 55.91589 | 4355.192 | 0.568429 | 8.723510 | 333.0990 |
| Std. Dev. | 3094.765 | 6.937207 | 234.3127 | 0.106257 | 0.377413 | 290.7360 |
| Skewness | 0.114993 | −0.254488 | −0.448348 | −0.364164 | −0.622106 | −0.733119 |
| Kurtosis | 2.052145 | 2.008619 | 2.260401 | 1.608524 | 2.793841 | 2.105325 |
| Jarque-Bera | 1.189153 | 1.552364 | 1.688837 | 3.083334 | 1.988209 | 3.687872 |
| Probability | 0.551796 | 0.460159 | 0.429807 | 0.214024 | 0.370055 | 0.158194 |

**TABLE 3 |** Stationarity test outcomes.

| | ADF | | PP | | ZA | | | |
|---|---|---|---|---|---|---|---|---|
| **Variables** | **Level** | **Δ** | **Level** | **Δ** | **Level** | **BD** | **Δ** | **BD** |
| GDP | −3.1841 | −5.6342* | −3.0870 | −7.7549* | −4.3620 | 2009 | −6.9401* | 2009 |
| FF | −1.9335 | −6.3504* | −1.3501 | −14.908* | −3.2085 | 2009 | −5.1032*** | 2010 |
| REC | −2.2638 | −5.6900* | −2.0003 | −3.6893* | −4.4897 | 2012 | −5.9305* | 2012 |
| GLO | −3.5439** | −4.2649* | −3.2743*** | −10.786* | −4.9147*** | 1997 | −6.2700* | 1999 |
| $CO_2$ | −1.9827 | −4.4882* | −1.1525 | −5.1370* | −3.6439 | 2012 | −4.9217*** | 2007 |
| FD | −2.2138 | −4.6796* | −2.5941 | −4.8097* | −3.7833 | 2008 | −5.2295** | 2008 |

**p < 0.01, **p < 0.05, and ***p < 0.10*

**TABLE 4 |** ARDL bounds test.

| F-bounds test | | Ho: No levels of association | | |
|---|---|---|---|---|
| **T-Statistic** | **Value** | **Signif.** | **I(0)** | **I(1)** |
| | | | Asymptotic: n = 1000 | |
| F-statistic | 5.6393* | 10% | 2.26 | 3.35 |
| k | 5 | 5% | 2.x62 | 3.79 |
| | | 2.5% | 2.96 | 4.18 |
| | | 1% | 3.41 | 4.68 |

**Table 4** presents the bounds test outcomes which are utilized to check the cointegration attributes of the variables of investigation. The Ho hypothesis of "no cointegration" is dismissed since the F-statistic is higher than the Lower and upper critical values. Therefore, we conclude that there is strong proof of an association between $CO_2$ and the exogenous variables in the long-run. This gives room for the ARDL utilization to catch the long-run interrelation between $CO_2$ and the regressors.

The association between $CO_2$ emissions and the exogenous variables is unveiled by the ARDL long and short-run outcomes in **Table 5**. The effect of GDP on $CO_2$ is found negative and significant at 5% which suggests that a 1% shift in the GDP will cause $CO_2$ to increase by 0.5301% by keeping other elements constant. The growth in Japan's economy is not eco-friendly i.e., it is not sustainable. Though in the short term, no significant association was found between GDP and $CO_2$.



**TABLE 5 |** ARDL outcomes.

| | Long-run | | | Short-run | | |
|---|---|---|---|---|---|---|
| **Variable** | **Coefficient** | **t-statistic** | **Prob** | **Coefficient** | **t-statistic** | **Prob** |
| GDP | 0.5301** | 2.3210 | 0.0310 | 0.7453* | 5.1570 | 0.0001 |
| GLO | −0.7024* | −5.0605 | 0.0000 | −0.5298 | −1.4639 | 0.1169 |
| FD | 0.1629** | 2.5853 | 0.0258 | 0.2336* | 2.9230 | 0.0100 |
| REC | −0.0348* | −3.2651 | 0.0039 | −0.1618*** | −1.9273 | 0.0719 |
| FF | 0.7668* | 6.4674 | 0.0000 | 0.7917* | 11.740 | 0.0000 |
| DUM | 0.2911 | −0.1503 | 0.8820 | — | — | — |
| ECT(-1) | — | — | — | −0.3967* | −6.5390 | 0.0000 |
| $R^2$ | 0.9383 | | | | | |
| Adjusted $R^2$ | 0.9237 | | | | | |
| F-statistic | 38.060 | | | | | |
| Prob (F-statistic) | 0.0000 | | | | | |

*Note: 1%, 5%, and 10% level of significance are denoted by *, **, and ***.*

**TABLE 6 |** Diagnostic tests.

| | $X^2$ (*p*-values) |
|---|---|
| Normality test | 0.9183 (0.8901) |
| RESET test | 0.2110 (0.8301) |
| Heteroskedascity test | 1.7941 (0.1803) |
| Serial correlation LM | 4.0836 (0.1101) |

This shows that similar to most Asia economies, Japan's policy is pro-growth. Therefore, policymakers in Japan need to re-strategize their policy regarding growth due to its damaging effect on the ecosystem. This outcome is preached by several scholars. For instance, the study of (Miao et al., 2022) for BRICS reported that the growth-emissions association is positive using the MMQR. Similarly, the studies of (Adebayo, 2022a) and (Adebayo, 2022b) for India and Spain respectively reported that GDP is the major cause of deterioration of the ecosystem. Moreover, the studies by Ali & Kirikkaleli (2021), Qayyum et al. (2021), Xu et al. (2022), Qayyum et al. (2022), Shabir et al. (2022) and Akadiri et al. (2022) disclosed similar findings.

Furthermore, we established that emissions increase in Japan is caused by financial development increases. Thus, a 0.16% surge in emissions in Japan is caused by a 1% increase in FD when other elements are constantly held. This shows that the financial system of Japan is at its early stage. In this stage, financial development is anticipated to worsen the ecosystem. The study of He et al. (2021) preached a similar result by establishing positive FD-emissions nexus. Similarly, the paper by Ahmad et al. (2021), Fakher et al. (2021), and Haseeb et al. (2018) reported that FD does not lessen emissions but rather amplifies it. Nonetheless, the research of Agyekum et al. (2022) established that decrease in emissions within the global context is caused by the amplification of FD. Contrarily, the study of Zhang et al. (2021) refuted the study of Kirikkaleli & Adebayo (2020), Güngör et al. (2021), and Kirikkaleli & Adebayo (2021) by establishing an insignificant FD-emissions connection.

Moreover, the effect of globalization on $CO_2$ is negative in both the short and long-run at 1% and 10% respectively. This implies that globalization favors the environment in Japan. Therefore 0.70% and 0.51% decrease in $CO_2$ in Japan in the short and long-term is caused by a 1% surge in globalization keeping other factors constant. This also corroborates the PHH-pollution hallow hypothesis for the case of Japan. A similar outcome is reported by the research of (Dingru et al., 2021) for BRICS using MMQR and dataset from 1990–2018. Likewise, the study (Adebayo, 2022a) using the load capacity facto which is a new proxy of ecological quality reported that globalization boosts the integrity of the environment. However, the research (Acheampong & Adebayo, 2021) for Australia reported positive globalization-emissions interconnection. This is also backed by the research of (D. Xu et al., 2022) who preached a positive emissions-globalization association.

As anticipated, negative emission-renewable energy surfaced. Therefore, the growth in REC in Japan is curbing $CO_2$. In terms of climate change, the use of renewable energy sources has been thought to have a substantial impact on ecological integrity by dropping GHG emission levels in the atmosphere. Besides, as noted by the OECD (2013), renewables investment is typically regarded to be less carbon-intensive than traditional energy. Nations may promote ecological responsibility and build a globally sustainable and resilient ecosystem by supporting the adoption of renewable energy. This result conforms with the research of Fareed et al. (2021, 2022) who reported that REC is vital for curbing the constant surge in emissions. Similarly, the studies of Anwar et al. (2021) and Alola et al. (2021) reported that the decrease in emissions is caused by REC intensification.

Fossil fuel use effect on $CO_2$ is positive, which is as expected. Therefore, a 0.766% upsurge in emissions is triggered by a 1% intensification in fossil fuels. Several studies revealed similar findings (Adebayo et al., 2022; Gyamfi, Adebayo, et al., 2022). Furthermore, the dummy variables does not have significant effect on $CO_2$ emissions. As expected, the coefficient of ECT is −0.39, which is significant and negative at significance level of 1%. The result proves that corrections made in previous periods can be corrected in subsequent periods. The diagnostic tests also revealed that there is no issue of serial correlation, normality and heteroscedasticity (see **Table 6**). In addition, **Figures 1A,B** affirm stability in the model. **Figure 2** presents the empirical results.



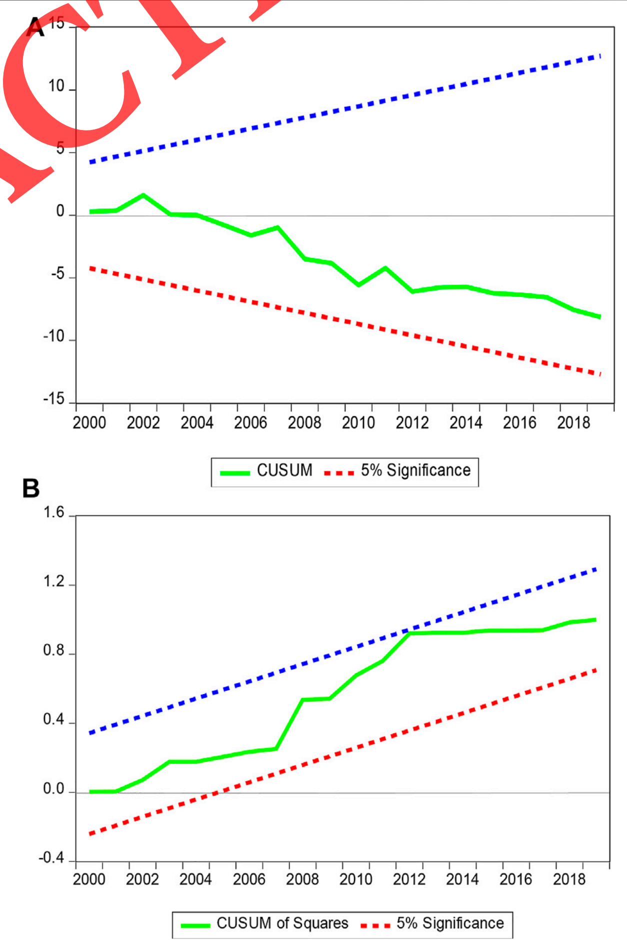


**FIGURE 1 | (A,B)** CUSUM.

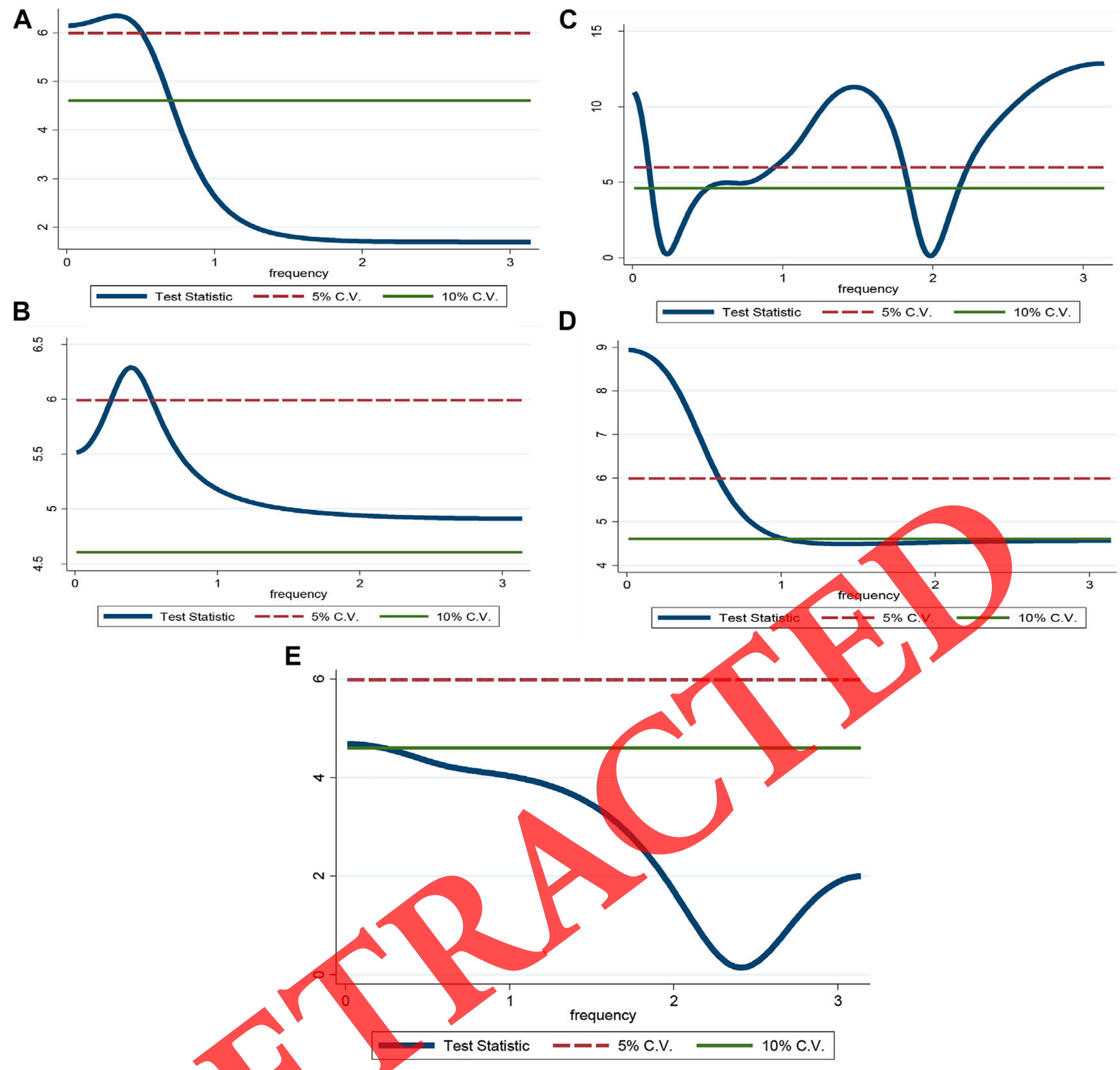


**FIGURE 2 | (A)** Spectral Causality from REC to $CO_2$. **(B)** Spectral Causality from GLO to $CO_2$. **(C)** Spectral Causality from FD to $CO_2$. **(D)** Spectral Causality from GDP to $CO_2$. **(E)** Spectral Causality from FF to $CO_2$.



Next, we examine the causal interrelationship between $CO_2$ and FD, GDP, REC, FF and GLO using the BC-breighton abd Calderon (2006) test which is presented in Figures. **Figure 2A** presents the causal link from REC to $CO_2$. At a level of significance of 5% and 10%, there is causality from REC to $CO_2$. Furthermore, evidence of causality from GLO to $CO_2$ is surfaced 5% level of significance which shows that in the long-run $CO_2$ can be predicted by GLO (See **Figure 2B**). Moreover, in all frequencies, causality from FD to $CO_2$ is evident which illustrates that in the short, middle and long-run FD can forecast $CO_2$ (**Figure 2C**). Furthermore, we established causality from both GDP to $CO_2$ in both the middle and long-term as shown in **Figure 2D** which suggests that $CO_2$ can be forecasted by GDP. Lastly, **Figure 2E** supports causality from FF to $CO_2$ suggesting that $CO_2$ can be forecasted in the long-term. These outcomes suggest that all the exogenous variables can forecast $CO_2$ mostly in the long-term which implies that any policy initiated for the exogenous variables will impact emissions of $CO_2$.

## 5 CONCLUSION AND POLICY SUGGESTIONS

### 5.1 Conclusion

Ecological dilapidation is one of the most immediate issues affecting modern society. Environmental degradation has gotten a lot of devotion from scholars and policymakers because of its huge influence on billions of people's lives. As a result, this empirical research probes the effect of renewable energy and globalization on $CO_2$ emissions in Japan using a dataset from 1990 to 2019. We also consider other determinants such as financial development and economic growth in the framework. The study employed the ARDL and frequency domain causality to probe these relationships. The findings from the ARDL disclosed that GLO and REC contribute to the mitigation of $CO_2$ emissions while fossil fuel, FD and GLO caused an upsurge in $CO_2$ emissions in Japan as shown in **Figure 3**. Furthermore, the frequency domain demonstrated that all the

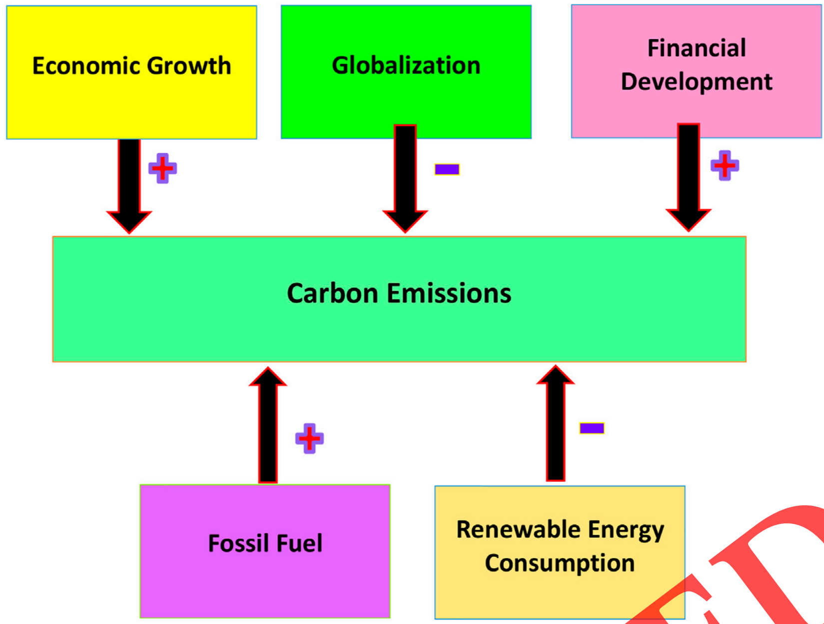


**FIGURE 3 |** Empirical findings.



exogenous variables can forecast $CO_2$ mostly in the long-term which implies that any policy initiated for the exogenous variables will impact emissions of $CO_2$. The problems of autocorrelation and heteroscedasticity was also investigated using diagnostic approaches. The results show that the accepted model has no contradictory concerns with heteroscedasticity and autocorrelation, as evidenced by a Chi-square value of higher than 0.10%.

## 5.2 Policy Recommendations

The aforementioned variables are significant aspects in Japan's environmental deterioration. To achieve more ecological profits, the government should concentrate on shifting away from non-renewable energy sources that add to growing CO2 levels and toward more reliable and cost-effective sources of renewable that maintain a better ecosystem and long-term growth. Furthermore, additional government funding should be allocated to research and development of more innovative approaches to the nation's environmental problems. Additional government energy research and development spending will raise the production of energy resource efficiency and attract FDI into the nation. Moreover, Japan's ecologically sustainable development goals may be met by swapping renewable energies for fossil fuels in order to lessen GHGs emissions.

Moreover, the growing impact of globalization on Japan's $CO_2$ emissions shows that the country is transitioning from ecological responsibility. Because globalization is a major driver of economic growth, the government should concentrate on luring and licensing investors that use environmentally beneficial technology. Likewise, technology brought into the nation for commerce should be ecologically benign in order to avoid harmful environmental consequences. Moreover, using ecologically sustainable techniques including polluter payments, carbon taxes, and pollution credits, the government should set guidelines for emissions, and corporations that violate these criteria and contaminate should be penalized. A program of this nature has the ability to both slow and ameliorate environmental degradation while boosting economic expansion.

## 5.3 Limitation of Study and Future Directions

This research has its limitations, which can be addressed in the future. Though the research assesses the effect of economic growth and energy (renewable and nonrenewable) on $CO_2$ emissions, the study did not verify the EKC hypothesis. Therefore, future studies can incorporate this into their model. Furthermore, future studies can also include interaction terms of financial development with other variables, such as economic growth, and energy use to comprehend its indirect effect on $CO_2$ emissions. Since the data was only available for a brief time, this study only investigated a few variables in the model. Future efforts in this area may include technology, environmental taxation, green innovation, and other variables to provide intriguing outcomes.

## AUTHOR CONTRIBUTIONS

SM, SA-G, and OL contributed to conception and design of the study. MA and EA organized the database. EBA performed the statistical analysis. EA wrote the first draft of the manuscript. SM, SA-G, OL, EA, SK and ME-N wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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