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The Nexus Between Fiscal Decentralization and Environmental Sustainability in Japan

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This paper adds to the existing body of knowledge by incorporating the role of fiscal decentralization (FD) in influencing CO_2 emissions. Therefore, this study looked at the effect of FD on CO_2 emissions in the presence of nonrenewable energy consumption (NRE), renewable energy consumption (REN), gross domestic product (GDP), and trade openness (TOP) for the period 1994–2018 in Japan. Thus, the current work intends to fill this knowledge gap by employing econometric techniques such as Bayer and Hanck cointegration, dynamic ordinary least squares (DOLS), fully modified ordinary least squares (FMOLS), and canonical cointegration regression (CCR). Additionally, the frequency domain causality analysis is used in the investigation to determine the causal impact of FD, NRE, REN, GDP, and TOP on CO2 emissions. The novelty of the frequency-domain approach is that it can differentiate between nonlinearity and causality levels and show causality among parameters with different frequencies. The DOLS, FMOLS, and CCR results reveal that NRE, GDP, and TOP augment CO_2 emissions in Japan, whereas FD and REN increase the quality of the atmosphere. Furthermore, the frequency causality test results show that FD, REN, GDP, and TOP have implications for CO_2 emissions in the long run, while NRE raises CO_2 emissions in the medium run. As a policy direction, the current study suggests expanding renewable energy consumption in Japan by emphasizing more on Sustainable Development Goals (7, 8, and 13).

Keywords: fiscal decentralization, CO_2 emissions, FMOLS, DOLS, Japan

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1 INTRODUCTION

Climate transformation and global temperature increase have recently emerged as two of the world's most serious and contentious issues, and there is expanding agreement that these issues must be discussed expeditiously (Ma et al., 2019). As per World Bank (2020) statistics, carbon dioxide (CO_2) emissions have increased rapidly over the last few decades, with a significant increase from 22,149.4 million tonnes in 1990 to 36,390.3 million tonnes in 2018. As a result, the global society has begun to pay interest to environmental issues caused by rising CO_2 emissions. In this prospect, many countries all over the globe have put in place a slew of initiatives to combat global climate transformation (Dong et al., 2020). On 31 October 2021, global leaders will met in Glasgow for the 26th Conference of the Parties (COP26). The procedure is governed by reaching an agreement, and the intensity is established by the nations that are least keen to participate. A sound verbal commitment was made at similar gatherings in Kyoto in 1997, Copenhagen in 2009, and Paris in 2015, but the output is not noticeable. Nations committed in Paris in 2015 to maintain the global temperature rise well below 2°C (Christoff, 2016). The United Kingdom is urging for an agreement to "relegate coal power to history," the United States intends a net-zero agreement, and the Association of Small Island States (AOSIS) has insisted that the Earth's temperature increase be kept well below the 1.5°C threshold. Least developing nations expect climate emitters to give billions in damages, while Like-Minded developing economies expect $100 billion in climate funding and carbon storage (Suresh, 2021).

Furthermore, environmentalists and energy activists shift their focus and strive to establish democracy for energy, which is an indication of grassroots decentralized patterns (Hager, 1992; Burke and Stephens, 2018). Worldwide, central governments have agreed to delegate responsibilities to lower-level authorities, a phenomenon known as fiscal decentralization (Hao et al., 2021). Fiscal decentralization in environmental viewpoints provides power over ecological resources between federal and provincial authorities, i.e., the proportion of revenues and expenditures is distributed by local authorities to promote the environment's performance (Liang and Yang, 2019). Nations can effectively enact initiatives designed to improve environmental performance by authorizing the lower unit of country. As a result, there is a robust link between FD and CO_2 emissions. To obtain the low CO_2 emissions benchmark and the energy-saving roles of fiscal expenses, it is critical to specify commitments at various stages of administration (Cheng, 2019).

In the current literature, there are two different views regarding the relationship between fiscal decentralization (FD) and CO_2 emissions. According to several academics, FD degrades environmental quality because some sectors set poor environmental standards in order to enhance their environment-related business at the expense of environmental loss (Kunce and Shogren, 2008; He, 2015; Yang et al., 2020a). Other perspectives contend that some sectors inhibit contaminating activities by enforcing strict environmental regulations, and in this situation, FD has been shown to restore the atmosphere (Millimet, 2003; Chen and Chang, 2020; Cheng et al., 2020). As a result, the relationship between FD and CO_2 emissions is unclear. Climate activists are still attempting to investigate the association between FD and environmental performance (Romero Molina 2018). Though it is critical to probe the approaches and institutes that aid in the recovery of environmental quality, aspects that lead to lower CO_2 emissions must also be investigated.

These contradictory shards of evidence motivate researchers to dig deeper into the FD topic with diverse ideas. The vast portion of existing research on the association between FD and environmental quality has been undertaken from the standpoint of advanced or emerging economies. To the best of our insight, no significant attempt has ever been made with a developed economy like Japan in mind. Similarly, in view of carbon output, the United States and the European Union are the second and third biggest emitters, respectively, though Japan is not an outlier. It is the world's fifth-highest polluter of greenhouse gases, with a 26 percent decrease in emissions intended between 2013 and 2030, contrasted to an 18–20 percent decrease in the United States and a 24% reduction in the European Union (Shahbaz et al., 2018). Japan intends to use nuclear energy for 20–22% of its electricity mix by 2030, up from 30% before the Fukushima nuclear disaster. It has set renewable energy priorities of 22–24% of the electricity mix, liquefied natural gas at 27%, and coal at 26% (Shahbaz et al., 2018).

As a result, it is critical to study the role of FD in decreasing CO_2 emissions. Therefore the main objective of this paper is to explore the importance of FD on CO_2 emissions in the case of Japan, this paper fills a gap in the current literature. Moreover, this study also incorporates nonrenewable energy consumption (NRE), renewable energy consumption (REN), economic growth (GDP), and trade openness (TOP) for the period 1994-to 2018 as significant factors of CO_2 emissions. Furthermore, by incorporating advanced time-series estimation techniques to investigate the influence of FD on environmental quality, this paper empirically extends the literature. The study's outcomes can aid in the development of FD and environmental policies in Japan.

The next section includes a summary of relevant work. The third section goes over the data and methods employed. The fourth section includes outcomes based on the approaches used. The fifth section describes the conclusion and future policy agenda.

2 LITERATURE REVIEW

2.1 Fiscal Decentralization and Environmental Sustainability

FD is the process of allocating mandate or command over regional economic exercise to regional or provincial authorities (Liu et al., 2019; Hao et al., 2020). As a result, FD has been identified as a worldwide trend over the last few decades (Wang & Lei, 2016). Furthermore, researches show that FD can have an impact on environmental performance both directly and indirectly (Li et al., 2021). According to the studies, FD has an effect on economic development and progression, which in turn has an effect on environmental performance and environmental deterioration. As a result, there is an indirect link between environmental efficiency and FD. On the contrary, the research shows that FD has a direct influence on environmental preservation and performance. The literature in this setting can be classified into two main groups of research findings.

In the first group, Fredriksson and Millimet (2002), Levinson (2003), Konisky (2007), and Cheng (2019) are among those who believe that FD has a positive impact on environmental performance. According to Konisky (2007), a high standard of FD is required for environmental improvement. Furthermore, Cheng (2019) asserted that it is critical to specify roles and responsibilities at various levels of government in order to effectively accomplish the benchmark of minimal CO_2 emissions and energy-saving aspects of fiscal spending. Recently, Khan et al. (2021) used a balanced panel data of seven Organisation for Economic Co-operation and Development (OECD) nations for 1990 and 2018 and examined the influence of FD on CO_2 emissions. According to the empirical findings, FD enhances the quality of the environment. Furthermore, advancements in institutional quality and human capital improvement enhance the connection between FD and ecological sustainability. Likewise, Ji et al. (2021) utilized data from seven extremely fiscally decentralized nations, namely Australia, Austria, Belgium, Canada, Germany, Spain, and Switzerland, between 1990 and 2018. Enhanced panel data econometric instruments that could cope with both heterogeneity and cross-sectional dependence issues were utilized for econometric investigation. The outcomes affirm that FD improves the atmosphere by lowering CO_2 emissions in both linear and nonlinear aspects. In the case of China, Cheng et al. (2021) investigated the influence of FD on CO_2 emissions from 2005Q1 to 2018Q4. They discovered that environmental quality improves as a result of an increase in FD. From 1990 to 2018, Tufail et al. (2021) examined panel data from seven highly fiscally decentralized OECD) nations. They utilized the cross-sectional autoregressive distributive lag model for their econometric investigation. The long-term outcomes show that FD reduces CO_2 emissions, which is good for the environment. Besides, Shan et al. (2021) looked into the impact of non-linear FD on CO_2 emissions. They used innovative econometric panel methods to analyse data for the top seven fiscally decentralised OECD countries between 1990 and 2018. The findings disclosed that the linear term of FD increases carbon emissions, whereas the non-linear term reduces them. The inverted U-shaped curve between FD and CO_2 emissions was confirmed.

The second set of research findings, which includes Millimet (2003), and Fell and Kaffine (2014), is more defeatist about FD's role in influencing environmental durability. Millimet (2003), for example, contended that in the phase of decentralization, nations sacrifice environmental performance due to the inadequate local atmosphere as a result of enhanced consent of the lower unit of the country. Likewise, Sigman (2014) postulated that free behavior among localities degrades environmental effectiveness as the level of FD increases. Zhang et al. (2017) examined the influence of FD on the useful mechanisms of environmental policy while adjusting for spatial correlations of CO_2 emissions utilizing panel data from 29 Chinese provinces from 1995 to 2012. The empirical findings suggest that environmental policy alone cannot attain the goal of lowering CO_2 emissions. Moreover, FD considerably stimulates CO_2 emissions, resulting in a green paradox.

2.2 Studies on Other Factors Affecting Environmental Sustainability

In addition to the fiscal decentralization, other elements, such as renewable energy, nonrenewable energy, economic development, and trade can affect CO_2 emissions. In particular, Adebayo et al. (2022a) analyzed the effect of nonrenewable energy, renewable energy and COVID 19 on carbon emission in United Kingdom by applying the Fourier ADL cointegration test, Markov switching regression, non-linear ARDL and Breitung and Candelon causality test. According to the findings of the study, renewable energy and COVID -19 cases were negatively associated while fossil fuel energy was positively associated with carbon emissions. Moreover, unidirectional causality was found to be present in all of the variables in the United Kingdom. Awosusi et al. (2022a) examined the impact of technological innovations, political risk, globalization, economic growth and nonrenewable energy on ecological footprints in BRICS countries. They found that nonrenewable energy, economic growth, political risk and technological innovations increased pollution levels, whereas globalization reduced pollution. For another study for Brazil, Russia, India, China, and South Africa (BRICS), Awosusi et al. (2022b) considered the impact of biomass energy consumption on ecological footprints controlling for the role of natural resources, globalization and gross capital formation. According to their findings, biomass energy consumption and globalization had a negative relationship with ecological footprints at all quantiles, while natural resources, gross capital formation and economic growth enhanced ecological footprints. Nawaz et al. (2021) analyzed the effect of nonrenewable energy, renewable energy, economic growth, and trade openness in BRICS economies. They found the negative effect of economic growth, positive effect of nonrenewable energy and insignificant impact of trade openness on carbon emission. For a study of ten Asian countries, Chien et al. (2021) investigated the nexus between renewable energy, nonrenewable energy, innovations, environmental taxes and environmental quality and observed that renewable energy, innovations and environmental taxation mitigated environmental deterioration but nonrenewable energy enhanced CO_2 emission.

In continuation, the study of Adebayo et al. (2022b) attempted to estimate the effect of tourist arrivals on CO_2 emission by controlling energy consumption, economic growth and globalization through Quantile on Quantile Regression. Globalization, economic growth, energy consumption and tourist arrivals increased CO_2 emission at different quantiles. Similarly, Adebayo (2022c) scrutinized the data for Spain to estimate the association between renewable energy, fossil fuels, economic complexity and FDI on load capacity factor (a measure for environmental degradation) by applying Wavelet Coherence Approach. The authors found that renewable energy improved, but fossil fuel energy deteriorated the environmental quality in the medium and short run. FDI improved the environmental quality at all frequencies, and economic complexity deteriorated environmental quality in the medium, short and long run. Fareed et al. (2022) attempted to estimate the moderating effect of innovations on financial inclusion on environmental quality relationship controlling for economic growth and renewable energy in 27 European countries. According to their findings, financial inclusion deteriorated the environmental quality, but innovations significantly reduced this negative association between financial inclusion and environmental degradation. According to their analysis, renewable energy was found to mitigate environmental pollution, whereas economic growth enhanced environmental degradation in studied countries. Adebayo et al. (2022d) scrutinized the data for Sweden and analyzed the role of renewable energy, trade openness and economic growth on CO_2 emission by applying Quantile on

Quantile regression. Trade openness and renewable energy were found to be negatively associated with CO_2 emission at low and medium Quantile and low and high Quantile, respectively. Economic growth also had a negative impact on CO_2 emission at many Quantiles.

Despite the fact that an expanding body of research has probed the environmental consequences of FD, a certain research gap is still present. Although several scholars have begun to concentrate on the influence of FD on CO_2 emissions, understanding of the effect of such decentralization on CO_2 emissions remains limited, especially in Japan. The current study provides a deeper understanding of the role of FD as a significant factor of CO_2 emissions.

3 THEORETICAL MODEL AND EMPIRICAL METHODOLOGY

3.1 Theoretical Model

To examine the effect of FD on CO_2 emissions in the existence of control variables such as NRE, REN, GDP, and TOP for the period 1994–2018, the empirical equation is displayed as:

$$\ln CO_{2t} = \alpha_0 + \alpha_1 \ln FD_t + \alpha_2 \ln NRE_t + \alpha_3 \ln REN_t + \alpha_4 \ln GDP_t + \alpha_5 \ln TOP_t + u_t \quad (1)$$

where CO_2 signifies carbon dioxide emissions, FD stands for fiscal decentralization, NRE is nonrenewable energy consumption, REN denotes renewable energy consumption, GDP is a gross domestic product, and TOP is trade openness. ln is the natural log, μ represents the error term, and t is the time period.

Following Cheng et al. (2021), Lingyan et al. (2021), and Tufail et al. (2021), FD is involved in the regression as a critical parameter. The research on the sign of the FD coefficient is uncertain. The theoretical justification for the negative relationship between FD and CO_2 emissions is that nations can effectively incorporate policies aimed at enhancing environmental efficiency by allowing the lower unit of government. FD, on the other hand, raises emissions due to the free-rider challenge between states, i.e., the higher the fiscal expenditure power given to lower units of the nation, the bigger the likelihood of degradation in environmental performance (Cheng, 2019). FD increases environmental performance if $\alpha 1 < 0$, otherwise the environment is ruined by a rise in FD. In addition, the model takes into account nonrenewable energy use. An increase in NRE due to the unnecessary usage of fossil fuels for the development process raises the level of emissions, resulting in a reduction in environmental quality (Yang et al., 2022; Yu and Qayyum, 2022). Therefore, we posit $\alpha_2 > 0$ if the relationship between NRE and CO_2 emissions is positive. Renewable energy can have a favorable impact on environmental efficiency by integrating alternate methods for growth and energy-efficient innovation (Qayyum et al., 2021a). So, we speculate $\alpha_3 < 0$ if REN and CO_2 emissions are negative. Increased economic activity leads to increased energy consumption, which has an adverse impact on environmental performance (Yang et al., 2020b; 2020c; Chunling et al., 2021; Qayyum et al., 2021b; Qayyum et al., 2022). We presume $\alpha_4 > 0$ if the association between GDP and CO_2 emissions is positive, if not, $\alpha_4 < 0$. Similarly, trade could have both favorable and unfavorable consequences. Detrimental effects include substantial amounts of carbon-emitting competence, extensive transportation utilization, and so on (Antweiler et al., 2001). The accusation that trade will boost revenue and facilitate cross-border green energy is well-founded. Developed economies can then afford renewable energy advancements, which will favor the environment for future generations run (Antweiler et al., 2001). So, we expect $\alpha_5 > 0$ if the association between TOP and CO_2 emissions is positive, if not, $\alpha_5 < 0$. **Table 1** shows the data sources, definitions, and variable units utilized in **Eq. 1**. **Figure 1** depicts the flow chart of the estimation performed in this research.

3.2 Empirical Methodology

3.2.1 Unit Root Test

The order of the integration should always be confirmed by analyzing the unit root tests until a cointegration test is conducted. Our period of study contains global transformation that results in structural breaks. Conventional unit root measures, such as ADF, KPSS, and DF-GLS, do not account for structural breaks and may yield insufficient results. As a result, we employ the Zivot and Andrews (2002) unit root method to assess the stationary properties of the factors and single structural breaks. The Zivot-Andrews unit root method is advantageous over others because it accounts for structural breaks when determining the series' stationarity level (Kirikkaleli and Athari, 2020; Özbay et al., 2022).

3.2.2 Cointegration Test

Following the stationarity confirmation, Bayer and Hanck's (2013) method is used to probe the cointegration association between the interest factors. This newly modified technique for cointegration provides a more appropriate finding by integrating many different test outcomes, such as those of Engle and Granger (1987), Johansen (1991), Peter Boswijk (1994), and Banerjee et al. (1998). The Fishers' equations for the Bayer-Hanck approach are as follows:

$$\mathrm{EG} - \mathrm{JO} = -2\left[\ln\left(\mathrm{P_{EG}}\right) + \ln\left(\mathrm{P_{JO}}\right)\right] \quad (2)$$

$$\mathrm{EG} - \mathrm{JO} - \mathrm{BO} - \mathrm{BDM} = -2\left[\ln\left(\mathrm{P_{EG}}\right)\right] + \ln\left(\mathrm{P_{JO}}\right) + \ln\left(\mathrm{P_{BO}}\right) + \ln\left(\mathrm{P_{BDM}}\right] \quad (3)$$

P_{EG}, P_{JO}, P_{BO}, and P_{BDM} are the possibility values for each of the above-mentioned cointegration tests. The cointegration of the underpinning parameters is determined by the formation of Fisher statistics.

3.2.3 Long Run Estimates

The current study also uses the fully modified ordinary least square (FMOLS), dynamic ordinary least square (DOLS), and canonical cointegration regression (CCR) methods, respectively, to identify the long-run effects of FD on CO_2 emissions in Japan, with NRE, REN, GDP and TOP employ as

TABLE 1 | Data description.

Variables	Description	Units	Source
CO2	Carbon emissions	Metric tons	Global Carbon Atlas, 2019 http://www.globalcarbonatlas.org/en/CO2-emissions
FD	Fiscal decentralization	An index is computed relying on the ratio of own revenues/expenditure to general government revenues/expenditures utilizing principal component analysis	International Monetary Fund, 2019 https://data.imf.org/?sk=1C28EBFB-62B3-4B0C-AED3-048EEEBB684F
NRE	Nonrenewable energy	kg of oil equivalent per capita	Word Development Indicators, 2019 https://databank.worldbank.org/source/world-development-indicators#advancedDownloadOptions
REN	Renewable energy	Percentage of total final energy consumption	Word Development Indicators, 2019 https://databank.worldbank.org/source/world-development-indicators#advancedDownloadOptions
GDP	Gross domestic product	Constant 2010 US Dollars	Word Development Indicators, 2019 https://databank.worldbank.org/source/world-development-indicators#advancedDownloadOptions
TOP	Trade openness	% of GDP	Word Development Indicators, 2019 https://databank.worldbank.org/source/world-development-indicators#advancedDownloadOptions

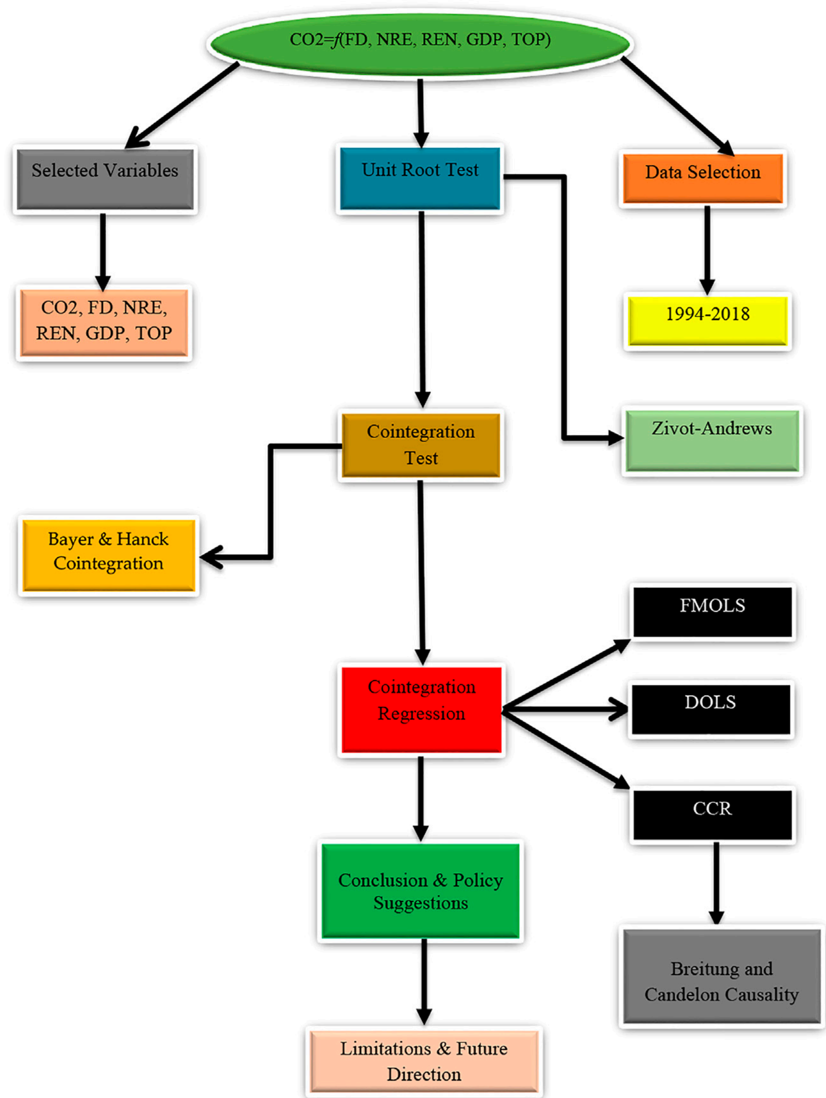

FIGURE 1 | Flow chart of the analysis.

TABLE 2 | Descriptive statistics.

	CO_2	FD	NRE	REN	GDP	TOP
Mean	3.034658	0.560293	3.531540	−1.041482	12.63558	1.376554
Median	3.048319	0.421852	3.544582	−0.801312	12.70443	1.381233
Maximum	3.121714	0.683467	3.612227	0.072894	12.79215	1.577717
Minimum	2.901830	−0.942951	3.393930	−2.629585	12.28614	1.199674
Std. Dev	0.460559	0.294171	0.562411	0.774850	0.949991	0.710919

controlled variables. To prevent the correlation concern, Phillips and Hansen (1990) formed the semi-parametric methodology FMOLS, emphasizing that the technique is asymptotically free of bias and accurate. CCR, a procedure comparable to FMOLS formed by Park (1992), is used to investigate cointegration sequences in a pattern where the order of the stationarity of time series variables is I(1). The biggest distinction between the FMOLS and CCR estimation methods is that the FMOLS focuses on both data and variable conversion, while the CCR only emphasizes data alteration (Wu et al., 2018). To counter simultaneity and small sample bigotries, the DOLS technique contains leads and lags. By dealing with disorderly variables, both DOLS and FMOLS estimation methods handle the concern of endogeneity and serial correlation (Yildirim and Orman, 2018; Kirikkaleli et al., 2021).

3.2.4 Breitung and Candelon Causality

Furthermore, while controlling for NRE, REN, GDP, and TOP, this paper investigates the causal effects of FD on Japan's CO_2 emissions at multiple frequencies. In this study, the frequency domain causality strategy of Breitung and Candelon (2006) is used. This strategy is based on Geweke's (1982) and Hosoya's (1991) preliminary research. According to Odugbesan and Adebayo (2020), the critical gap between time domain and frequency domain techniques is that the time domain methodology locates a particular transition within a time series, while the frequency domain methodology constitutes the intensity of specific changes within a time series.

TABLE 3 | Unit root test results.

Variables	At level		At first difference	
	Test statistic	Time break	Test statistic	Time break
Level				
CO_2	−1.5311	1989Q2	−5.7195***	1983Q2
FD	−1.3889	2002Q2	−4.8576*	2000Q2
NRE	−3.7634	1987Q2	−6.0762***	1983Q2
REN	−1.1656	1981Q2	−6.2025***	1984Q1
GDP	−2.7517	1983Q2	−5.7068***	1991Q2
TOP	−4.4029	1985Q2	−5.7325***	1994Q4
Critical value				
1%	—	−5.34	—	—
5%	—	−4.93	—	—
10%	—	−4.58	—	—

** and *** show significance at 10 and 1% levels, correspondingly.*

4 RESULTS AND DISCUSSIONS

Table 2 reports the descriptive statistics of the variables employed in the current investigation. The natural logarithm of the CO_2 emissions, FD, REN, REN, GDP, and TOP was utilized. CO_2 emissions fluctuated from 2.90 to 3.12, FD ranged from -0.94 to 0.68, NRE varied from 3.39 to 3.61, REN ranged from -2.63 to 0.07, GDP fluctuated from 12.29 to 12.79, and TOP reached from 1.19 to 1.57.

The next process is to investigate the variables' stationary properties. In order to identify a set of stationary attributes in the likeness of a structural break, we used the Zivot-Andrews unit root technique. The unit root method demonstrates that none of the parameters is stationary at the level, as shown in **Table 3**. Furthermore, all of the factors become stationary after the first difference is made.

The present research investigates the cointegration characteristics of variables using the composite Bayer-Hanck technique for cointegration. **Table 4** articulates the results of the Bayer-Hanck methodology. The findings show that long-term cointegration persists between CO_2 emissions, FD, NRE, REN, GDP, and TOP at the 5% level of significance.

After founding cointegration between the parameters, we explored the long-term relationships between CO_2 emissions and FD, NRE, REN GDP, and TOP. As a result, we employed FMOLS, DOLS, and CCR methods to investigate the long-run impact of FD, NRE, REN, GDP, and TOP on CO_2 emissions (**Table 5**). Throughout all three methods, the indication, direction, and significance of coefficients are almost or considerably similar. According to **Table 5**, FD decreases CO_2 emissions by 0.283% in FMOLS, 0.240% in DOLS, and 0.3027% in CCR, respectively. It implies that numerous environmental prevention guidelines, such as fiscal expenses and environmental costs, are also imposed *via* fiscal decentralization. According to the findings, FD is connected with more efficient and comprehensive financial and monetary reforms, which may enhance environmental sustainability through accountable governance. These findings are comparable to those of Fredriksson and Millimet (2002), Cheng et al. (2021), and Tufail et al. (2021). A greater degree of FD is required for environmental improvement. As a result, it is critical to specify duties at various levels of authority in order to effectively attain the goal of reduced CO_2 emissions and energy-saving mechanisms of fiscal expenses.

As per our findings, a 1% raise in NRE results in a 0.546, 0.511, and 0.548% boost in CO_2 emissions, respectively. The NRE findings support the commonly held belief that NRE is the

TABLE 4 | Results of bayer-hanck cointegration.

	Fisher statistics	Fisher statistics	Cointegration
$CO_2 = f$ (FD, NRE, REN, GDP, TOP)	EG-JO 15.4213	EG-JO-BO-BDM 26.0567	Yes
5%	Critical value 10.576	Critical value 20.143	—

TABLE 5 | Long-run results.

Variables	FMOLS	DOLS	CCR
FD	−0.2832*** (−2.4651) [0.0001]	−0.2401*** (−2.7631) [0.0009]	-0.3027*** (−2.9782) [0.0471]
NRE	0.5461*** (4.1038) [0.0001]	0.5114** (2.5284) [0.0124]	0.5484*** (4.2107) [0.0000]
REN	−0.0549*** (-4.0507) [0.0001]	-0.0571*** (−4.9796) [0.0033]	−0.0565*** (−4.2184) [0.0000]
GDP	0.3507*** (2.6769) [0.0081]	0.3273* (1.8898) [0.0605]	0.3476*** (2.7784) [0.0060]
TOP	0.3597*** (3.7431) [0.0003]	0.3326*** (2.8369) [0.0065]	0.3656*** (4.2172) [0.0007]
Constant	−4.1959*** (−4.1959) [0.0001]	−4.3099*** (−2.9988) [0.0031]	−4.1947*** (−4.1947) [0.0000]
R^2	0.9441	0.9525	0.9441
Adjusted R^2	0.9426	0.9439	0.9427

, **, and * show significance at 10, 5, and 1% levels, correspondingly.*

primary root of environmental pollutants. So, our findings corroborate empirical facts presented by Shabir et al. (2022) and Saud et al. (2019). The empirical findings also indicate that the studied economy consumes a lot of energy, which is bad for the atmosphere. It is suggested that Japan should enhance energy performance by increasing the use of alternative energy sources, which will cut pollution. Hence, the Japanese government must focus on developing approaches that can boost energy utilization. When referring to the connection between REN and CO_2 emissions, we can see that the REN has a negative and substantial impact. A 1% augment in REN diminishes CO_2 emissions by 0.054, 0.057, and 0.056%, respectively. It contends that renewable energy is a coherent and important factor in boosting the effectiveness of the atmosphere. Our findings on REN are familiar with those of other studies, which show that utilizing REN increases environmental performance (Dogan and Seker, 2016; Wolde-Rufael and Weldemeskel, 2020; Shah et al., 2021; Hanif et al., 2022). Our results propose that increasing the use of renewable energy could be a useful strategy framework for improving Japan's environmental sustainability.

GDP results indicate that it has a favorable and significant impact on CO_2 emissions. It suggests that a 1% upsurge in GDP will contribute to 0.350, 0.327, and 0.347% spikes in CO_2 emissions, respectively. It must be acknowledged that an upsurge in a nation's GDP has a strong impact on the ecosystem, and prolonged and irregular use of a country's resources further degrades the performance of the atmosphere. As a result, the level of CO_2 emissions will eventually increase. This signifies that as the gross domestic product rises, nations will shift their focus to more industries, further raising demand for greater levels of energy usage. The outcomes corroborate those of Salahuddin et al. (2018), Umar et al. (2020), and Kirikkaleli et al. (2022). Likewise, TOP has a substantial favourable influence on CO_2 emissions. It insinuates that TOP adds to the deterioration of the environment. A 1% raise in TOP boost CO_2 by 0.359, 0.332, and 0.365%, respectively. Because of the spike in export sales, this result may be justified; however, the scale effect may have aided in contamination by raising the growth of the economy. This conclusion also suggests that future studies must look into imported advanced technology in the aspect of ecological issues. Finally, the composition effect could as well be the

TABLE 6 | Results of Frequency domain causality test.

Direction of Causality	Long-term		Medium-term		Short-term	
	ω_i = 0.01	ω_i = 0.05	ω_i = 1.00	ω_i = 1.50	ω_i = 2.00	ω_i = 2.50
FD →CO_2	5.7999* (0.0550)	5.8058* (0.0549)	0.1947 (0.9073)	0.1695 (0.9188)	0.1797 (0.9141)	0.1865 (0.9110)
NRE →CO_2	0.3831 (0.5611)	0.3281 (0.9321)	6.2921** (0.0211)	6.4941** (0.0731)	2.7233 (0.5914)	3.0649 (0.4100)
REN→CO_2	6.4268** (0.0137)	6.7621** (0.0235)	0.2513 (0.1777)	0.2173 (0.1935)	0.4183 (0.4497)	0.1657 (0.5295)
GDP→CO_2	6.856** (0.0237)	6.0521** (0.0430)	5.5686 * (0.0758)	6.8754** (0.0353)	0.3142 (0.2266)	0.2853 (0.3715)
TOP→CO_2	6.8562** (0.0529)	6.4472** (0.0242)	0.2093 (0.9007)	0.1646 (0.9210)	0.1506 (0.9274)	0.1451 (0.9300)

*The values within () indicate p-value. → Indicates the direction of causality. * and ** indicate significance at 10 and 5% levels, respectively. SIC, determines the lag lengths for the VAR models.*

rationale for the favorable impact of international trade on carbon emissions. These outcomes are akin to the conclusion of Fan et al. (2020), Nawab et al. (2021), and Yang et al. (2021).

A frequency-domain causality method is used in this research to evaluate the causal connection between parameters (**Table 6**). The frequency value of 0.01–0.05 for the long, 1.00–1.50 for the medium, and 2.00–2.50 for the short-run to test the causal association between variables. The results indicate that FD, REN, and TOP emit CO_2 in the long term. However, NRE only contributes to CO_2 emissions in the medium term. Likewise, GDP causes CO_2 in the medium to long-term. As a result, any strategy change in FD, REN, or TOP has repercussions for CO_2 emissions in the long term. Likewise, any strategy adjustment in NRE affects CO_2 in the medium term. Furthermore, any policy change in GDP affects CO_2 in the medium to long term.

5 CONCLUSION AND POLICY RECOMMENDATIONS

The rapid rising CO_2 emissions have piqued the interest of scholars who are attempting to identify the aspects that influence CO_2 emissions. Several research works have been performed in order to determine the primary issue of environmental deterioration. Nevertheless, apart from foreign direct investment, globalization, and technological innovation, researchers frequently ignore a nation's political structure because of its indirect, difficult-to-measure impact on carbon minimization. In the case of Japan, this study looked at the effect of FD on CO_2 emissions in the presence of NRE, REN, GDP, and TOP. When developing strategies to acquire sustainable development, it is critical to acknowledge the relationship between FD and CO_2 emissions. The empirical analysis yields reliable outcomes: a) CO_2 emissions, FD, NRE, REN, GDP, and TOP are long-run cointegrated variables; b) FD, NRE, REN, GDP, and TOP are prominent components in understanding CO_2 emissions in Japan; c) FD and REN are useful in decreasing CO_2 emissions in Japan; d) NRE, GDP, and TOP are detrimental to environmental performance; e) any plan change in FD, REN, GDP, and TOP has repercussions for CO_2 emissions in the long-term.

The research's conclusions can aid in the development of FD and environmental reforms in Japan. Japan must develop solutions to combat emissions in order to control declining environmental performance. Encouraging energy-efficient schemes to modify the industries to renewable energies is essential. Furthermore, to ease the process, it is critical to specify tasks at various tiers of authority in order to effectively reach the benchmark of reduced pollution and energy-saving fiscal expense systems. It is necessary to concentrate on environmentally friendly advanced technologies that shift economic expansion contributors away from nonrenewable energies to renewable and sustainable sources of energy. These environmentally friendly advancements have far-reaching impacts on the ecosystem and global warming. Furthermore, in order to encourage innovations, Japanese economic structures must be altered.

However, this research only offers introductory empirical support and some constraints are still. One such constraint is associated with the control parameters utilized in this research; in future studies, it would be informative to incorporate additional control parameters into our model. Another difference is that we only used Japan as a case study. The study's findings can be expanded to other nations or groups of countries.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/ Supplementary Material.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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