https://doi.org/10.52131/joe.2023.0503.0155

*i*RASD Journal of Economics

Volume 5, Number 3, 2023, Pages 690 – 712

Journal Home Page:
https://journals.internationalrasd.org/index.php/joe

Eco-Friendly Transitions in Top Ten CO2 Producing Countries: A Dynamic Panel Investigation of Green Finance, Technology Transfer and Financial Development for Reducing Environmental Degradation

Amna Shafqat[1], Sadia Idrees[2], Sarfraz Zaman[3], Muniba Ghaffar[4]

[1] MS Scholar, Faculty of Management Science and Business Administration, Superior University, Lahore, Pakistan. Email: amnashafqat111@gmail.com
[2] Faculty of Economics and Commerce, Superior University, Lahore, Pakistan. Email: sadia.visiting@superior.edu.pk
[3] Associate Professor, Faculty of Management Science and Business Administration, Superior University, Lahore, Pakistan. Email: sarfraz.zaman@superior.edu.pk
[4] MPhil Scholar, Faculty of Economics and Commerce, Superior University, Lahore, Pakistan. Email: munibaghaffar11@gmail.com

ARTICLE INFO

Article History:
Received: June 28, 2023
Revised: August 26, 2023
Accepted: August 27, 2023
Available Online: August 29, 2023

Keywords:
Green Finance
Financial Development
Technology Transfer
NARDL
Green Investments

JEL Classification Codes:
B23, E22, F65, P34, L24

Funding:
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

OPEN ACCESS

ABSTRACT

This study delves into the imperative challenge of fostering eco-friendly transitions within the top 10 CO2 producing countries, employing a sophisticated dynamic panel investigation. Centered on the pivotal drivers of green finance, technology transfer, and financial development, the research seeks to comprehensively understand their synergistic role in mitigating environmental degradation. Utilizing advanced econometric techniques, notably the Nonlinear Autoregressive Distributed Lag (NARDL) model, the investigation unfolds the intricate dynamics and nonlinear relationships shaping the effectiveness of these transitions over time. The findings not only contribute empirical insights but also bear substantial policy implications. They underscore the necessity for robust regulatory frameworks and international cooperation to incentivize green investments, facilitate technology transfer, and promote financial development geared towards sustainability. In addressing the environmental challenges posed by these leading CO2 emitters, this research advocates for a holistic approach that integrates economic growth with environmental stewardship, thereby paving the way for transformative and resilient eco-friendly practices on a global scale.

Corresponding Author's Email: tasirkhan199@gmail.com

Citation: Shafqat, A., Idrees, S., Zaman, S., & Ghaffar, M. (2023). Eco-Friendly Transitions in Top Ten CO2 Producing Countries: A Dynamic Panel Investigation of Green Finance, Technology Transfer and Financial Development for Reducing Environmental Degradation. *IRASD Journal of Economics*, *5*(3), 690–712. https://doi.org/10.52131/joe.2023.0503.0155

1. Introduction

Without a doubt, universal warming is the most substantial difficulty embroidery the modern experience. Pollution exhalations have increased greatly by virtue of nations prime to use more energy and raw materials from diverse sources to solve the best quality of monetary growth. Severe storms, erratic rainfall, and rising sea levels are all consequences of environmental degradation and global warming. The most pressing issue that the modern world is facing today is undoubtedly global warming. The need for economic growth has led nations to consume more energy and natural resources, causing pollution emissions to skyrocket. This has resulted in environmental degradation, leading to extreme weather, periodic precipitation, and rising sea levels. All of these are serious consequences of global warming. Designing environments for humans and animals is significantly impacted by these changes. The growing concerns about the environment and global warming have focused academics' attention on finding the most effective ways to cut carbon dioxide emissions without causing the economy to grow more slowly (Boutabba, 2014; Kanwal, Khalid, & Alam, 2023).

"China stands as the world's leading (CO_2) emissions, primarily due to rapid industrialization and heavy reliance on coal for energy production (Lee, Chang, & Chen, 2008). Canada, despite its smaller population, exhibits notably high per capita emissions, largely driven by energy-intensive industries, such as the extraction of oil sands (Alahdad, Hai, Holburn, & Rivard, 2020). India ranks as one of the major global CO_2 emitters due to its burgeoning population and expanding coal usage for energy generation (Ibrahim et al., 2021). Indonesia faces rising emissions attributed to deforestation and land-use changes (Galiatsatos et al., 2020). Japan, historically a significant emitter, has made efforts to reduce emissions through energy efficiency measures and renewable energy adoption (Gao, Hiruta, & Ashina, 2020). Germany, a European industrial powerhouse, maintains a substantial carbon footprint, even as it transitions towards renewable energy sources (Berger et al., 2022). Russia's emissions are driven by its extensive energy sector and vast landmass (Bank, 2021). Saudi Arabia's emissions are primarily a result of its heavy reliance on oil (Grand & Wolff, 2020; Qadri et al., 2023; J. Zhao et al., 2023). The United States ranks among the top global emitters, with emissions originating from energy and transportation sectors (VEAL, 2021). Lastly, Brazil experiences increasing emissions from deforestation and agriculture, notably in the Amazon rainforest (Dawood, ur Rehman, Majeed, & Idress, 2023; Friedlingstein et al., 2020; Shahzadi, Ali, Ghafoor, & Rahman, 2023).

Apart from spearheading Mission Innovation and other global partnerships such (Ullah, ur Rahman, & Rehman, 2023; Zahra, Nasir, Rahman, & Idress, 2023). Research, development, and deployment (RD&D) funding for sustainable energy has increased significantly in India and is a prominent participant and leader at international conferences (Chaudhary, Nasir, ur Rahman, & Sheikh, 2023; Hafiza et al., 2022).

China's per capita CO2 emissions in 2019 were estimated to be 7.05 metric tonnes per person by the Kohl (2019) study, and it contributed around 28% of global CO_2 emissions (Khan & Saif-ur-Rehman; C. Shahid, Gurmani, Rehman, & Saif, 2023; Usman, Rahman, Shafique, Sadiq, & Idrees, 2023). Canada had a relatively high per capita CO_2 emissions rate, estimated at 16.85 metric tons per person in 2019. However, its contribution to global CO2 ejaculations was approximately 1.6%. per capita diffusions of India is (1.9 tons) and provide (7%) to all-encompassing CO2 emissions (Ilyas, Banaras, Javaid, & Rahman, 2023; Saboori, Sapri, & bin Baba, 2014). Indonesia had a per capita CO_2 emissions rate of around 2.12 metric tons per person in 2019, contributing about 2.6% to global CO_2 emissions. Japan had a per capita CO_2 emissions rate of approximately 7.29 metric tons per person in 2019 and contributed about 3.8% to global CO_2 emissions. Germany's per capita CO_2 emissions were around 9.07 metric tons per person in 2019, contributing approximately 2.1% to global CO_2 emissions (Awan, Rahman, Ali, & Zafar, 2023; Ilyas et al., 2023; Sachs, Woo, Yoshino, & Taghizadeh-Hesary, 2019). Russia had a per capita CO_2 emissions rate of about 11.07 metric tons per person in 2019 and contributed around 5.3% to global CO_2 emissions. Saudi Arabia's per capita CO_2 emissions were relatively high, at approximately 15.94 metric tons per person in 2019. It contributed about 2.4% to global CO_2 emissions Li et al. (2022) and (Fatima, Jamshed, Tariq, & Rahman, 2023; Shahzadi, Sheikh, Sadiq, & Rahman, 2023; Wang, Kang, Wang, & Xu, 2017). The United States had a per capita CO_2 emissions rate of about 16.56 metric tons per person in 2019 and contributed approximately 14% to global CO_2 emissions. According to Zerbib (2019), Brazil's contribution to global CO2 emissions in 2019 was 2.6%, with a per capita rate of 2.14 metric tons per person (Javaid, Noor, Hassan Iftikhar, Rahman, & Ali, 2023; Mukhtar et al., 2023).

In addition, the transition from a living economy reliant on labor and animals to a nonliving economy reliant on energy-hungry technology that needs to endure in a toxic and contaminated environment (Mujtaba, Jena, & Mukhopadhyay, 2020; Nawaz, Rahman, Zafar, & Ghaffar, 2023; Tabassum, Rahman, Zafar, & Ghaffar, 2023; Zulfiqar, Naveed, Khoula, & Rahman, 2023). Furthermore, the climate is one of the changes that have happened internationally, according to (Nathaniel, Yalçiner, & Bekun, 2021). This shift is detrimental to the environment because of all the issues it causes, including pollution, deforestation, global warming, and climate change (Hassan, Sheikh, & Rahman, 2022; Ozcan, Ulucak, & Dogan, 2019; S. u. Rahman, Chaudhry, Meo, Sheikh, & Idrees, 2022; Usman et al., 2023). According to many environmental economists, global warming—primarily caused by greenhouse gas emissions—poses the biggest threat to the extinction of humans (Gozgor, 2017; Khoula, ur Rehman, & Idrees, 2022; Li et al., 2022; Park et al., 2018). The United Nations Framework Convention on Climate Change (IPCC) studies indicate that the main cause of the 20-year increase in greenhouse gas emissions has been the emission of carbon dioxide. According to an IEA calculation from 2011, airborne carbon dioxide contributes more than 60% of the greenhouse gas content. Government and nonprofit organizations in an attempt to reduce greenhouse gas emissions (Halicioglu, 2009).

Even though a variety of factors combine to produce CO2 emissions, certain studies, like those conducted by T. Chen, Gozgor, Koo, and Lau (2020); Erdoğan, Yıldırım, Yıldırım, and Gedikli (2020); Fatima et al. (2023); Sharif, Raza, Ozturk, and Afshan (2019), Confirm that the main cause of rising CO2 emissions is the use of non-renewable energy. This study used an empirical model to investigate the asymmetrical effects of financial development (FD), green finance (GF), technology transfer (TT), and foreign direct investment (FDI) on CO2 emissions in Brazil, India, and other countries. Germany, Canada, Saudi Arabia, the US, Indonesia, China, Japan, and Russia. The explanation for this is that the economies of the top ten nations are characterized by instability, rapid growth, and a heavy reliance on fossil fuels, all of which significantly increase atmospheric carbon dioxide emissions and the ensuing degradation of the environment Global signatures on a number of international agreements, including the Kyoto Convention (Hafiza et al., 2022; Zulfiqar et al., 2022).

FDIs (foreign direct investments) are a potent instrument for the transfer of technology, money, and other talents. They have three effects: social, political, and economic. The likelihood of a cultural shift in society is the main worry of the social repercussions, while the insecurity of national independence is the main emphasis of the political effects. In general, FDI inflows truly dictate a nation's level of technical advancement. At first, a number of researchers (Khachoo & Sharma, 2016; C. Shahid, Muhammed, Abbasi, Gurmani, & ur Rahman, 2022; Shahzadi, Sheikh, et al., 2023).

By analyzing the dynamic interaction between green finance, technology transfer, financial development, and environmental degradation in the context of the top 10 CO2 producing nations, the study seeks to close a gap in the literature. It contributes by providing empirical insights into the effectiveness of these factors in promoting eco-friendly transitions in these nations. The annual panel data utilized for this study was collected between 1990 and 2020. Reliable econometric methods were employed to fulfil the objectives of the study. The results showed that every variable was first identified as stationary and cointegrated throughout time. Using the unique technique of NARDL, which displays both positive and negative shock, the elastic effects of the predictors on the response variable were investigated (S. u. Rahman et al., 2022; Sarwar, Ali, Bhatti, & ur Rehman, 2021).

The asymmetric effect of these mentioned factors on CO2 emissions, specifically with respect to the top 10 CO2 generating countries, has not been well-explored in the literature (Younas, Idrees, & Rahman, 2021; Zhu, Fang, Rahman, & Khan, 2023). In this study, the nonlinear interactions and lagged effects between the independent and dependent variables are captured by the NARDL model, These studies concentrate on particular developing nations, however in order to provide useful information for these nations' policy makers, we are concentrating on both developed and emerging nations (the top 10 CO_2 producing economies) (Shafique, Rahman, Khizar, & Zulfiqar, 2021).

The study's remaining section is organized as follows: The "Review of literature" portion displays the literature review, whereas the "Materials and methods" section illustrates the material and method (Ali, ur Rahman, & Anser, 2020; Attahiru et al., 2019). The experiment's findings and debates are displayed in the section titled "Empirical findings and discussion." "Conclusions and Policy Implications" provides concluding remarks, suggestions for additional research, and policy implications (Attahiru et al., 2019; Khoula et al., 2022).

2. Literature Review

Numerous empirical studies observed an association among CO_2 emissions and economic booms for a pattern of rich and/or growing international locations, together with BRIC nations Arouri, Youssef, M'henni, and Rault (2012); Pao and Tsai (2011); Saboori et al. (2014) and small-economic system countries (Lee et al., 2008).

According to current research, carbon dioxide (CO_2) emissions could be decreased, and green financing could be used to pay for environmental regulations (Brandi, Schwab, Berger, & Morin, 2020; Li et al., 2022; Nouira, Hammami, Frein, & Temponi, 2016). It can cut fossil fuel consumption by 26%, potentially resulting in a 12.4% reduction in CO_2 emissions (Thrän et al., 2017). Further research indicates that inexperienced financing can enhance environmental quality through the reduction of carbon dioxide (CO_2) emissions and support for environmentally related laws (Brandi et al., 2020; Li et al., 2022; Nouira et al., 2016). It can reduce the use of fossil fuels by 26%, which would result in a 12.4% reduction in CO_2 emissions (Thrän et al., 2017). Several sustainable improvement goals are directly and indirectly associated with inexperienced finance, and they may be attained by encouraging personal contributions to green finance and investment (Sachs et al., 2019).

While many studies have looked at the symmetric impact of things on CO_2 emissions, very few presently available studies estimate the asymmetric effect on CO_2 emissions. Wang et al. (2017) found that CO_2 emissions and different variables had been definitely and drastically correlated in 95 nations between 1996 and 2007. It was also found that decreasing CO_2 emissions at some point in the production method was a successful strategy for halting global warming. As a result, we've divided this into 4 sections.

Many empirical studies have looked at the relationship between money growth and CO_2 emissions for a range of developed and developing countries, such as the OECD Saboori et al. (2014), small-economic system countries Lee et al. (2008), MENA countries Arouri et al. (2012), BRIC countries Pao and Tsai (2011), industrialized countries Saboori et al. (2014), and small-financial system countries (Arouri et al., 2012). Recent research indicates that it is possible to reduce carbon dioxide (CO_2) emissions and use inexperienced finance to pay for environmental law (Brandi et al., 2020; Li et al., 2022; Nouira et al., 2016). According to IEA estimates from 2017, a 26% decrease in fossil fuel use would translate into a 12.4% decrease in CO_2 emissions (Brandi et al., 2020; Li et al., 2022; Nouira et al., 2016).

Encouragement of personal contributions to inexperienced finance and investment can assist in achieving some of the sustainable improvement dreams, which can be both without delay and in a roundabout way associated with green finance (Attahiru et al., 2019; Sachs et al., 2019).

Few studies that are currently available estimate the uneven impact on CO_2 emissions, despite the fact that many studies examine the symmetric impact of things on CO_2 emissions.

Between 1996 and 2007, Li et al. (2022) observed a positive and giant correlation among CO2 emissions and different variables in ninety-five extraordinary nations. Additionally, it was discovered that decreasing CO2 emissions through the production method became an effective way to prevent international warming. As a result, we've divided this into four sections. The first one is prepared as follows and discusses the connection between economic growth and CO2 emissions:

2.1. CO_2 Emission and Green Finance

Reducing carbon emissions by 40 percent by 2030 will require both money and technology (Deng et al., 2021). This highlights the role of green finance in tackling climate change. This is achieved by pooling resources from public, private and alternative funding sources and providing support for adaptation and mitigation programmers.

Despite its growing popularity, not many experts have conducted research on the relationship between green money and environmental quality. The direct relationship between green money and environmental degradation remains unclear, despite its importance. The transition from a growth economy to a green economy requires financing from green sources. Therefore, national leaders should provide green financing for these projects (Dong et al., 2020).

Dong et al. (2020) argue that green finance has a positive impact on CO2 emissions, economic growth and energy constraints Wei, Zhu, and Glomsrød (2018) Government and encouraging green financial policies can increase investment in renewable energy (Romano, Scandurra, Carfora, & Fodor, 2017). More specifically, compared to other financial arrangements, green bonds are a much more sensible way to fight climate change because they channel money to projects that benefit the environment.

Previous research on green finance includes green bond prices Flammer (2021); Gianfrate and Peri (2019); Hachenberg and Schiereck (2018); Zerbib (2019), Market and response to green bond issuance (Tang & Zhang, 2020). However, to the best of our knowledge, no research has been conducted to examine the relationship between Greenfields and CO2 emissions using NARDL Green investments support the goals of sustainability as described by Sachs et al. (2019) and (Dikau & Volz, 2018). Environmentally conscious private investment reduces carbon emissions and makes developing economies low-carbon and green, (Azhgaliyeva, Kapsaplyamova, & Low, 2018). However, a small number of scientists have opinions that differ from the majority. The issuance of bank loans is negatively affected by the growth of green financing, which also worsens environmental conditions and reduces the profitability of investments in renewable energy. Thus, a positive change in green financing can have a greater impact on CO2 emissions than a negative one.

2.2. CO2 Emission and FDI

Many studies agree 628 foreign direct investment (FDI) is necessary for economic growth, despite conflicting data on FDI and environmental impacts. Bashir provides a brief summary of research on the pollution haven theory. "And pollution is According to the theory, an increase in the volume of direct investment could encourage economic growth, which would increase the host dioxide emissions. The first leads to higher energy consumption and CO2 emissions. The latter argue that developed countries should change their carbon-intensive economic activities to provide developing countries with shelter from pollution (Aliyu, 2005). Various dirty and inefficient industrial and infrastructure projects are said to be caused by rich countries sending direct investment to developing countries (Jorgenson, Dick, & Mahutga, 2007).

The connection between carbon emissions and foreign direct investment is the main focus of the Pollution Haven theory According to this theory, dirty technology transfers resulting from foreign direct investment (FDI) technological progress from rich countries to emerging economies increase carbon dioxide emissions (S. Rahman & Idrees, 2019; Sun et al., 2017).

The different effects of factors on direct investment and remittances are the subject of many studies (Brown, McFarlane, Campbell, & Das, 2020; Haug & Ucal, 2019). According to the literature, FDI and remittances have different environmental effects. In addition, studies show that foreign direct investment (FDI) dramatically reduces CO2 emissions over time (Bakhsh, Yin, & Shabir, 2021; Pazienza, 2019). But according to a recent study of the Indian economy by F. Shahid, Zameer, and Muneeb (2020), innovation and FDI inflows have had long-term negative effects on CO2 emissions. Therefore, direct investment has a large impact on CO2 emissions.

2.3. CO2 Emission and Technology Transfer

Similarly, Park et al. (2018) examined the relationship between CO2 emissions and patent development—proxies for technological innovation—in 36 OECD countries between 1996 and 2015 using a panel quantile regression model. The review then examines theoretical models and empirical studies investigating the relationship between technology transfer and CO2 emission reductions. For this, it would be necessary to assess the extent to which trade agreements, foreign direct investments and international cooperation help developing countries adopt low CO2 practices and technologies (Shahbaz, Raghutla, Song, Zameer, & Jiao, 2020). Found no significant correlation between carbon dioxide emissions and carbon-free energy patents between China and the central and western regions, but between the country and the eastern regions. Saboori et al. (2014) showed that green patents had a positive effect on reducing CO2 emissions except in the central region, the whole country and China in the eastern and western regions. The negative correlation between Beijing's CO2 emissions and energy technology patents was also verified by (Wang et al., 2017).

2.4. CO2 emission and financial development

Meng, Guo, Chai, and Zhang (2011) argues that there is a complex relationship between foreign direct investment (FDI) and China's carbon emissions. Economic analysis shows that FDI can contribute to carbon emissions. However, Abbasi and Riaz (2016) found that FDI has little effect on reducing carbon emissions. The study by A. U. Shahid et al. (2022) on the impact of Japanese foreign direct investment (FDI) and global carbon dioxide emissions confirming Kuznetsand#039 environment. Concept Finally, Jiang and Ma (2019) examine the relationship between global carbon dioxide emissions and food insecurity. Their findings may be useful for developing or emerging economies, but may not be relevant for developing countries.

Emissions are more strongly influenced by the growth of financial institutions and the stock market. They continued that as economies grow, developing countries experience both positive and negative effects. China and factors affecting carbon emissions were investigated by Shen et al. in 2021. The results showed that while food distribution and resource use lead to higher emissions, green investments have a negative correlation, i.e. lower emissions with carbon dioxide emissions. Xu, Sheraz, Hassan, Sinha, and Ullah (2022) conducted a more recent study that confirmed F.D. emissions of carbon dioxide. Excessive dependence on natural resources further weakens the financial systems of the economy (Park et al., 2018; Umar, Ji, Mirza, & Li, 2022). Explaining compliance with economic development and policy implementation is difficult. According to some researchers Bowen et al. (2017); Okafor, Onyeisi, and Ogbuagu (2023), financial development is calculated by dividing the gross domestic product by the ratio of domestic credit to the private sector. Growing bank lending to the private sector boosts production and sector growth. What is important, however, is how companies actually use these resources to channel through banks. Current research on bank loans explains their impact on carbon emissions in two ways.

According to Nasir, Huynh, and Tram (2019), domestic loans to the private sector increase pollution and harm carbon emissions. In a recent study, Xu et al. (2022) also confirmed F.D. positive effect emissions of carbon dioxide. On the other hand, Yi, Ko, Park, and Park (2018) and Zaidi, Zafar, Shahbaz, and Hou (2019) showed that F.D. harms carbon dioxide emissions. Thus, it has a detrimental effect on CO2 emissions.

3. Methodology

This study uses annual data on technology transfer (TT), economic development (FD), green finance (GF), foreign direct investment and carbon emissions (kilotons, Kt). CO2 is measured in kilograms (kt), financial development (FD) is domestic credit to the private sector relative to GDP, and direct investment is measured in tons-year. Renewable energy consumption is a green financing (GF) measure. A telephone subscription contract for 100 people is a technical transfer (TT) procedure. All information except economic development is from the (Bank, 2021). Based on data availability, 1990-2022 was selected as the study period. Data from the top 10 CO2-emitting countries (Brazil, China, Canada, India, Indonesia, Japan, Germany, Russia, Saudi Arabia, and the United States) were analyzed using various econometric methods. Table 1 provides descriptions of variables, units of measurement, and data sources. This section also discusses the test for asymmetric causality using nonlinear autoregressive regression (NARDL) developed by Shin, Yu, and Greenwood-Nimmo (2014). In addition to CD tests, group root tests and various covariance tests, a non-linear ARDL approach is used to investigate the asymmetric effects of components on CO2 emissions. This estimation strategy is based on the following objectives: (i) It is possible to integrate nonlinear and convergent symmetries in a single equation. NARDL models consider positive and negative effects on the dependent variable when the variable shows positive and negative changes. (ii) the model can be applied to small samples; (iii) It is simple because there is no need to enter variables in a specific order. (iv) a dynamic demonstration of error correction that shows valid results despite the small sample size;

$$CO\_2 = \rho(GF, FDI, TT, FD) \tag{1}$$

CO2, GF, FDI, TT, FD stand for financial development, technology transfer, green and carbon finance, in that order. We argue that these variables are the main drivers of CO2 emissions and high emissions.

Table 1
Variable Description

Variables	Sources and measuring units
Carbon dioxide (CO_2) emissions	Build the PCA. World Bank-world development indicators-WDI-2022. Kilo ton (Kt) I made a PCA should mentioned?
FDI (FDI) inflow	World Bank-world development indicators-WDI-2022. (% of GDP inflows)
Financial Development (FD)	International Monetary Fund-2022(domestic credit to the private sector to GDP)
Green Finance (GF)	World Bank-world development indicators-WDI-2022.(Renewable energy consumption)
Technology Transfer (TT)	Build the PCA. World Bank-world development indicators-WDI-2022.(Fixed telephone subscriptions (per 100 people)

3.1. Panel Unit Root Test

To examine the characteristics of panel-based unit root tests, the first generation of models was created with the presumption that the data is uniformly and independently distributed among people. Levin, Lin, and Chu (2002) and Breitung (1997) developed the first unit root tests. Typically, the following univariate regression serves as the foundation for this specific panel unit root test:

$$\Delta x_{it} = \rho_i x_{it-1} + Z_{it}\, x + \mu_{it} \quad (2)$$

For every t = 1, 2..., T time series observation that is accessible, where i = 1, 2..., N is the individual, its μ_it is a stationary process, and its z_it is the deterministic component. It z_it could be a temporal trend (t), zero, one, the fixed effects (μ_i), or a fixed effect.
Here is the null hypothesis:

$$\rho_i = 0 \; \forall\, i \quad (3)$$

The extent of heterogeneity assessed by the alternative hypothesis is a key factor in the designed tests. Levin et al. presents the new results of panel unit root testing. Levin et al. (2002) and then LLC. They generalize the model to account for individual heterogeneity of deterministic effects (constant and/or linear time trend) and error terms and #039; heterogeneous serial correlation structure assuming homogeneous first-order autoregressive parameters. Although T grows faster than N, they believe that N/T will eventually be zero. LLC compares the null hypothesis H_0: _i = 0 with the alternative hypothesis H_a: _i = 0 for all i using model (2) as an example. This is achieved by assuming that the individual autoregressive coefficients are homogeneous, i.e. _i= for all I's. This procedure limits the cross equation to zero first-order partial autocorrelation coefficients, eliminating the need to maintain a separate unit for each individual from the roots.

The structure of the LLC analysis may be specified as follows:

$$\Delta x_{it} = \rho x_{it-1} + \alpha_{0i} + \alpha_{1i} t + \mu_{it}, \; i = 1, 2, \ldots\ldots, N, \; t = 1, 2, \ldots., T \quad (4)$$

"Where individual impacts and a temporal trend ($\alpha_{1i}t$), are combined. Since the coefficient on the lagged variable must be homogeneous across all items in the panel, it should be noted that the deterministic components form an important basis of heterogeneity in this model. Assume that μ_(it) is freely distributed across individuals and fixed for each individual by a fixed reversible ARMA process.

$$\mu_{it} = \sum_{j=1}^{\infty} \emptyset\, ij\, \mu_{it-j} \; \epsilon_{it} \quad (5)$$

The Phillips (1987) and Phillips-Perron Phillips and Perron (1988) unit root tests are anticipated to produce weak convergence under disturbed moment conditions (Im, Pesaran, & Shin, 2003). IPS, therefore, presents a novel, more flexible, and computationally easier panel root test approach (referred to as the t-bar statistic) that takes into account both stationary and non-stationary series at the same time. IPS uses the mean of the ADF statistic for each cross-sectional unit of the panel as an alternative to pooling if the model error terms u are serially correlated, possibly across cross-sectional units with distinct serial correlation patterns. Details

$$\Delta x_{it} = \alpha_{0i} + p_i x_{it-1} + \sum_{j=1}^{pi} \propto ij\, \Delta x_{it-1} + \epsilon_{it} \quad (6)$$

Where, as usual, i = 1, 2..., N, t = 1, 2..., T.

The null hypothesis is: $H_0 : \rho_i = 0 \; for\ all\ i$

$$H_a : \begin{cases} Pi < 0 \; for\ i = 1, \ldots\ldots.. N_1 \\ Pi = 0 \; for\ i = N_1 + 1, .. N \end{cases} \quad \text{With } 0 < N_1 \le N \quad (7)$$

This permits unit roots for some (but not all) of the individual series. For each of the N cross-section units, IPS calculates a single unit root test, and its t-bar statistic is defined as a straightforward average of each ADF statistic t_iT, for the null as:

$$= \frac{1}{N} \sum_{i=1}^{N} T\, it \tag{8}$$

3.2. Model Specification

Using panel data from 1990 to 2020, this study empirically evaluates the asymmetric link between green finance, FDI, financial development, and technology transfer on CO2 emissions. However, we looked at the top ten countries as a group. The United States, Brazil, Canada, China, India, Indonesia, Japan, Germany, Russia, and Saudi Arabia are among these countries. CO2 emissions are measured in kilotons of CO2 equivalent in this study. The amount of renewable energy consumed measures green finance. FDI, on the other hand, is expressed as a percentage of GDP inflows. The number of fixed phone subscriptions measures technological transfer, but GDP measures financial development through domestic lending to the private sector. Except for financial development statistics, World Development Indicators (WDI) provide data on dependent and independent components. A linear econometric model investigates the relationship between independent and dependent variables. The model specifications can be found here.

$$CO2_{it} = \beta_0 + \beta_1\, GF_{it} + \beta_2 FDI_{it} + \beta_3\, TT_{it} + \beta_4\, FD_{it} + \mu_{it} \tag{9}$$

The letters t, I, and CO2 in this example stand for time, nation, green funding, foreign direct investment, and financial development, respectively.

3.3. NARDL Approach

This section describes the Nonlinear Autoregressive Delay (NARDL) developed by Shin et al. (2014) and This section describes the nonlinear autoregressive delay (NARDL) developed by Shin et al. (2014). The study investigates the asymmetric effects of technology transfer, economic development, and green finance on CO2 emissions using a non-linear ARDL approach. This assessment method aims to achieve the following objectives:

- It allows nonlinear asymmetry and Cointegration to be combined into one equation. The NARDL model examines how changes in the deconstructed variables, both positive and negative, affect the dependent variable.
- The model remains valid despite the small sample size. It is adaptable and does not need the integration of the variables in the same order as it is basically a dynamic error correcting representation. Although the sample size is tiny, the empirical results are strong. Equation (8), which displays changes in both positive and negative descriptive variable values as well as logarithmic changes, is expressed as follows:

$$CO2_{it} = \propto_{it} + \delta_{it} + \beta^{+}\, GF_{it}^{+} + \beta^{-}\, GF_{it}^{-} + \beta^{+}\, FDI_{it}^{+} + \beta^{-}\, FDI_{it}^{-} + \beta^{+}\, TT_{it}^{+} + \beta^{-}\, TT_{it}^{-} + \beta^{+}\, FD_{it}^{+} + \beta^{-}\, FD_{it}^{-} + u_{it} \tag{10}$$

The error, β are the variable coefficients, ln is the natural logarithm, i stands for countries, and δ are the trending effects. The structure of Eq. (9)'s nonlinear autoregressive distributed lag (NARDL) is expressed as follows:

$$\Delta CO2_{it} = \mu + \rho CO2_{it-1} + \vartheta^{+} GF_{it-1}^{+} + \vartheta^{-} GF_{it-1}^{-} + \emptyset^{+} FDI_{it-1}^{+} + \emptyset^{-} FDI_{it-1}^{-} + \omega^{+} TT_{it-1}^{+} + \omega^{-} TT_{it-1}^{-} + \omega^{+} FD_{it-1}^{+} + \omega^{-} FD_{it-1}^{-} + \sum_{j=1}^{n-1} \alpha\, j CO2_{it-j} + \sum_{j=0}^{n2} (\overset{+}{\pi^{j}}\, \Delta GF_{it-j}^{+} + \pi_{j}^{-} \Delta GF_{it-j}^{-}) + \sum_{j=0}^{n3} (\overset{+}{\tau^{j}}\, \Delta FDI_{it-j}^{+} +$$

$$\tau_j^- \Delta FDI_{it-j}^-) + \sum_{j=0}^{n4}(\sigma^+ TT_{it-1}^+ + \sigma^- TT_{it-1}^-) + \sum_{j=0}^{n5}(\rho^{\overset{+}{j}} \Delta FD_{it-j}^+ + \rho_j^- \Delta FD_{it-j}^-) + \epsilon_{it} \quad (11)$$

The short-run NARDL elasticities with an error correcting mechanism can be computed using the following equation:

$$\Delta CO2 = \mu + \sum_{j=1}^{n-1} \alpha\, j\ \Delta CO_{2it-j} + \sum_{j=0}^{n2}(\pi^{\overset{+}{j}}\ \Delta GF_{it-j}^+ + \pi_j^- \Delta GF_{it-j}^-)\ \sum_{j=0}^{n3}(\tau^{\overset{+}{j}}\ \Delta FDI_{it-j}^+ + \tau_j^- \Delta FDI_{it-j}^-) + \sum_{j=0}^{n4}(\forall^+ TT_{it-1}^+ + \forall^- TT_{it-1}^-) + \sum_{j=0}^{n5}(\varepsilon^+ FD_{it-1}^+ + \varepsilon^- FD_{it-1}^-) + \emptyset ECM_{it-1} + \epsilon_{it} \quad (12)$$

The impacts of the variables GF, FDI, TT, and FD can be separated into positive and negative components As we have shown in Eq. (6),

$$GF_{it} = GF_0 + GF_{it}^+ + GF_{it}^- \quad (13)$$
$$FDI_{it} = FDI_0 + FDI_{it}^+ + FDI_{it}^- \quad (14)$$
$$TT_{it} = TT_0 + TT_{it}^+ + TT_{it}^- \quad (15)$$
$$FD_{it} = FD_0 + FD_{it}^+ + FD_{it}^- \quad (16)$$

In all three equations (13, 14, 15) in which GF_0, FDI_0, TT_0, FD_0,shows the random initial value and then $GF_{it}^+ + GF_{it}^-$, $FDI_{it}^+ + FDI_{it}^-$, $TT_{it}^+ + TT_{it}^-$ and $FD_{it}^+ + FD_{it}^-$ represent partial sum approaches, which collect the corresponding positive and negative changes, all of which are explained as follows:

$$GF_{it}^+ = \sum_{j=1}^{it} \Delta\, GF_{it}^+ = \sum_{j=1}^{it} max\left(\Delta GF_j, 0\right),$$
$$GF_{it}^- = \sum_{j=1}^{it} mini\left(\Delta GF_j, 0\right) + \epsilon_{it} \quad (17)$$
$$FDI_{it}^+ = \sum_{j=1}^{it} \Delta\, FDI_{it}^+ = \sum_{j=1}^{it} max\left(\Delta FDI_j, 0\right),$$
$$FDI_{it}^- = \sum_{j=1}^{it} mini\left(\Delta FDI_j, 0\right) + \epsilon_{it} \quad (18)$$
$$TT_{it}^+ = \sum_{j=1}^{it} \Delta\, TT_{it}^+ = \sum_{j=1}^{it} max\left(\Delta TT_j, 0\right),$$
$$TT_{it}^- = \sum_{j=1}^{it} mini\left(\Delta TT_j, 0\right) + \epsilon_{it} \quad (19)$$
$$FD_{it}^+ = \sum_{j=1}^{it} \Delta\, FD_{it}^+ = \sum_{j=1}^{it} max\left(\Delta FD_j, 0\right),$$
$$FD_{it}^- = \sum_{j=1}^{it} mini\left(\Delta FD_j, 0\right) + \epsilon_{it} \quad (20)$$

To examine the long-run symmetry (θ+ = θ−) and asymmetry (θ+ ≠ δ−) of the asymmetric cumulative dynamic multipliers on CO_2 of a unit change in GF_{it}^+, GF_{it}^-, FDI_{it}^+, FDI_{it}^-, TT_{it}^+, TT_{it}^-, FD_{it}^+, FD_{it}^-

$$m_h^+ = \sum_{j=0}^{h} \frac{\delta CO_{2it+j}}{\delta GF_{it-1}^+},\ m_h^- = \sum_{j=0}^{h} \frac{\delta CO_{2it+j}}{\delta GF_{it-1}^-},$$
$$m_h^+ = \sum_{j=0}^{h} \frac{\delta CO_{2it+j}}{\delta FDI_{it-1}^+},\ m_h^- = \sum_{j=0}^{h} \frac{\delta CO_{2it+j}}{\delta FDI_{it-1}^-},$$
$$m_h^+ = \sum_{j=0}^{h} \frac{\delta CO_{2it+j}}{\delta TT_{it-1}^+},\ m_h^- = \sum_{j=0}^{h} \frac{\delta CO_{2it+j}}{\delta TT_{it-1}^-},$$
$$m_h^+ = \sum_{j=0}^{h} \frac{\delta CO_{2it+j}}{\delta FD_{it-1}^+},\ m_h^- = \sum_{j=0}^{h} \frac{\delta CO_{2it+j}}{\delta FD_{it-1}^-},\ m_h^+ \quad = 0, 1, 2 \ldots. \quad (21)$$

3.4. Principal Component Analysis

To construct PCA, we adhered to the research conducted by (Li et al., 2022), and (Ali et al., 2020). In this study, we use annual data on CO2 emissions, which are proxies for greenhouse gas emissions. We then use Principal Component Analysis, or PCA, to create a comprehensive set of proxies for greenhouse gas emissions. The the feature indices in PCA are expressed as follows:

$$CO_{2_j} = M_{j_1} N_1 + M_{j_2} N_2 \quad (22)$$

We constructed equation for technology transfer (TT), index using the PCA approach as follows

$$IQ_j = O_{j1}P_1 + O_{j2}P_2 \quad (23)$$

Here, TTj betokens the basis of institutional performance. The agnate constant weights are adumbrated by Oj1 and P1j, respectively. P1, P2, .P6 announce the ethics of institutional achievement indicators. Furthermore, we accomplish Principal Component Analysis (PCA) already afresh for blooming advance afterwards assessing the "Technology Alteration Barometer: Fixed Blast Subscriptions (per 100 people), Patent Applications (residents), and Analysis and Development Amount (% of GDP)."

4. Analysis

The aboriginal purpose of the abstraction was to assess the agreement amid CO2 emissions and technology transfer. Another analysis of the abstraction is to acquire out the accord amid CO2 emissions and bread-and-butter development. The third cold of the abstraction is to acquire out the accord amid CO2 emissions and absolute investments. The fourth aim of the abstraction is to investigate the accord amid CO2 emissions and blooming finance.

Table 2
Descriptive Analysis

	CO2	TT	GF	FDI	FD
Mean	6.001	0.849	19.281	1.840	0.581
Median	5.925	1.128	13.430	1.638	0.587
Maximum	7.039	1.128	58.440	12.731	0.933
Minimum	5.210	-2.000	0.010	-2.757	0.018
Std. Dev	0.453	0.992	17.358	1.732	0.206
Skewness	0.512	-1.903	0.585	1.533	-0.220
Kurtosis	2.390	5.928	1.881	8.863	2.082
Jarque-Bera	17.912	287.400	32.905	598.447	12.086
Probability	0.000	0.000	0.000	0.000	0.000

Table 3
Unit Root Test

At Level											
Individual Intercept						Individual Intercept And Trend					
Variables	Common Unit Root	Individual Unit Root			HADRI	Common Unit Root		Individual Unit Root			HADRI
	LLC	IPS	ADF	PP		LLC	BREITUNG	IPS	ADF	PP	
CO2 emission	0.008*	0.921	0.669	0.099*	0.000*	0.259	0.772	0.534	0.634	0.620	0.000*
Green finance	0.989	1.000	0.999	0.999	0.000*	0.000*	0.285	0.001*	0.014*	0.000*	0.011*
FDI	0.013*	0.069*	0.092*	0.105	0.000*	0.014*	0.499	0.044*	0.074*	0.074*	0.000*
Financial Development	0.845	0.004*	0.007*	0.002*	0.000*	0.845	1.000	0.006*	0.013*	0.043*	0.061*
Technology Transfer	0.010*	0.058*	0.092*	0.107	0.000*	0.000*	0.287	0.001*	0.016*	0.000*	0.012*

Basis: Calculation by authors.
*Specifies the statistically significant at 1% levels.

The outcomes of the modeled variables' anecdotic statistics are apparent in Table 2. Table 2 shows anniversary variable's mean, median, skewness, kurtosis, minimum and best ethics for the years 1990–2022. Based on the data, the boilerplate CO2 amount is 6.001, with a minimum of 5.210 and a best of 7.039. Additionally, TT has a beggarly account of 0.849 with a ambit of ethics from -2.000 to 1.128. GF has an boilerplate amount of 19.281 and a minimum and accomplished amount of 0.010 and 58.440, respectively. Comparably, FDI has a beggarly amount of 1.840 and a ambit of -2.757 to 12.731. When evaluating the course of residuals, FD has an boilerplate amount of 0.581, with everyman and accomplished ethics of 0.018 and 0.933, appropriately (Thadewald & Büning, 2007). The anticipation amount shows that the "residuals are commonly distributed" CR absent antecedent is rejected. But in macro abstracts analysis, we may use our archetypal after affair the course acceptance because it won't affect the connections. As of 1974, Amemiya.

Table 4
Unit Root Test

At First Difference Individual Intercept						**Individual Intercept And Trend**					
Variables	**Common Unit Root**	**Individual Unit Root**			**HADRI**	**Common Unit Root**		**Individual Unit Root**			**HADRI**
	LLC	IPS	ADF	PP		LLC	BREITUNG	IPS	ADF	PP	
Co2 emission	0.000*	0.000*	0.000*	0.000*	0.226	0.000*	0.000*	0.001*	0.001*	0.000*	0.014*
Green finance	0.000*	0.000*	0.000*	0.000*	0.334	0.000*	0.001*	0.063*	0.0137*	0.000*	0.008*
FDI	0.021*	0.000*	0.000*	0.000*	0.007*	0.468	0.652	0.038*	0.018*	0.000*	0.000*
Financial Development	0.001*	0.000*	0.000*	0.000*	0.019*	0.038*	0.998	0.000*	0.000*	0.000*	0.000*
Technology Transfer	0.010*	0.058*	0.092*	0.107	0.000*	0.000*	0.287	0.001*	0.016*	0.000*	0.012*

Basis: Calculation by authors.
* Specifies the statistically cogent at 1% levels.

The outcomes of console assemblage basis tests are represented in this area of the empirical study. To actuate the akin of stationarity of the variables activated in the model, we aboriginal ran a few console basis tests. Table 2 lists the outcomes of several console assemblage basis tests, including the Lin, Levin, and Chu, PP, ADF, and IPS tests, the Pesaran and Shin W-stat tests, and the Hadri (2000) tests. The aboriginal cavalcade of Table 2 lists the capricious names acclimated in the models, and the aboriginal row of the table lists the names of assorted assemblage basis tests. The empiric after-effects of anniversary assemblage basis assay are presented at both the akin and the aboriginal aberration for the anniversary series. All variables are anchored at the aboriginal difference, according to the empiric results, while some are acceptably anchored at the level. As a result, console Cointegration empiric assay can be agitated out. A lot of antecedent studies accept that the assay of console Cointegration is advantageous for an appraisal if all archetypal variables are anchored at the aboriginal difference (Pesaran, Shin, & Smith, 2001).

Table 5
Pedroni (Engle-Granger based) Test.

Alternative Hypothesis: Common AR Coef. (Panel A: Within-Dimension)			
Panel co-integration test	**Individual intercept Prob.**	**Weighted Statistics**	**Prob.**
Panel v-Statistic	0.0242*	2.380166	0.0087*
Panel rho-Statistic	0.1678	1.668827	0.9524
Panel PP-Statistic	0.0000*	-1.078237	0.1405
Panel ADF-Statistic	0.0000*	-1.908058	0.0282*
Alternative Hypothesis: Individual Ar Coefs. (Panel B: Between-Dimension)			
Panel co-integration test	Individual intercept Prob.	Statistics	
Group rho-Statistic	0.9992	3.163082	
Group PP-Statistic	0.4078	-0.233250	
Group ADF-Statistic	0.0510*	-1.635356	

Foundation: authors and calculations Schwarz Info criteria were used to select the delay duration. Note: Significance is indicated at the 1%, 5%, and 10% levels by ***, **, and *. Pedroni's panel Cointegration test analysis provides bivariate test statistics: between-dimensional and within-dimensional test statistics.

H0 and H1 of panel Cointegration were compared. At a significance level of 10%, 5%, or 1%, Pedroni's panel Cointegration tests indicate that H0 can be rejected in the absence of Cointegration. Panel Cointegration results are consistent with (Adebayo et al., 2023).

Table 6
Kao (Engle-Granger-based) Test

ADF (Prob.)	Residual variance	HAC variance
0.0006*	0.0074	0.0034

Authors' calculations are the source. Modified Hannan-Quinn was used to choose the lag duration.
Note: Significance is indicated at the 1%, 5%, and 10% levels, respectively, by ***, **, and *.
Specifies the statistically cogent at 1% levels.

Table 6 displays balance about-face and HAC about-face afterward the probability-based Augmented Dickey-Fuller (ADF) Kao console co-integration test, which produces a cogent aftereffect of 0.003. For every cogent variable, a abiding accord is accepted based on the co-integration assay results. Based on the outcomes of the Kao console co-integration test, the absent antecedent that there is no co-integration may be alone at the 10%, 5%, or 1% akin of significance. The abiding relationships amid CO2 emissions and banking development, blooming financing, adopted absolute investment, and technology.

4.1. NARDL Long-Run and Short-Run Valuations

Table 6 shows the abiding and concise admiration after-effects of the console NARDL model. The capital cold of the analysis is to affirm the non-linear aberration of absolute investment, technology transfer, bread-and-butter development, carbon dioxide emissions, and blooming finance.

Table 7
Long Run and Short Run Estimation NARDL

Variable	Coefficient	Std. Error	t- statistics	Prob
FD_POS	0.6108	0.0883	6.9143	0.000
FD_NEG	-0.012	0.008	-1.600	0.111
FDI_POS	-0.027	0.006	-4.231	0.000
FDI_NEG	-0.014	0.005	-2.599	0.010
GF_POS	0.047	0.020	2.330	0.020
GF_NEG	-0.024	0.001	-15.406	0.000
TT_POS	5.204	35.481	0.1466	0.883
TT_NEG	-15.68	88.924	-0.176	0.860
		Short Run		
ECT	-0.696	0.052	-1.834	0.068
d(CO2(-1))	-0.198	0.166	-1.195	0.233
d(FD_POS)	0.086	0.033	2.585	0.010
d(FD_NEG)	-0.109	0.239	-0.457	0.647
d(FDI_POS)	0.000	0.003	0.054	0.956
d(FDI_NEG)	0.001	0.004	0.322	0.747
d(GF_POS)	-0.122	0.033	2.585	0.033
d(GF_POS)	-0.086	0.066	-1.833	0.068
d(TT_POS)	-0.236	0.437	-0.540	0.589
d(TT_NEG)	-0.574	0.312	-1.835	0.067

The abiding archetypal and after-effects appearance the affected coefficients of absolute and abrogating sums for accretion and abbreviating addle variables. The Cointegration analysis accepted the abiding alterity amid greenhouse gases and the bargain variables. Blooming advance accessory estimates acquired from abiding console NARDL abstracts are 2.15 for absolute blinds and -2.09 for abrogating blinds. The abiding and concise admiration after-effects of the panel's NARDL archetypal are apparent in Table 6. Ensuring a non-linear, ages accord amid carbon dioxide emissions and blooming finance, banking development, adopted absolute investment, and technology alteration is the capital objective abstraction. Longitudinal archetypal observations appearance the affected coefficients of absolute and abrogating sums for accretion and abbreviating addle variables. The Cointegration analysis accepted the abiding alterity amid greenhouse gases and the bargain variables. Based on NARDL abstracts from abiding panels, the blooming advance accessory estimates for absolute and abrogating blinds are 2.15 and -2.09, respectively. Long-term constraints arise even though it might be difficult to offer accurate estimates for computations without technology transfer. Governments should, therefore, make logical judgements and control all aspects in the near future, according to empirical evidence (Moss et al., 2008). Any factor having an immediate effect has the potential to cause positive shocks. For instance, CO_2 will rise by 0.010 if green financing increases by one unit. However, when green investments experience adverse shocks, controlling CO_2 emissions may become challenging. The CO_2 will drop by 0.647 units, for instance, if green investment increases by one unit. According to empirical research, the government must make rational decisions and retain short-term control over all factors in order to provide accurate estimations for computations, which eventually become long-term obstacles (Khanal, Rahman, Khanam, & Velayutham, 2022).

The long-run after-effects appear that estimates for both increases in Blooming accounts (GF) and losses in GF are both absolute and negative. One-unit access in blooming costs (GF-POS) is additionally associated with a 0.020 access in greenhouse gas emissions, according to the results, but a one-unit abatement in blooming accounts (GF-NEG) is associated with a 0.000 access in greenhouse gas emissions. Furthermore, we ascertain that improvements in blooming investments (GF-POS) accept a greater aftereffect on greenhouse gas emissions than decreases in investments (GF-NEG).

Our after-effects add to the anatomy of affirmation acknowledging the abiding alterity amid CO_2 and adopted absolute emissions. The after-effects appearance that CO_2 emissions abatement by 0.000 for every assemblage access in adopted absolute advance (FDI_POS) and by -0.010 for every assemblage abatement in adopted absolute advance (FDI_NEG). Compared to FDI_NEG, we acquire that FDI_POS has beneath of an appulse on CO_2 emissions. As declared by Lubitz, Teeter, Parker, Dalton, and Dyck (2023). The projections for assets and decreases in banking development (FD) are both absolute and negative, based on the long-run results. The after-effects appear as a one-unit acceleration in Banking development In contrast, a one-unit abrogating shock in Banking development (FD -NEG) after-effects in a 0.111 abiding abridgment in CO_2 emissions. (FD_POS) additionally causes a 0.000 access in CO_2 emissions. Furthermore, we acquire that banking development advancements (FD-POS) accept a bigger appulse on CO_2 emissions than banking development setbacks (FD-NEG). These investigations abutment Khanal et al. (2022) findings. According to Wang et al. (2012c), a one-unit abatement in technology alteration (TT_NEG) after-effects in a 0.860 abatement in CO_2 emissions, admitting a one-unit acceleration in technology alteration (TT_POS) after-effects in a 0.883 access (R. Zhao et al., 2015).

4.2. Findings

In contemporary decades, researchers, scholars, economists, and policymakers accept accustomed banking development (FD) an abundant accord of absorption (Z. Chen, Mirza, Huang, & Umar, 2022). Numerous studies accept approved that adopted absolute advance (FDI) is advantageous to the abridgement due to the technology alteration it generates (Bustani, Khaddafi, & Ilham, 2022). A country's adeptness to advance economically and socially depends on its banking sector. Consider the ecology appulse of FD as well. Many studies accept advised the accord amid FD and ecology quality, but the after-effects are not absolutely reliable. The best frequently acclimated measures are deposits (bank funds), aqueous liabilities, and adopted absolute advance (FDI) as a allotment of GDP in calm acclaim to the clandestine area (Bustani et al., 2022; Usman & Balsalobre-Lorente, 2022). According to the first, FD lowers carbon dioxide emissions, appropriately convalescent the affection of the environment. Analysis has approved a absolute alternation amid FD and ecology abasement (Altarawneh et al., 2022; Jalil & Feridun, 2011) . Among the top ten countries, Salahuddin and Alam (2015) apparent that FD had a CO2-reducing effect.Dogan and Seker (2016) additionally looked at the affiliation between FD and ecology affection in ten altered nations. The allegations are in a band with analysis conducted in 2017 by Abdouli and Hammami (2017) by Sharif et al. (2019), and in 2017 by Sun et al. (2017). However, investments in blooming activity technology and bread-and-butter advances can enhance ecology affection(Hafeez et al., 2019). Zakari and Khan (2022) begin that there was an absolute alternation amid the akin of ecology aegis in the countries beneath abstraction and the empiric after-effects of the NARDL archetypal and #039, advertence that abatement in blooming accounts had the adverse effect. On the added hand, advantageous modifications to GF_POS abundantly lower CO2 emissions. Blooming innovations abundantly aid in the administration of ecology accidents through the use of new technology. Consequently, the amplification of blooming patents enhances the sustainability of the environment. According to the results, animal resource-based technology alteration tends to access carbon dioxide emissions in China in the abreast future, while infrastructure-based technology alteration tends to abate emissions. The after-effects advance that abbreviating abundance reduces the carbon acuteness of the top 10 countries. The aftereffect confirms the after-effects of Dong et al. (2020) and Van Vuuren and Riahi (2008) assuming the aftereffect of accretion abundance and that it mainly acquired an about-face from accepted biomass to atramentous and advanced carbon intensity.

5. Conclusion and Policy Implication

Using agree agent amid variables and Shin et al. (2014) with a nonlinear autoregressive broadcast lag (NARDL) model, this abstraction investigates the age furnishings of bread-and-butter development (FD), blooming accounts (GF), technology alteration (TT), and FDI (FDI) on carbon emissions amid the top ten countries. There is no one-size-fits-all answer, and the after-effects will depend on abounding factors, including the attributes of the investment, the authoritative environment, activity sources, and industry structure. Effective action measures and acceptable practices are acute to ensuring that these factors accord absolutely to abbreviation CO2 emissions and mitigating the furnishings of altitude change. Addressing the all-around claiming of altitude change requires absolute and adaptive strategies that accent the acceptance of blooming finance, technology transfer, and acceptable practices while demography into annual the assorted impacts of FDI and banking development. Politicians and stakeholders charge assignment calm to acquisition an antithesis that promotes bread-and-butter advance while abbreviation carbon emissions, appropriately accidental to an acceptable approaching for our planet.

Add properly Policy implication (at least one/two page)

1) Implement a carbon tax that places a price on carbon emissions, incentivizing individuals and businesses to reduce their carbon footprint.
2) Enforce renewable energy mandates that require a certain percentage of electricity generation to come from renewable sources, promoting a shift away from fossil fuels.
3) Energy Efficiency Standards: Set and enforce strict energy efficiency standards for buildings, vehicles, and appliances to reduce energy consumption and CO2 emissions.
4) Develop comprehensive regulatory frameworks that incentivize and mandate financial institutions to allocate a certain percentage of their funds to green projects. This can include tax benefits, reduced interest rates on green loans, and credit guarantees for sustainable initiatives.
5) Foster collaboration between public and private sectors to co-finance green projects. Governments can offer subsidies or grants to encourage private investments in eco-friendly ventures, thereby reducing the financial burden on businesses.

6) Promote the creation of green bonds, green banks, and other innovative financial instruments to mobilize capital specifically for environmentally sustainable projects.
7) Implement programs to educate individuals and businesses on the benefits of green finance, encouraging them to make eco-conscious investment decisions.
8) Create policies that balance the protection of intellectual property rights with the need for wider technology dissemination. This may involve compulsory licensing, patent pools, or technology-sharing agreements.
9) Invest in education and skills development to ensure that recipient countries have the expertise to effectively implement and adapt imported technologies.
10) Introduce incentives such as tax credits or subsidies for businesses that engage in technology transfer partnerships. This encourages both technology providers and recipients to participate in knowledge exchange.
11) Engage in international agreements and partnerships that promote technology transfer. These agreements can involve knowledge-sharing commitments and financial support for clean technology projects in developing countries.

5.1. Future Direction

Although this study yielded useful results, it has some limitations. These should be seen as opportunities for further research on this topic. The model can be extended to add variables Economic growth/industrial growth R&D, economic growth, energy consumption and principal component analysis can be done for technology transfer and various gases can be used as independent variables, additional forms of environmental pollution, or economic development Future research on different samples, such as developed, emerging, and developing economies, can be considered a potential area of research. Since this study used only secondary data, future researchers should develop another technique.

Authors' Contribution
Amna Shafqat: introduction section and writing—original draft and supervision
Sadia Idrees: interpretation of findings and writing—original draft and supervision
Sarfraz Zaman: analysis and explanation results, proofreading, and supervision
Muniba Ghaffar: writing—literature review and methodology and data curation

Conflict of Interests/Disclosures
The authors declared no potential conflicts of interest w.r.t the research, authorship and/or publication of this article.

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