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Analyzing the Asymmetric Effects of Green Finance, Financial Development and FDI on Environment Sustainability: New Insights from Pakistan Based Non-Linear ARDL Approach

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ABSTRACT

This research examines the Asymmetric Effects of Green Finance, Financial Development, Financial technology, economic growth, foreign direct investment, and financial development on environmental sustainability. It accomplishes this by applying the Asymmetric Autoregressive Distribution of Lag (NARDL) approach on information obtained from Pakistan from 1997 to 2022. The Data is collected from the Economic Survey of Pakistan and WDI. By analyzing these factors' intricate dynamics within the context of Pakistan, the study seeks to ascertain the short- and long-term effects on environmental sustainability. Using the NARDL paradigm, we address the nonlinearities and asymmetric effects that may exist in this Model. Our findings demonstrate that Pakistan's attempts to protect the environment are aided or hindered by green finance initiatives, technology advancements, economic growth trends, FDI, and financial development. The study investigates how these linkages evolve over time, which aids in developing methodological and policy recommendations for promoting environmental sustainability across the country. This study adds to the body of previous research, Businesses, legislators, and other interested parties attempting to reconcile environmental protection with economic expansion in a world-changing world will find the results to be an invaluable resource. Policymakers should prioritize the development of green financial instruments, support sustainable economic growth, draw in foreign investments with an environmental focus, and use innovations to address the urgent problem of reducing carbon emissions and promoting a more sustainable future for Pakistan. The limitation of the study is that determining the validity of observed trends may be difficult because data for some variables may only be available for a brief period of time.

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1. Introduction

The 21st century has seen a considerable increase in worldwide concern towards a sustainable environment being a consequence of initiatives aimed at reducing the phenomenon's destructive impacts. The excessive releases of greenhouse gases into Earth's atmosphere, notably carbon dioxide (CO_2), are the primary cause of this issue (Ivic, 2023; Seyboth, 2013). The burning of fossil fuels, deforestation, and industrial activity are the main human-caused sources of CO_2 emissions, which constitute a significant factor in the current climate catastrophe. Additionally, the most recent report from the Intergovernmental Panel on Climate Change. Osman-Elasha (2012) demonstrates the strong correlation between CO_2 emissions, and it among other human behaviors, include the combustion of petroleum and natural gas and forest destruction as well as the worsening climate crisis. Understanding CO_2, the main objective of this study. Furthermore, greenhouse gas emissions are a significant contributor to climate change. According to BP figures for CO_2 emissions, the amount of emissions from the use of fossil fuels increased by 33890.799 million tons in 2018 compared to just 11,190 million tons in 1965. On the other hand, a 2019 BP analysis found that in 2018, carbon emissions rose at the fastest yearly rate ever, or 2.0% (Olivier & Peters, 2010).

Pakistan is one of the emerging nations in which the majority of individuals still cook using conventional techniques, leading to a dramatic increase in atmospheric carbon emissions. For example, carbon emissions in the 19th century varied from 260 to 290 parts per million. The fast increase in CO_2 emissions, which have already surpassed 386 items per million annually and have a mean concentration greater than two components per millions, has, however, entirely altered the situation (Ates, 2023; Shahzad, Ferraz, Nguyen, & Cui, 2022). sPakistan's susceptibility to environmental contamination increased worldwide awareness of it. The two main sources of pollution, accounting for half of all pollution, are the energy and transportation industries. In Pakistan, CO_2 emissions (Farooq, Ozturk, Majeed, & Akram, 2022).

Green money has a big impact on environmental pollution. Therefore, fiscal measures may play a significant role in halting deforestation. Since it has been demonstrated that effective governance has a positive and considerable impact on the environment, its importance is only growing (Cadman & Sarker, 2022). The environmental issue cannot be solved by the current economic policies, which involve taxes, levies, and other financial penalties. A later research Postula and Radecka-Moroz (2020) inspected financial methods accustomed towards mitigate degradation of the surroundings, despite taxation and expenditures by governments were two of the most significant budgetary instruments. Feng, Du, Lin, and Zuo (2020) examined second Chinese research that examined the various ways in which the framework affects environmental integrity.

They discovered that growing carbon emissions are mostly due to increased road traffic, but their concept searches for ways to reduce carbon emissions and increase economic growth by analysing Pakistan's financial development metrics. Given that 152 extreme weather events between 1999 and 2018 cost Pakistan US$3792.52 million in economic damages and 0.598% of its GDP (David, Vera, & Laura, 2021). In the previous 20 years, Pakistan was among the 10 nations that have been most adversely impacted by climate change. Pakistan's annual CO_2 emissions per person have risen by 3% on average per year over the past 10 years (Shahzadi, Sheikh, Sadiq, & Rahman, 2023). Pakistani researchers have reached a number of findings on the connection between rising economic activity and greater carbon dioxide emissions. Thinking about the results Several studies (Khaskheli, Wang, Yan, & He, 2023). Jamil et al. (2021) have concluded that Pakistan's increasing GDP is the reason for the country's rising CO_2 emissions.

This study looks at the complex link between environmental sustainability and technology , taking into account the ways that fintech solutions might promote both environmental preservation and economic prosperity (Rizvi, Naqvi, & Tanveer, 2018) . In the most recent study, conducted in 2021 and published by Li et al. (2020) the effects of Pakistan's economic growth, energy consumption, environment, technology development, and financial development were also investigated. The results showed a significant asymmetric cointegration between technology and CO2 emissions. It suggests that some of the benefits of technology could negatively affect carbon dioxide emissions.

The overall effect of foreign direct investment on the state of the environment has been the subject of ongoing discussion. Certain scholars assert that there exists a dichotomy of correlations between foreign direct investment (FDI) and environmental preservation. Remitted foreign direct investment (FDI) can assist countries in lowering their air pollution levels by providing profitable and practical technology (Stretesky & Lynch, 2009). However, a significant number of other experts contend that foreign direct investment contributes to air pollution. They argue that increased productivity from foreign direct investment (FDI) drives economic growth and increases energy use. Though there aren't many research that link technology and finance, green finance is the nexus between environmentally friendly behavior and the financial and economic spheres (Gonenc & Scholtens, 2017). According to Brodny, Tutak, and Saki (2020) encourages investment in cutting-edge concepts and technology like renewable energy.

1.1. Significance of the Study

The importance of this work stems from its analysis of the intricate relationships between several crucial variables and how those connections impact environmental sustainability. The relevance of the dependent variable environmental sustainability has increased as a result of human activity's increasing threat to natural ecosystems (Malhi et al., 2020). Through an analysis of the effects of various independent variables, such as green finance, economic growth, financial technology, financial development, and foreign direct investment, this study seeks to shed light on the complex interactions between financial and economic factors and the environment. Understanding these connections may assist governments, businesses, and the general public in creating policies that reduce current environmental issues while promoting sustainable growth in the economy. In short, this study has the potential to influence essential policy formulation and decision-making aimed at maintaining a healthy balance between economic advancement and environmental preservation (Bakator, Đorđević, Đorđević, Bogetić, & Ćoćkalo, 2020).

1.2. Objective of the Study

OB.1.To determine the Impact of green finance on environmental sustainability
OB.2.To determine the Impact of Financial Development on environmental sustainability
OB.4.To determine the Impact of Financial Technology on environmental sustainability
OB.5.To determine the Impact of Economic Growths on environmental sustainability

1.3. Research Questions

Q1. How does green finance affect environmental sustainability?
Q2. How Does Financial Development affect environmental sustainability?
Q3. How Does Foreign Direct Investment affect environmental sustainability?
Q4. How Does Financial Technology affect environmental sustainability?
Q5. How Does Economic Growths affect environmental sustainability?

2. Literature Review
2.1. Overview of Theoretical Work

Environmental sustainability has emerged as a divisive issue of debate on a global scale as governments attempt to achieve an equilibrium among the protection of the environment and the expansion of the economy. Simulations of the Environmental Kuznets Curve (EKC) can be used to cognitively analyze this intricate relationship. The article examines the ways in which significant factors such as freedom of trade, development of finance, foreign direct investment, or and growth in the economy interact dynamically with Sustainable development within Pakistan. Investments in eco-friendly companies, or "green money," have the potential to significantly increase environmental sustainability. It harmonizes environmental protection with economic growth (Bashir et al., 2020). Green finance projects in Pakistan have advanced, which may have an impact on the trajectory of the EKC. By diverting investments towards green initiatives, policies fostering green finance can spark sustainable development (Chaudhry & Amir, 2020). And Digital payments and mobile banking are two examples of financial technology that may be integrated to improve efficiency and financial inclusion. However, the energy sources used to power digital infrastructure determine its environmental effect (Ahmer et al., 2022). Even if Pakistan's economic development is important for comprehending the EKC dynamics. Increased industrialization and consumerism might put pressure on the environment as the economy expands (Bashir et al., 2020). In the framework of the EKC, various research examining the connection between FDI and environmental sustainability have produced conflicting findings. According to several research, foreign direct investment (FDI) exacerbates environmental deterioration, particularly in sectors with lax environmental regulations (Hossain, Asaduzzaman Chowdhury, & Kchaou, 2021). Other study, however, suggests that FDI has a constructive role in advancing cleaner technology and improved environmental practices (He, Liu, Yoneyama, Nishiyama, & Tsubaki, 2006). For Some studies claim that financial development initially causes environmental deterioration, while others point out how it might hasten the transition to better environmental quality (Abbasi et al., 2020). To test and improve the EKC hypothesis in the Pakistani context, further empirical research is required. This will provide insightful information for policymakers attempting to strike a balance between economic growth and environmental preservation.

2.2. Empirical Literature
2.2.1. CO2 Emission and Financial Development

Amjad, Asghar, and Rehman (2021) looked into the expansion of the financial sector and the link among pollution as well as GDP. The Research time period covers the from 1980 through 2020. Positive financial development shocks improve Pollution reduction and growth in the economy are shown by the Non-linear Autoregressive Distributed Lag (NARDL) econometrics technique's findings. Even if the unfavorable shocks caused by financial development increased pollution and economic expansion. Since increased energy consumption leads to both increased economic growth and more environmental degradation, globalization has had a negative impact on economic growth. To encourage individual investors to use low-carbon technologies, Amjad et al. (2021) Researchers used panel data from 97 nations and a regional econometric model to examine the relationship between financial development and CO_2 emissions between 2000 and 2014. They were able to do this by applying the model to data that was gathered between 2000 and 2014. The data showed that the amount of carbon dioxide emissions generated during this period in the various nations was correlated geographically. More significantly, we discovered that the economic growth of a country's neighbors may have an effect on that country's carbon dioxide emissions. To be more precise, the overall impact of financial development on CO_2 emissions was significantly negative because of its significantly negative indirect effect, which outweighed its slightly negative direct effect (Iqbal, Wang, Ali, Amin, & Kausar, 2023). This resulted from the direct effect, which was quite advantageous. The relationship between financial development and CO2 emissions has been the subject of extensive research, but no consensus has been reached (Ahmad, Ahmed, Yang, Hussain, & Sinha, 2022).

2.2.2. CO2 Emission and Foreign Direct Investment

Mahmood (2022) demonstrated, utilizing data covering the years 1974–2010, that there is a bidirectional causal relationship between FDI and CO2 emissions for Turkey. In addition, they come to the conclusion that Turkey supports the EKC as a theory. Using Malaysia as a case study, foreign direct investment (FDI) lowers carbon dioxide emissions over the long and short terms. It was discovered that CO2 emissions' long-term elasticity in relation to FDI was 0.07 by Lau, Choong, and Eng (2014), demonstrating statistically significant and significant impacts. Contrarily, over the years 1979 to 2010, the effect of FDI on CO2 emissions for CAFTA members and the Dominican Republic was investigated (Frutos-Bencze, Bukkavesa, & Kulvanich, 2017). The findings demonstrated that FDI had a detrimental effect on CO2 emissions. Rehman, Ali, Idrees, Ali, and Zulfiqar (2022) analyzed the Gulf Cooperation Council countries between 1990 and 2014 and discovered a negative the relationship among carbon dioxide emissions along with foreign direct investment.

2.2.3. CO2 Emission and Green Finance

Meo and Abd Karim (2022) performed study in the top 10 nations that support green funding (Japan, United States, Canada, Switzerland, New Zealand, Denmark, Norway, Sweden, Hong Kong, and the United Kingdom) to determine the connection among the emission of carbon dioxide (CO2) emissions and sustainable funding. This study uses the on-quantile regression (QQR), first developed by Shafique, Rahman, Khizar, and Zulfiqar (2021), to examine the distribution of the relationship between carbon dioxide emissions and sustainable spending. Although financing for green initiatives and CO2 emissions generally had a negative association, we also discovered that the strength of this relationship varied among the quantiles of both of these variables.

2.2.4. CO_2 Emission and Financial Technology

By minimizing the environmental effect of traditional banking operations, technology adoption can help to reduce carbon emissions (Claessens, 2019). This is accomplished by making financial transactions more efficient and ecologically friendly. Technology has expedited the shift to an economy free of carbon and made it simpler to invest in environmentally beneficial projects, which has led to an increase in the amount of green currency (Li et al., 2020). Blockchain technology, the foundation of fintech, has also been studied for its potential to improve the efficacy and transparency of carbon trading markets, hence improving emissions monitoring (Larsson, Elofsson, Sterner, & Åkerman, 2019). However, empirical research has not refrained from highlighting the challenges and risks associated with this connection, including concerns around data privacy, cybersecurity, and legal (Elheddad, Benjasak, Deljavan, Alharthi, & Almabrok, 2021). Due to regional disparities in technological infrastructures and regulatory frameworks, fintech adoption patterns and their impact on emissions have also been noted (ŞENYIL & BÜYÜKŞAHİN, 2021).

2.2.5. CO2 Emission and Foreign Direct Investment:

The sectoral mix of trade and investment as well as governmental rules and regulations have an impact on the link between trade openness, emitters of carbon dioxide and foreign direct investment in Pakistan. For instance, the study highlights the importance of trade in items with a high carbon footprint and the need for strict environmental rules to ensure that trade openness and FDI lead to emissions reductions (Khan, Yu, Belhadi, & Mardani, 2020).

3. Methodology

3.1. Data and Variables

Growth in the economy, foreign direct investment (FDI), technological advances, the preservation of the environment, and the effect of green financing on environmental degradation were the five factors that the research looked at. This research also analyses the "World Bank Indicator and Economic Survey of Pakistan" data that was gathered from 1997 and 2022. The CO2 emissions (a proxy for environmental degradation), financial development (FD), financial technology progress, green finance (GF), and foreign direct investment (FDI) inflows are all calculated using yearly data in this study. Technological innovation is assessed in kilograms of oil equivalent per person, as opposed to CO2, which is measured in kilo tons (kt). BOP, the FDI amount is calculated in current US dollars.

Table.1 includes a list of the variable's definition, and data source And Table.2 provides the measurement technique. This section covers the Hatemi-j (2012) asymmetrical causation, the kinked exponential growth model, and the NARDL mode proposed by Demir, Simonyan, García-Gómez, and Lau (2021). The asymmetrical Utilizing the nontraditional ARDL approach, the consequences of the variables on the release of carbon are investigated.

Table 1
Description of Variables

Variables	Symbols	Sources
Environment sustainability	CO_2	*WDI*
Green Finance	*GF*	Economy survey of Pakistan
Economic Growth	*EG*	*WDI*
Financial Technology	*Tech*	Economic Development indicator
Financial Development	*FD*	*WDI*
Foreign Direct Investment	*FDI*	*WDI*

Tables 2
Units of Measurement

Variables	Unit of Measurable
Environment sustainability	% of total fuel combustion (CO2 emission)
Green Finance	% of renewable energy consumption
Economic Growth	% of annual GDP
Financial Technology	Mobile cellular subscription (per 100 people)
Financial Development	GDP per capita at constant US$
Foreign Direct Investment	Net (BOP current us$)

In earlier studies, the interactions between green finance ,technology as well as the connections between development regarding finance , foreign direct investment, and carbon emissions were examined using a variety of time series techniques, including Granger causality, cointegration, vector error correction model, unencumbered VAR model, and traditional ARDL (Usman, Zarebanadkouki, Waseem, Katsoyiannis, & Ernst, 2020). The only techniques used in the NARDL time series related to CO2 emissions, funding for, and environmentally friendly technology are those that were just described. In order to determine the asymmetry in the connection between the variables, the study also used a nonlinear (NARDL) technique (Shin, Yu, & Greenwood-Nimmo, 2014).

The linear technique the ARDL method is enhanced by the novel approach Nardl (Pesaran, Shin, & Smith, 2001). As opposed to the traditional ARDL approach, The non-linear (NARDL) bound evaluation a cointegration technique divides green finance, technology, economic growth, and foreign direct investment into positive and negative shocks to identify their effects upon emissions of carbon simultaneously, whereas other methods only detect the positive or negative shocks. For example, correlations between the pertinent variables across both short and long time frames are provided by the asymmetry technique. Additionally, we simulate CO2 emission using the method described below as a function of the factors considered:

$$CO2 = f\,(GF, EG, Tech, FD, FDI) \tag{1}$$

Equation (1) may be expressed as follows when explanatory variables experience both positive and negative changes during a logarithmic transformation:

$$\ln \mathrm{CO}_{2t} = \alpha_t + \delta_t + \beta^+ \ln GF_t^+ + \beta^- \ln GF_t^- + \beta^+ \ln EG_t^+ + \beta^- \ln EG_t^- + \beta^+ \ln TECH_t^+ + \beta^- \ln TECH_t^- + \beta^+ \ln FD_t^+ + \beta^- \ln FD_t^- + \beta^+ \ln FDI_t^+ + \beta^- \ln FDI_t^- + \mu_t \tag{2}$$

Here, the error term with time t is represented by, the trend effects by, the variable coefficients by δ, and the natural logarithm by ln. The following is an expression for the nonlinear autoregressive distributed lag (NARDL) framework found in Eq. (2)

$$\Delta\ln \mathrm{CO}_{2t} = \mu + \ln CO_{2\,t-1} + \theta^+ \ln GF_{t-1}^+ + \theta^- \ln GF_{t-1}^- + \vartheta^+ \ln EG_{t-1}^+ + \vartheta^- \ln EG_{t-1}^- + \omega^+ \ln TECH_{t-1}^+ + \omega^- \ln TECH_{t-1}^- + \varphi^+ \ln FD_{t-1}^+ + \varphi^- \ln FD_{t-1}^- + \gamma^+ \ln FDI_{t-1}^+ + \gamma^- \ln FDI_{t-1}^- + \sum_{j=0}^{n1} \Delta\ln CO_{2\,t-j} + \sum_{j=0}^{n2}(\theta_j^+ \Delta\ln GF_{t-j}^+ + \theta_j^- \Delta\ln GF_{t-j}^-) + \sum_{j=0}^{n3}\left(\vartheta_j^+ \Delta\ln EG_{t-j}^+ + \vartheta^- \Delta\ln EG_{t-j}^-\right) + \sum_{j=0}^{n4}\left(\omega_j^+ \Delta\ln TECH_{t-j}^+ + \omega^- \Delta\ln TECH_{t-j}^-\right) + \sum_{j=0}^{n5}(\varphi_j^+ \Delta\ln FD_{t-j}^+ + \varphi^- \Delta\ln FD_{t-j}^-) + \sum_{j=0}^{n6}(\gamma_j^+ \Delta\ln FDI_{t-j}^+ + \gamma^- \Delta\ln FDI_{t-j}^-) + \epsilon_t \tag{3}$$

Use the following formula to get the short-run NARDL elasticities with error correction.

$$\Delta\ln \mathrm{CO}_{2t} = \mu + \sum_{j=0}^{n1} \Delta\ln CO_{2\,t-j} + \sum_{j=0}^{n2}\left(\theta_j^+ \Delta\ln GF_{t-j}^+ + \theta_j^- \Delta\ln GF_{t-j}^-\right) + \sum_{j=0}^{n3}\left(\vartheta_j^+ \Delta\ln EG_{t-j}^+ + \vartheta^- \Delta\ln EG_{t-j}^-\right) + \sum_{j=0}^{n4}\left(\omega_j^+ \Delta\ln TECH_{t-j}^+ + \omega^- \Delta\ln TECH_{t-j}^-\right) + \sum_{j=0}^{n5}\left(\varphi_j^+ \Delta\ln FD_{t-j}^+ + \varphi^- \Delta\ln FD_{t-j}^-\right) + \sum_{j=0}^{n6}\left(\gamma_j^+ \Delta\ln FDI_{t-j}^+ + \gamma^- \Delta\ln FDI_{t-j}^-\right) + \emptyset ECM_{t-1} + \epsilon_t \tag{4}$$

The influences of the variables GF, EG, TECH, FD, and FDI can possibly be segregated into portions that are favorably and unfavorably skewed, just as we have shown in Eq. (2).

$$\ln GF_t = \ln GF_0 + \ln GF_t^+ + \ln GF_t^- \tag{5}$$
$$\ln \mathrm{EG}_t = \ln \mathrm{EG}_0 + \ln \mathrm{EG}_t^+ + \ln \mathrm{EG}_t^- \tag{6}$$
$$\ln TECH_t = \ln TECH_0 + \ln TECH_t^+ + \ln TECH_t^- \tag{7}$$
$$\ln FD_t = \ln FD_0 + \ln FD_t^+ + \ln FD_t^- \tag{8}$$
$$\ln FDI_t = \ln FDI_0 + \ln FDI_t^+ + \ln FDI_t^- \tag{9}$$

Here $\ln \mathrm{EG}_0, \ln GF_0, \ln TECH_0, \ln FD_0$ *and* $\ln FDI_0$ depict the arbitrary starting value, as

$$\ln \mathrm{GF}_t^+ + \ln \mathrm{GF}_t^-, \ln EG_t^+ + \ln EG_t^-, \ln TECH_t^+ + \ln TECH_t^-, \ln FD_t^+ + \ln FD_t^- \textit{ and } \ln FDI_t^+ + \ln FDI_t^-$$

provide procedures that compute the partial amounts of the positive and negative changes, respectively, and are described as

$$\ln GF_t^+ = \sum_{j=0}^{t} \Delta\ln GF_t^+ = \sum_{j=0}^{t} \max(\Delta\ln GF_{j,0}) + \epsilon_t \tag{10}$$
$$ln\, GF_t^- = \sum_{j=0}^{t} \Delta ln\, GF_t^- = \sum_{j=0}^{t} max(\Delta\, ln\, GF_{j,0}) + \epsilon_t \tag{11}$$
$$ln\, EG_t^+ = \sum_{j=0}^{t} \Delta ln\, EG_t^+ = \sum_{j=0}^{t} max(\Delta\, ln\, EG_{j,0}) + \epsilon_t \tag{12}$$
$$\mathrm{Ln}\, EG_t^- = \sum_{j=0}^{t} \Delta\ln EG_t^- = \sum_{j=0}^{t} \min(\Delta\ln EG_{j,0}) + \epsilon_t \tag{13}$$
$$\ln TECH_t^+ = \sum_{j=0}^{t} \Delta\ln TECH_t^+ = \sum_{j=0}^{t} \max(\Delta\ln TECH_{j,0}) + \epsilon_t \tag{14}$$
$$\ln TECH_t^- = \sum_{j=0}^{t} \Delta\ln TECH_t^- = \sum_{j=0}^{t} \min(\Delta\ln TECH_{j,0}) + \epsilon_t \tag{15}$$
$$\ln FD_t^+ = \sum_{j=0}^{t} \Delta\ln FD_t^+ = \sum_{j=0}^{t} \max(\Delta\ln FD_{j,0}) + \epsilon_t \tag{16}$$

$$\ln FD_t^- = \sum_{j=0}^{t} \Delta \ln FD_t^- = \sum_{j=0}^{t} \min(\Delta \ln FD_{j,0}) + \epsilon_t \quad (17)$$
$$\ln FDI_t^+ = \sum_{j=0}^{t} \Delta \ln FDI_t^+ = \sum_{j=0}^{t} \max(\Delta \ln FDI_{j,0}) + \epsilon_t \quad (18)$$
$$\ln FDI_t^- = \sum_{j=0}^{t} \Delta \ln FDI_t^- = \sum_{j=0}^{t} \min(\Delta \ln FDI_{j,0}) + \epsilon_t \quad (19)$$

4. Empirical Results and Findings

The current study carefully examines the unit root test and descriptive statistics before assessing the asymmetrical long-lasting along with short-term outcomes in this part.

4.1. Descriptive Statistics

Understanding Pakistan's environmental and economic dynamics requires a descriptive examination of the relationships among green finance, financial development, economic growth, foreign direct investment, and financial technology in the context of CO2 emissions. The Pakistani government and financial institutions' promotion of environmentally friendly investments has led to a surge in green finance activities. The goal of this descriptive research is to determine how these reforms will affect various aspects of the economy.

Data from Table.3 descriptive statistics show how the means for FD, Tech, and GF are all lower than those for and FDI. With the exception of the variable FD, the "Jarque-Bera" test examines whether the data are normal and finds that all variables are more significant than 1%. Table 3 further shows that, with the exception of EG, all variables are positively skewed. Kurtosis demonstrates all of the factors that lead to Leptokurtosis.

Table.3
Correlation Matrix

Variables	CO2	EG	FD	FDI	TECH	GF
Mean	332710.4	4.132602	2418.664	1.074999	28.49056	8.751470
Median	329561.6	4.396457	2309.000	0.735837	28.26698	4.832817
Maximum	454781.5	7.546860	3185.700	3.668323	33.47209	28.26698
Minimum	218193.7	-1.274087	1714.800	0.355613	23.26815	-1./274087
Std. Dev.	75551.10	1.980937	514.9038	0.914240	2.622864	9.584578
Skewness	0.111608	-0.600477	0.279945	1.876156	0.094098	1.357063
Kurtosis	1.780046	3.416730	1.637427	5.244938	2.426386	3.111279
Jarque-Bera	1.602202	1.683284	2.260501	19.91624	0.379636	7.686321
Probability	0.448834	0.431002	0.322952	0.000047	0.827109	0.021426
Sum	8317759.	103.3150	60466.61	26.87497	712.2640	218.7867
Sum Sq. Dev.	1.37232	94.17865	6363021.	20.06005	165.1060	2204.739
Observations	25	25	25	25	25	25

4.2. Unit Root Test

Unit root tests are important techniques in time series analysis because they determine if a particular time series has a unit root, which indicates non-stationarity. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are two popular unit root tests. To ascertain if a time series includes a unit root, Dickey and Fuller created the 1979 Augmented Dickey-Fuller test (Arltová & Fedorová, 2016). The ADF test compares the null hypothesis that a time series follows a unit root process, which indicates non-stationarity with the alternative hypothesis, that it follows a stationarity process. By accounting for delayed changes in the time series to account for autocorrelation, this test is enhanced.

The null hypothesis is rejected and the series is considered stationary if the test statistic is more negative than the critical values. The ADF test can be replaced with the Phillips-Perron exam, which was created by Phillips and Perron (1988) Along with other deterministic and error-related model hypotheses, it investigates the possibility of a unit root. Compared to the ADF test, the PP test is more flexible and is particularly helpful when the data may not exactly match the test's assumptions. The stationarity of time series data, a key tenet of many time series models and statistical analysis, may be ascertained using these unit root tests (Zuo, 2019).

The results of these unit root tests are crucial for understanding the statistical properties of time series data and evaluating if differencing is necessary to achieve stationarity. In order to determine if the variables are stable, the current study used the two well-known tests ADF test "Cheung and Lai (1995) and Phillips and Perron (1988)". Tests of "ADF and PP" show that all variables are stationary at the first difference despite the LNREN_GF being stationary at levels and at the first difference. The ** and *** means variables are stationary at 1% and 5% levels of significance. The data analyses also show that the variables under study would display uneven long- and short-run cointegration, which is supported by the findings that are in conflict. The lag time was calculated using the SBIC, and the significance criteria (in parenthesis) * and ** represent 1% and 5%, respectively. Results are shown in below table.

Table 4
Unit Root Test

	Unit Root at Level		Unit Root at First Difference	
Variables	**ADF**	**PP**	**ADF**	**PP**
CO2	(0.561)	(0.491)	(0.000) ***	(0.000) ***
EG	(0.367)	(0.478)	(0.000)***	(0.000) ***
FD	(0.592)	(0.779)	(0.001) **	(0.000) ***
FDI	(0.914)	(0.477)	(0.002) **	(0.000) ***
TECH	(0.000)***	(0.024)**		
GF	(0.069)**	(0.026) **		

4.3. F-statistics Bound Test

A statistical test employed in the Nonlinear Autoregressive Distributed Lag (NARDL) method is the F-statistics bound test. The NARDL model is employed to investigate the long-term associations between variables in circumstances where shock adaptation may be asymmetric. The model's need for asymmetric effects in the short run is assessed using the F-statistics bound test. The F-statistics bound test evaluates if there is a significant difference between the short-run coefficients of one or more lagged variables in the context of NARDL modelling. This identifies any imbalances in the immediate results. If the F-statistic is higher than a predetermined threshold, the model can be asymmetric. This data suggests a nonlinear link as well as concealed cointegration between the exogenous variables of GF, FDI, Financial technology, FD, and EG and the environmental sustainability (CO2 emission). The upper bound observation is exceeded by the nonlinear F-Statistic value (4.212) that was computed that is shown in Table.5. The long- and short-term interactions between the endogenous and exogenous components are supported by the current knowledge of cointegration among the variables.

Table.5
Bound Test

Test-Statistics	F-statistics	Sig. Level	Lower bound	Upper bound	Decision
NARDL	4.212	5%	2.02	3.12	
		10%	1.71	2.83	cointegration exit

Note: The critical value of linear-ARDL from Pesaran et al. (2001) *** and *** are represents the 1%, 5%, and 10% significance levels of critical bound values, the value of F- Statics is greater than the upper bound value which confirms the strong cointegration relationship. The null hypothesis of asymmetric cointegration is p = θ = θ=0

4.4. NARDL Modelling

The study investigates any possible asymmetric relationships between green finance, financial development, foreign direct investment, economic growth, financial technology, and environmental sustainability in the section that follows. The study is carried out utilizing a nonlinear framework that Herron (1967) has suggested.

Table 6 and Table 7 displays the outcomes of the NARDL model's long-run and short-run estimations. Finding the nonlinear asymmetric link between foreign direct investment, economic growth, financial technology, financial development, and green finance is the main goal of this work. The result from the long-term modelling displays the coefficients that have been estimated for both the adverse and beneficial sums of the modifications in the deconstructed elements. It is proven that the structural factors and emissions of carbon dioxide are out of equilibrium over a prolonged period. A not linear a long-term connection among the variables in question is possible, based on the nonlinear constraint test outcomes of 4.212, whose have significance at the one percent levels.

4.5. Long-Term Estimation

According upon the long-term NARDL information, the decomposing green finance model with positive as well as negative impacts yields estimated coefficients of 0.059 and 0.067, correspondingly. It is projected that an increase in green financing will result in a 0.00% decline in carbon dioxide emissions, while an increase in carbon dioxide emissions will induce a 0.01 percent increase in green financing. At the five percent level, the rising/falling green finance indices are noteworthy. Therefore, there is an imbalance in the relationship among each of the variables (Attahiru et al., 2019; Neog & Yadava, 2020; Rahman & Idrees, 2019). For example, recommended that Pakistan's government provide investors the choice to develop projects for technical innovation and green financing, which have a substantial influence on the long-term sustainability of the natural environment (control of CO2 emissions).

Furthermore, there is a significant association between environmental sustainability (CO2 emission) and the negative shock of green finance, thus a reduction in "green finance" of 1% would result in a decline for environmental resilience of 0.068 units. The financial market may be unstable as a result, and firms or financiers may not have the funds necessary to fund initiatives that would cut CO2 emissions.

A 1% increase in FDI will lead to a boost in the CO2 emissions of 0.031 since the 4.0 industry uses certain clean technology that slows down the growth of environmental sustainability and raises CO2 emissions. At a 5% level of significance, the "foreign direct investment" "positive shock" also has a positive and substantial impact, suggesting that a one percentage point rise in FDI is going to have this effect as well. Due to their negative connection, a 1% decrease in foreign direct investment will result in a 0.213 decrease in CO2 emissions. The detrimental consequences of foreign direct investment will impede the pace of emissions of carbon dioxide. Yet, the results demonstrate that certain companies have not utilized renewable energy due to imports and a lack of foreign investment, which has since then had a detrimental effect on the environment. Due to industrial activity, the same line that cleans the environment also releases 93.45 milligrams per of toxic metals into the water supply (Rahman, Chaudhry, Meo, Sheikh, & Idrees, 2022; Shafique et al., 2021; Thomas, 2021; Younas, Idrees, & Rahman, 2021; Zhu, Fang, Rahman, & Khan, 2023).

There is also an asymmetry relationship between each variable, as shown by the coefficients of the TECH_POS and TECH_PSSOS, which are 0.183 and 0.292, respectively, and significant at 5% and 10%. Therefore, a unit gain in technology will lead to a 0.183 unit rise in environmental sustainability. The efficacy of "technology development" can help to eradicate environmental contaminants. The environment's 4.0 technologies also employed a number of tools that reduced CO2 emissions. Consequently, it was shown by Shi, Cui, and Zhao (2021) that machine learning helped to reduce CO2 emissions, effectively saving the 30% cost of environmental sustainability. As seen by the large bad shock that occurs in Table.6 and Table.7, green technology will likewise have a negative shock that lowers carbon emissions and enhances environmental appropriateness; in other words, a reduction of one unit in environmental technology will have the opposite impact. Furthermore, the EG_POS and EG_NEG exhibit significant coefficients of 0.028 and 0.042, respectively, at the 5% level of significance, indicating the existence of an asymmetric connection. For every 1% increase in the use of renewable energy, the EG_POS predicts a 0.183% rise in ecological sustainability. Additionally, thermal power is an especially environmentally friendly choice because it lowers carbon emissions into the atmosphere (Bañales, 2020; H. Hassan et al., 2022; Hassan, Sheikh, & Rahman, 2022; Khoula, ur Rehman, & Idrees, 2022; Li et al., 2022; Rehman et al., 2022; Zulfiqar et al., 2022). The EG_NEG shock, however, shows a decrease in carbon emissions and an inverse relationship among the variables in question. Since the procedure for treatment consumes a lot of energy and a shortage of clean energy results in carbon emissions that hurt the environment, a 1% reduction in renewable energy will result in a 0.042% reduction in carbon dioxide emissions.

Table 6
Lon Run Estimates

Variables	Coefficient	Prob.
FD_POS	0.141	0.016**
FD_NEG	0.012	0.024**
GF_POS	0.059	0.012**
GF_NEG	0.067	0.027**
FDI_POS	0.03	0.014**
FDI_NEG	0.318	0.029**
EG_POS	0.028	0.027**
EG_NEG	0.042	0.096*
TECH_POS	0.183	0.007**
TECH_NEG	-0.292	0.097*

Table 7
Short Run Estimates

Variables	Coefficient	T-statistics	Prob.
ECM	-0.471	2.32	0.026**
D(FD_POS)	-0.042	2.451	0.012**
D(FD_NEG)	0.007	4.242	0.002**
D(EG_POS)	0.019	-8.624	0.001**
D(EG_NEG)	0.002	3.214	0.000**
D(GF_POS)	0.023	-6.322	0.001**
D(GF_NEG)	0.061	-4.145	0.002**

4.7. NARDL short run Estimation

The goal of the present study is to explain the short-run dynamic estimation finding. The short-term equation indicates a long-term association between environmental appropriateness and the variable that is independent FD, and the present the model's coefficient for this relationship is -0.042, with a 1% level of significance. Both the positive and negative "green finance" shocks have a big impact right away. Because green finance presents opportunities in the form of loans and green projects that support both an increase in environmental sustainability (CO2 emission) and an improvement in carbon emissions, an increase of 1 unit in green financing will consequently result in an increase of 0.023 units in environmental sustainability (carbon dioxide emission). These studies are align with (Chaudhary, Nasir, ur Rahman, & Sheikh, 2023;

Dawood, ur Rehman, Majeed, & Idress, 2023; Ilyas, Banaras, Javaid, & Rahman, 2023; Qadri et al., 2023; Shahzadi, Ali, Ghafoor, & Rahman, 2023; Shahzadi, Sheikh, et al., 2023; Usman, Rahman, Shafique, Sadiq, & Idrees, 2023; Zahra, Nasir, Rahman, & Idress, 2023; Zhao, Afshan, Ali, Ashfaq, & Idrees, 2023).

Similar results are obtained for the negative shock of green finance, which finds that a decrease of 1 unit in green finance corresponds to a decrease of 0.061 unit in ecological sustainability. This demonstrates how negative shock may soon hinder environmental sustainability (CO2 emissions). As a consequence, the industry has experienced a significant positive shock, and a 1% rise in industrial activity will enhance environmental sustainability (CO2 output). The firms have improved their environmental sustainability (CO2 emission) practices by utilizing clean technologies or renewable energy. Negative industry shocks will momentarily reduce CO2 emissions and preserve the environment. The method of reducing CO2 emissions and enhancing ecological sustainability will be improved by developments related to environmental technologies. These results aligning with previous work (Awan, Rahman, Ali, & Zafar, 2023; Fatima, Jamshed, Tariq, & Rahman, 2023; Ilyas-Lecturer, Awan, Kanwal-Lecturer, & Banaras, 2023; Javaid, Noor, Hassan Iftikhar, Rahman, & Ali, 2023; Mukhtar et al., 2023; Nawaz, Rahman, Zafar, & Ghaffar, 2023; Shahzadi, Ali, et al., 2023; Tabassum, Rahman, Zafar, & Ghaffar, 2023).

Yet, the adverse shock has significant negative effects on ecological health and raises carbon dioxide levels in Pakistan. In addition, the procedure of environmental sustainability (CO2 emission) is boosted by positive renewable energy. Negative shock, however, slows down the process of environmental sustainability (CO2 emission) in the near term and has an inverse relationship with it.

4.8. CUSUM And CUSUMSQ Test

Using CUSUM and CUSUMSQ to evaluate the model's data stability was advised by Brown, Durbin, and Evans (1975). In econometric and time serial analysis, the CUSUM and CUSUMSQ tests are statistical techniques that are frequently used in combination with the Nonlinear Autoregressive Distributed Lag (NARDL) methodology. Popular methods for assessing the stability of computed coefficients in a NARDL model are the CUSUM and CUSUMSQ tests. Time series data from the economic and financial domains are frequently linked to fundamental flaws that might lead to an unanticipated change in the relationship between the variables. These studies are quite helpful in these kinds of circumstances. For the CUSUM test, the cumulative sums of the estimated coefficients are computed over time. There may be a structural break in the data if these cumulative sums significantly deviate from zero, indicating that the relationships between the variables have changed.

The CUSUMSQ examination, on the other hand, focuses on the cumulative sum of squared residuals of the calculated NARDL model. Departures from zero in this test show the existence of conditional heteroscedasticity or differences in volatility across time. These tests are particularly useful for the NARDL technique because they enable scientists to assess the consistency of links that the model depicts and identify any structural cracks, asymmetries, or changes to the long-run equilibrium. The study by Bahmani-Oskooee and Alse (1994) is used as an example of how the CUSUM, CUSUMSQ, and NARDL techniques can be realistically used to economic research to examine Iran's demand for cash. It also has to do with the coefficients' long-term stability. In the images above, the blue lines at a 5% level of significance are located between the upper and lower critical bounds, showing that the data are stable. This situation illustrates the stability of the coefficients. As the trending line in Figure A and B chart is close to or coincides with the blue line, it indicates that the data is behaving as expected and has not greatly diverged from the starting point. This may be seen as a favorable result in quality control or process monitoring since it demonstrates that the process is consistent and not undergoing any significant changes.

FIG.A

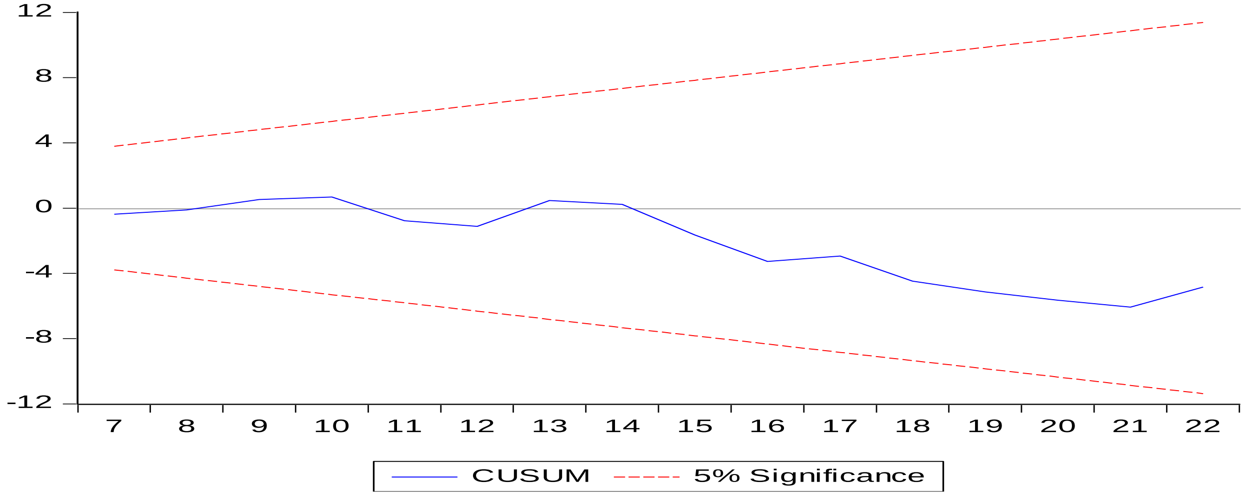

Figure A: CUSUM Graph

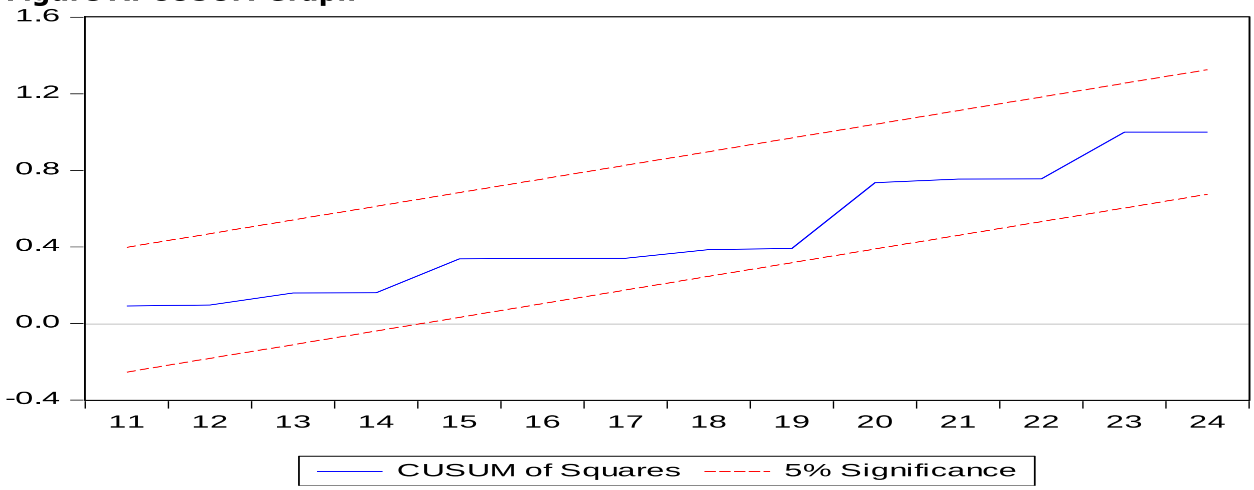

Figure A: CUSUMSQ Graph

5. Conclusion

A thorough investigation was carried out using the Nonlinear Autoregressive Distributed Lag (NARDL), cumulative Sum (CUSUM), and Cumulative summed of Squares (CUSUMQ) examines to evaluate the interaction between green finance, financial development, economic growth, foreign direct investment (FDI), and financial technology in affecting carbon dioxide emissions in the setting of Pakistan's attempts to combat CO2 emissions and their impact on the natural world. The study's findings offer a number of significant insights. First off, green funding is essential for Pakistan's efforts to reduce CO2 emissions. It serves as a catalyst for beneficial to the environment investment and initiatives, ultimately lowering carbon emissions.

Although the research also demonstrates a favorable correlation between an increase in financial development and a decline in emissions of carbon dioxide, a financially developed financial sector may help green activities go better. Second, it was found that there was a complex relationship between CO2 emissions and economic growth. It has been shown that economic growth encourages expenditures in energy-efficient technologies and clean technology, which may lead to a long-term decrease in pollution even though it would cause emissions to increase due to rising industrial activity and energy consumption. Thirdly, foreign direct investment is a key factor in lowering carbon dioxide (CO2) emissions.

Foreign investors usually give the host country cutting-edge technology and eco-friendly practices, which can reduce carbon footprints. The study also showed how integrating financial technology may boost the effectiveness of green finance and sustainable investments. Innovations may streamline processes, increase the accessibility of green funding, and simplify the monitoring of environmental performance, all of which can reduce CO2 emissions. In setting of Pakistan's attempts to lower its CO2 emissions, the analyses' conclusions show the intricate links between green finance, financial development, economic growth, foreign direct investment, and financial technology. Policymakers should priorities the development of green financial instruments, support sustainable economic growth, draw in foreign investments with an environmental focus, and use FinTech innovations to address the urgent problem of reducing carbon emissions and promoting a more sustainable future for Pakistan. In addition Islamic economic systems may also help the environmental sustainability. As according to Awan, Ali, Rehman, and Idrees (2023) Islamic economic system are the finest economic systems for boosting the economy. This is because Islam places much emphasize of importance on Trading and the environment (Kamla, Gallhofer, & Haslam, 2006).

5.1. Future Directions

Future research on the relationships between Pakistan's CO2 emissions, green finance, financial development, economic growth, foreign direct investment (FDI), and financial technology can concentrate on a few key areas to give a more in-depth understanding of the dynamics and inform policymaking. Here are some suggestions for research subjects:

- Research how green finance and sustainable investments affect specific industries like manufacturing, agriculture, energy, and transportation. This can provide details on the sectors with the greatest potential to reduce emissions as well as the places where targeted interventions are most effective.
- Take into account how FDI, financial development, and CO2 emissions are related and how environmental regulations and their enforcement are affected. To promote sustainability, think about enhancing regulatory frameworks.
- Consider the possibilities of FinTech innovations, such as blockchain for trading carbon credits or AI-driven sustainability assessments, to assist green investing and sustainable financing. In the context of Pakistan, consider the practicality and effectiveness of various technologies.
- Analyze investor and customer behavior with regard to sustainable products and finance. Understand how behavioral incentives and nudges may influence people and businesses to take environmentally responsible actions.
- Analyze how much Pakistan's sustainable development and green finance are aided by international accords and collaboration.
- Talk about the data problems related to Pakistan's carbon emissions reporting and monitoring. Examine ways to enhance the accuracy and gathering of data, which is essential for monitoring progress and formulating policies.
- Assess the potential financial and economic risks that Pakistan may face as a result of climate change. Examine how financial stability and the need for adaptation measures may be impacted by climate-related risks and events. Analyze the effects of green funding initiatives on equity and society. Analyze how these programs affect different social groups and if they reduce the wealth gap.
- Determine the long-term viability of the endeavors and expenditures in green financing. Assess if the short-term benefits of cutting emissions are sustained over time and whether any unanticipated consequences may arise.

- Investigate the degree to which present FDI, green finance, and FinTech policies align with emission reduction objectives. Find problems with the present policy and provide fixes.

Investigators can learn more about how financial technology, economic growth, foreign direct investment, and green finance interact to support sustainable development and lower CO2 emissions in Pakistan by concentrating on these research directions. This will ultimately help with efforts to combat climate change on a global scale.

5.2. Limitation of the Study

The data for some variables may only be available momentarily, it may be difficult to conduct long-term study or evaluate the validity of observed trends. Determining the relationship between the variables under consideration in an economic evaluation may prove to be difficult. The inquiry could concentrate on connections and correlations without proving causation.

Even in cases where the NARDL and CUSUM(CUSUMQ) tests yield positive results, the analysis may become more complex. The functional forms and lag lengths can have a substantial impact on the outcomes in addition to other model parameters. The choices made in selecting these standards might lead to confusion. The study's handling of endogeneity concerns was deficient, especially considering how financial development, economic growth, and CO2 emissions are related. The study's conclusions are limited to Pakistan, making it challenging to extrapolate to other nations or areas with various legal systems, economic setups, and stages of development.

It is plausible that the research may have overlooked some social and policy elements that impact Pakistan's capacity to execute environmental legislation and green finance projects. Prospective studies ought to try to enhance data quality and protection, take into consideration more complex econometric approaches, perform robustness examinations, and use qualitative techniques with the goal to overcome these limitations and provide a more thorough understanding of the complex connection among these variables in the setting of the country's carbon dioxide (CO2) reduction.

Authors' contribution
Amna Kanwal: Main Idea, Introduction, Literature Review and Original Draft of the study
Salman Khalid: Methodology and Analyses
Muhammad Zaheer Alam: Results and Discussion, Conclusion

Conflict of Interests/Disclosures
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