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Examining the Impact of Fiscal Decentralization and Renewable Energy on CO2 Emissions: Insights from Pakistan

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ABSTRACT

The relevance of fiscal decentralization in environmental sustainability cannot be overstated. Some believe that fiscal decentralization is essential to long-term environmental health. However, to what extent fiscal decentralization (FSD) hinders or promotes ecological sustainability is a topic of heated debate. Knowing how fiscal decentralization impacts the environment is vital because it cannot be disregarded while working toward the Sustainable Development Goals of a clean environment and minimizing climate change. This study determines the relationship between FSD, NRE, RNE, GDP, and CO2 excretion, taking data from 2005 to 2021. We employed the ARDL model to investigate the association between study variables. The empirical findings show that fiscal decentralization, NRE, and GDP exert beneficial effects on CO2 exhalation and harm the environment, while RNE cleans the environment by decreasing CO2 outflow; yet, all study variables are positively connected with the ecological footprint. Based on the recommendations for Pakistan, It is suggested that policymakers and the government of Pakistan should allocate funds for green infrastructure to combat CO2 emissions.

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1. Introduction

Carbon emissions, specifically greenhouse gases, are blamed for worldwide natural disasters (Cao et al., 2022; Chishti, Ahmad, Rehman, & Khan, 2021). GHGs, especially CO2, are damaging to Earth in many ways, according to most research. As a result of this convincing evidence, scientists are concentrating on energy use as a contributor to greenhouse gas emissions from power plants (Faheem, Chaudhry, Farooq, & Anwer, 2021; Faheem, Farooq, Shaukat, & Yousuf, 2022; Tanveer, Song, Faheem, & Chaudhry, 2022). CO2 emissions that result from GHGs are the main culprits behind environmental degradation for recent and past decades; it is the greatest risk to environmental (Amen et al., 2021; Huang, Sadiq, & Chien, 2021).

Breathing in CO2 has a major impact on the complex web of our ecosystem (Anwer, Farooq, Faheem, & Yousuf, 2023; Chaudhry, Faheem, Farooq, & Ali, 2021; Farooq, Faheem, & Nousheen, 2023). Governments are seeking strategies to attain sustainable economic development and the well-being of humanity by reducing CO2 emissions, which have become a global problem (Ulucak, Danish, & Ozcan, 2020; Ulucak, Yücel, & Koçak, 2019).

Climate crises pose several environmental issues, including biodiversity loss, waste production, and rising water and air pollution. Industrial enterprises are prioritizing production costs over CO2 emissions as the world population grows. Due to the growing population in emerging countries, renewable energy demand is expected to rise (Farooq et al., 2023). Global energy usage in emerging and developed nations is causing environmental degradation. Climate change and global warming are constantly threatened by this trend. Large-scale non-renewable energy use emits greenhouse gases. The rising temperatures threaten human survival. Massive CO2 emissions are the biggest hurdle to reaching Sustainable Development Goals (SDGs), hence they must be addressed (Faheem, Farooq, Umar, & Yousaf, 2023). It's no secret that governments and officials throughout the world have been fixated on the issue of CO2 emanation, as it is the most influential factor in environmental depletion (Ehigiamusoe & Dogan, 2022; Zhao, Wang, & Xu, 2023). Worldwide CO2 has risen substantially in the present era, from 2149.4mt in 1990 to 36390.3mt in 2018 (Bank, 2020).

The destruction of the environment is becoming a major problem all across the world, and its effects are apparent to be rather serious (Chaudhry, Nazar, Ali, Meo, & Faheem, 2022; Yilanci, Bozoklu, & Gorus, 2020). It has become a dire demand for countries to focus on a clean atmosphere, As the extreme weather patterns and the uncertain temperature have affected the economy and the quality of life (Chishti, Alam, Murshed, Rehman, & Balsalobre-Lorente, 2022; Udeagha & Muchapondwa, 2023). Developing nations compromise environmental standards to attract development aid and international investment meant to boost their economies (Konisky, 2007; The Phan et al., 2021). The need for a cumulative indicator to address sustainable development and ecological decline arises from the fact that carbon dioxide emissions could not be a reliable yardstick of environmental quality in the mining, forestry, and oil industries (Khan, Ali, Dong, & Li, 2021; Solarin & Bello, 2018). An innovative tool for gauging environmental quality and sustainability, the ecological footprint has gained widespread attention recently (Z. Khan et al., 2021; Solarin & Bello, 2018).

The fundamental component in raising public sector productivity, which in turn raises living standards and GDP, is FSD (Tufail, Song, Adebayo, Kirikkaleli, & Khan, 2021; Zhang, Wang, & Cui, 2011). FSD plays a pivotal role in resource allocation to overcome the deficiency in different departments; it also enhances expertise and improves the quality of life (Oates, 1993; The Phan et al., 2021). FSD is regarded as a tool to promote public goods allocation performance (Safi, Wang, & Wahab, 2022; Thiessen, 2003). One of the most important aspects of FD is expanding access to finance so that people and companies may start and build their own businesses (Faheem, Ali, Farooq, & Hussain, 2023; Tanveer, Song, Faheem, Daud, & Safdar, 2023). Fiscal decentralization has become a hot debate topic in international economic models (Wang & Lei, 2016; Zahra & Badeeb, 2022). Various researchers found contradictory outcomes when examining the affiliation between FSD and the environment (Ali, Masood, Siddique, Naureen, & Ahsen, 2022; Li & Haneklaus, 2022). Due to variances in prevalence estimates, time periods, and econometric approaches, all researchers have produced ambiguous empirical results. Many empirical and theoretical literature demonstrate distinct consequences of FSD on allocating public goods like quality of environment (Li et al., 2021; Liu, Ding, & He, 2019).

Local governments benefit from fiscal decentralization because they are more competent to meet the needs of their communities in terms of environmental quality, so this approach has the potential to enhance environmental protection (Li et al., 2021; Wang & Lei, 2016). The delivery of community services on a regional basis is enhanced by fiscal decentralization because it is more efficient and effective than at the national level (Qiao, Martinez-Vazquez, & Xu, 2008;

Zhao, Shao, & Ye, 2022). Globally, the central government acknowledges the importance of fiscal decentralization by deputing responsibilities to local governments (Hao, Umar, Khan, & Ali, 2021; Yuan, Li, Ahmed Memon, Ali, & Nawaz, 2022). It is widely accepted that local governments have a greater responsibility under fiscal decentralization to implement economic progress and improve environmental quality and people's standard of living (Khan, Khan, & Rehan, 2020). Since municipal administrations have a greater grasp of what is needed to maintain or improve environmental quality in their areas, fiscal decentralization may be an effective means of doing so (Li et al., 2021; Wang & Lei, 2016). Yet, some intellectuals say FSD leads to environmental decline and a "race to the bottom" (Liu et al., 2019; Udeagha & Muchapondwa, 2023).

The persistent spread of energy use is the main cause of resource exhaustion, leading to CO2 discharge and loss of biodiversity (Jiang, Rahman, Zhang, Guo, & Xie, 2022; Sun & Razzaq, 2022). The correlation between energy, GDP, and carbon ejections has become a hot debate among policymakers and researchers due to sustainability concerns (Kang, 2021; Ulucak et al., 2020). As countries invest in cleaner energy to meet climate objectives, understanding the link between RNE and the need for mineral resources is essential for environmentally friendly and long-term (Chaudhry et al., 2022; Faheem, Ali, et al., 2023). An ecologically sound setting is essential for achieving the 2030 SDGs, and green legislation and practices can help make that a reality (Farooq et al., 2023). One way to help fight climate change is to switch to RNE sources, which can significantly reduce carbon dioxide emissions (Anwer et al., 2023; Chaudhry, Faheem, & Farooq, 2021; Faheem et al., 2022).

Technological innovations, urbanization, globalization, and industrial progress are the salient factors responsible for the high energy demand globally; between 1990 and 2018, In the Middle East, the demand for energy surged by 170%, in Africa by 70%, in India by 91%, and in the United States by 20%. Overall energy demand has increased 39% globally (IEA, 2021). Nuclear energy has been considered an important means of mitigating CO2 emissions (Lee, Kim, & Lee, 2017; Saidi & Omri, 2020). It is argued that the combustion of fossil fuels at a large scale is the eminent cause of climate change, so it is globally addressed in the context of sustainability in the economy and the environment (Hao et al., 2021; Martins, Barreto, Souza, & Souza, 2021). The "energy information Administration" (EIA) reports that the utilization of RNE sources has increased rapidly to curb the adverse effects of greenhouse gas emissions (Inglesi-Lotz, 2016; Salari, Javid, & Noghanibehambari, 2021). Employing renewable energy sources has become increasingly crucial in recent years due to their ability to significantly abate CO2 exhalation (Jin & Kim, 2018; Saidi & Omri, 2020). Economic growth and energy utilization are regarded as the main culprits behind high CO2 emissions; they both show different results for different locations (Chen, Zhao, Lai, Wang, & Xia, 2019). Globally, it is observed that developed countries contribute to emitting CO2 more than other countries (Mukhtarov, Aliyev, Aliyev, & Ajayi, 2023). UNEP 2020 Emissions Gap Report finds that despite rapid reductions in global CO2 emissions because of the COVID-19 epidemic, global CO2 emissions are still high and rising (Hao & Chen, 2023; Kang, 2021). The UN's Clean Energy and Climate Targets 2030 is ramping up efforts to establish ecological norms and advocate for the utilization of RNE sources instead of fossil fuels (Khan et al., 2020; Pata, Kartal, Adebayo, & Ullah, 2023).

When a country moves from an agricultural to an industrial economy, energy consumption rises along with it. Industries can't function without consuming energy, which in turn increases carbon ejection. As a result, there is a one-to-one connection between GDP and the environment (Mohsin, Naseem, Sarfraz, & Azam, 2022; Naseem, Mohsin, Zia-Ur-Rehman, Baig, & Sarfraz, 2022). Since the past decade, an upsurge in energy demand for economic development has been observed, which causes CO2 excretion (Ali, Gong, Ali, Wu, & Yao, 2021). During the early phases of development, economic expansion is prioritized over environmental protection, leading to environmental degradation as economies make sacrifices for economic growth while relying on inefficient technologies (Ali et al., 2021; Dinda, 2004). Sustainable economic development is a dire need of the country’s economic policy; however, economic growth may adversely affect the climate and cause global warming (Ahmad et al., 2016; Salari et al., 2021). Increasing the economy's output is important for a number of reasons, including lowering poverty and raising both living standards and general quality of life, but it also has unanticipated consequences for the natural world. In the two centuries since the Industrial Revolution began, the world's CO2 output has increased by more than 50% (IEA, 2021). Plenty of work has been done on the collision between GDP and EF, claiming economic development is liable for environmental depletion in many countries (Ahmed, Adebayo, Udemba, Murshed, & Kirikkaleli, 2022; Murshed, Elheddad, Ahmed, Bassim, & Than, 2022). Greater economic activity may increase energy usage and, thus, pollution levels. On the other hand, new systems or processes could use less power and produce less harmful byproducts than traditional methods (Dauda, Long, Mensah, & Salman, 2019; Fernández, López, & Blanco, 2018).

Although there has been progress made in prior publications on the impact of FSD in influencing the environment, many important areas still have not been studied. The present research makes use of such details to add substantially to the existing body of work. It is the first study to examine the dynamic union between FSD and the environment with respect to RNE, NRE and GDP in Pakistan, and it sheds a better understanding of the specific steps involved via which this link may function. To add to this, no prior studies have used a sophisticated estimating technique, such as the ARDL simulation model, to investigate the link between FSD and ecological sustainability. Lastly, another reason for conducting this study is that preceding attempts at identifying the relevant point have proven unsuccessful. This paper's findings are novel and substantial, adding to the existing knowledge in several ways that can be used to shape environmental policies that are both effective and long-lasting.

This research sheds light on the complex relationship between FSD and a country's environmental impact. The current examination reveals fiscal decentralization as a crucial factor in Pakistan's ecological footprint, despite the vast amount of studies on this subject. The researchers hope that policymakers will use these results to come up with new ways to reduce carbon dioxide emissions.

2. Literature review

Li et al. (2021) reviewed the affiliation between FSD, institutional quality, government size, and CO_2 outflow using the ARDL model from 1984 to 2018 for Pakistan. The empirical findings revealed a favorable nexus between expenditure decentralization, revenue decentralization, and CO_2 emissions. On the contrary, institutional quality inversely influenced CO_2 emissions in Pakistan. Employing BARDL, Shahzad and Fareed (2023) assessed the correlation between renewable energy intensity, fiscal decentralization, and CO_2 discharge. Information was gathered from 1960 to 2018 in Canada for the study. Results showed a favorable interconnection between the intensity of renewable energy and the flow of CO_2 and a negative one-way causal bond between FSD and CO_2 emissions. Udeagha and Muchapondwa (2023) scrutinized the nexus between trade openness, green technological innovations, population size, FSD, institutional quality and CO_2 emissions adopting the NARDL from 1960 to 2020 for South Africa. The estimated observations displayed that fiscal decentralization, population, energy usage, green technological innovations, and institutional quality negatively influenced the environment, while trade openness positively influenced CO_2 emissions. GDP showed positive, and GDP square revealed a negative association with CO_2 emanation. For China, over the period 2003 to 2019, Zhao et al. (2023) examined the tie between FSD, economic development, the level of urbanization, transport infrastructure, and CO_2. The empirical findings showed the negative influence of FSD on CO_2; in contrast, environmental regulation and transport infrastructure positively affected CO_2 environment.

Yuan et al. (2022) discovered the association between fiscal decentralization, trade openness, RNE, GDP, NRE, and CO_2 emanation, adopting novel econometric techniques like DOLS FMOLS for Japan. The analysis manifested the favorable reverberations of trade openness, GDP, and NRE on CO_2 outflow; on the contrary, fiscal decentralization and RNE negatively influence CO_2 emissions in Japan. Shan et al. (2021) estimated the bond between institutional quality, GDP, FSD, energy prices, and CO_2 emissions adopting cross-sectional ARDL for OECD countries. The observed estimations exhibited a negative ramification of NRE prices and institutional quality on the environment; conversely, GDP and FSD enhanced CO_2 ejection. For OECD countries, Tufail et al. (2021) contended the association between FSD, GDP, and CO_2 outflow using different econometric techniques the Westerlund test. The observed results displayed the mitigating effect of FSD and TNRR on CO_2 discharge; in contrast, GDP stimulated CO_2 ejection. Safi et al. (2022), for OECD from 1990 to 2018, probed the causal nexuses between technological innovations, FSD, RNE, GDP, and CO_2 ejection. The statistical observations revealed that FSD, renewable energy R & D, economic growth, international trade, and eco-friendly technological innovations showed a negative influence on CO_2. Using a novel dynamic panel ARDL method, The Phan et al. (2021) looked into the connection between FSD, GDP, and CO_2 radiation. Information was gathered from nine different Asian countries between 1984 and 2017. According to the data, FSD control CO_2 ejection, whereas GDP damaged the environment. Ali et al. (2022) experimented with the affiliation between FSD, institutional quality, GDP, and environmental quality by applying Westerlund and CS-ARDL model for 4 Asian countries. The empirical upshots indicated negative influences of FSD, and institutional quality on CO_2 discharge, whereas economic growth positively impacted the environment.

Khan et al. (2020) evaluated the association between FSD, human capital, institutional quality, eco-friendly technological innovations, GDP, and CO_2 emissions utilizing CS-ARDL methodology for 7 OECD countries from 1990 to 2018. The estimated observations disclosed a negative reverberation human capital index, fiscal decentralization, eco-friendly technological innovations, and institutional quality on the environment; in addition, GDP boosted CO_2 outpouring. Liu, Feng, Zhai, and Razzaq (2022) evaluated the bond between FSD, RNE, FDI and CO_2. The research gathered data from European Union nations from 2000 to 2020. The research utilized CS-ARDL. The estimated results indicated negative impacts of FSD and RNE on CO_2 ejection; in contrast, GDP and FDI positively impacted CO_2 discharge. Sun and Razzaq (2022) indicated the association between CO_2 emissions composite fiscal decentralization, green innovations, institutional governance index, GDP, and population employing FMOLS and MMQR estimators for 32 OECD countries. The factual results indicated the negative ramification of composite fiscal decentralization and green innovations on CO_2 radiation. Institutional governance also showed a negative aftermath on CO_2 outflow. yet GDP and population surge CO_2 discharge. Qiao, Yang, Ahmad, and Ahmed (2022) used the CS-ARDL approach to conduct experiments on the association between GDP, FSD, technical innovation, economic globalization, and CO_2 exhalation. Eight countries that are part of the APEC were surveyed for the study, covering the years 1990 through 2018. The data showed that increasing our use of energy, our GDP, and our urbanization all have a beneficial effect on the planet. In contrast, the ecology was harmed by fiscal decentralization and technological advancements. Zahra and Badeeb (2022) inspected the alliance between green energy, FSD, environmental sustainability, and economic policy by applying the NARDL model for OECD economies. The empirical results showed a symmetric connection between green energy, economic policy and environment. The results showed an asymmetric linkage between ecological footprint and fiscal decentralization in long run only in USA and Australia; in contrast, in the case of the UK, the asymmetric affiliation was not found.

Chen et al. (2019) observed the tie between GDP, NRE, RNE, and CO_2 discharge. The study collected data over the period 1995 to 2012 from China. The estimated calculation of the research showed an inverse impact of NRE CO_2 ejection in the Eastern, western, and central regions, while GDP positively impacted CO_2 emissions in study regions except western region. Renewable energy curb CO_2 in the Eastern and western regions but the positively central region. Through an ARDL apporach, Khan et al. (2020) analyzed the connection between GDP, energy use and CO_2. Pakistani data were collected for the study between 1965 and 2015. According to the data, energy utilization and GDP both have a beneficial effect on CO_2 discharge in Pakistan.

Azam, Khan, and Ali (2023) discovered the bond between alternative energy sources, government expenditure, natural resources, GDP, and carbon radiation by employing FMOLS and GMM techniques. The analysis gathered data from France from 1990 to 2018. The analysis revealed GDP aggravated CO_2 outflow; alternative energy sources, natural resources and government expenditure negatively influenced the environment. Mahmood (2019) concluded the affinity between GDP, and carbon by utilizing the ARDL. They found a positive repercussions of GDP and trade openness on CO_2; yet, GDP square abate CO_2. Ali et al. (2021) verified the link between energy usage, net domestic credit, GDP, and CO_2 outflow by employing the ARDL for Pakistan. The experiment results of analysis displayed a positive effect of net domestic credit, and energy utilization on CO_2; meanwhile, GDP lessen CO_2 discharge in Pakistan. Aydoğan and Vardar (2020) estimated the affiliation between NRE, GDP, energy utilization, agricultural value added, renewable energy usage, and carbon exhaustion using DOLS and FMOLS techniques. They found the beneficial affiliation of CO_2 emanation with NRE, real GDP, and agricultural value added. In contrast, RNE and square of GDP revealed a negative association with CO_2 emanation.

The Phan et al. (2021) stated the effect of technology, population density, GDP on CO_2 emanation using a CUP-FM for BRICS over the period spanning from 1992 to 2018. The estimated outcomes unfold the positive influence of GDP and population density on CO_2 emanation, but technologies reduce CO_2. Economic complexity confirmed an inverted U-shape curve. Ahmed et al. (2022) investigated the convergence of GDP, RNE, economic complexity, democratic accountability, and FD on ecological footprint by applying a CUP-FM and the Dumitrescu and Hurlin test for G7 countries. The calculation of the study exhibited the inverse effect of renewable energy budget FD, and economic complexity on the EF; in addition, GDP induced EF. Sikder et al. (2022) tested the bond between energy, GDP, Industrialization, and CO_2 release for 23 developing countries covering the period 1995 to 2018. Statistical estimations disclosed that GDP, energy usage, urbanization, and Industrialization stimulated CO_2 outflow. The panel causality analysis unfolded a two-way causality between all examined variables. Das and Sethi (2023) investigated the affiliation between institutional quality, tertiary education level, economic freedom, GDP, financial development, and CO_2 emissions utilizing generalized system methods of moments and quantile regression methods. The study used data from 74 countries from 1996 to 2018. The statistical results confirmed the positive repercussions of FD, GDP, economic freedom, and tertiary education, but on the other hand, institutional quality negatively influenced the environment.

Li and Haneklaus (2022) for G7 countries from 1979 to 2019, found the affinity between GDP, clean energy, trade openness, and CO_2 emanation via the ARDL techniques. Empirical analysis revealed that trade openness and GDP increase CO_2, while clean energy exploitation, GDP2 and urbanization negatively influenced CO_2 discharge. Gozgor (2017) evaluated the causal correspondence between GDP and CO_2 outpouring by utilizing PMG for 35 OECD countries. The findings disclosed that energy use extended CO_2; furthermore, trade negatively influenced the environmental quality of GDP and showed a positive influence on carbon emissions. Mohsin et al. (2022) scrutinized the correlation between FDI, GDP, personal remittances, and CO_2 by executing the ARDL for European and central Asian countries. They found that GDP, energy and FDI ramped up CO_2. In contrast, personal remittances revealed a positive impact on CO_2. Dauda et al. (2019) evaluated the causal connection between innovations, GDP and CO_2 emissions for 18 developed and developing countries by applying FMOLS and DOLS. The study's empirical findings declare that energy consumption positively affected CO_2 emanation in all panel countries. In contrast, innovation negatively influenced CO_2 discharge in G6 countries but positively influenced MENA and BRICS economies. GDP positively affects CO_2 emissions in BRICS. FDI also showed mixed results. FDI aggravated CO_2 in main and G6 panels while negatively in BRICS economies. Trade openness revealed a positive influence in all panels except G6 countries.

Ali et al. (2021) reviewed the affinity between GDP, energy consumption, inward FDI, GDP square, and CO_2 outpouring by implementing the ARDL model. The study gathered data from Pakistan from 1975 to 2014. The estimated findings confirmed the positive impact of GDP, energy deploy, and FDI on CO_2 discharge, while the square of economic development negatively influenced the carbon outflow in Pakistan. Salari et al. (2021) looked over the nexus between energy use, renewable, GDP non-renewable, residential, industrial, , and CO_2 discharge using two-step systems GMM. The research collected data from the U.S. from 1997 to 2016. Empirical findings of the analysis displayed that total, industrial, non-renewable energy, and residential energy usage positively influenced environmental quality, but renewable energy usage confessed a negative association with CO_2 excretion. Shen et al. (2021) evaluated the affinity between FD, green investment, energy usage and CO_2 radiation utilizing CS- ARDL model. The study accumulated data from 30 provinces in China from 1995 to 2017. The estimated observations revealed the positive influence of national nature resources rent, FD and energy consumption on CO_2 emanation. But, green investment showed negative influence on environment. Islam, Khan, Tareque, Jehan, and Dagar (2021) evaluated the affiliation between FDI, globalization, GDP, trade, urbanization, innovation, energy utilization, and CO_2 radiation using a dynamic ARLD simulation model for estimation. The research assembled data from Bangladesh over the period spanning from 1972 to 2016. The study showed that FDI, globalization, institutional quality, and innovations negatively influencedCO_2discharge.Moreover, trade, GDP, energy consumption, and urbanization stimulate CO_2 exuding.

Khan, Hou, and Le (2021) explored the affiliation between RNE, natural resources, biocapacity population growth, NRE, and CO_2 outflow employing the GMM techniques. The study heaped data from the USA from 1971 to 2016. The findings of analysis manifest a positive consequence of population growth, NRE and bio-capacity on CO_2 exhalation; Additionally, RNE and natural resources impedes CO_2emanation. Kirikkaleli, Awosusi, Adebayo, and Otrakçı (2023) verified the union between RNE, CO_2 intensity of GDP, energy consumption, GDP,andCO_2 outflow by utilizing the NARDL model. The study analyzed data from Portugal over the period from 1990 to 2019. The empirical findings confessed that energy utilization, GDP, and intensity of GDP deteriorate the environment, while RNE improve the environmental quality. Real GDP, energy use, EPU and CO_2 radiation were analyzed by Adedoyin and Zakari (2020) using the ARDL model for UK from 1985 to 2017. Verifiable findings demonstrated a favorable relationship between real GDP, energy, and CO_2 radiation, while economic policy uncertainty had a negative effect on CO_2emission. Mukhtarov et al. (2023) inspected the tie between real GDP, exports, renewable energy, imports, and CO_2exhalationby using DOLS over the period 1993 to 2019 for Azerbaijan. The outcomes of the calculation unfold that RNE and export elevated the environmental quality; in contrast, imports and GDP decline the environment.

Appiah, Worae, Yeboah, and Yeboah (2022) evaluated the association between imports, GDP, exports, energy use, urban population, industry, and CO_2 emanation by OLS method over the period 1971 to 2013 for emerging economies. The verifiable evidence uncovered those imports, energy use, and industrialization positively influenced carbon emissions. Furthermore, economic growth, exports, and urbanization negatively influenced the environment. Sun et al. (2020) experimented with the causal link between GDP, energy consumption, trade openness, and CO_2 ejection by employing FMOLS from sub-Saharan African countries ranging from 1990 to 2014. The statistical calculation of the research demonstrated that energy consumption, GDP, and trade openness positively squealed the CO_2emanation.Employing FMOLS approach, Sicen, Khan, and Kakar (2022) evaluated the association between GDP, FDI, mineral rents, non-renewable energy, oil rents, forest rent, total natural resources rent and CO_2 radiation over the period 1995 to 2018 for BRICS economies. The analyzed results showed a positive reverberation of GDP, oil rents, mineral rents, and total natural resources on CO_2 emissions; yet, FDI inversely correlatedCO_2withemissions. Yang, Ali, Hashmi, and Jahanger (2022) demonstrated into the causal linkage between INSQ, GDP, energy, industrialization, trade, income inequality, and CO_2leakage for 42 developing economies from 1984 to 2016. The empirical outcomes displayed that industrialization, economic development, energy consumption, institutional quality, and trade openness enhanced environmental quality. Besides, income inequality beneficial impacted CO_2 emissions without an interaction term but negatively impacted CO_2 emissions with an interaction term.

Tachie et al. (2020), for EU-18 countries over the period 1990 to 2015, reported the tie between GDP, trade openness, energy consumption, urbanization, and CO_2exudingby employing AMG. The estimated outcomes of the analysis revealed a positive impact of GDP, energy consumption, and urbanization on CO_2 emissions; on the hand, GDP square and trade openness negatively influenced the environment. Jiang et al. (2022) discovered the association between energy use, FD,GDP,institutionalquality,andCO_2emanation using the Discoll-Kraay model. The study collected data from 57 B&R nation from 1995 to 2018. The calculated outcomes of the research manifested that GDP, financial development, natural resources rent and fossil fuel inferred a positive aftermath on CO_2 discharge. Yet, renewable energy and institutional quality adversely impacted CO_2 ejection. Hao et al. (2021) found the linkage between CO_2, renewable energy, trade openness, green innovations, FDI, GDP, financial innovations, and inflation rate by employing CCR model, over the period 1990 to 2020 for E7 countries. The estimated outcomes of the survey indicated the negative impact of renewable energy, financial innovations, green innovations, and trade on CO_2; meanwhile, GDP, inflation, and FDI beneficial influence environmental quality. Saidi and Omri (2020) reviewed the connection between nuclear energy, RNE, and CO_2 emanation from 1990 to 2018 for OECD countries. RNE and nuclear energy ameliorate environment.

2.1. Theoretical framework

Over the few decades, FSD has become a global trend (Li et al., 2021; Wang & Lei, 2016). FSD is an eminent factor in public finance theory; it can be defined as the shifting of revenues and expenditures from central authorities to the local or regional authorities (Oates, 1993; Safi et al., 2022). There are two different points of view on FSD regarding the environment. "Race to top" and "Race to bottom" are two views of FSD (Jiang et al., 2022; Tufail et al., 2021). FSD plays a very important role in enhancing the efficiency in allocating assets, stimulating Improvements in technology have helped lower the price of environmental regulation, better allocation of funds, strengthening institutional quality, and enhancing environmental sustainability. The" Race to top" theory prompts FSD in $FD_{it}>0$ the system (Gozgor, 2017; Helland & Whitford, 2003; The Phan et al., 2021).

The "Race to bottom" theory refers to the industrial economies. The countries that rely on industries face the "race to bottom" theory. Due to fragile institutional quality, inadequate environmental policies, and weak control on environmental quality for captivating foreign investment to boost economic growth. Such structure magnifies non-renewable energy utilization, leading to high CO_2 emanation to the atmosphere. This mechanism disseminated a positive connect between fiscal decentralization and CO_2discharge, $FD_{it}<0$ (Tufail et al., 2021). The EKC hypothesis by represents the tie between the environment and GDP. The EKC hypothesis proclaims an inverse linkage between income and environment. According to this hypothesis, as a country's economy grows, the level of CO_2 outflow also grows at the initial stages of economic development (Kaika & Zervas, 2013; Sikder et al., 2022). According to pollution intensity, The EKC can be split into three stages. The first stage states that pollution rises swiftly, but per capita income is low. In the next phase, people's income level increases, which empowers people to consume renewable energy. The second phase represents a watershed moment in the fight to better our planet's ecology. The third stage of EKC demonstrates a reduction in environmental depletion (Chen et al., 2019; Zoundi, 2017).

3. Methodology

This research attempted to discover the affiliation between fiscal decentralization, renewable energy consumption, GDP, non-renewable energy, ecological footprint and CO2. In this research, CO2 and ecological footprint are the dependent variables, while fiscal decentralization, non-renewable energy, renewable energy, and GDP are independent variables. The investigation analyzed the time series data from 2005 to 2021 in the Pakistan context.

The current study collected data from different sources; fiscal decentralization data is taken from the IMF, while CO2, NRE, RNE, and GDP data is extracted from World Bank indicators. Table 1 displays the variable's illustration. Data is turned into a logarithm to avoid any ambiguity.

Table1
Variable's Description

Variable's	Symbol	Estimation	Sources of data
Carbon emission	CO_2	CO_2 emissions (kt)	WDI
Non-renewable energy consumption	NRE	Fossil fuel energy consumption (% of total)	WDI
Renewable energy consumption	RNE	Renewable energy consumption (% of total final energy consumption)	WDI
Gross domestic product	GDP	GDP per capita growth (annual %)	WDI
Ecological footprint	EF	Carbon	https://data.footprintnetwork.org/?
Fiscal Decentralization	FSD	Revenue decentralization (ratio of own revenues to general government revenues)	IMF

To evaluate the long and short run results, we estimated the association of study variables using ARDL technique.

$$CO2 = f\ (FSD, NRE, RNE, GDP) \qquad (1)$$
$$EF = f\ (FSD, NRE, RNE, GDP) \qquad (2)$$

Where CO_2 is carbon emissions and is dependent variable, FSD represents fiscal decentralization, RNE expresses renewable energy consumption GDP stands for economic growth and NRE serves as non-renewable energy consumption.

$$CO_{2_t} = \psi_{02} + \phi_1 FSD_t + \psi_{03} NRE_t + \psi_{04} RNE_t + \psi_{05} GDP_t\ + + \mu_t \qquad (3)$$
$$EF_t = \psi_{02} + \psi_1 FSD_t + \psi_{03} NRE_t + \psi_{04} RNE_t + \psi_{05} GDP_t\ + + \mu_t \qquad (4)$$

The ARDL methodology has great dominance over other estimation approaches. (i) By applying the ARDL approach. We can estimate short and long-run elasticity with a single model (ii). The ARDL method capitulates vigorous measures when the series is stationary at I (0) and I(i) but vice versa for stationary at I (ii). (iii) In the ARDL approach, different lags of dependent and independent can be utilized (iv) The ARDL methodology is the outstanding option to avoid correlation and endogeneity (v) The error correction term (ECT) is an excellent criterion to measure the long-run correlation between used variables (Banerjee, Dolado, & Mestre, 1998). To drive the long-run combined co-integration correlation among variables ARDL bound test can used (Hao et al., 2021; Rjoub, Odugbesan, Adebayo, & Wong, 2021). ARDL bound test is almost the same as the traditional combined co-integration test but has some priorities over the traditional combined co-integration test. Firstly, it is vigorous for small sample sizes; secondly, it can be applied for integrated variables with different orders.

$$\Delta CO_{2_t} = \psi_{02} + \sum_{b=1}^{g} \psi_{03_i} \Delta\, CO_{2_{t-1}} + \sum_{b=0}^{h} \psi_{04_i} \Delta\, FSD_{t-i} + \sum_{b=0}^{i} \psi_{05_i} \Delta\, NRE_{t-i} + \sum_{b=0}^{j} \psi_{06i} \Delta RNE_{t-i} + \sum_{b=0}^{k} \psi_{07i}\, \Delta GDP_{t-i} + \forall_{02} CO_{2_{t-1}} + \forall_{03} FSD_{t-1} + \forall_{04} NRE_{t-1} + \forall_{05} RNE_{t-1} + \forall_{06} GDP_{t-1} + \mu_t \qquad (5)$$

$$\Delta EF_t = \psi_{02} + \sum_{b=1}^{g} \psi_{03_i} \Delta\, EF_{t-1} + \sum_{b=0}^{h} \psi_{04_i} \Delta\, FSD_{t-i} + \sum_{b=0}^{i} \psi_{05_i} \Delta\, NRE_{t-i} + \sum_{b=0}^{j} \psi_{06i} \Delta RNE_{t-i} + \sum_{b=0}^{k} \psi_{07i}\, \Delta GDP_{t-i} + \forall_{02} EF_{t-1} + \forall_{03} FSD_{t-1} + \forall_{04} NRE_{t-1} + \forall_{05} RNE_{t-1} + \forall_{06} GDP_{t-1} + \mu_t \qquad (6)$$

The ECT equation is given as under

$$\Delta CO_{2_t} = \psi_{02} + \sum_{b=1}^{g} \psi_{03_i} \Delta\, CO_{2_{t-1}} + \sum_{b=0}^{h} \psi_{04_i} \Delta\, FSD_{t-i} + \sum_{b=0}^{i} \psi_{05_i} \Delta\, NRE_{t-i} + \sum_{b=0}^{j} \psi_{06_i} \Delta RNE_{t-i} + \sum_{b=0}^{k} \psi_{07_i} \Delta GDP_{t-i} + \lambda ECT - 1 + vt_t \quad (7)$$

$$\Delta EF_t = \psi_{02} + \sum_{b=1}^{g} \psi_{03_i} \Delta\, EF_{t-1} + \sum_{b=0}^{h} \psi_{04_i} \Delta\, FSD_{t-i} + \sum_{b=0}^{i} \psi_{05_i} \Delta\, NRE_{t-i} + \sum_{b=0}^{j} \psi_{06_i} \Delta RNE_{t-i} + \sum_{b=0}^{k} \psi_{07_i} \Delta GDP_{t-i} + \lambda ECT - 1 + vt_t \quad (8)$$

The λ value in the above equation indicates the error correction term.

4. Empirical Finding and Discussions

Table 2 demonstrates the variables and their estimates. CO2 has the highest mean value (90.99533), and Fiscal decentralization (0.38665) has the lowest mean value. Economic growth represents the highest standard deviation (120.0779), and FSD shows the lowest standard deviation (0.021734). Other measures like skewness probability, Kurtosis and the sum of standard deviation are also mentioned.

Table 2
Descriptive Statistics

	CO_2	EF	FSD	GDP	NRE	RNE
Mean	90.99533	2.307294	0.38665	7.973148	87.46085	13.57676
Median	98.59281	2.426577	0.374627	7.134524	87.40786	13.43
Maximum	11.135682	2.54496	0.483199	13.63582	88.89836	17.44
Minimum	58.24625	1.683226	0.338094	1.995558	85.87274	11.34
Std. Dev.	16.69814	0.275417	0.036856	2.739501	0.737253	1.794889
Skewness	-0.65276	-1.13279	1.051898	0.113317	-0.04895	0.567698
Kurtosis	2.099561	2.883008	3.782412	3.234659	2.932228	2.430869
Jarque-Bera	1.781564	3.645462	3.568673	0.075387	0.010043	1.142564
Probability	0.410335	0.161584	0.167908	0.963008	0.994991	0.564801
Sum	1.55E+08	39.224	6.573048	135.5435	1486.835	230.805
Sum Sq. Dev.	4.46E+13	1.213675	0.021734	120.0779	8.696678	51.54605

Table 3
Stationary Results

Variable	ADF		PP	
	Level	1st Diff	Level	1st Diff
CO_2	-1.154	-5.271***	-1.272	-5.554***
EF	-0.173	-5.453***	-0.236	-5.454***
FSD	-4.435***	-9.862***	-4.435***	-10.103***
NRE	0.303	-5.626***	0.272	-5.522***
RNE	0.962	-7.465***	0.820	-6.632***
GDP	-4.033***	-10.63***	-3.506***	-6.169***

Note: *** denotes significance level at 1%.

All the study variables are stationary at mixed order of integration. None of the study variables are stationary at (II). In ADF and PP unit root test, CO_2, EF, NRE, and RNE are Stationary at I(I), yet GDP and FSD is stationary at I(0) as well as at I(1) in both test results.

Tables 4 and 5 present the bound test outcomes for both model cases. The findings affirm the presence of co-integration over the long term.

Table4
***Bound* Test Model 1 (CO_2)**

F-stat	Range	I(0) bound	I(1) bound
8.738	10%	2.45	3.52
	5%	2.86	4.01
	1%	3.74	5.06

Table 5
***Bound* Test Model 2 (EF)**

F-stat	Range	I(0) bound	I(1) bound
4.227	10%	2.45	3.52
	5%	2.86	4.01
	1%	3.74	5.06

Table 6-9 denotes the long and short-run results. Marvelously, fiscal decentralization inferred significant adverse ramifications in the long run for in Pakistan. The conclusions are the same as those of Safi et al. (2022) for OECD economies, Liu et al. (2022) for EU countries, and Shahzad and Fareed (2023) for Canada. Amazingly, NRE is positively affiliated with CO2 and EF in the long run in Pakistan. The results are similar to those of Jiang et al. (2022) for BRI countries and Yuan et al. (2022) for Japan. Surprisingly, GDP showed a significant favorable nexus with CO2 emission and ecological footprint in the long-run, while in the short period, economic growth showed an insignificant positive association with CO2 and ecological footprint for Pakistan's economy. The results parallel Chen et al. (2019) for China and Aydoğan and Vardar (2020) for E7 countries. The long and short-run upshots confessed inverse ramification of RNE on CO2 pouring and EF. The results imply that RNE favorably works for the betterment of environmental quality. The results are similar to Kirikkaleli et al. (2023) for Portugal and Jiang et al. (2022) for BRI countries.

Table 6
Long RunCO_2 Model

Variables	Coefficient	[S.E]	{T-st}
FSD	-4.18**	[1.42]	{2.93}
NRE	9.27**	[3.09]	{-2.99}
RNE	-0.29	[0.18]	{-1.54}
GDP	0.42*	[0.18]	{2.33}
C	60.62***	[14.66]	{4.13}

Table 7
Long Run EF Model

Variables	Coefficient	[S.E]	{T-st}
FSD	-0.64**	[0.24]	{2.63}
NRE	2.03***	[0.19]	{10.64}
RNE	-0.08**	[0.03]	{2.43}
GDP	0.03	[0.02]	{1.53}
C	-15.88***	[1.74]	{-9.08}

Table 8
Short Run (CO_2 Model)

Variables	Coeff	[S.E]	{T-ST}
D(L CO_2(-1))	-0.30	[0.25]	{-1.22}
D(L CO_2(-2))	0.33	[0.33]	{ 0.98}
D(LFSD_1)	0.18	[0.20]	{ 0.90}
D(LFSD_1(-1))	-0.93***	[0.24]	{ -3.75}
D(LNRE_1)	4.55**	[1.52]	{ -2.98}
D(LNRE_1(-1))	-2.05	[1.79]	{ -1.14}
D(LRNE_1)	-0.09*	[0.04]	{-2.06}
D(LGDP_3)	0.02	[0.01]	{ 1.19}
D(LGDP_3(-1))	-0.02	[0.01]	{ -1.64}
CointEq(-1)	-0.31**	[0.09]	{ -3.25}

Table 9
Short run (EF Model)

Variables	Coeff	[S.E]	{T-ST}
D(LFSD)	0.139	[0.09]	{ 1.43}
D(LNRE)	1.56***	[0.31]	{ 4.93}
D(LGDP)	0.00	[0.00]	{ 0.76}
D(LRNE)	0.06	[0.04]	{ 1.28}
D(LRNE(-1))	-0.07	[0.05]	{ -1.55}
CointEq(-1)	-0.59***	[0.16]	{-3.62}

Note: For reference, *** denote level of significance at 1%, ** at level 5%, and * at level 10%.The t-statistic {} and standard error [] are displayed by the square brackets.

5. Conclusion and Policy Recommendations

This research explored the convergence of FSD, NRE, RNE, and GDP on the Pakistan economy's CO_2 emissions and ecological footprint from 2005 to 2021. This paper applies the ARDL to scrutinize the repercussions of FSD on CO_2 outflow and ecological footprint. Particular research on the linkage between FSD, CO_2 emanation, and EF is available. However, previous research is based on both the panel and signal countries and is only limited to FSD influence on CO_2. This study also evaluates the fiscal decentralization effect on ecological footprint. Apart from previous research, this study includes RNE and NRE, which still needs to emphasize the Pakistan economy.

The estimated outcomes manifested the existence of long-run co-integration between study variables; additionally, the ARDL confirms a significant negative affiliation of fiscal decentralization with CO_2 emissions and EF in the short and long periods. The results recommend that the policymakers should set off a "Race to top" among the local authorities by setting strict environmental regulations. Fiscal decentralization may help invite foreign investment, enhancing environmental quality and reducing CO_2 emissions. NRE indicates a significant adverse affiliation with CO_2 ejection. Still, NRE consumption reveals a positive tie with the EF. RNE unfolds an inverse affinity with CO_2 discharge, whereas, with the ecological footprint, it shows a beneficial association with EF. The government should allocate funds for R&D in renewable sources. The country should focus on solar energy instead of conventional methods. GDP exacerbates CO_2 & EF and damages the environment, which implies that the government should promote environmentally friendly economic activities by encouraging the public and private sectors to invest in green technology.

Authors Contribution

Dr. Muhammad Faheem: conceptualization, complete writing, mathematical equations, data analysis and econometric analysis.
Dr. Fatima Farooq: conceptualization, supervision, analysis verification.
Asma Nousheen: proofreading, theoretical support, results verification, mathematical equations, and analysis verification.
Dr. Furrukh Bashir: results support and reference verification.

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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