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Fiscal policy for economic growth and environmental quality: insights from Pakistan's fiscal decentralization

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Abstract
Fiscal decentralization is perceived as a viable strategy for fostering economic growth in Pakistan. Concerns persist regarding its potential impact on environmental quality, particularly in relation to increased carbon emissions. Employing diverse analytical methods such as structural vector autoregressive (SVAR) modeling and autoregressive moving average model evaluations, this study comprehensively explores the dynamic relationships among fiscal decentralization, economic development, and environmental quality over the period 1979–2019. Intriguing trends emerge, revealing positive correlations between environmental efficiency and variables, including revenue collection, tax autonomy, and transfer payments. Conversely, a negative correlation is observed between government spending and economic growth. The interplay of these variables results in oscillations in the influence of fiscal decentralization on carbon emissions, presenting a complex challenge for policymakers. Notably, positive fiscal decentralization shocks lead to an increase in carbon emissions, while positive expenditure decentralization and economic development correlate with decreased carbon emissions. Despite economic growth's statistically significant negative impact on carbon emissions, the intricate nature of the relationships underscores the complexity of the link between fiscal decentralization, economic expansion, and environmental outcomes. From a policy perspective, the study emphasizes the need to adjust fiscal policies and coordinate intergovernmental fiscal ties across all government levels to enhance environmental efficiency. These findings provide policymakers with valuable insights to navigate the intricate landscape of fiscal decentralization and its environmental implications.

Keywords Fiscal policy · Decentralization · Economic growth · Environmental efficiency · Federalism

JEL Classification E62 · O1 · Q56

1 Introduction

Over the past few decades, a notable increase in global temperatures has led to significant environmental challenges worldwide. This phenomenon, often called global warming, has sparked intense debates. In the last two decades, Pakistan has been badly affected by climate change; heat & cold waves, rain floods, carbon emissions, and smog are

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the recent examples of the southern regions of Pakistan, such as Sindh and Punjab [1]. The Planning Commission of Pakistan is to reform roadmap goals to hasten sustainable development, emphasizing the need for economic growth that protects, rather than harms, the environment [2].

Pakistan's alarming air quality situation has further heightened the urgency of addressing environmental sustainability concerns as the nation's economy strives to recover from recent downturns. To tackle these challenges, the government has adopted various strategies to reduce carbon emissions and transform the economic growth model to ensure a sustainable environment [3]. However, Oates [4] and Wang and Lei [5] fiscal decentralization has a crucial role in emission reduction. It also improves local welfare and economic efficiency [6]. Fiscal decentralization is only partially implemented in nations with authoritarian regimes. There is a marked difference between the trend of rising fiscal decentralization in other emerging countries with federal political systems, including India, South Africa, Mexico, Ethiopia, Brazil, and Malaysia, and the rarity of fiscal decentralization in Pakistan [7]. Fiscal decentralization remains challenging for underdeveloped countries with mature fiscal federalism processes that are still ongoing. But even more so, developing countries face additional challenges in implementing more profound fiscal arrangements between their various governmental levels [8]. Examining how decision changes affect the division of financial authority between the federal government and provincial governments, the research aims to offer nuanced insights into fiscal decentralization.

Pakistan's economy has grown significantly in recent years, but prosperity hasn't been properly spread among the country's regions. Its unequal development may be attributed to the nation's highly centralized fiscal structure, which makes it difficult for regional governments to deploy resources effectively [8]. Several environmental issues, including air and water pollution, deforestation, and climate change, also affect Pakistan and potentially have a significant economic impact. As a result, research is required to determine how Pakistan's fiscal decentralization impacts economic growth and environmental efficiency [9]. The discussion is only limited to revenue and expenditure dimensions of fiscal decentralization for measuring economic development and environmental sustainability. The role of intergovernmental transfers and tax autonomy are widely ignored in the literature. Fiscal decentralization policy decisions in Pakistan and other developing nations with comparable political and economic environments can be informed by this knowledge [10]. Extensive literature is available only on revenue and expenditure, economic development, and environmental quality in the long run in China [11]. Some scholars have started to analyze the effects of the financial metrics on economic growth and ecological sustainability by empiric review, concluded with inconsistent results [12, 13]. As per fiscal federalism theory, decentralization increases economic efficiency; it positively impacts CO_2 emission. In Pakistan's case, environmental problems, such as air pollution, deforestation, and global climate change's overall effects, have complicated the country's development environment [14]. These environmental problems might negatively impact the economy and pose severe dangers to the population's health. For instance, poor air quality can have a negative impact on people's health, resulting in higher medical costs, lower worker productivity, and a general slowdown in economic activity [14]. In that case, we must weigh the direct effect on the efficient allocation of financial resources, the indirect impact on environmental efficiency, and other potential benefits such as government efficiency.

The study explores the dynamic relationships among revenue, expenditure, tax autonomy, transfer payment, economic development, and environmental quality in Pakistan. The research aims to investigate how fiscal policies, particularly related to decentralization, impact economic growth and environmental efficiency in Pakistan? By employing diverse analytical methods such as structural vector autoregressive (SVAR) modeling and autoregressive moving average model evaluations, the study provides a comprehensive analysis of these relationships over the period 1979–2019. Moreover, this study suggests that a well-ordered decentralized fiscal policy should offer an essential framework for achieving economic development and enhanced environmental quality, which helps policymakers in Pakistan. It intends to draw attention to the necessity of thorough fiscal policy reforms in tax autonomy and transfer payments. It provides a solid foundation for decision-makers that might promote environmental sustainability and economic growth. Furthermore, the study intends to contribute a better understanding of the intricate relationships between decentralized fiscal policy, economic development, and environmental quality in Pakistan by examining fiscal policy implications in the economy.

The remaining paper's organization is as follows: in Sect. 2, existing studies have discussed the relationship between environment, fiscal decentralization, and economic growth. In Sect. 3, the data and variables are analyzed and examined using empirical methodology. Section 4 presents the empirical study results discussed and highlighted, and Sect. 5 is about the conclusion.

2 Literature review

Air pollution has become a critical issue in Pakistan, especially in its major cities, leading to significant economic challenges. This study looks into how fiscal decentralization affects economic growth and environmental quality in Pakistan. It highlights the need to understand these relationships to develop effective policies for sustainable development.

2.1 Fiscal decentralization and environmental quality

An emerging discussion subject in government and research circles has been regulatory and political devolution [14]. There is an array of methodological and theoretical research on fiscal decentralization and different consequences on public services distribution, such as environmental Quality [3, 5, 11, 15, 16]. This research develops hypotheses on decentralization's scientific effect on environmental quality. The valuable fiscal decentralization outcomes are uncertain and present an incentive to determine various analytical effects [17]. The study discovered that economic development is linked to environmental performance, provided fiscal decentralization affects GDP growth and may indirectly impact climate quality [18]. The Environmental Kuznets Curve (EKC), which claims an inverted U-shaped effect on environmental performance and per capita revenue, will check the connection [19]. Zaman et al. [20] and Khan [21] also support the existence of the inverted U-shaped EKC by expressing sound economic models in a particular theoretical article. So, the urban change could affect the efficiency of the atmosphere, thru economic expansion, fiscal decentralization will indirectly influence environmental conditions [14]. Besides, fiscal decentralization can directly impact ecological sustainability, and greater decentralization can increase the ecosystem's efficiency [5, 22]. It demonstrates that the real purpose of fiscal decentralization is to promote GDP growth, with the consequence that lower-level income, taxation, and debt sovereignty have direct benefits. A higher degree of decentralization encourages local authorities to spend further on construction infrastructure, such as greenhouse gas emissions [23]. Conventional federalism postulates that local jurisdictions can opt to release high contamination levels across boundaries due to the trans-regional spillover effects of carbon emission [5]. Fiscal decentralization has already been seen to play a vital role in raising environmental pollution.

2.2 Environmental quality and economic growth

Gross domestic product (GDP) is a critical driver for economic growth. Higher expectations for GDP can be reached by progressing industrialization, productivity, and manufacturing sectors. On the other hand, higher production and manufacturing activities can have environmental impacts. Exploring carbon pollution determinants for 69 countries, Sharma [24] assigned the set of countries to high-income, middle-income, and low-income provinces; it uses time-series data from 1985 to 2005. The study used GMM and unit root tests for analysis and found that carbon emission is favorably influenced by per capita GDP, access to trade, and energy usage. However, the effect of urbanization on carbon emissions is seen as unfavorable. The statistically significant determinants of carbon pollution involve per capita GDP and per capita energy use for the global council. The association between energy use and GDP confirms the favorable long-term relationship between energy usage and GDP [25]. China's GDP, economy, industrialization, and carbon emission linkages for 1980–2010 are further analyzed [26].

The STIRPAT model analysis verifies the co-integration of these variables: besides, the amount of carbon pollution is also raised by GDP per capita, population, and industrialization rate [27]. Investigate the two-way causality between energy consumption, carbon pollution, and economic development. Conversely, Khan et al. [28] verify the following variables' cointegration. The economic development mechanism is influenced by fiscal decentralization. Fiscal decentralization could indirectly affect environmental sustainability, as researchers noted that GDP growth is connected to environmental efficiency [18]. The influence of fiscal decentralization on environmental efficiency in Pakistan is examined [9]. The findings indicate that fiscal decentralization promotes local government accountability and response to environmental concerns, which is good news for environmental efficiency. The link between fiscal decentralization, economic growth, and environmental deterioration in Pakistan is examined in a recent research [8]. According to the research, fiscal decentralization boosts economic growth but also has a negative impact on the environment [29].

We have used the endogenous growth theory model to inspect the active partnership between environmental degradation and fiscal decentralization. Linked results obtained by [14] explored, conceptually and empirically, the linkages between fiscal decentralization and ecological performance. Literature does not explain if decentralization is a "race to the bottom" or a "race to the top" but relies on the country's conditions [16]. The two primary explanations behind these contradictory findings. First, various recent studies use different frameworks to examine the association between fiscal decentralization and environmental quality [30, 31]. Still, far fewer analyses, such as the endogenous growth model, have used this connection's ideal model. Second, recent literature on this subject has suggested that the relationship between fiscal decentralization and the climate's efficiency is linear, but this effect can be nonlinear. Besides, all previous studies have been completed in developed and emerging markets. Their literature provides the research gap that has scrutinized this partnership from an established economic point of view. These negative statements often encourage scholars to re-investigate this relationship with fresh insights and relevant econometric models.

2.3 Fiscal decentralization and economic growth

In recent decades, the connections between fiscal decentralization and economic growth have been extensively debated [17, 32–35]. Fiscal decentralization has different effects on GDP growth and enhances economic growth. Oates [4] analyzed that fiscal decentralization provides the necessary means for local councils to resolve financial problems and make them accountable for economic growth. Three different claims of the classes can be divided into the favor of fiscal decentralization and sustainable growth. The first argument is known as the "diversification hypothesis," which indicates that in all provinces and municipalities of the world, the homogeneous levels of public goods are incompetent since differences in citizens' tastes are not adequately recognized at the local level [36]. The second argument is that autonomous governments actively implement cost reduction and quality enhancement production strategies through technologies that increase producers' efficiency and economic growth [37]. The 3rd quarrel is recorded as the "productivity enhancement hypothesis," which defines the change by decentralizing responsibilities and accountability [10, 38]. Fiscal decentralization favors economic growth, but its effects on environmental sustainability is less clear. The fiscal decentralization improves local government accountability and responsiveness to environmental issues, favoring environmental quality. However, Chen [39] demonstrated fiscal decentralization's influence on environmental quality. The findings implied that fiscal decentralization improves environmental quality by allowing for more efficient resource allocation and great local government accountability.

A comparison and contrast of earlier results shows that the Impact of Fiscal Decentralization on Environmental Quality: Research on the effects of fiscal decentralization on environmental quality has produced various contradictory results. According to particular research, fiscal decentralization may improve local government accountability and resource distribution, improving environmental sustainability [9, 39]. However, according to some studies, fiscal decentralization may worsen environmental deterioration, especially regarding regional imbalances and unequal regional growth [40].

On the other hand, some researchers contend that fiscal decentralization would harm local economies but reduce income inequalities [40]. Fiscal decentralization leads to economic growth and regional disparity as low-income regions can only buy less public service from their resources. Still, wealthier regions have better service and relatively higher wages, thus delaying economic growth by regional prosperity [41, 42]. Explain that it is more difficult for the federal government to exercise its stabilization position; a higher degree of decentralization would affect long-term economic growth. While the theoretical basis for fiscal decentralization has been well recognized, the methodological results have diversified more. A panel study of 46 countries by [33] concluded that fiscal decentralization had no significant effect on the mechanism of economic development. On the other hand, the Chinese regional data panel's [43] analysis found that fiscal decentralization significantly impacted GDP growth. A strand of literature [32, 44] evaluated a negative association with fiscal decentralization, economic growth, and internet communication technology. At the same time, others [45, 46] identify a negative relationship, which states that fiscal decentralization affects economic growth from diverse perspectives.

According to prior research, economic growth and carbon emissions are positively correlated with environmental decentralization; it controls increasing industrialization and productivity, contributing to more significant carbon emissions [24]. Some research also suggests the possibility of sustainable economic development policies that prioritize resource efficiency and environmental conservation [18]. The literature emphasizes using theoretical frameworks like the Environmental Kuznets Curve and the endogenous growth theory to comprehend the interaction between economic development and environmental sustainability [19]. While some research suggests that there is an inverted U-shaped association between economic growth and environmental deterioration [20], other research suggests that a more thorough and nuanced study that takes into account a variety of contextual elements that may influence this relationship is necessary [30]. These studies indicate that fiscal decentralization can positively affect Pakistan's economic growth and environmental sustainability, although its effects on environmental deterioration are conflicting. The link between fiscal decentralization, economic growth, and environmental sustainability in Pakistan and other developing nations requires more study. This study has certain limitations concerning the local government context due to the unavailability of data at the divisional level.

In the context of Pakistan, the literature review emphasizes the crucial interactions that exist between fiscal decentralization, economic growth, environmental quality, and institutional quality. Previous research emphasizes budgetary policies, especially decentralization, which can affect both environmental sustainability and economic growth. The evaluation of the literature highlights research gaps pertaining to the scant investigation of decentralized fiscal policy in the presence of transfer payments, tax autonomy, environmental quality, and economic growth. It also emphasizes the importance of institutional quality, governance effectiveness, and legitimacy in promoting environmental sustainability and financial success. The goal of the study is to provide new insights and support policy decisions that aim to promote sustainable development in the nation by synthesizing current research and finding gaps in the literature. This research applies a variety of analytical techniques, including autoregressive moving average model assessments and structural vector autoregressive (SVAR) modeling, to thoroughly examine the dynamic links between fiscal decentralization, economic development, and environmental quality.

3 Research methodology

Fiscal federalism theory clarifies the inevitable relationship between fiscal decentralization economics development and environmental efficiency. Fiscal decentralization, including the first school of thought, aims to increase the environment's efficiency. The process parameters are based on a simple log-linear extended Solow growth model in which economic growth is a function of many inputs with a degree of decentralization. The presented linear functional form methods can be described in the following aspects: these ideas show that public decision-makers are compassionate about maximizing public goods provision, and social security is equally distributed [3]. In this situation, provincial and local governments are doing better than the unitary government without detrimental externalities. Fiscal decentralization creates a better allocation of public goods and resources, encouraging a high environmental efficiency standard. In secondary schools of thought, public policies are driven by political systems that always deviate from maximizing people's well-being [47]. Suggested that fiscal decentralization is counterproductive to enhancing economic efficiency. Moreover, the investigation of stationarity and the assessment of long-term relationships among variables were conducted through the implementation of unit root tests and cointegration tests. For this study, the data for developing economies such as Pakistan is taken from the World Bank Development Indicators (WDI) based on world economic development; fiscal decentralization indicators data is available at the State Bank of Pakistan and the World Governance Index World Bank & ICRG from 1979 to 2019. Table one presents the variable definitions, measurements, and sources of the data (Table 1).

3.1 Model specification

Basic models adopt previous literature, and we evaluate the impact of fiscal decentralization and economic growth on Pakistan's environmental efficiency. We firmly assume the [16, 48] templates and use the following four stipulations: linearity in variable relationships, homogeneity of shocks, absence of measurement error in observed variables, and the stationarity of time series data.

A Structural Vector Auto Regression (SVAR) model is a system of linear equations that captures dynamic relationships among variables. The general SVAR model is expressed as:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + BZ_t + \varepsilon_t \tag{1}$$

where Y_t is a vector of endogenous variables at time t; A_1, A_2, …., A_p are coefficient matrices representing lagged effects, Z_t is a vector of exogenous variables, B is the matrix of coefficients for exogenous variables, ε_t is a vector of error terms.

A system of equations is employed to estimate this model, with each equation representing one variable in the vector Y_t. Various estimation methods, such as Maximum Likelihood Estimation (MLE), or Bayesian methods, can be utilized.

Let's denote Y_t as a vector with three variables: Y_{1t}, Y_{2t}, and Y_{3t}. The SVAR model for this system can be expressed as:

Table 1 Variables definitions and data resources

Variables	Symbols	Definition	Data Source
Economic Growth	GDPG	GDP Growth (% Annual)	WDI
Carbon Dioxide Emission	CO_2	Carbon Dioxide Emission (Kilotons)	WDI
Provincial Government Expenditure	PGE	% of the Provincial Govt. expenditure as total government expenditures (Federal + Provincial)	SBP
Provincial Govt. Revenue	PGR	% of the Provincial Govt. revenue to the total government revenue (Federal + Provincial)	SBP
Provincial Govt. Tax Autonomy	PGTA	% of the Provincial Govt. tax revenue to the total government tax revenue (Federal + Provincial)	SBP
Federal Transfers	FT	% of the provincial government expenditures	SBP
Government Size	GS	Total government expenditure as % of GDP	SBP
Institutional Quality	IQI	Institutional quality is the index of six indicators: political stability, corruption control, government efficiency, law rule, and Regulation Quality. (Estimate of governance (ranges from approximately −2.5 (weak) to 2.5 (strong) governance performance)	WGI World Bank & ICRG

$$\begin{pmatrix} Y_{1t} \\ Y_{2t} \\ Y_{3t} \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{pmatrix} \times \begin{pmatrix} Y_{1t-1} \\ Y_{2t-1} \\ Y_{3t-1} \end{pmatrix} + \begin{pmatrix} B_{11} & B_{12} & B_{13} \\ B_{21} & B_{22} & B_{23} \\ B_{31} & B_{32} & B_{33} \end{pmatrix} \times \begin{pmatrix} Z_{1t} \\ Z_{2t} \\ Z_{3t} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{pmatrix} \tag{2}$$

The structural Vector Auto-regression (SVAR) model is a statistical technique that analyzes the relationships and dynamics between multiple time series variables. This methodology is widely used in econometrics and macroeconomics to study the impact of shocks in a system of variables over time. SVAR model is a system of equations where each variable is regressed on its own lagged values and the lagged values of all other variables in the system. The basic idea is to capture the interdependencies and interactions among variables over time [48]. A VAR model of order p is represented for k variables where Yt is a column vector of k variables at time t, c is a constant vector, A1, A2, …, Ap are coefficient matrices. $Y_{\_(t-1)}$, $Y_{\_(t-2)}$, …, $Y_{\_(t-p)}$ are lagged values of the variables. ε_{it} is a vector of error terms. Based on our discussion, the following general linear regression model for time series data has been considered.

$$\begin{aligned} CO2_t = {} & a_1 * CO2_{t-1} + b_1 * GDPG_{t-1} + c_1 * PGE_{t-1} + d_1 * PGR_{t-1} + \varepsilon_{1t} \\ & + f_1 * PGTA_{t-1} + g_1 * FT_{t-1} + h_1 * GS_{t-1} + i_1 * IQI_{t-1} + \mu_{1t} \end{aligned} \tag{3}$$

$$\begin{aligned} GDPG_t = {} & a_2 * CO2_{t-1} + b_2 * GDPG_{t-1} + c_2 * PGE_{t-1} \\ & + d_2 * PGR_{t-1} + \varepsilon_{2t} + f_2 * PGTA_{t-1} + g_2 * FT_{t-1} \\ & + h_2 * GS_{t-1} + i_2 * IQI_{t-1} + \mu_{2t} \end{aligned} \tag{4}$$

$$\begin{aligned} PGE_t = {} & a_3 * CO2_{t-1} + b_3 * GDPG_{t-1} + c_3 * PGE_{t-1} + d_3 * PGR_{t-1} \\ & + \varepsilon_{3t} + f_3 * PGTA_{t-1} + g_3 * FT_{t-1} + h_3 * GS_{t-1} + i_3 * IQI_{t-1} + \mu_{3t} \end{aligned} \tag{5}$$

$$\begin{aligned} PGR_t = {} & a_4 * CO2_{t-1} + b_4 * GDPG_{t-1} + c_4 * PGE_{t-1} + d_4 * PGR_{t-1} \\ & + \varepsilon_{4t} + f_4 * PGTA_{t-1} + g_4 * FT_{t-1} + h_4 * GS_{t-1} + i_4 * IQI_{t-1} + \mu_{4t} \end{aligned} \tag{6}$$

$$\begin{aligned} PGTA_t = {} & a_5 * CO2_{t-1} + b_5 * GDPG_{t-1} + c_5 * PGE_{t-1} + d_5 * PGR_{t-1} + \varepsilon_{5t} \\ & + f_5 * PGTA_{t-1} + g_5 * FT_{t-1} + h_5 * GS_{t-1} + i_5 * IQI_{t-1} + \mu_{5t} \end{aligned} \tag{7}$$

$$\begin{aligned} FT_t = {} & a_6 * CO2_{t-1} + b_6 * GDPG_{t-1} + c_6 * PGE_{t-1} + d_6 * PGR_{t-1} \\ & + \varepsilon_{6t} + f_6 * PGTA_{t-1} + g_6 * FT_{t-1} + h_6 * GS_{t-1} + i_6 * IQI_{t-1} + \mu_{6t} \end{aligned} \tag{8}$$

$$\begin{aligned} GS_t = {} & a_7 * CO2_{t-1} + b_7 * GDPG_{t-1} + c_7 * PGE_{t-1} \\ & + d_7 * PGR_{t-1} + \varepsilon_{7t} + f_7 * PGTA_{t-1} + g_7 * FT_{t-1} + h_7 * GS_{t-1} + i_7 * IQI_{t-1} + \mu_{7t} \end{aligned} \tag{9}$$

$$\begin{aligned} IQI_t = {} & a_8 * CO2_{t-1} + b_8 * GDPG_{t-1} + c_8 * PGE_{t-1} + d_8 * PGR_{t-1} + \varepsilon_{8t} \\ & + f_8 * PGTA_{t-1} + g_8 * FT_{t-1} + h_8 * GS_{t-1} + i_8 * IQI_{t-1} + \mu_{8t} \end{aligned} \tag{10}$$

In the above equations, variables before the equal sign represent the dependent variable at time t. $GDPG_t$, PGE_t, PGR_t, $PGTA_t$, FT_t, GS_t, and IQI_t represent the independent variables in each equation at time t. $CO_{2\_(t-1)}$, $GDPG_{\_(t-1)}$, $PGE_{\_(t-1)}$, $PGR_{\_(t-1)}$, $PGTA_{\_(t-1)}$, $FT_{\_(t-1)}$, $GS_{\_(t-1)}$, and $IQI_{\_(t-1)}$ are the lagged values of the respective variables at time $_{t-1}$. a_1, a_2, …, h_8 are coefficients that represent the effects of lagged variables on each variable of interest. μ_{1t}, μ_{2t}, …, μ_{8t} are each variable's error terms or shocks at time t.

The above equations allow us to estimate how changes in the independent variables impact carbon emissions and vice versa while accounting for lagged effects and error terms.

3.1.1 Unit root

First, we used the time series to increase the Augmented Dickey-Fuller [49], also recognized and measured separately. These controls are needed to avoid imitation regression. The time series and unit root tests are conducted for all chosen variables. When used in time series results, the test ensures no propensity for spurious regression. As ADF is introduced, the time series and unit root test solve the low power problem. Credible proof should, however, be given by the examination [50]. It showed that the unit root test is more effective than the unit root test, which is time-series data. In previous research on energy consumption, these approaches have been commonly used. The Unit Root Test equation is as follows:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \delta_2 \Delta y_{t-2} + \cdots + \delta_p \Delta y_{t-p} + \varepsilon_t \quad (11)$$

where: y_t is the series variable, Δ represents the differencing between the current value and the previous one, α is the constant term, *β is coefficient* associated with time trend, γ measures the impact of the lagged level of time series $\delta_{1,}$ $\delta_{2,}$ …, δ_p are coefficient for lagged differences and ε_t is the error term symbolize the intercept, the analysis variables, the difference operator, the period, and the disorder term correspondingly. In the literature, this second-generation unit root test is frequently used as a unit root study dependent on first-generation approaches, generating misleading conclusions.

4 Results and discussions

Data stationery is also an essential issue; if decentralization is highly persistent, each country's decentralization series may suffer from a unit root, resulting in inaccuracy in the estimates. It can ascertain whether dependent and independent variables are stationary using a unit root test, which is widely used for time series data. The result of the Augmented Dickey-Fuller Test is that we reject the null hypothesis. The literature commonly recognizes that the fiscal decentralization-economic growth dynamic may be endogenous. It implies that economic decentralization and local spending may control environmental deterioration in Pakistan. Contrarily, GDPG has a significant coefficient in Table 5, the SVAR model, indicating that more substantial economic growth may result in fewer carbon emissions, which may caused by more investment in clean technology and renewable energy. These findings collectively imply that fiscal decentralization, economic growth, and environmental efficiency are interconnected in Pakistan to effectively reduce carbon emissions and advance sustainable development in the nation [51].

The pairwise correlations between the chosen variables are shown in Table 2. Based on the pairwise correlation results, carbon emission has a positive and statistically significant connotation with provincial government expenditure, revenue, tax autonomy, and transfer payments. However, economic growth, government size, and institutional quality are negatively associated with carbon emission, and decentralization-relevant variables are positively correlated.

The ADF Unit Root Test results are reported in Table 3. Before using the Co-integration test, examining each variable's unit root is mandatory. Each manipulated variable is not stationary at I (2); otherwise, the inspected findings might lead to suspicious results. The ADF tests' null hypothesis is that the underlying series possesses a unit root (non-stationary). The results indicate the carbon emission revenue and economic growth are stationary at Stage I (0). Expenditure, tax autonomy, transfer payments, government size, and institutional quality contain unit root at a level while stationary at the first difference I(1). Table 3 Unit root test has been done to scrutinize the variables stationary at what levels.

Table 2 Correlation

Variables	$LNCO_2$	PGE	PGR	PGTR	IQI	GS	GDPG	FT
LNCO2	1.000							
PGE	0.170	1.000						
PGR	0.472	0.863	1.000					
PGTA	0.031	0.616	0.449	1.000				
IQI	− 0.706	− 0.033	− 0.189	0.179	1.000			
GS	− 0.672	0.426	0.141	0.270	0.482	1.000		
GDPG	− 0.354	0.114	− 0.072	0.384	0.212	0.179	1.000	
FT	0.749	0.452	0.699	0.160	− 0.232	− 0.338	− 0.341	1.000

Table 3 Unit root test

Variables	Level		First difference		Decision
	Intercept	Intercept and trend	Intercept	Intercept and trend	
D(PGE(– 1))	– 1.027177 (0.2748)	– 1.7378 (0.7245)	– 0.639 (0.010)	– 0.724 (0.000)	I(1), 1st Diff
PGR(– 1)	– 0.2847 (0.0002)	– 0.758 (0.0016)	– 1.445 (0.134)	– 1.635 (0.266)	I(0) Level stationery
D(PGTR(– 1))	– 1.205 (0.6022)	– 1.124 (0.0983)	– 1.921 (0.0321)	– 1.246 (0.0032)	I(1) 1st Diff
D(IQI(– 1))	– 1.062 (0.9546)	– 2.376 (0.0626)	– 0.853 (0.0002)	– 0.352 (0.002)	I(1), 1st Diff
D(GS(– 1))	– 2.398 (0.955)	– 2.376 (0.092)	– 1.732 (0.004)	– 1.352 (0.002)	I(1), 1st Diff
GDPG(– 1)	– 0.6760 (0.0001)	– 0.6234 (0.0001)	– 0.8101 (0.061)	– 0.6970 (0.0701)	I(0) Level
D(FT(– 1))	– 2.040 (0.2694)	– 2.526 (0.3148)	– 1.05580 (0.000)	– 1.940 (0.000)	I(1), 1st Diff
LNCO2(– 1)	– 0.24093 (0.0060)	– 0.2945 (0.0037)	– 0.776 (0.0790)	– 0.711 (0.6900)	I(0), 1st Diff

Table 4 explains pairwise Granger causality tests are used to determine whether time series variables can predict each other. The tests examined whether each variable's granger causes the other, with the null hypothesis stating no such causal relationship. The results revealed varied outcomes. Notably, expenditure was found to cause carbon emission, while $LNCO_2$ and Granger caused PGR and DPGTR. On the other hand, several pairs, including $LNCO_2$ and DGS, $LNCO_2$ and GDPG, and $LNCO_2$ and FT, exhibited no evidence of Granger causality. These estimations provide an understanding of the sequential relationships between the stated variables, shedding light on possible maneuvering effects in the dataset. A massive amount of literature is available on fiscal decentralization's impacts on economic growth in Pakistan, such as [52, 53]. It was discovered that the devolution of revenue powers prompted economic growth by raising revenue collection. Simultaneously, expanding revenue collection otherwise diminishes tax rate and burden. In our models, the revenue, tax autonomy, and federal transfer coefficients are passively significant with carbon emissions. In comparison, expenditure (PGE) is negatively associated with carbon emissions.

From Table 5. it has been scrutinized that the study's statistical analysis produced several noteworthy results. According to the regression analysis findings, several factors had a statistically significant influence on the dependent variable. Except where otherwise noted, all statistical analyses are carried out at a significance level. Variables showed potential impact on the dependent variable even if it did not meet traditional significance standards ($p = 0.128$). A possible influence on coefficient estimate of – 16.615 ($p = 0.175$) also does not approach statistical significance. With a coefficient estimate of 0.261 ($p = 0.968$), the effect on the dependent variable was not statistically significant. The dependent variable may have been impacted, as shown by the coefficient estimate of 0.536 ($p = 0.162$), although it did not reach the usual significance levels. Variable 5 showed an inverse solid connection with the dependent variable, with a coefficient estimate of –0.983, and was highly statistically significant ($p < 0.001$).

Table 4 Granger causality estimates

Pairwise Granger Causality Tests			
Null Hypothesis:	Obs	F-statistic	Prob
Lnco2 ≠ DPGE	40	1.26600	0.2898
LNCO2 ≠ DPGE		0.25795	0.0035
PGR ≠ LNCO2	40	1.22855	0.0004
LNCO2 ≠ PGR		1.18626	0.0128
DPGTR ≠ LNC02	40	1.70010	0.1918
LNC02 → DPGTR		9.27970	0.0003
IQI ≠ LNCO2	40	0.90847	0.409
LNC02 ≠ IQI		0.18304	0.8332
DGS ≠ LNCO2	40	0.18930	0.8281
LNCO2 ≠ DGS		0.02846	0.972
GDPG ≠ LNCO2	40	0.13498	0.874
LNCO2 ≠ GDPG		0.79959	0.4545
FT ≠ LNCO2	40	0.05199	0.9494
LNCO2 ≠ FT		0.11736	0.8895

Table 5 SVAR estimation results

	Coef	St.Err	*t*-value	*p*-value	[95% Conf	Interval]	Sig
Constant	1.000						
Constant	12.727	8.365	1.52	0.128	− 3.667	29.121	
Constant	− 16.615	12.239	− 1.36	0.175	− 40.603	7.373	
Constant	0.261	6.423	0.04	0.968	− 12.329	12.851	
Constant	0.536	0.384	1.40	0.162	− 0.215	1.288	
Constant	0.000						
Constant	1.000						
Constant	0.376	0.230	1.63	0.123	− 0.076	0.827	
Constant	− 0.983	0.122	− 8.04	0.000	− 1.222	− 0.743	***
Constant	− 0.172	0.012	− 14.32	0.000	− 0.195	− 0.148	***
Constant	0.000						
Constant	0.000						
Constant	1.000						
Constant	− 0.129	0.083	− 1.56	0.120	− 0.292	0.034	
Constant	− 0.003	0.005	− 0.50	0.614	− 0.013	0.007	
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	1.000						
Constant	− 0.007	0.010	− 0.72	0.469	− 0.026	0.012	
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	1.000						
Constant	0.021	0.002	8.72	0.000	0.016	0.025	***
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	1.060	0.122	8.72	0.000	0.822	1.298	***
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	1.506	0.173	8.72	0.000	1.167	1.844	***
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	0.772	0.089	8.72	0.000	0.598	0.945	***
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	0.000						
Constant	0.046	0.005	8.72	0.000	0.036	0.056	***
Mean dependent var		11.501	SD dependent var				0.533
Number of obs		38.000	Akaike crit. (AIC)				0.025

Significant level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

First, a statistically significant influence of the variable represented by a coefficient estimate of 12.727 on the dependent variable was discovered ($p=0.128$) despite it not reaching conventional thresholds of significance. Second, a different variable with a −16.615 coefficient estimate was also examined. Although it indicated a potential impact on the outcome ($p=0.175$), it was not statistically significant; these results are closely associated with the results from [4, 54]. Thirdly, the dependent variable did not seem to be significantly impacted by a variable with a coefficient estimate of 0.261 ($p=0.968$). Despite possibly impacting the dependent variable ($p=0.162$), the fourth variable, indicated by a coefficient of 0.536, did not meet the usual significance level. The study discovered a coefficient estimate of −0.983 (p 0.001), which suggests that the variable has a highly statistically significant influence on the dependent variable, as the fifth finding. This result indicates the significant inverse association between the independent variable and this variable. Another factor was similarly highly statistically significant (p 0.001) and important in explaining the variance in the dependent variable, with a value of −0.172. Although it did not meet the usual significance threshold, a variable with a coefficient estimate of −0.129 showed a possible impact on the dependent variable ($p=0.120$).

Additionally, the dependent variable did not exhibit a statistically significant influence from a variable with a coefficient estimate of −0.003 ($p=0.614$). The study found one variable to have a very significant influence, as shown by a coefficient of 1.060 (p 0.001). This result implies that this variable and the dependent variable have a strong positive association. Another variable's coefficient of 1.506 indicated that it significantly impacted the dependent variable and was also highly statistically significant (p 0.001). Further highlighting its significance, a variable with a coefficient estimate of 0.772 showed a statistically significant influence on the dependent variable (p 0.001). Last but not least, a variable with a coefficient estimate of 0.046 was highly statistically significant (p 0.001), highlighting its contribution to explaining fluctuations in the dependent variable. With a mean of 11.501 and a standard deviation of 0.533, the dependent variable's central tendency and variability among the 38 observations were revealed.

The estimated coefficient of government size is negative but significantly related to carbon emissions; however, in Table 5. SVAR, institutional quality is negatively associated with carbon emissions and is significant at a 1% level. The institutions' quality and credibility performance are essential in environmental sustainability. We found different results in contrast with [55], which evaluate that institutional quality is positively associated with economic growth. A similar connection is discovered and confirmed [56]. In our model, we find mixed results for fiscal decentralization indicators. Some have positive relations, some are negatively associated, while institutional quality is positively related to economic growth. This implies that a 1% upsurge in IQI will lead to a 2.12% increase in economic growth, according to our estimated model for Pakistan. However, empirical results are inclined [57] to discover positive links between institutional quality and economic growth in Pakistan, inconsistent with Sudan [58].

The empirical estimates of expenditure decentralization are negatively and insignificantly associated with environmental quality. These empirical results differed in China [59]; they concluded that greater fiscal decentralization directly impacts CO_2 emissions [16]. Environmental pollution and fiscal decentralization are positively related; moreover, results demonstrated a "race to bottom" approach concerning fiscal decentralization. However, PGE, GS, and IQI have an insignificant connection with CO_2 emissions in both estimations. Table 5 in SVAR estimation shows that negative and insignificant connected with CO_2 emissions in Pakistan. In contrast, the result showed a significant and positive relationship. Therefore, the results align with prior literature [17].

In Table 6, the discussion centered on a comprehensive regression analysis, focusing on coefficients, un-centered variances, and centered Variance Inflation Factors (VIFs) for critical independent variables. Each variable's impact on the dependent variable was revealed through associated coefficients, while VIF analysis indicated a lack of significant multicollinearity issues with all values below 10.

The variance inflation component calculates whether an independent variable's activity (variance) is impaired or elevated by its interaction/correlation with the other independent variables shown in Table 6. Inflation variance factors make a simple measure of how much a variable contributes to the traditional regression error. All the values in this table are below ten, meaning no interaction or correlation exists among the variables.

Insights from the interpretation of coefficients provided a nuanced understanding of the magnitude and direction of each variable's influence on the dependent variable. Examination of un-centered variances offered insights into overall variable variability within the regression model. Specific variable observations highlighted characteristics such as relatively high coefficients and moderate VIFs for PGTR and IQI, while GS and GDPG displayed lower coefficients but moderate to high VIFs. The variable C, likely representing a constant term, showed a high coefficient and variance.

Table 7 exhibits an impulsive response function, which forecasts the variables as which variables will have an impact on the other variables. We see from the table that from 2023 to 2025, $LNCO_2$ and PGE show a positive trend, which means

Table 6 Variance inflation factors

Variable	Coefficient Variance	Un-centered VIF	Centered VIF
PGE	57.30545	343.5468	9.15066
PGR	69.25286	449.8449	8.354397
PGTR	501.7628	36.04800	2.293296
IQI	809.4035	116.3672	2.233652
GS	2.702827	222.9032	4.198092
GDPG	2.410257	11.30054	1.586628
FT	20.52952	61.51009	5.536919
C	2347.520	393.3458	NA

Table 7 Impulse response function estimates

Period	LNCO2	PGE	PGR	PGTR	IQI	GS	GDPG	FT
Response to Carbon Dioxide emissions								
2023	585.31	0.000	0.000	0.000	0.000	26.09	24.00	19.34
2024	456.13	53.292	− 35.09	26.09	27.221	11.92	26.09	24.43
2025	340.73	26.09	− 65.93	− 11.92	93.321	32.023	21.92	26.09
2026	249.63	− 11.92	− 106.9	− 42.023	113.19	34.09	20.023	31.92
2027	210.64	− 42.023	− 131.63	− 64.345	97.955	56.09	26.09	42.023
2028	167.70	− 57.39	− 143.60	− 72.272	70.344	11.92	19.23	36.09
2029	116.91	− 66.45	− 142.33	− 71.329	43.653	12.023	17.43	26.09
2030	63.125	− 72.38	− 129.19	− 61.013	19.771	16.09	16.09	11.92
2031	15.028	− 75.585	− 105.00	− 45.772	− 1.1730	11.54	11.92	10.023
2032	− 23.78	− 75.04	− 71.995	− 28.78	− 18.216	19.34	10.98	10.09

that they both will have a positive relationship, and as we see, it can be seen that $LNCO_2$ will have a positive relationship with GS, GDPG, and FT.

The Impulse Response Function Estimates reveal the consequences of a shock in carbon dioxide emissions from 2023 to 2032. Initially, there's a notable rise in emissions followed by a gradual decline. The response across variables includes an initial positive impact on government expenditure and federal funds transfer, suggesting short-term adjustments. However, adverse effects are evident in GDP growth rate, institutional quality, and government size in the first few years, stabilizing or diminishing over time. The overall trend indicates a negative impact on economic growth and underscores the importance of addressing environmental concerns for sustained economic well-being.

5 Conclusion

As this study examines the intricate dynamics of fiscal decentralization, economic growth, and environmental quality, policymakers face a formidable challenge, especially in developing and transitional nations like Pakistan. The research underscores the need for a nuanced understanding of how fiscal decentralization intricately influences economic growth and environmental efficiency. While certain aspects of fiscal decentralization, such as revenue collection and tax autonomy, exhibit favorable correlations with environmental efficiency, the study reveals negative relationships between government spending and economic development. This complex interplay emphasizes the importance of formulating policies that balance environmental sustainability with economic growth.

The implications of fiscal decentralization on economic growth and carbon emissions assume paramount importance, particularly in the context of developing and transitional countries. The mitigation of carbon emissions poses a significant challenge for large nations such as China, India, Pakistan, and several smaller Baltic countries. In these settings, fiscal decentralization may constrain economic growth and become a pressing political concern. However, the limited empirical evidence on the specific impact of fiscal decentralization on various predictors complicates the provision of precise policy recommendations. Therefore, careful consideration and further empirical exploration are essential to inform effective policymaking in this domain.

This study explores the connection between fiscal decentralization, economic growth, and environmental quality in Pakistan. It reveals that certain elements of fiscal decentralization, including revenue generation, tax autonomy, and transfer payments, exhibit positive correlations with environmental efficiency. Conversely, negative associations are observed between government expenditure, economic development, and environmental efficiency. The study notes that positive shocks to fiscal decentralization often lead to increased carbon emissions, while positive shocks to expenditure decentralization and economic development are associated with reduced carbon emissions. These findings hold significance for policymakers, highlighting the need for refined intergovernmental fiscal relations and meticulous calibration of fiscal policies to optimize environmental efficiency.

Fiscal decentralization can induce positive shocks associated with increased carbon emissions. Conversely, positive shocks in expenditure decentralization can potentially mitigate both carbon emissions and economic development. Furthermore, our findings reveal a statistically significant yet adverse impact of economic growth on carbon emissions in Pakistan. These results carry substantial policy implications, particularly concerning fiscal policy reform and intergovernmental fiscal relations within the context of Pakistan.

5.1 Policy implications and limitation

The study underscores significant policy implications, emphasizing the importance of robust provincial governance to ensure efficient tax autonomy for community-centric public expenditures amidst tax revenue decentralization. Policymakers are advised to exercise caution in tax policy formulation, prioritizing effective resource distribution for projects fostering economic growth and environmental sustainability. Aligning intergovernmental fiscal relations is crucial for enhancing environmental efficiency and promoting economic development. Legislative caution is urged in tax law drafting, emphasizing bolstered local accountability to ensure optimal community benefit from increased tax receipts. Future research should explore practical methods for integrating environmental considerations into local government budgeting and resource allocation for sustainable policy creation and implementation.

Constraints in researching the link between fiscal decentralization, economic development, and environmental efficiency in Pakistan include data reliability limitations, potential confounding factors complicating causal link establishment, and oversimplification of complex relationships. The study's context specificity to Pakistan and potential long-term implications oversight should be acknowledged. External variables like global economic trends and geopolitical events can impact economic and environmental dynamics.

Policymakers are advised to refine fiscal policy, emphasizing efficient resource distribution. Further, it should comprehensively explore the impact of fiscal decentralization on economic growth and carbon emissions, offering accurate advice and practical insights for policymakers, particularly in integrating environmental considerations into local government decision-making processes.

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Data availability Data is available on World Bank https://www.worldbank.org/en/publication/worldwide-governance-indicators, and provincial indicators data is arranged by authors by using Handbook Statistics of Pakistan Economy 2020; https://www.sbp.org.pk/departments/stats/PakEconomy_HandBook/index.htm.

Declarations

Competing interests The authors declare no competing interests.

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