

Environmental Taxes, Innovation, and Institutional Quality: Pathways to Reducing Carbon Emissions in Pakistan

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Abstract

This paper explores the dynamic nature of the environmental taxes, innovation, and institutional quality in bringing down carbon dioxide emission in Pakistan between 2000 and 2024. Based on time series data with the application of the Phillips-Perron unit root test, the Johansen cointegration approach, and the Vector Error Correction Model, the study examines short-term and long-term relationships among the variables. The findings affirm that the carbon dioxide emissions, REC, research and development, domestic credit, industrialization, urban population, institutional quality, and environmental tax are all integrated together of order one. The cointegration analysis confirms that there is a long-term equilibrium relationship between these variables. The results of the Vector Error Correction Model show that the first lag of carbon dioxide emissions has a significant and negative impact on the present time emissions with a coefficient value of -0.74 and probability value of 0.009 which means a self-correcting behavior. The consumption of renewable energy presents a positive and significant short-run impact with a coefficient value of 0.03 and a probability value of 0.002 which portrays persistence in the adoption of renewable energy. Both domestic credit and industrialization have considerable negative impacts on carbon dioxide emissions with coefficients of -0.94 and probability value of 0.041, indicating that financial and industrialization development is a contributor to emission cutbacks on efficiency level. Nonetheless, the short-run impacts of research and development, institutional quality, and environmental tax are statistically insignificant but could have a long-term impact in facilitating a sustainable transition. The study concludes that environmental taxes alone are insufficient without supportive institutional and innovation frameworks. Improvement in institutional quality, making innovation the main focus by investing more in research and development, and introducing properly planned environmental tax policies will play a significant

role in the realization of long-term emission reduction in Pakistan. These results are effective in guiding policymakers to ensure that the development of the economy and environmental sustainability are balanced.

Keywords: Environmental Quality, Environmental Tax, Innovation, Institutional quality, Vector error, Correction Model

Introduction

Human population is growing at an alarming rate and this brings about serious issues like global warming, shortage of resources and environmental degradation. Sustainable policies, practices, and control measures should be encouraged to solve these critical concerns and provide the sustainable future of all people (Aydin and Esen, 2018). Environmental degradation through high carbon emission requires environmental protection policies to prevent the degradation. Taxation is one of the most common fiscal measures that governments resort to, most specifically, against the activities that have a negative effect on the environment (Mehta, 2024). Environmental taxes or these taxes are meant to persuade consumption, through financial expenses, on the activities that contribute to increasing their carbon footprints and degrade the environment. It is destined to reduce environmental harm and promote more sustainable ways of doing things by individuals, organizations, and industries (Allan et al., 2014; Bao et al., 2013; Gemechu et al., 2012; Chenghao et al., 2024; Yang, 2009). Environmental taxes are the important fiscal policy instrument promoting negative externalities, as they impact the expenditure choices as well as protect the environment (Aydin and Esen, 2018; Gago et al., 2014; Wolde-Rufael and Mulat-Weldemeskel, 2021). Environmental taxes have been introduced in some African nations such as Niger, Rwanda, South Africa, Togo and Tunisia as a measure to contain carbon emission to the environment and curb environmental degradation. In the past ten years, African countries have experienced impressive progress in terms of economic development and international power (Chinoda & Kapingura, 2024).

In 1995, per capita income in African countries was in the range of 999 to 8,000 dollars which in turn increased to 900-12,000 dollars in 2003 and eventually to 2,000 19,000 dollars in 2023. These trends in per capita income are upward indicating the efforts and relentless effort of African countries to provide economic growth and reach favorable results. According to the Environmental Kuznets Curve theory, economic development and carbon emission have a positive relationship (Grossman and Krueger, 1995). The need of developing countries to grow at a fast pace in terms of industrialization (Pata, 2018; Ullah et al., 2020), urbanization (Pata & Caglar, 2021), financial growth, tourism, and technological growth (Ullah et al., 2021) predisposes them to higher levels of emissions. Consequently, carbon emissions in the African region have been on the rise since 1995. In that year, the cumulative carbon emissions were approximately 19.62 billion tons, which increased to 29.04 billion tons by 2005 (Friedlingstein et al., 2023). A slower speed of industrialization, human and economic activity, and stronger environmental policies have helped reduce emissions. CO₂ decreased in OECD economies during the COVID-19 epidemic, in 2020. From 2017-2020, the overall OECD economies' environmental quality improved, reducing carbon dioxide emissions (tons per capita) from 8.69-7.64%. Canada and Australia emitted 15.3%, the United States 15%, & Luxembourg 14.7%, making them the highest emitters of carbon dioxide per capita among OECD economies, while Colombia (1.5%), Sweden (3.4%), & Mexico (3.6%) were the lowest.

Therefore, nations undergoing industrialization and economic development are expected to increase their energy consumption for production and industrialization. Another argument is that

greater economic growth entails increased energy consumption, which, if renewable energy sources are not used, leads to greater environmental deterioration. As far as we are aware, no empirical study has ever looked at how 37 OECD economies are affected by financial development, institutional quality, technological innovation, and environmental quality factors. Important insights have been provided by recent research of OECD members, including Martínez-Zarzoso et al. (2019), Paramati et al. (2020), Ozcan et al. (2020), Cheng et al. (2021), Petrović and Lobanov (2020), Saidi and Omri (2020), and Teng et al. (2020).

According to a number of academics, financial development could improve environmentally friendly technologies or energy efficiency. Environmental pollution and carbon emissions will decline, claims Pata (2018). The main reason for this strong assumption is the belief that increased financial openness and the growth of financial intermediaries draw more foreign direct investment, which may raise the standard of research and development and aid in the advancement of climate-related issues (Frankel & Romer, 1999; Mahalik et al., 2017). Numerous studies evaluated the impact of various factors on carbon emissions, including urbanization (Ali et al., 2019a, 2019b), tourism (Jebli et al., 2019), financial development (Ali et al., 2020), globalization (Xu et al., 2018), renewable energy (Sharif et al., 2019), and institutional quality information and communication technology (Godil et al., 2020), and technological innovation (Erdoğan et al., 2020; Bakhsh et al., 2021). The key contributions of this paper are twofold: first, unlike most previous studies that narrowly assess Carbon dioxide using isolated indicators. This approach offers a more holistic and policy-relevant understanding the reduction of carbon emission. Second, while much of the existing literature focuses separately on environmental tax, innovation and carbon emission, particularly in the context of Pakistan. This study employs a VECM model to explore both the short-run and long-run effects of environmental tax, innovation and Carbon dioxide emission. The remaining sections of the paper are structured as follows: Section 2 reviews relevant literature on Carbon emission and other variables. Section 3 details the data sources, variables, and methodology used in the analysis. Section 4 presents the empirical results and discusses key findings. Section 5 concludes with major insights, policy recommendations, limitations, and directions for future research.

Literature Review

The literature review of this study is threefold: first, this study reviews the theoretical literature related to this study Carbon emission with others independent variables of this study. Second, this section presents reviews of empirical studies directly or indirectly related to this study. Final the study will find out the gap this study fills.

Environmental taxes are an efficient policy instrument to decrease greenhouse gas (GHG) emissions (Babatunde et al., 2017; Ghaith & Epplin, 2017). The concentration of CO₂ is negatively correlated with environmental tax reforms, as these taxes aim to target carbon emissions, which are the most common source of GHG emissions (Sundar et al., 2016; Hammar & Sjöström, 2011). Tamura et al. (1996) also indicated that environmental taxes decrease the total carbon emissions through raising the price of fossil fuel which in turn decreases the level of fossil fuel demand. The review of the EU policies regarding mitigation of carbon emissions by Barker et al. (2001) has concluded that the effectiveness of environmental taxes are stronger in cases where EU directives are supplemented by national regulations. Despite the fact that environmental taxes mainly focus on carbon emissions, other categories of taxes are energy tax, fuel tax that generate environmental protection objectives as stipulated by the international agreements like the Kyoto Protocol and the Paris Climate Agreement (Scrimgeour et al., 2005). A

number of researches have affirmed the effectiveness of environmental taxes in decreasing emissions, but some scholars assert that their consequences are small (Meng et al., 2013; Jiang and Shao, 2014; Chen et al., 2017; Lin and Li, 2011). Vera and Sauma (2015) established that the levels of environmental taxes imposed on the years 2014-2024 would only lead to a 1 percent decrease in the GHG emissions. However, environmental taxes can be used to reduce carbon emissions and stimulate renewable energy and enhance energy efficiency (Clough, 2016). To explore the relationship between environmental taxes and carbon emissions, the Computable General Equilibrium (CGE) model, Leontief input output model, and GCAM model, and OSE 2000 model are some of the analytical models used (Scrimgeour et al., 2005; Vera and Sauma, 2015; Tamura et al., 1999). More recently, Micekiene et al. (2018) noted that environmental taxes significantly improve environmental quality when innovation in the energy and environmental sectors is prioritized.

According to Tamazian and Rao (2010), FDV has made it possible for the listed companies to use new technologies and increase energy efficiency. Al-Mulali et al. (2015) and Moyer and Hughes (2012) have also demonstrated that technological advancements lower environmental emissions because of the impact of technology spillover. Ibrahim (2020) claims that the relationship between CO₂_Emiss, TINNOV, renewable energy resources, economic growth, and FDV in Egypt (1971–2014) demonstrated that although TINNOV and renewable energy improve the country's environmental quality, FDV slows down economic growth. According to Rafique et al. (2020), there were long-term, significant, and negative correlations between CO₂_Emission and FDI, TINNOV, and FDV in the BRICS economies. According to numerous studies, TINNOV improves environmental quality and lowers CO₂ emissions (Tan et al. 2019; Lin and Zhu 2019; Chen and Lee 2020; Shahbaz et al. 2020). The cointegration results verified that the variables under consideration had a long-term relationship. Additionally, advancements in the energy sector raise both energy consumption and efficiency. According to Koondhar et al. (2021), the use of modern technologies is growing in tandem with CO₂ emissions as a result of the widespread use of fossil fuels. The study went on to say that the main cause of the rise in CO₂ emissions is the increased use of fossil fuels to power modern technology.

Kaufmann et al. (2010) state that various elements of governance are concentrated on a specific component of an institution. Halkos and Tzeremes (2013) assert that the effects of different aspects of governance quality on the emission of CO₂ might differ. Second, an accumulating literature has focused on the relationship between environmental taxes, innovation, and institutional quality and its impact on carbon emission especially in developing economy. In case of Pakistan, Yousaf and Mahtab (2023) used a nonlinear ARDL to investigate the asymmetric impacts of financial development and institutional quality on environmental degradation. They found that CO₂ emissions are greatly cut with the improvement of institutional quality whether in the short or long term. Similarly, Arif and others (2022) analyzed the overbearing feature of governance in relation to the excellence of the environment and concluded that political stability, corruption, and regulation quality has a critical contribution to environmental sustainability in the long run.

In addition, it has been proved that the implementation of the environmental policies and taxation can influence the amount of emissions. In the research of Miceikiene et al. (2023), the environmental taxes are supposed to enhance the quality of the environment with the related innovation and institutional efficiency. The direct empirical studies on the issue of environmental taxation in Pakistan are still lacking, yet, the international experience (Tamura et al., 2021; Barker et al., 2019) can confirm that, under the right design, environmental taxes could lead to a

substantial reduction in the level of GHGs emissions because of the disincentive to use fossil fuels. Finally, the interdependence between institutional quality, innovation and policy measures have been dynamic and they are subjected to complex econometric models. Ullah et al. (2020) applied QARDL model to the case of Pakistan and disclosed that institutional reforms and green innovation are closely interrelated in their positive impact on the quality of the environment. All these research findings underpin the roles of environmental taxation, institutional quality and technological innovation in affecting the low carbon transition of Pakistan.

Literature Gap

Considering that there has been a substantial body of empirical research linking environmental taxes to innovation and the work of environmental taxes to the institutional quality to environmental performance, much remains to be discovered. Most of the existing studies of environmental taxation are connected with developed economies (e.g., Babatunde et al., 2017; Barker et al., 2001; Vera and Sauma, 2015), but the evidence provided by developing countries- perhaps Pakistan-is the most important yet very scarce. Also, a lot of studies examine these factors individually rather than examining their interactive or mediating effects on carbon emissions. Indicatively, studies about technological innovation (Rafique et al., 2020; Sohag et al., 2015) ignore the moderating effect of the institutional quality, which can affect the effect of the policies of innovation-induced emission reduction. Past studies (Hammar and Sjoström, 2011; Miceikiene et al., 2018) have been largely based on the use of an econometric approach that is constant, leaving the prospect of the nonlinear and asymmetric relationships as a factor in the dynamics of the environmental, economic, and institutional relations. The current research bases have only a few studies that have incorporated the concept of environmental taxation, innovation, and institutional quality on the same empirical platform to assess their role in the process of Pakistani CO₂ emissions. This creates a significant gap in research on how these mechanisms interact and influence the environmental sustainability of the emerging economies in a transition in terms of their governing system. Therefore, the study contributes to the existing body of research interested in exploring the joint and interactive impact of environmental taxation, technological innovations, and institutional quality on carbon emissions in the context of Pakistan using recent data and advanced econometric specifications. By investigating these new connections, the research provides new evidence to policy-makers on the ways to develop holistic environmental and innovation-based policy schemes towards sustainable development.

Methodology

This paper aims at discussing the Environmental Taxes, Innovation, and Institutional Quality: Pathways to Reducing Carbon Emissions in Pakistan 1990 to 2024 on behalf of Pakistan. The data on the dependent and independent variables was gathered at World Bank (2025) to guarantee that the results are consistent and reliable across time and nations. This work will be of great help in offering useful information on how the technology advancement could enhance Environmental Taxes, Innovation, and Institutional Quality and lead to the long-term agricultural prosperity of the country. It is required to have multidimensional strategy to include environmental taxes, innovation and high quality of institutions to mitigate Co₂. Environmental taxes are market-oriented tools which internalize externality and facilitate cleaner production (OECD, 2021). The research and development would lead to innovation that would result in increased energy efficiency and easy change to renewable energy technologies, and the reduction of carbon emissions would be significantly reduced (Porter and van der Linde, 1995; IEA, 2021). These efforts are further enhanced by institutional quality whether it means successful policy

implementation, transparency, and compliance with regulations (North, 1990; Acemoglu and Robinson, 2012). In that regard, the functioning institutions allow the environmental taxes and innovation policies to operate together in order to promote sustainable industrial activities and alleviate the extent of environmental degradation in Pakistan. The data of the variables were retrieved using the World Bank data sources. The dependent variable in this paper is carbon dioxide emissions per capita whereas the independent variables are Environmental tax, Institutional quality index, Research and Development expenditure, Domestic credit to private sector, Renewable energy consumption, Industrial value added / share of industry and urban population (World Bank, 2025). Together, these variables provide a comprehensive framework to analyze the factors influencing Environmental quality. The details description of the study's variables is given below in the Table 1.

Table 1: Description of the study's variables

Variable	Abbr.	Measurement
Dependent Variable		
Carbon dioxide emissions per capita	CO ₂	Carbon dioxide emissions per capita Metric tons per capita
Independent Variables		
Environmental tax	ENT	Environmental taxation % of GDP or tax revenue
Institutional quality index	IQI	Index
Research & Development expenditure	RD	Research & Development expenditure % of GDP
Domestic credit to private sector	DCP	Credit available to private sector % of GDP
Renewable energy consumption	REC	Renewable energy consumption % of total energy consumption
Industrial value added / share of industry	IND	Industrial value added / share of industry % of GDP
Urban population	UP	Urban population % of total population

Carbon dioxide emissions per capita, Environmental tax, Institutional quality index, Research & Development expenditure, Domestic credit to private sector, Renewable energy consumption, Industrial value added / share of industry and urban population.

This study employed Environmental Taxes, Innovation and Institutional Quality and other control variables on Environmental quality using the following functions.

Moreover the following econometric model was employed to explore Environmental Taxes, Innovation, and Institutional Quality: Pathways to Reducing Carbon Emissions in Pakistan:

$$CE = f(ENT, IQI, RD, DCP, REC, IND, UP) \quad (1)$$

$$\ln CE_t = \alpha_0 + \alpha_1 \ln ENT_t + \alpha_2 \ln IQI_t + \alpha_3 \ln RD_t + \alpha_4 \ln DCP_t + \alpha_5 \ln REC_t + \alpha_6 \ln IND_t + \alpha_7 \ln UP_t + u_t \quad (2)$$

In the equation number 1, the subscript t represents the time period. The parameters $\beta_0, \beta_1, \beta_2, \dots, \beta_7$ correspond to the intercept and slope coefficients for each independent variable, while ε_t denotes the error term capturing unobserved factors. The following log-log model is specified to estimate the impact of key factors on Carbon emission: In the above equation, Carbon emission is modeled as a function of Environmental tax, Institutional quality index, Research & Development expenditure, Domestic credit to private sector, Renewable energy consumption, Industrial value

added / share of industry and Urban population. Traditional unit root, Phillips-Perron (PP) tests, is employed to examine the stationarity of time series variables. Stationarity is a fundamental requirement in time series econometrics, as the presence of non-stationary data can lead to spurious regression results and biased inferences. These tests were performing to check the stationarity and all the variables are stationary at first difference. Since time series data may exhibit structural breaks due to events such as technological changes, policy reforms, or environmental shocks, advanced unit root tests that account for structural breaks Philips Perron tests can also be applied for more robust results.

Vector Error Correction Model (VECM)

After confirming co-integration, the study proceeds to estimate the Vector Error Correction Model (VECM). The VECM is suitable for analyzing both the short-run dynamics and the long-run relationships between the dependent and independent variables. The VECM can be written as follows:

$$\Delta CE_t = \alpha_1 + \beta_1 \Delta ENT_t + \beta_2 \Delta RD_t + \beta_3 \Delta IQI_t + \beta_4 \Delta REC_t + \beta_5 \Delta DCP_t + \beta_6 \Delta IND_t + \beta_7 \Delta UP_t + \gamma_1 ECM_{t-1} + \varepsilon_t$$

Where:

Δ represents the first difference operator (change in the variable),

α_1 is a constant term, $\beta_1, \beta_2, \beta_3, \dots, \beta_8$ are the short run coefficient of the differenced independent variables

γ_1 is the coefficient of the error correction term (ECM), which shows the speed of adjustment to long run equilibrium,

ECM_{t-1} is the lagged error correction term, and ε_t is the error term that is also called residual. The ECM captures the deviations from the long-run equilibrium in the previous period and indicates how quickly the system returns to equilibrium after a shock. If the ECM coefficient is statistically significant, it suggests that the system adjusts towards the long-run equilibrium.

Following the results of the unit root tests, the VECM model was selected as the most appropriate econometric technique to analyze the dynamic relationship between dependent and its key explanatory variables. The VECM approach is particularly well-suited for time series methodology in which all the variables are stationary at first difference. In this study, the model investigates the effects of Carbon dioxide emissions per capita, Environmental tax, Institutional quality index, Research & Development expenditure, Domestic credit to private sector, Renewable energy consumption, and Industrial value added / share of industry and urban population for Pakistan. The dependent variable ΔCE_t represents the first difference of Environmental Quality, while lagged differences of the explanatory variables capture both long run and short-run dynamics.

Results and Discussions

Table 2 presents the descriptive statistics for the variables used in this study: carbon dioxide emissions, renewable energy consumption, research and development, domestic credit to the private sector, industrialization, urban population, institutional quality index, and environmental tax. Domestic credit to the private sector shows a mean of 2.81 and a standard deviation of 0.19, suggesting moderate variation in credit availability. Industrialization has a mean of 2.97, with relatively low variability, indicating stable industrial development levels. The urban population records a mean of 3.56, with very low variability, highlighting consistent urbanization trends across the sample. The institutional quality index averages 1.06, with values ranging between 0.84

and 1.82, reflecting heterogeneity in governance and institutional performance. Finally, environmental tax records the highest mean value of 7.43, with a standard deviation of 0.42, ranging from 6.72 to 8.04, showing some variability in environmental tax policies across countries.

Table 2 Results of Descriptive Statistics

Statistic	CO ₂	REC	RD	DCP	IND	UP	IQI	ENT
Mean	0.81	45.91	0.25	2.81	2.97	3.56	1.06	7.43
Std. Dev.	0.08	3.38	0.12	0.19	0.07	0.04	0.17	0.42
Min	0.69	39.53	0.10	2.44	2.84	3.50	0.84	6.72
Max	0.99	51.50	0.61	3.19	3.09	3.65	1.82	8.04

The Phillips-Perron unit root test is an important test in the panel data analysis as it establishes the stationarity of the variables of interest. Stationarity refers to the fact that the mean, variance, and covariance of a variable are constant with time. It is important to determine that a variable is non-stationary as non-stationary variables will cause spurious regression outcomes, which will be misleading in the interpretation of variable relationships. This is why before estimating any econometric model; it is substantial to test the stationarity of the data series. Phillips-Perron (PP) test is specifically effective in time series as it is rather effective in correcting the risk of serial correlation and heteroskedasticity of the error terms without adding lagged differences, as it would be done in the Augmented Dickey-Fuller (ADF) test. In practice, particularly with macroeconomic, financial or environmental variables, correlations in the residuals due to shocks (i.e. policy changes, technological or market changes) tend to be present in real-world data sets and the standard unit root tests are inapplicable. The Phillips-Perron test is the solution to this; it uses non-parametric corrections to test statistics to increase the robustness and reliability. According to the test report, the carbon dioxide emissions, the use of renewable energy, research and development spending, domestic credit to the private sector, the level of industrialization, the urban population, the quality of the institutions, and the environment tax are stationary variables when the change has been first differenced. This means that all the variables are of order one, I (1). The results are also significant in making methodological decisions since they confirm the use of econometric tools, including cointegration analysis and long-run estimation models, which are appropriate in I (1) variables. Unit root tests Phillips-Perron guarantees the validity and reliability of the empirical findings through confirming the mixing order of the data and eliminating the spurious regression findings.

Table 3 Findings of the Unit Root Tests

Variable	t-Statistic	Conclusion
CO ₂	-2.99**	I(1)
REC	-4.71**	I(1)
RD	-3.71**	I(1)
DCP	-3.13**	I(1)
IND	-4.33**	I(1)
UP	-10.67**	I(1)
IQI	-2.12**	I(1)
ENVTax	-11.24**	I(1)

Note: *, ** show level of significance at 1% and 5% respectively

Table 4 Vector Error Correction Model (VECM)

The results of the Vector Error Correction Model (VECM) indicate both short run and long run adjustment process of CO2 emissions, renewable energy consumption, research and development expenditure, domestic credit to the private sector, industrial value added, urban population, institutional quality and environmental tax. The overall model fits well with a R² of between 0.47 and 0.86 with statistically significant Chi-square statistics ($p < 0.05$ in most instances) which illustrates that the explanatory variables have a significant joint effect on the dependent variables. The error correction term (ce1 L1) is positive (0.040) though not significantly important ($p = 0.351$) in CO2 equation meaning that CO2 emission does not significantly alter towards long-run equilibrium after experiencing short-term shocks. This indicates that there is poor long-run correction of environmental results which are in line with the time perpetuation of emissions. Their past values have a strong impact on CO2 emissions in the short-run dynamics. The CO2 first lag CO2 first lag (LD1) has a large negative correlation (-0.74, $p = 0.009$), and this is a self-correcting effect, the growth of CO2 emissions is negated by a decline in the following periods. On the same note, the second lag of CO2 (LD2) is negative (-0.58) although not statistically significant. The positive and significant effect of renewable energy consumption is observed at the first lag (0.03, $p = 0.002$), which is the result that higher adoption of renewable energy in the past period contributes to a more advanced effect of renewable energy in the current period. Nonetheless, the second lag is not significant, which means that its effect decreases with the course of time. There are some negative correlations between domestic credit (LD2) and industrial value added (LD2) and CO2 emissions (-0.94, $p = 0.041$) implying that financial access expansions and industrial expansion programs lead to short-term emission reduction, perhaps due to structural changes or loss of inefficiency. Conversely, the short-run effects of research and development, urban population, institutional quality, and environmental tax are statistically non-significant on CO2 emissions though their coefficients demonstrate a possibility of long-run effects. In sum, the outcomes of the VECM underline that the CO2 emissions are high path-dependent and their individual history, and renewable energy is active in maintaining the current state of its existence over time. The financial growth and changes in industrial sectors become important short-term factors of emission changes, and institutional quality and environmental taxation can take longer before they have a considerable impact.

Table 4 VECM Results

Equation	PMSE	RMSE	R ²	Chi ²	P>Chi ²
D_co2	9	0.05	0.51	14.85	0.05
D-rec	9	0.57	0.53	15.56	0.03
D_rd	9	.056	0.47	14.29	0.04
D_indcp	9	.058	0.73	39.25	<0.01
D_inind	9	0.45	0.65	32.21	0.02

D_lnup		9	<0.01	0.84	77.54	<0.01		
D_lniqi		9	<0.01	0.86	76.45	<0.01		
D_lnenvtax		9	.310	0.57	19.12	0.02		
Dependent	Independent	Lag	Coeffi	Std. Err	Z	prob > z	95% Confident Interval Lower	95% Confident Interval Upper
D_co2	ce1	L1	0.040	0.05	0.93	0.351	-0.05	0.14
	co2	LD1	-0.74	0.28	-2.63	0.009	-1.30	-0.19
		LD2	-0.58	0.36	-1.60	0.110	-1.30	0.133
	Rec	LD1	0.03	0.01	3.06	0.002	0.014	0.06
		LD2	0.018	0.02	0.91	0.362	-0.02	0.05
	Rd	LD1	0.04	0.18	0.24	0.813	-0.32	0.40
		LD2	0.38	0.29	1.30	0.194	-0.19	0.95
	Dcp	LD1	-0.14	0.20	-0.70	0.482	-0.53	0.25
		LD2	-0.94	0.46	-2.04	0.041	-1.85	-0.037
	Ind	LD1	-0.42	0.29	-1.44	0.151	-0.99	0.153
		LD2	-0.94	0.46	-2.04	0.041	-1.85	-0.037
	Up	LD1	-5.00	2.83	-1.76	0.078	-10.56	0.56
		LD2	-0.30	4.47	-0.07	0.945	-9.08	8.46

	Iqi	LD1	0.06	0.05	1.24	0.216	-0.04	0.17
		LD2	-0.001	0.08	-0.02	0.985	-0.17	0.17
	Envtax	LD1	0.043	0.03	1.41	0.158	-0.01	0.10
		LD2	-0.04	0.04	-0.87	0.382	-0.13	0.05
	_constant		2.12	2.55	0.83	0.406	-2.88	7.13

Theoretical Background of the study

This paper discusses the effects of environmental tax, innovation, institutional quality, and financial development, use of renewable energy sources, industrialization and urbanization as a combination of factors affecting the level of carbon dioxide per capita emission in Pakistan. The amount of carbon dioxide emission per capita is the average environmental consumption associated with economic performance, energy use and population patterns, and it measures the performance of a nation in managing the growth and environmental sustainability. The environmental tax is one of the most important policy instruments that is based on Pigovian theory which argues that the negative externalities of emissions are internalized by imposing a price on pollution, which in turn promotes clean production and consumption. It has been empirically proven that environmental taxes lower CO₂ emission through changing the cost-benefit relationship of the polluting activities and through encouraging investment in the low-carbon technologies (OECD, 2023; Al Shammre, 2023). One of the key elements in facilitating a successful implementation and enforcement of environmental regulations is institutional quality that involves the effectiveness of the governance, quality of regulations, and the rule of the law. Well-established institutions enhance compliance and coordination of policies to increase the efficiency of the fiscal and environmental policy in decreasing the emission (World Bank, 2024).

Technological advancement that is based on research and development (R&D) spending is a notion that is based on endogenous growth theory (Romer, 1990) that asserts that technological advancement is a resultant product of the conscious investment in knowledge development. Higher R&D expenditure fosters innovation in renewable energy technologies and energy efficiency, reducing the carbon intensity of production and consumption (Diao et al., 1999). Financial development, proxied by domestic credit to the private sector, influences emissions through the financial channel-greater credit availability can fund energy-efficient projects and renewable investments but may also finance polluting industries in the absence of green finance policies. Hence, the impact of financial development on CO₂ emissions depends on regulatory conditions and credit allocation (Acheampong, 2019; Wijethunga, 2023). Renewable energy consumption theoretically contributes to emission reduction by substituting fossil fuels with cleaner energy sources. The transition to renewable energy lowers CO₂ emissions per capita, provided that renewable deployment is adequately supported by infrastructure and regulatory incentives (IEA, 2025; Li, 2023). Industrial value-added, on the other hand, reflects the structural composition of the economy. According to structural transformation theory, industrialization typically increases emissions due to higher energy intensity, though its long-term impact depends on the adoption of cleaner technologies and energy-efficient processes (Mulabdic et al., 2025). Urbanization, measured through the urban population, influences carbon emissions through patterns of energy consumption, transport demand, and infrastructure design. Well-planned and compact urbanization can reduce per-capita emissions through efficient public transport and energy use, whereas uncontrolled urban sprawl may exacerbate pollution (Luqman et al., 2023).

Conclusions and Policy Recommendations

Recent studies are geared towards determining the nature of the relationship between Environmental Taxes, the Innovation and Institutional Quality. This paper analyses Environmental Taxes, Innovation and Institutional Quality: The pathways to reduction of carbon emissions in Pakistan between 2000 and 2024 through a mixture of the unit root tests, cointegration techniques and the VECM method. Unit root tests are used to establish whether the variables are stationary or have unit roots. The results demonstrate that there are also variables that do not change in the first difference, which implies that a cointegration method should be used to examine the relationship between the selected variables in the long-term. The findings of the unit root tests validate the stationarity features of major economic variables, in that they experience both the temporary and long-term changes. Non-stationarity in some of the series highlights the necessity of further investigation, in which both short- and long-term effects are to be taken into account when determining the determinants of Environmental quality in Pakistan. The obtained results of the cointegration prove the existence of the long-run relationship between Environmental Taxes, Innovation, and Institutional Quality: Pathways to Reducing Carbon Emissions in Pakistan. These results denote that the variables are likely to be brought to equilibrium in the long run even though they fluctuate in the short term. This show how there is a need to get policies that facilitated the quality of institutions, Innovation and Environmental Tax, in order to achieve Environmental quality in Pakistan. A multi-dimensional approach that incorporates environmental taxation, innovation, and institutional quality reforms should be used to effectively reduce carbon emissions in Pakistan by the government. To start with, implement

environmentally sound environmental tax incentives and subsidies to motivate industries to implement cleaner and energy-efficient technologies, including renewable energy solutions, carbon capture technologies as well as waste-to-energy technologies. These fiscal policies ought to be supplemented with specific programs offering technical training and the financial assistance to the companies that are going to be switching to green production processes. Secondly, encourage technological change through more public and private research and development (R&D) especially in renewable energy, sustainable industrial processes, and low-carbon technologies. Enhancing cooperation between institutions of higher learning, research institutes, and the business sector will help to bridge the gap between the laboratories and industries, increasing the spread of cleaner technologies. Third, improve institutional quality through clarity in its regulatory systems, good enforcement of environmental laws and good governance systems to fight corruption and efficiency of using environmental taxes. Policies in institutions should be centered on the stability of policies, efficient bureaucrats, and the institution should be held accountable to make sure that the environmental taxes collected are invested in the green infrastructure and technological development. The second step to follow is to urge financial institutions to offer green credit facilities and low-interest rates on renewable energy projects, energy-efficient industrial equipment, and friendly business practices. The increase of the financial inclusion will contribute to the implementation of sustainable technologies and the adherence to environmental rules by the small and medium enterprises.

Limitations and Future Research Direction

This research offers significant knowledge on the nexus of environmental taxes, innovation, institutional quality and carbon emissions reduction in Pakistan, it presents some limitations. To begin with, the analysis is highly dependent on secondary data, which can have measurement errors, reporting discrepancies, or lack of data, which could affect the quality of the empirical findings. The study can be improved by using primary data in the form of survey or interviews with policymakers and industry practitioners and environmental agencies in future studies to obtain more background information. Second, the article is limited to Pakistan and this restricts the extrapolability of the results to other third world countries that have varying institutional, economic and environmental aspects. The comparative research on the South Asian or emerging economies may offer a more comprehensive way to understand the interaction between the institutional quality and the innovation and the environmental taxation in different governance contexts. Third the use of the model fails to explicitly explain structural breaks due to policy reforms, world economic shocks, or technological shocks which may be of great concern in the dynamics of carbon emissions. The current studies need to be extended through the implementation of more sophisticated econometric methods, including nonlinear or threshold cointegration models, to be able to capture these intricate relationships. Also, this paper looks at the role of innovation using research and development expenditure, but it does not distinguish the type of innovation such as the technological, process or policy innovation that can have different levels of effects on the reduction of emissions. The research may be improved by focusing on the future to disaggregate indicators of innovations in order to have a more nuanced perspective. Lastly, the scope of the topic should be extended to cover environmental awareness, quality of governance on the provincial level, and the efficacy of green financing policies that might help to make the policy recommendations stronger.

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