Government Expenditure and CO_2 Emissions in Pakistan: An Empirical Analysis

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ABSTRACT: The research analyzes short-run and long-run relationship between government expenditure and CO_2 emissions per capita in Pakistan from 1990 to 2020. It uses ARDL Bounds test to check cointegration among CO_2 emissions, government expenditure, GDP per capita, Energy use and Trade openness. All variables are I(1) integration. F-Bound statistics 8.31 exceeds one percent finite sample upper critical bound establishing robust cointegration. Government expenditure (coefficient 0.0542, p-value <0.05) shows that it has positive and significant long-run effect on CO_2 emissions. It means that one percent increase in expenditure to GDP ratio is associated with 5.4 percent(approximately) increase in CO_2 per capita emissions. Energy use per capita is the influential factor among them (elasticity= 2.44, p-value< 0.01). trade openness has small negative and significant effect (-0.010, p<0.05) and GDP per capita is statistically insignificant. The error correction coefficient -0.603 (p<0.01) indicates that about 60 percent of short run deviation are corrected annually. CUSUM test confirms that parameters are stable. CUSUM sq tells us possible variance instability from around 2015 onwards, which may be the reason of macro fiscal changes due to CPEC period. This is acknowledged as limitation of this research. The findings suggest that environmental criteria should be integrated into Pakistan's fiscal policy.

KEYWORDS: Government Expenditure, CO_2 Emissions, Environmental Quality, ARDL, Energy Use, Trade Openness, Clean Energy, Cointegration

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Introduction

Pakistan stands in a difficult situation between economic development and environmental problems. Pakistan is highly vulnerable nation to the climate change. Pakistan mostly relies on fossil fuels which make around 64 percent of primary energy supply (World Bank, 2024). CO_2 per capita emissions over the past three decades have increased from 0.56 metric tons in 1990 to 0.95 metric tons in 2020 even so Pakistan's share of global cumulative emissions is comparatively small. This upward trajectory means Pakistan development heavily relies on fossils fuels, subsidies on energy, intensive infrastructure and public spending, all these contributed to carbon emissions. And regrettably environmental sustainability is mostly ignored.

In literature Government expenditure is surprisingly mostly unexplored factor of CO_2 emission in developing economies. Significant research effort has been directed to effect of financial development, trade openness, income growth, foreign direct investment and urbanization on emissions. Direct role of fiscal channel has received relatively less attention e.g. How government spending and its scale affect emission in the long run. This gap is not just an academic concern. When Government expenditure has an impact on CO_2 emission in the long-run. This means, climate commitments and development are not separate policy issues.it means they both relies on the same fiscal resource.

This question is relevant in case of Pakistan. From 1990 to 2020, Pakistan moved back and forth between fiscal expansion and IMF strict controls which causes variation in government expenditure to GDP ratio. It ranges from 8.7 to 15.1 percent ever adopting of sustainable or low carbon spending strategy. China-Pakistan Economic Corridor (CPEC) in 2015 estimated around 62 billion USD also intensified the dynamics. Its first phase i.e. coal-based energy power plants pushed Pakistan into years of fossils-fuel financing commitment by capacity payment guarantee. It directly linked public spending into emissions path.

EKC hypothesis is widely used in Pakistan environmental economic literature. In literature fiscal policy is generally ignored as the direct determinant of CO_2 emission and is widely used as a secondary factor in emission studies. There are many studies which on trade, FDI, energy consumption but study that focuses on government expenditure a determent of emission Pakistan and using time series framework is rare. Those research who do they rarely consider CPEC and apply full diagnostic test, this is the research gap I will fill.

This will provide time series evidence on relationship between fiscal policy (government expenditure) and CO_2 emission in Pakistan. it covers the CPEC period a context which is mostly theoretical and less empirically tested in literature. it helps us understanding that development and environmental goals are not separate. they are linked to a single policy which is fiscal policy. Increasing public spending carries clear and measurable environmental cost.

Literature Review

The relation between government spending and climate outcomes depends on what the government is spending. Two conceptual distinctions in literature. first one between productive and unproductive spending. Productive spendings e.g. Roads, power plants, infrastructure, industrial capacity. It grows the economy but also increases demand for energy. In fossil-fuel dependent country increase in the demand of energy directly results in higher emission through the scale effect (Grossman & Krueger, 1991; Andreoni & Levinson, 2001). Subsidies and transfer payments (pension, welfare trust etc.) are unproductive spendings it triggers aggregate demand without bringing technological improvement that could reduce emissions. Second is between green and brown government spending. Green expenditure includes investment I green technologies, renewable energy, environmental regulation, public transport can reverse fiscal-emission links. Brown expenditure is fossils fuel infrastructure, coal power plants, subsidies renewable energy sources reinforce emissions. Most developing countries sit in the brown category including Pakistan. This is why theoretical expectation of a positive link between government expenditure and emission is strong in this context.

Cross-country panel studies support positive fiscal and emission relationship for developing economies. Their intensity and channels vary. Across 47 emerging economies Le and Ozturk (2020) found that government expenditure and financial development both independently raised emission. the EKC hypothesis was observed in their data. Higher income reduces emission (EKC hypothesis) the process is very slow to offset scale effect of fiscal expansion. These finding are relevant n case of Pakistan as Pakistan income level lies below turning point.

Nguyen and Duong (2025) used non-linear ARDL and found fiscal expansion and restraint do not have equal and opposite effect on emission. When government expenditure increases emissions rise by more than it falls when the spending is cut by same amount. It's because fiscal expansion i.e. power plants, factories continue to generate emission even when spending is reduced later. This asymmetry is directly related to Pakistan. Where frequent fiscal expansion by IMF programs and CPEC it indicated that emission cost of Pakistan is larger. It's difficult for a simple linear model to capture.

Fiscal multiplier literature adds an important aspect. When government spending generates economic activity which last years e.g. large infrastructure projects. The total the total emissions impact is larger than any single year would estimate. Di Bucchianico et al. (2025) explains this for united states. They found that emission impact of federal spending decreased as environmental regulation get stringer. For Pakistan it's clear when environmental cost is never taken into account in fiscal decisions. Barra and Zotti (2018) studies founded that government spending reduces emission once country regulatory quality reaches a certain level. Below that level fiscal expansion rises emission it does not matter on what money is spent. Pakistan regulatory institution is below than that point meaning government spending will push emission upward.

Jafri et al. (2023) applied ARDL and NARDL to Pakistan from 1975 to 2019. They found an increase and decrease in government spending do not have same and equal effect on emissions. They noticed that when spending is increased CO_2 emission in long run increased by 0.08 percent. And when spending was cut by same amount CO_2 emissions was not reduced by same degree. They found another interesting thing that investment specific spending actually reduced emissions. This means it's not important how much government spend what government spend it on really matters. Pakistan government mostly spends on large energy and infrastructural projects which result in high emissions for years. CPEC made this even worse.

Li et al. (2024) modelled seven different CPEC scenarios. They found fully renewable and clean CPEC could theoretically bring emissions to zero electricity, half of the total capacity by 2030. Coal based energy generation was the first phase of CPEC it generated electricity and also massive emissions. The emission reduction was very small. this triggers the long run emission path for Pakistan. Waheed et al. (2025) added governance prespective.in their study they observed poor policy in different areas of CPEC causes more environmental damages than investment volume. These studies confirm Pakistan CPEC era not just maintain existing pattern of emission but it also significant increased it.

Evidence from advance economies provide us a useful comparison Oh (2023) study based on south Korea used two stages dynamic GMM. Government spending specific on-air quality resulted in reduction of net emissions. Direct emission reduction result was higher than the indirect effect of higher income on emission. Pakistan regulatory institution is far weaker than of south Korea mean same strategy won't generate same outcomes. Tshiaba and Liao (2025) provide evidence from China. They found emission cost of government spendings depends on technology of the physical capital. Pakistan's CPEC energy project is primarily coal-based built after 2015 placing it at high intensity emission. this suggests emission cost in Pakistan is among the largest that this literature would predict.

Even so this growing literature, government expenditure is surprisingly is quite unexplored variable in Pakistan's environmental time series studies. Existing Pakistan studies focuses on including government expenditure as a part of aggregate demand frame work. Or they used CPEC scenario modelling analysis rather than formal econometric estimation. Studies are quite limited to test long run relationship between government expenditure CO_2 emission using time series data. Our study fills the gap by focusing on ARDL model, testing the impact of government spending on CO_2 emissions. It treats energy use, trade openness and income as control variables. This will give clear view of fiscal policy and CO_2 emissions link. This study is relevant in academic literature on fiscal policy and environment and need of including environmental goals in fiscal (spending) policy.

Theoretical Frame Work

Government expenditure effects environment through two channels. The scale effect and composition effect. Scale effect: when public spending rises it increases economic activity and energy demand also rises. Economy based on fossil fuel energy system the emissions automatically rise irrespective of on what money is spent. Composition effect means where the money goes. Power stations, industrial zones etc. have high emission patterns and are difficult and costly to reverse. directing funds on clean technology and regulation will lower emission over time. Currently a large portion of public spending is spent on pension, debt servicing, subsidies and wages and the remaining portion is mostly spent on infrastructure. The result is composition effect is not balancing scale they both push emission in the same direction

Trade can either increase or decrease emissions it depends. Pollution haven hypothesis says "dirty industries move to developing countries where regulation and standards are low". Technique effect is against the view of pollution haven. technique effect says "trade brings efficient and better technology making domestic industries to international standards".

EKC theory suggests that as income rises pollution also rises after a certain point it decrease making inverted u-shaped curve. Pakistan is on the rising part of the curve due to its low income and is less likely to see downward shifts. In case of Pakistan income affects the emissions through energy demand not by structural shift like shifting towards service sector. Fuel subsidies keep the prices low due to which there is no incentive to use energy efficiently

Methodology

Data

Annual data for Pakistan from 1990-2020 is used in this research. All the variable's data used in this research are taken from world development indicators (WDI). In Table 1 below each variable is defined, its symbol, its WDI code, and how it entered the model. CO_2 emissions, GDP per capita and energy use are used in natural log form to reduce skewness and for elasticity interpretation. Government expenditure and trade openness are expressed as GDP ratios.

Table 1

Variables Description

Variable	Description	Symbol	WDI Code	Model Form
CO_2 per capita	Metric tons per person	LN_CO_2	EN.ATM.CO_2E.PC	Natural log
Govt. expenditure	Final consumption, % GDP	GOVEXP	NE.CON.GOVT.ZS	Levels
GDP per capita	Constant 2015 USD	LN_GDPC	NY.GDP.PCAP.KD	Natural log
Energy use p.c.	Kg oil equivalent per person	LN_ENERGY	EG.USE.PCAP.KG.OE	Natural log
Trade openness	(Exports + Imports) % GDP	TRADE	NE.TRD.GNFS.ZS	Levels

Source: WDI, sample Pakistan-1990 to 2020 (n=31)

Unit Root Test

Augmented dickey fuller test is used to check the stationarity of the data. AIC automatic lag selection maximum lag-7 is applied at level and at first differences. A variable is I(1) means stationary at first difference if the unit root null hypothesis is not rejected at level but is rejected at first difference. It's used to check the appropriate analysis method. If any variable is I(2) the ARDL method is not valid for it. Throughout this study the significance levels are reported in 1%,5%,10% which is standard in time series research. The government expenditure is significant at 5% which is our key result.

ARDL Bounds Testing

The Autoregressive Distributed Lag (ARDL) Bounds test by Pesaran, Shin, and Smith (2001) is used. unrestricted error correction form (UECM) form is;

$$\Delta LN\_CO_{2t} = \alpha_0 + \gamma_1 LN\_CO_{2t-1} + \gamma_2 GOVEXP_{t-1} + \gamma_3 LN\_GDPC_{t-1} + \gamma_4 LN\_ENERGY_{t-1} + \gamma_5 TRADE_{t-1} + \Sigma\delta_i{\cdot}\Delta LN\_CO_{2t-i} + \Sigma\beta_j{\cdot}\Delta GOVEXP_{t-j} + \Sigma\lambda_k{\cdot}\Delta LN\_GDPC_{t-k} + \Sigma\mu_l{\cdot}\Delta LN\_ENERGY_{t-l} + \Sigma\nu_m{\cdot}\Delta TRADE_{t-m} + \varepsilon_t \ldots (1)$$

The null hypothesis H:0 ($\gamma_1 = \ldots = \gamma_5 = 0$) that there is no long run relationship. The null hypothesis is tested using f-statistics against the critical bounds from Narayan (2005) for observation(n=30). The null hypothesis is rejected when f-statistics is larger than the upper bound I(1). Akaike's Information Criterion (AIC) with maximum two lags. ARDL (1,0,0,0,1) was selected after analyzing 162 different models.

Long-Run and Error Correction Estimation

After confirming cointegration the long-run coefficients are estimated from the level equations. The error correction model (ECM) is:

$$\Delta LN\_CO_{2t} = \alpha_0 + \Sigma\delta_i{\cdot}\Delta LN\_CO_{2t-i} + \Sigma\beta_j{\cdot}\Delta X_{t-j} + \varphi{\cdot}ECT_{t-1} + \mu_t \ldots (2)$$

A significant negative φ (-1 to 0) indicates the speed of adjustment towards long-run equilibrium

Diagnostic Tests

After estimation several diagnostic tests are ran to check the reliability of the estimation technique. Breusch-Godfrey serial LM test is conducted to check serial correlation using lag two. For heteroscedasticity Breusch pagan test is used. The Ramsey reset test is used to see is the model is correctly specified and Jarque Bera test for residual normality. CUSUM and CUSUM square recursive estimates are used to check structural stability of the model. Variance inflation factor (VIF) test is used to see the problem of multicollinearity among the independent variables.
Note: this study uses EViews 12 software.

Analysis and Result

Descriptive Statistics and Unit Root

Descriptive statistics of all the variables are shown in table 2. Mean of LN_CO_2 (-0.343) which approximately 0.71 metric tons per capita suggests Pakistan's position low to moderate carbon emitter. GOVEXP averages 11.04 percent of GDP with positive skewness 0.989 indicating it increases in later years especially after 2015. Jarque Bera test rejects normality for GOVEXP p-0.049 (at 5%) not for any other variable. It does not affect estimation because ARDL requires residual normality not the normality of regressor. Trade standard deviation (4.879) is highest means it's the most volatile variable.

Table 2

Descriptive Statistics (1990–2020, n = 31)

Statistic	LN_CO_2	GOVEXP	LN_ENERGY	LN_GDPC	TRADE
Mean	−0.3426	11.041	6.037	7.078	30.791
Median	−0.3538	10.750	6.044	7.091	31.319
Maximum	−0.0519	15.137	6.125	7.361	38.499
Minimum	−0.5762	8.656	5.906	6.857	21.460
Std. Dev.	0.1296	1.443	0.060	0.153	4.879
Skewness	0.406	0.989	−0.430	0.356	−0.198
Kurtosis	2.773	3.866	2.418	1.904	1.942
Jarque-Bera	0.920	6.026	1.391	2.207	1.649
JB p-value	0.631	0.049*	0.499	0.332	0.439

ADF results are shown in table 3. All variables are integrated of I(1). Trade is weakly stationary at the 10% level(p=0.089). all the variable rejects the null hypotheses at first difference all p-values are less than 1%, 5%, 10% at first differences. No variable is I(2) it confirms ARDL approach is appropriate.

Table 3

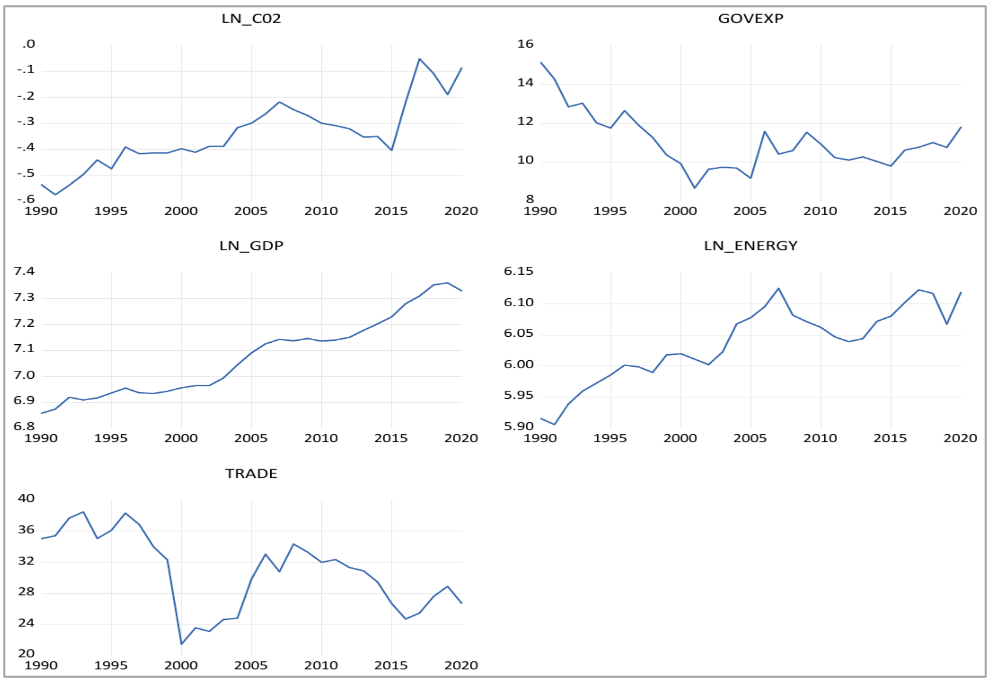
ADF Unit Root Test Results

Variable	p-value at Level	p-value at 1st Diff.	Order	decision
LN_CO_2	0.6925	0.0175**	I(1)	Stationary after 1st difference
GOVEXP	0.3117	0.0000***	I(1)	Stationary after 1st difference
LN_GDPC	0.8392	0.0225**	I(1)	Stationary after 1st difference
LN_ENERGY	0.4490	0.0004***	I(1)	Stationary after 1st difference
TRADE	0.0892	0.0003***	I(1)	Stationary after 1st difference

Note: ADF with AIC-based automatic lag selection (maximum 7 lags). *** $p < 0.01$, ** $p < 0.05$. All variables are I(1)

Figure 1

Time Series Plot of Variables (Pakistan 1990-2020)



LN_CO_2 = log per capita CO_2 emissions.
GOVEXP = government expenditure (% GDP).
LN_GDPC = log GDP per capita.
LN_ENERGY = log energy use per capita.
TRADE = trade openness (% GDP).
Note: *each variable is plotted over the period of 1990 to 2020.*

ARDL Model and Bounds Test

Table: 4 reports ARDL (1,0,0,0,1) regressions. LN_CO_2 R-squared (0.922) and adjusted R2(0.902) with overall F-statistics 45.37 ($p<0.0001$) and DW= 1.884 indicates that the models capture around 90% of variation in CO_2 emissions and the model has high explanatory power.

Table 4

ARDL (1, 0, 0, 0, 1) Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.	Sig.
LN_CO_2 (−1)	0.3970	0.1250	3.178	0.0042	***
GOVEXP	0.0327	0.0100	3.255	0.0035	***
LN_GDPC	−0.0249	0.1219	−0.204	0.8399	n.s.
LN_ENERGY	1.4732	0.3082	4.780	0.0001	***
TRADE	−0.0036	0.0030	−1.211	0.2381	n.s.
TRADE(−1)	−0.0027	0.0028	−0.943	0.3556	n.s.
Constant	−9.0814	1.5930	−5.701	0.0000	***

Note: Sample (adjusted): 1991–2020 (n = 30). Model selected by AIC among 162 models. *** p < 0.01, n.s. = not significant at 10% level

ARDL F-Bounds Test for Long-Run Cointegration

F-Bounds test with f-statistic 8.31 exceeds all Narayan (2005) upper values as shown in table 5 below. Because of which the null hypothesis is rejected "there is no cointegration" and confirms that there is long-run relationship among the variable in the model.

Table 5

F-Bound Test Estimates

	Value	10% I(1)	5% I(1)	2.5% I(1)	1% I(1)	Decision
F-statistic	8.3102	3.56	4.223	4.87	5.84	Cointegrated at 1%

K (regressor) =4, sample (n = 30) critical bounds from Narayan (2005). F-statistic of 8.31 exceeds all upper bounds. Case2: Restricted constant, no trend.

Long Run Estimates

$$LN\_CO_2 = -15.062 + 0.054 \cdot GOVEXP - 0.041 \cdot LN\_GDPC + 2.443 \cdot LN\_ENERGY - 0.010 \cdot TRADE$$

Table 6

Shows Estimated Long Run Relationship

Variable	Coefficient	Std. Error	t-Statistic	Prob.	Sig.
GOVEXP	**0.0542**	0.0214	2.536	0.0185	**
LN_GDPC	−0.0413	0.2066	−0.200	0.8433	Insignificant
LN_ENERGY	2.4432	0.6175	3.957	0.0006	***
TRADE	−0.0104	0.0050	−2.069	0.0499	**
Constant	−15.062	2.599	−5.794	0.0000	***

Government expenditure is 0.0542(positive) and significant (p value=0.019).it means it has positive and significant effect on CO_2 emissions. 1 percentage point increase in government expenditure (share of GDP) increases 5.4 percent increase in CO_2 emissions in the long run. This is our key finding in the research.

LN-ENERGY (Energy use per capita) has the strongest effect on CO_2 emissions. With the positive coefficient (2.4432) and high significant value p=0.0001 can be interpreted that 1 percent increase in energy consumption leads to 2.44 percent increase in CO_2 emission in the long-run. This suggests that Pakistan is heavily dependent on fossil fuel which increases pollution. Changing it to cleaner energy system is effective in reduction of emissions.

Trade openness has negative sign (-0.0104 and p-value of 0.050 meaning that it has negative and significant effect on CO_2 emission. it indicates that trade attract cleaner technology to the country. GDP per capita (p=0.8433) is statistically insignificant. This does not mean that income has no effect on CO_2 emissions, actually Pakistan economy grows at the same rate as the energy consumption. It's because income and energy use moves together separating individual effect for the model is difficult. This was confirmed by centered VIF 6.18 for GDP per capita suggesting multicollinearity. The insignificant of GDP per capita is the limitation of this study not that income is irrelevant to CO_2 emissions.

Error Correction and Short-run Dynamics

ECM is shown in table 7. Adjustment coefficient Cointeq (-1) is 0.6030 having p < 0.0000 lies within required range of (-1,0). It means that 60 percent deviation of short run from the long run equilibrium is corrected in one year. D(trade) in not significant (p=0.1286) in the short run it means that trade reducing emissions are gradually in the long run.

Table 7

Error Correction Estimates

Variable	coefficients	Std. error	T-statistics	Prob.	sig
D(TRADE)	-0.003627	0.002301	-1.576	0.1286	Insignificant
CointEq (-1)	-0.6030	0.0774	-7.791	0.0000	***

R^2 =0,669 Adj.R^2=0.657 AIC = -3.750 DW = 1.884 n=30

Note: due to ARDL (1,0,0,0,1) zero short run lag were assigned to GOVEXP, LN_GDPC and LN_energy. Because of this no first difference terms in ECM.

Diagnostic and Stability Tests

In table 8 all the diagnostic tests are summarized. Breusch Godfrey f= 1.230 and p=0.313 indicating no serial correlation issue. Breusch pagan Godfrey f= 0.972 and p = 0.466 it confirms homoscedasticity mean no heteroscedasticity issue. There is no functional form problem Ramsey rest test f=1.229 with p = 0.280 and the residual are normally distributed JB= 4.789, p= 0.091 does not reject it at 5 % level. This confirms that the estimation technique is reliable.

Table 8

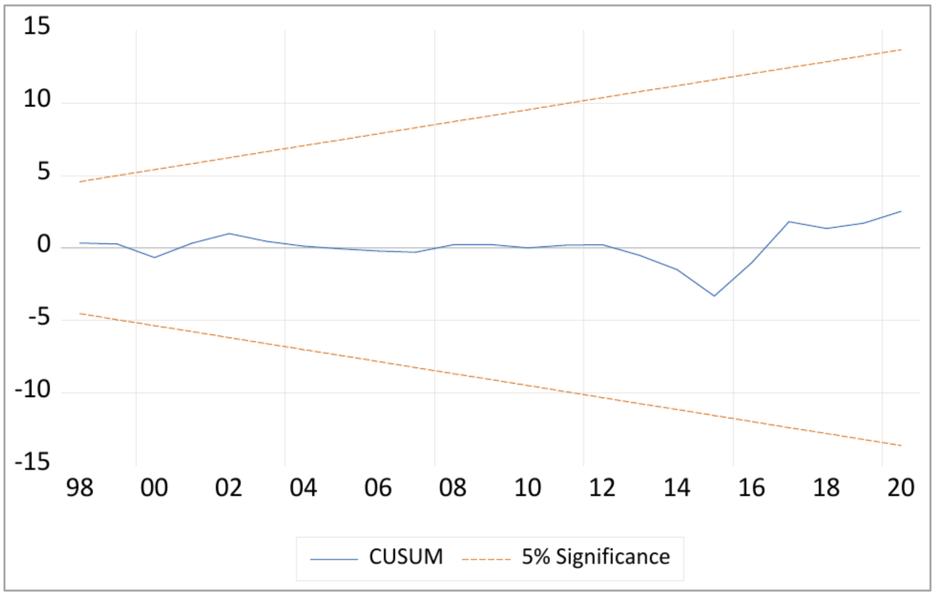
Diagnostic Tests

TEST	Null hypothesis	statistics	p-value	Results
Breusch Godfrey LM(2lags)	No serial correlation	F =1.230	0.3126	pass
Breusch pagan Godfrey	homoscedasticity	F =0.972	0.4659	pass
Ramsey RESET	Correct functional form	1.229	0.2796	pass
Jarque-Bera (Residuals)	Residuals are normal	JB= 4.789	0.0912	pass

Long run parameter stability was confirmed by CUSUM test. The recursive statistics remain within its 5 percent boundary throughout the observation period. The CUSUM square test for variance stability it shows possible change in residual variance after 2014. The long run results remain valid because it's a variance shift not necessarily break in long run coefficients. This suggests means the long run results are reliable because CUSUM remains stable.

Figure 2

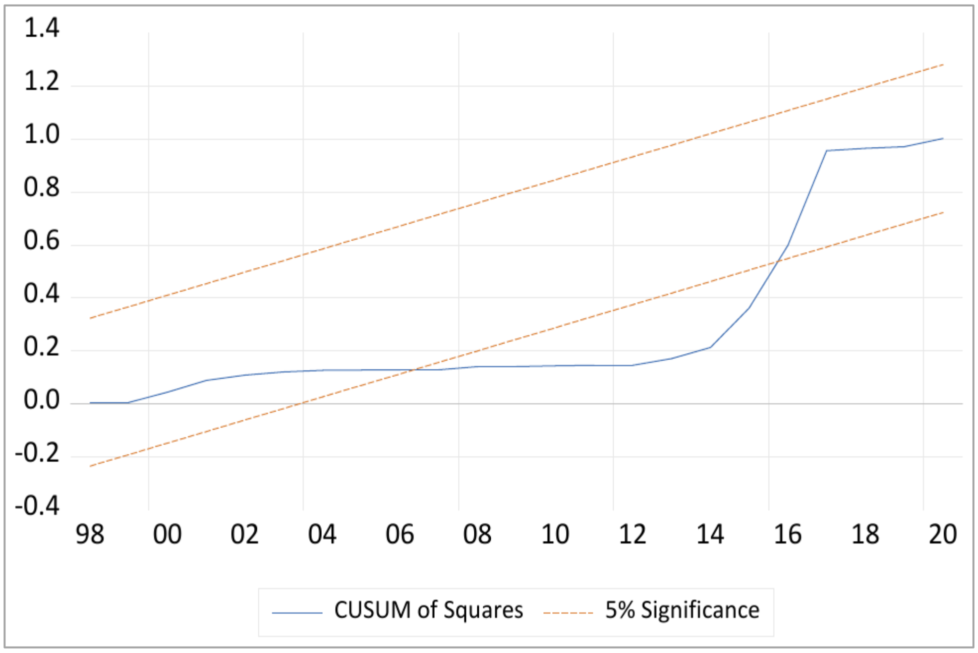
Cumulative Sum



5% critical bound represented by straight lines. The cusum statistic remain inside the bounds 1998 to 2020.cusum uses initial observation for estimation

Figure 3

CUSUM-sq Test for Variance Stability



Cusum-sq statistics remains within critical bound limit (5%) till 2014. And it crosses the upper boundary after 2014.

2015 timing align with CPEC phase in Pakistan (huge investment in energy sector). The IMF stabilization program and major macro fiscal changes. Any of these can be the reason for increase in residual variance. CUSUM can not identify the exact factor effecting it. It signals further research into it. Further work related to this should apply formal structure break test i.e. Zivot Andrews (1992) for single break and bai and perron (2003) for multiple breaks.

Variance Inflation Factor

It is used to check the problem of multi collinearity. All centered VIF less than 10 moderate multicollinearity exists. LN_GDPC (VIF=6.18) LN_ENERGY VIF = 5.63.it reflects the structural income-energy correlation in developing countries i.e. Pakistan. And all other variables centered VIF are below than 5 which is acceptable range no issue of multi collinearity.

Table 9

Variance Inflation Factor

Variable	Coeff. Variance	Centered VIF	Assessment
LN_CO_2(−1)	0.01561	4.33	Acceptable (< 5)
GOVEXP	0.00010	2.89	Acceptable (< 5)
LN_GDPC	0.01485	6.18	Moderate – interpret cautiously
LN_ENERGY	0.09498	5.63	Moderate – interpret cautiously
TRADE	8.97e-06	3.97	Acceptable (< 5)
TRADE(−1)	8.01e-06	3.55	Acceptable (< 5)

Discussion

GOVEXP (0.054, p=0.019) the long-run coefficient is the main finding in our study. It shows that Pakistan public spending is actually harmful for the environment. Increasing in the fiscal activity costs measurable effect on CO_2 emissions. From 1990 to 2020 government expenditure varied by more than 6 percent of the GDP. This reveals fiscal policy played a meaningful role in Pakistan's CO_2 emissions path.

The mechanism runs through two channels scale and composition. Current expenditure i.e. Development spending on large infrastructure and wages, energy subsidies, debt servicing m expenditure for public spending. Both of these heavily effects carbon emissions. Energy subsides lower fuel prices which increases the consumption of fuel and increase the demand for fossils. Infrastructure spending creates durable physical capital which generates emission for years. CPEC magnifies both effect due to its long term guarantees of coal and gas powerplant meaning the commitment for paying fossils fuel emission. Our finding is supportive of le and Ozturk (2020) who found positive relation between government spending and emissions across the larger sample for developing economy. Jafri (2023) had the same findings in particular for Pakistan.

Energy use per capita has the major effect on CO_2 emissions having elasticity of 2.443. this shows Pakistan heavy dependency on coal for Pakistan's energy mix mainly after 2015. It means that fiscal and emissions relationship primary work through energy system. Cleaning of energy mix is not just energy policy issue but also a fiscal policy issue. As long the government supports coal-based energy plants and fuel subsides the CO_2 emissions will go up. The insignificant of GDPC supports this interpretation. economic growth in Pakistan has not led Pakistan toward clean energy-based economy it just increased the energy demand.it indicates income alone will not bend the emission curve (reduce emissions).

In long run trade has negative effect (-0.0104, p=0.0499) in our model. It suggests trade openness reduces emissions in Pakistan instead of increasing. Major trading partner of Pakistan i.e. EU, USA, CHINA progressively demand that their suppliers meet certain energy efficient standard. This causes Pakistan trader to adopt clean and efficient energy-based practices. That's the reason in short run effect of trade is insignificant and significant in the long run because clean technology diffusion happens gradually.

Following policy are recommended from findings of this research. Government spending framework should include environmental assessment. Standard fiscal management mostly focuses on budget balance and spending without considering its impact on emissions. Therefore an "emission assessment" should be required for major development project. This will make sure that spending decisions are aligned with Pakistan national climate commitment.

CPEC energy investment projects should prioritize renewable and clean energy as the CPEC coal and gas capacity payment agreements expires new capacity payment agreements based on clean and renewable energy e.g. solar, wind etc. should be planned. It will redirect government towards clean energy and will weaken fiscal-emission relation.

Conclusion

ARDL Bounds testing framework is used using Eviews12 software to analyze the long and short run relationship between government expenditure and CO_2 emission per. It uses annual data from 1990-2020 for Pakistan. F-bound statistics 8.31 exceeds all the upper bound confirming the existence of long run cointegration. Government expenditure has positive and significant effect on CO_2 emission 0.0542 and $p<0.05$ meaning that fiscal expansion carries environmental cost along itself. Energy use has most of effect on emissions elasticity 2.4432, $p<0.05$ suggests that Pakistan energy system is carbon intensive driven. Trade openness has small negative effect -0.0104 and $p<0.05$ on CO_2 emissions indicating that trade integration brings cleaner technology (energy) to the country. The ECM -0.603 shows approximately 60 percent of short run disequilibrium is corrected within one year. All diagnostic tests are passed no problem of serial correlation (p-value =0.3126) heteroscedasticity p=0.4659, function form p=0.2796 residual normality p=0.0912. Parameter are stable across the sample CUSUM test confirmed it.

Possible variance instability is seen after 2014 signaled by CUSUM square. since the parameter stability is confirmed by CUSUM it does not establishes a confirm structural break in the long run coefficients. Formal break testing is recommended i.e. Zivot Andrews or bai and Peron. The small sample n=30 is also a limitation, Narayan (2005) finite sample critical bound is used to address this limitation. The result of this study should be interpreted with caution. For future research NARDL is recommended to capture asymmetric effect of public expenditure on emissions.

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