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ASYMMETRIC ASSOCIATION OF CONSUMPTION AND PRODUCTION-BASED CARBON EMISSIONS WITH TOURISM DEVELOPMENT IN PAKISTAN

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Abstract
The study examines the impact of consumption-based and production-based carbon emissions on tourism development in Pakistan from year 2000 to 2024. Using Autoregressive Distributed Lag (ARDL) and Nonlinear ARDL (NARDL) models, the research examines environmental and macroeconomic factors such as CBCE, PBCE, economic growth, inflation, and exchange rate. The results support the Growth-Led Tourism Hypothesis, indicating that economic growth significantly influences tourism development. However, CBCE and PBCE show asymmetric effects, with increases in carbon emissions associated with a decline in tourism activity, while reductions do not significantly improve growth. Inflation and exchange rate volatility also negatively influence tourism performance. The findings suggest that sustainable tourism development in Pakistan requires policy action, including reducing industrial carbon emissions, promoting eco-tourism, and maintaining macroeconomic stability. Policymakers should focus on improving environmental regulations, encouraging ecotourism, and lowering emissions through cleaner technologies. Sustainable tourism plans that combine macroeconomic stability and environmental preservation are crucial for long-term growth and support for Pakistan's sustainable development goals.
Keywords: *Tourism, Consumption-based Carbon Emission, Production-based Carbon Emission, Economic Growth, Exchange Rate, Inflation*

INTRODUCTION

Tourism is a sociocultural phenomenon that includes people travelling both inside and outside of their country for a variety of reasons, such as leisure, work, or economic reasons (Kumail, Ali, Sadiq & Abbas 2023). A key and sustainable engine of economic expansion, it is considered as a dynamic factor in keeping the nation on track of development since it helps to increase income per capita, inflows of funds, tax income, jobs, infrastructure, economic activity, and foreign investments in the economy (Warsame et al., 2022; Ali et al., 2023). The global tourist industry has expanded rapidly in recent decades, encouraging governments to improve their tourism infrastructure to fulfill unique tourism demands (Abbasi et al., 2021; Audi, 2025). However, its rapid expansion raises environmental concerns such as CO2 emissions and pollution, endangering sustainable development and tourism demand (Oyebanji et al., 2023; Marc et al., 2025; Iqbal et al., 2025). Nevertheless, the tourism industry exacerbates environmental problems despite its economic advantages. Increased tourism results in waste mishandling, overuse of natural resources, harm to delicate ecosystems, and increased carbon emissions from transportation. Economic gains must be matched with eco-friendly methods, since environmental quality has a crucial influence on tourist choices and long-term tourism industry development.

Environmental degradation (ED) is a critical issue in Pakistan, where effective environmental protection measures are difficult to implement due to a lack of resources and weak governance structures. Deforestation, air and water pollution, resource depletion, and waste accumulation are just a few of the problems that fall under the umbrella of ED and endanger both ecological balance and economic stability (Ali & Rehman, 2015). The focus is now on consumption-driven environmental responsibility because of the consumption-based carbon emissions, which highlight the intricate relationship between global trade, consumption patterns, and environmental impact, including emissions from the production of goods and services consumed in other nations (Firdous, Abbasi, Salman, Sahin & Hamza, 2024). As tourism keeps growing, its unchecked expansion makes Environmental degradation (ED) worse, which eventually lowers the industry's long-term sustainability and has a negative effect

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on tourism. According to the Environmental Kuznets Curve (EKC) hypothesis, environmental deterioration rises with economic expansion at first but then falls as economies advance and place a higher priority on sustainability. However, because of uneven governance and inadequate institutional frameworks, its relevance to Pakistan is still unclear (Haldar & Sethi 2021; Sulehri et al., 2024).

It is evident from the existing literature that carbon emissions influenced tourism (Ali et al., 2021; Oyebanji et al., 2023; Longston et al., 2025). Few studies have investigated the relationship between tourism-related energy usage, tourism-related carbon emissions, and tourism-based development (Ji and Yang, 2024; Haldar and Sethi, 2021; Marc et al., 2025). However, literature has not found a comprehensive study which considered tourism development as dependent variable in the post and pre covid data on impact of carbon emission of the case of Pakistan. In contrast to other studies that treated tourism development as an independent variable and determinant, this study concentrated on it as a dependent variable. By examining the development-oriented tourist development hypothesis (GLTH), this study adds to the body of previous material. Research shows that institutional quality and governance are the keys to solving ED, but internal conflicts often divert resources from environmental priorities. Addressing these interlinked issues is crucial for sustainable development and the achievement of UN SDGs (Mehmood et al., 2021; Batool et al., 2025). The carbon footprint in Pakistan is the multi-dimensional problem that requires a complete study combining both consumption-based and territory-based data (Usman, Rafndadi, & Sarkodie 2021; Khan et al., 2025).

REVIEW OF LITERATURE

This section reviews key studies on carbon emissions and tourism development. It highlights major findings, methodologies and regional focuses as summarized in Table 1. The review aims to find common trends and gaps in the existing literature to guide future research.

Table 1: Studies on Tourism development and Carbon Emissions

Reference(s)	Time Period	Country	Methodology	Main Findings
Adeel et al. (2025)	2000-2024	Pakistan	NARDL, DOLS, and FMOLS	A 5% increase in emissions corresponds to a 10% increase in transportation operations; transportation and power use are major contributors to CO_2 emissions.
Ahmad et al. (2022)	1970-2018	Pakistan	ARDL	Exchange rate and trade balance both factors have a positive impact on economic growth in the long term. CO_2 emissions have no immediate impact on economic output but have a negative long-term impact.
Ahmed et al. (2024)	1995-2021	Pakistan	OLS	The findings show that strategic planning, investment, and e-marketing have a positive impact on the growth of tourism in Pakistan.
Ali, (2023)	2021-2022	Pakistan	binomial regression method	These findings provide important recommendations for managing natural resources and preserving the region's unique landscapes and historical places.
Almulhim et al. (2025)	1996-2020	BRICS countries	MMQR, OLS, GMM, and CEMG	The results from MMQR reveal that GDP has a positive and statistically significant effect on CCO_2 emissions across all quantiles
Altaf et al. (2023)	1997-2022	Pakistan	ARDL	ARDL analysis revealed that CO2 emissions positively impact energy, GDP, and tourism.
Chishti et al. (2023)	1990-2017	Pakistan	ADF, ARDL, NARDL	The research indicates that Pakistan implements stricter environmental regulations in trade policies, encourage renewable energy adoption, and promote eco-friendly exports.
Firdous et al. (2024)	1990-2021	Pakistan	ARDL	Institutional quality and foreign direct investment have a negative impact on territory-based emissions, while internal conflict and GDP growth have a positive impact on both consumption- and territory-based emissions.

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Guo et al. (2024)	1975-2020	Pakistan	ARDL	Short- and long-term results show that energy efficiency helps reduce carbon emissions, whereas urbanization, financial development, and FDI contribute to increased emissions in Pakistan.
Hussain et al. (2024)	1978-2022	Pakistan	non-probabilistic sampling methods	The study found that international and domestic tourism, as well as infrastructural growth, had a significant impact on livelihoods and community dynamics.
Imran and Ali (2024)	1995-2012	Pakistan	ADF	The long-term tourist coefficient shows a significant positive association with economic expansion.
Iqbal et al. (2024)	1995-2022	Pakistan	ARDL Model	Long-run estimates show a positive impact of tourism growth on GDP growth in Pakistan.
Jafri et al. (2023)	1975-2019	Pakistan	ARDL	Positive investment changes have a significant negative impact on the environment in Pakistan
Ji, & Yang, (2024)	2001-2022	BRICS nations	AMG test	The study reveals that tourism, renewable energy, and digital economy positively impact green economic growth.
Khan et al. (2022)	1995-2017	Pakistan	ARDL	The results show that terrorism negatively affects the tourism sector in Pakistan, while tourism expenditure and inflation strongly influence its performance.
Kumail et al. (2023)	1980-2018	Pakistan	ARDL	Positive correlation between trade openness, economic growth, and energy use on tourism development, but a negative relationship with CO2 emissions.
Nawaz and Shakeel (2025)	1995-2018	EU economies	ARDL, fixed effects, and GMM models	The interaction of tourism and institutional quality has a negative effect on CO_2 emissions.
Oad et al. (2022)	1995-2014	Pakistan	Granger Causality Test	The results of the study showed that no parameters have a significant effect on CO_2 emissions in the long-term.
Rauf et al. (2022)	1995-2019	Pakistan	ARDL	Political stability impacts tourism positively, while political instability impacts tourism negatively
Ullah et al. (2023)	1995-2018	BRICS countries	CS- ARDL	Technological innovation, natural resources, and economic growth have a positive impact on CO_2 emissions, while tourism has a negative impact.

MODEL SPECIFICATION, DATA AND METHODOLOGY

To determine the effect of consumption-based and production-based carbon emission on tourism development; we will follow the work by (Firdous, Abbasi, Salman, Sahin, & Hamza, 2024; Amir, Siddique, Ali, Bukhari, & Kausar, 2022), and specify the following model:

$$TOURt = f\,(CBCE_t, PBCE_t, GDPPC_t, EXR_t, INF_t\,) \qquad (1)$$

Due to the non-linarites in the time series data, the current investigation is conducted in a non-linear setting. For the following reasons, the study may have been carried out in a non-linear setting: Thus the time series data may contain asymmetries, structural discontinuities, and hidden co-integration if the series components are co-integrated. The following nonlinear model was used to examine the asymmetric interactions between variables:

$$TOURt = f\,(\,CBCE_t + PBCE_t + GDPPC_t + EXR_t + INF_t,) \qquad (2)$$

Table 2 presents a description of the variables used in the study along with their measurement units and data sources. These variables cover consumption-based and production-based carbon emission and tourism development relevant to the analysis

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Table 2: Variables Description, Measurement Unit and Data Sources

	Abbreviation	Description	Unit	Data Source
Dependent Variable	TOUR	International tourism, expenditures for travel items	(current US$)	WDI
Independent Variables	CBCE	Consumption-based carbon emission	Per-person tones of CO2 (tCO_2/person)	Global carbon atlas (GCA) database
	PBCE	Production-based carbon emission	Per-person tones of CO2 (tCO_2/person)	GCA
	GDPPC	Per-Capita GDP growth	annual %	WDI
	EXR	Official exchange rate	LCU per US$, period average	WDI
	INF	Inflation based on consumer prices	annual %	WDI

The asymmetric relationship among environment, growth, the following model was used to estimate inflation, exchange rates, and tourism development by using ARDL and NARDL:

$$D(TOUR_t) = \lambda_0 + \alpha_1 CBCE_{t-1} + \alpha_2 PBCE_{t-1} + \alpha_3 GDPPC_{t-1} + \alpha_4 INF_{t-1} + \alpha_5 EXR_{t-1} + \sum_{i=1}^{p_1} \beta_i \Delta(TOUR_{t-i}) + \sum_{i=0}^{p_2} \gamma_i \Delta(CBCE_{t-i}) + \sum_{i=0}^{p_3} \theta_i \Delta(PBCE_{t-i}) + \sum_{i=0}^{p_4} \delta_i \Delta(GDPPC_{t-i}) + \sum_{i=0}^{p_5} \eta_i \Delta(INF_{t-i}) + \sum_{i=0}^{p_6} \phi_i \Delta(EXR_{t-i}) + \mu_t \quad (3)$$

$$D(TOUR_t) = \lambda_0 + \alpha_1 CBCE\_P_{t-1} + \alpha_2 CBCE\_N_{t-1} + \alpha_3 PBCE\_P_{t-1} + \alpha_4 PBCE\_N_{t-1} + \alpha_5 GDPPC_{t-1} + \alpha_6 INF_{t-1} + \alpha_7 EXR_{t-1} + \sum_{i=1}^{p_1} \beta_i \Delta(TOUR_{t-i}) + \sum_{i=0}^{p_2} \gamma_i \Delta(CBCE\_P_{t-i}) + \sum_{i=0}^{p_3} \gamma_i^* \Delta(CBCE\_N_{t-i}) + \sum_{i=0}^{p_4} \theta_i^* \Delta(PBCE\_P_{t-i}) + \sum_{i=0}^{p_5} \theta_i \Delta(PBCE\_N_{t-i}) + \sum_{i=0}^{p_6} \delta_i \Delta(GDPPC_{t-i}) + \sum_{i=0}^{p_7} \eta_i \Delta(INF_{t-i}) + \sum_{i=0}^{p_8} \phi_i \Delta(EXR_{t-i}) + \mu_t \quad (4)$$

In this Equation, αi represent the long-run parameters. λi represent the intercept and μ represent the error term. While the other represent the Short-term impacts which are estimated by an error correction model and to see the asymmetric impacts of independent variables on tourism demand we'll use a non-linear co-integration equation.

RESULTS AND DISCUSSION

In this section Correlation analysis and descriptive statistics are explained. There is significant variance in tourism activity over years, as seen by the smallest value of 250 million and the greatest value of 2.20 billion. This huge variability is confirmed by the 543 million standard deviation. The kurtosis value 2.52 is around the usual value of 3, and the data is negatively skewed –0.63, suggesting a concentration of higher values. The mean values of CBCE are 0.92 and 0.82 for production-based emission (PBCE). These variables exhibit moderate dispersion, indicating a propensity toward higher values. They have a light-tailed distribution, as indicated by their kurtosis values, which are little bit below 3. GDP per capita growth (GDPPCG) reflects periods of economic boom and recession, with a mean value of 1.86 and maximum value is –3.04 and minimum is 5.20.

Table 3: Descriptive Statistics of Selected Variables (2000-2024)

	TOUR	CBCE	PBCE	GDPPCG	EXR	INF
Mean	1.31E+09	0.9214	0.8177	1.8646	110.60	9.5058
Median	1.41E+09	0.8796	0.7929	1.7214	93.395	7.9210
Maximum	2.20E+09	1.2296	1.0713	5.2024	280.35	30.768
Minimum	2.50E+08	0.6945	0.6619	-3.0388	53.648	2.5293
Std. Dev.	5.43E+08	0.1552	0.1135	2.1644	64.095	6.5202
Skewness	-0.626814	0.4667	0.6908	-0.2733	1.5463	1.5962
Kurtosis	2.5200	2.1733	2.5112	2.4910	4.5880	5.7751
J.B	1.8770	1.6194	2.2375	0.5811	12.590	18.638
Prob.	0.3912	0.4449	0.3266	0.7478	0.0018	0.0000
Observations	25	25	25	25	25	25

However, the inflation rate and exchange rate have non-normal distributions. Mean of EXR is 110.60 and a substantial standard deviation is 64.10, minimum value of EXR is 53.64 and maximum value is 280.36. The minimum value of GDP per capita growth is -3.04 and maximum values is 5.20 and has a mean value of 1.86, represents both economic boom and crisis. The standard deviation is rather large 2.16, and the distribution is somewhat left-skewed -0.27.

Table 4: Correlation Analysis of Selected Variables (2000-2024)

Correlation	TOUR	CBCE	PBCE	GDPPCG	EXR	INF
TOUR	1					
CBCE	0.714	1				
PBCE	0.556	0.732	1			
GDPPCG	0.378	-0.077	0.045	1		
EXR	0.478	0.829	0.355	-0.245	1	
INF	0.256	0.493	0.233	-0.453	0.612	1

All the explanatory factors have a positive correlation with the variable TOUR. With a value of 0.7141, the largest correlation a substantial positive association is found between tourism and consumption-based carbon emissions (CBCE). The correlation results show that the TOUR has a positive connection with the EXR and PBCE, and a high positive relationship with CBCE. Additionally, there is a slight positive association shown between TOUR, INF and GDP growth. The significant correlation between CBCE, EXR, and PBCE suggests that changes in the exchange rate and production activities have a direct impact on emission levels. In the meanwhile, GDP growth has negative correlations with inflation, CBCE, and EXR, suggesting that exchange rate volatility and inflationary pressure may have a detrimental impact on economic growth. Both CBCE and EXR have a positive correlation with INF.

Table 5: Results of ADF Unit Test on Level

Variables	None	Prob.	Intercept	Prob.	Intercept and Trend	Prob.	Conclusions
TOUR	-0.04	0.65	-2.33	0.16	-2.73	0.23	1(1)
CBCE	1.44	0.95	-0.60	0.85	-2.17	0.48	1(1)
PBCE	-0.10	0.63	-2.43	0.14	-3.93	0.03	1(1)
GDPPC	-2.45	0.01	-3.54	0.01	-3.49	0.06	1(0)
INF	-5.54	0.00	-9.21	0.00	-10.04	0.00	1(0)
EXR	1.09	0.92	1.61	0.99	-0.54	0.97	1(1)

The test statistics for the variables tourism (TOUR), consumption-based carbon emissions (CBCE), production-based carbon emissions (PBCE), and exchange rate (EXR) across the majority of specifications do not reject the null hypothesis of a unit root at the 5% significance level, indicating that the variables are non-stationary in level form. This suggests that their integration is of order one I(1). However, it is confirmed that GDPPCG and Inflation are integrated of order zero, I(0), since they are determined to be stationary at level, with significant test statistics and p-values less than 0.05. Since the data comprises a mix between I(0) and I(1) variables and none are integrated

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of order two, the Autoregressive Distributed Lag (ARDL) approach is deemed appropriate for investigating both short-run and long-run relationships among the variables.

Table 6: Bounds Test (For Linear and Non-Linear ARDL)

ARDL Bounds Test				
Test Statistics	Value	Signif	l(0)	I(1)
F-Statistics	3.8	10%	2.5	3.38
K	5	5%	2.81	3.76
		1%	3.5	4.6
NARDL Bounds Test				
F-Statistics	3.7	10%	2.0	3.1
K	7	5%	2.3	3.5
		1%	2.9	4.2

The critical value for the upper limit at the 5% significance level is 3.76, while the computed F-statistics in the ARDL bounds test is 3.8. The F-statistic offers modest support for a long-term link between the variables because it is somewhat higher than this value. Although the data indicates a long-term link, it is not particularly strong because it is so near to the boundary. The evidence is insufficient at the 1% level. As a result, the ARDL model provides a hazy signal that the variables may eventually move in tandem. In contrast, a stronger and clearer result is obtained using the NARDL limits test, which is intended to capture asymmetric effects. The crucial upper bound at the 5% level is 3.5 (with K = 7), and the F-statistic is 3.7 in this case. There is a substantial long-term relationship, as indicated by the F-statistic being higher than this number. This indicates that the model provides unmistakable proof of a long-term relationship, even when we take into account the potential that changes in the independent variables, both positive and negative, may have distinct effects on the dependent variable.

Table 7: Linear ARDL Long Run Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CBCE	3.9422	1.1757	3.3529	0.0044
PBCE	-3.4533	1.1008	-3.1371	0.0068
GDPPCG	0.1384	0.0352	3.9246	0.0014
INF	0.0424	0.0121	3.4934	0.0033
EXR	-0.0140	0.0033	-4.2347	0.0007
@TREND	0.1076	0.0234	4.5916	0.0004

A one-unit increase in consumption-based emissions is linked to a 3.94 unit increase in tourism inflow, according to the positive and statistically significant coefficient of Consumption-Based Carbon Emissions (CBCE) at the 1% level of $\beta = 3.94$, $p = 0.0044$. This could be a reflection of economic activity associated with higher consumption. On the other hand, tourism is negatively and significantly impacted by production-Based Carbon Emissions of $\beta = -3.45$, $p = 0.0068$, indicating that increased emissions associated to industry may discourage travellers, maybe as a result of pollution or environmental deterioration. Furthermore, there is a positive and substantial correlation between Growth in GDP per capita and tourism ($\beta = 0.14$, $p = 0.0014$), indicating that increases in income levels help the tourist industry by improving services and infrastructure. A positive and substantial influence is also shown by inflation (INF) ($\beta = 0.042$, $p = 0.0033$), which may suggest that moderate inflation is a reflection of demand-driven growth that supports tourism. Conversely, EXR displays a negative and highly significant coefficient ($\beta = -0.014$, $p = 0.0007$), suggesting that tourism suffers when the native currency depreciates, maybe as a result of higher travel expenses for tourists from other countries. Additionally significant and positive ($\beta = 0.107$, $p = 0.0004$) is the temporal trend variable, which shows a steady long-term rise in tourism over the research period.

The asymmetric impacts of both positive and negative shocks in carbon emissions on tourism are highlighted by the nonlinear ARDL long-run results, which offer more profound insights than the linear ARDL model.

The findings indicate that tourism is positively and significantly impacted by positive shocks in consumption-based carbon emissions (CBCE_POS) ($\beta = 26.97$, $p = 0.0135$), indicating that growth in the tourism industry is linked to increases in consumption-related emissions, which are probably related to energy and economic activity.

On the other hand, negative shocks in CBCE (CBCE_NEG) show a substantial negative effect (β = -12.74, p = 0.0198), suggesting that economic slowdowns may be reflected in the suppression of tourism caused by decreases in consumer emissions.

Table 8: Non-Linear ARDL Long Run Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CBCE_POS	26.972	7.8038	3.4563	0.0135
CBCE_NEG	-12.740	4.0425	-3.1515	0.0198
PBCE_POS	-26.448	8.1494	-3.2453	0.0176
PBCE_NEG	13.930	7.1649	1.9442	0.0999
GDPPCG	-0.0176	0.0627	-0.2806	0.7884
INF	-0.0485	0.0375	-1.2929	0.2436
EXR	-0.0034	0.0098	-0.3548	0.7348

The idea that increasing industrial pollution may discourage visitors is supported by the fact that positive shocks in production-based carbon emissions (PBCE_POS) have a substantial negative effect on tourism (β = -26.45, p = 0.0176). Although the result is statistically weak, negative shocks in production emissions (PBCE_NEG) seem to have a positive but marginally significant effect (β = 13.93, p = 0.0999), suggesting that lowering production-based emissions could improve the tourism environment. As indicated by their strong p-values, GDP per capita growth (GDPPCG), inflation (INF), and exchange rate (EXR) all have negligible long-term impacts on tourism in comparison to the emission factors. According to these results, environmental factors particularly carbon emissions have a greater impact on long-term tourist patterns in the nonlinear specification than the chosen macroeconomic variables.

Table 9: Long Run and EC Results (For Linear and Non-Linear ARDL)

ECM Regression for ARDL				
Variable	Coefficient	Std-error	t-Statistics	Prob.
C	20.86	3.5	5.8	0.0
D(GDPPCG)	0.10	0.0	5.3	0.0
CointEq(-1)*	-1.05	0.1	-5.8	0.0
ECM Regression for NARDL				
C	29.86	3.951	7.558	0.000
DLOG(TOUR(-1))	0.333	0.124	2.670	0.037
D(CBCE_POS)	11.52	3.551	3.244	0.017
D(CBCE_NEG)	-5.227	3.819	-1.368	0.220
D(PBCE_POS)	-9.472	3.401	-2.784	0.031
D(PBCE_NEG)	8.010	2.756	2.906	0.027
D(GDPPCG)	0.078	0.020	3.877	0.008
D(EXR)	0.019	0.007	2.621	0.039
D(INF)	0.003	0.012	0.307	0.768
CointEq(-1)*	-1.509	0.20	-7.516	0.000

The error correction term in the ARDL model is negative and extremely large (-1.05), suggesting a strong and quick return to long-term equilibrium. Growth in GDP per capita also has a positive and significant short term effect. There is sign of unequal effects and an even faster adjustment to equilibrium (-1.51) in the NARDL model. Changes in CBCE and PBCE that are positive or negative have different effects on the dependent variable. For example, while the negative impact on CBCE has no identifiable, positive CBCE considerably raises the dependent variable. On the other hand, negative PBCE raises the result, while positive PBCE decreases it. While inflation seems to be insignificant, GDP growth and exchange rates both have significant beneficial impacts.

Their non-stationarity is further supported by the incredibly weak values displayed by CBCE and EXR (e.g., MZa = -0.06 and 0.65). Although the negative MZa and MZt statistics presented by GDPPC and PBCE are comparatively stronger, these values are still insufficient to verify stationarity at the level. Conversely, INF does not entirely fulfill the criterion across all statistics, although it does exhibit considerable stationarity at level with MZa = -4.03 and MZt = -1.42. The findings show that TOUR, CBCE, PBCE, and GDPPC become stationary after calculating the initial differences since their MZa and MZt values significantly improve and fall within the acceptable range. The fact that these variables are integrated of order one, or I(1), is thereby confirmed. Interestingly, with MZa = -33.43 and MZt = -4.05., GDPPC shows extremely strong evidence of stationarity at first difference. However, even at first difference, INF and EXR still do not clearly show stationarity, especially INF very irregular values (e.g., MSB = 1.45, MPT = 122.07), which might indicate structural fractures or the need for additional transformation. The ARDL modelling technique is justified for further empirical study as the Ng-Perron test often accepts heterogeneous integration orders among the variables.

Table 10: Ng-Perron Unit Root Test

At Level	MZa	C.V	MZt	C.V	MSB	C.V	MPT	C.V	Conclusions
TOUR	-3.85	-8.10	-1.25	-1.98	0.32	0.233	6.41	3.17	I(0)
CBCE	-0.06	-8.10	-0.02	-1.98	0.41	0.233	14.97	3.17	I(0)
PBCE	-10.12	-8.10	-2.23	-1.98	0.22	0.233	2.46	3.17	I(1)
GDPPC	-11.05	-8.10	-2.34	-1.98	0.21	0.233	2.22	3.17	I(1)
INF	-7.67	-8.10	-1.93	-1.98	0.25	0.233	3.28	3.17	I(0)
EXR	0.65	-8.10	0.22	-1.98	0.33	0.233	13.36	3.17	I(0)
At Ist Difference	MZa	C.V	MZt	C.V	MSB	C.V	MPT	C.V	
TOUR	-11.38	-8.10	-2.38	-1.98	0.20	0.233	2.15	3.17	I(1)
CBCE	-11.18	-8.10	-2.35	-1.98	0.21	0.233	2.20	3.17	I(1)
PBCE	-9.93	-8.10	-2.09	-1.98	0.21	0.233	2.95	3.17	I(1)
GDPPC	-33.43	-8.10	-4.05	-1.98	0.12	0.233	0.82	3.17	I(1)
INF	-11.34	-8.10	-1.97	-1.98	0.17	0.233	3.57	3.17	I(1)
EXR	-1.82	-8.10	-0.91	-1.98	0.50	0.233	12.83	3.17	I(0)

The stability test examines stability of the models. The model's stability has been examined using by CUSUM and CUSUM of Squares at the 5% significant level. The CUSUM and CUSUM of Squares tests were used to evaluate the model's structural stability over time. In order to identify any possible structural fractures or instability in the calculated parameters, these diagnostic tools are crucial. The cumulative sum of recursive residuals stays under the 5% significance bounds for the whole 2019–2024 sample period, according to the CUSUM test plot. This suggests that the parameters of the model stay constant throughout time and that there are no notable structural changes. In a similar vein, the CUSUM of Squares test indicates that there are no significant changes in the model's variance because the cumulative sum of squared residuals falls below the critical boundaries at the 5% significance level. The combined findings of the two tests verify that the model is physically stable and that the predicted coefficients are dependable and constant during the time period under study.

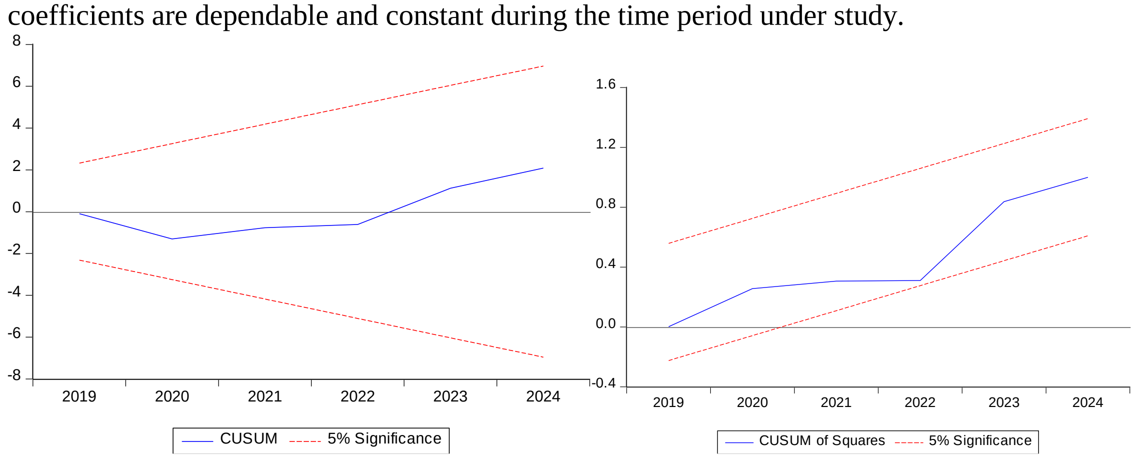

Figure 1: Stability of Consumption Based Carbon Emission

Test of Stability for Nonlinear, the stability of the model is explained by ARDL. To do this, the CUSUM and CUSUM of Squares tests are employed. Both the CUSUM and CUSUM of Squares tests were used to evaluate

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the stability of the estimated model. According to the CUSUM test findings, the parameters of the models are not stable over time since the blue line crosses the 5% significance limits. This implies that during the sample period, there were structural alterations in the connection between the variables. On the other hand, the CUSUM of Squares test indicates that the line stays within the 5% significance bounds, confirming that the residuals' variance is steady. Consequently, the overall model coefficients may have changed over time, suggesting possible structural fractures in the data, even while the model's residuals do not exhibit any indications of instability.

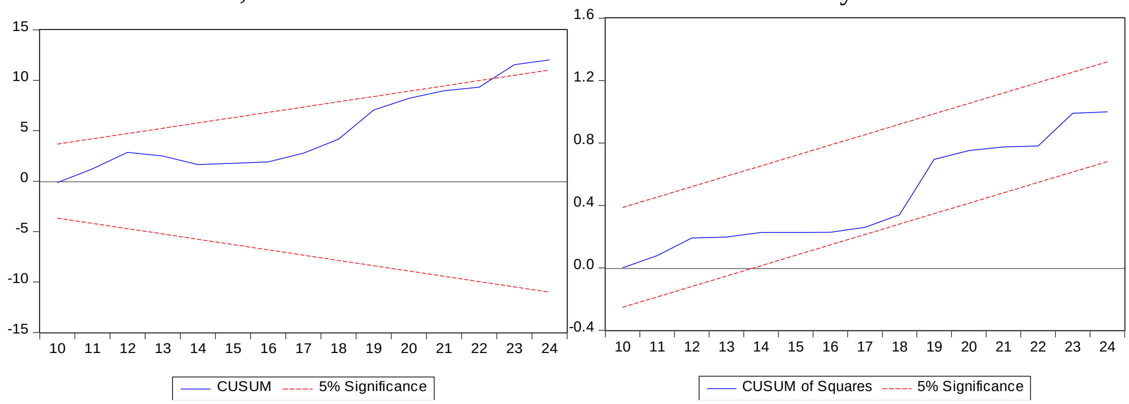

Figure 2: CUSUM and CUSUM Square Tests

CONCLUSIONS

The study explores the asymmetric association of consumption and production-based carbon emissions with tourism development in Pakistan by uses time series data from 2000 to 2024 and applies ARDL and NARDL models to examine both linear and nonlinear relationships. The analysis reveals that economic growth significantly enhances tourism development in Pakistan, supporting the Growth-Led Tourism Hypothesis (GLTH). Carbon emissions from consumption and production sources show asymmetric impacts, where increases harm tourism, but reductions do not yield equivalent benefits. Macroeconomic instability through inflation and exchange rate fluctuations also undermines tourism, highlighting the need for stable policies and sustainable environmental practices.

Some policies in accordance with consumption, production change and economic growth are as follows.

- Promote eco-friendly tourism infrastructure that meets high service standards with minimal environmental impact.
- Enforce stricter industrial emission controls and support cleaner production technologies to protect tourist-attracting environments.
- Integrate tourism into national growth strategies through infrastructure development and destination-focused investment.
- Adopt stable monetary and fiscal policies to control inflation and keep tourism affordable.
- Stabilize exchange rates to reduce uncertainty and maintain price competitiveness for international tourists.

RECOMMENDATIONS FOR FUTURE RESEARCH

- Future studies should include more environmental indicators such as renewable energy use, carbon pricing policies, or air quality indices to capture a large view of environmental impact on tourism.
- Researchers are encouraged to use panel data or cross-country comparisons to enhance the generalizability of findings beyond a single-country context like Pakistan.
- Applying alternative econometric techniques such as structural break models, GMM, or machine learning could offer deeper insights into nonlinear or dynamic relationships.
- Researcher should explore to comprehend their sectorial influence on tourism to investigate more categorized forms of carbon emissions (such as emissions from energy, transportation, and particular sectors).

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