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# Investigating Relationships Between Tourism, Economic Growth, and $CO_2$ Emissions in Brazil: An Application of the Nonlinear ARDL Approach

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Global tourism has witnessed a significant positive implication on the development of developing economies. Despite the positive implication of tourism, it imposes a serious environmental cost such as environmental pollution. Brazil receives a large number of tourists each year that potentially affects economic growth and development. Therefore, this study investigates the effect of tourism on GDP and $CO_2$ emissions in Brazil. We used a nonlinear ARDL approach to examine the nexus between tourism, economic growth, and $CO_2$ emissions in Brazil for the period 1995–2018. The outcomes of this study reveal both short-run and long-run associations between tourism, GDP per capita, and $CO_2$ emissions in Brazil. Nevertheless, both tourism and economic growth cause significant deterioration of the environment quality in Brazil. These findings suggest that the policymakers shall look for more sustainable and eco-friendly economic growth and tourism policies to preserve the environmental quality in Brazil.

**Keywords: tourism, economic growth, environment, nonlinear ARDL, Brazil**

## INTRODUCTION

The global tourism industry has changed remarkably with exponential growth in tourism demand in the past few decades. This trend consequently causes environmental degradation and a high level of energy consumption at the tourist destination. The ultimate effect of high energy consumption results in environmental pollution, mostly in the form of $CO_2$ emissions. The $CO_2$ emission from the last few decades as a result of global warming has become a growing concern of researchers. The $CO_2$ emissions, as the leading contributor to global warming, have nearly quadrupled since the early 1960s (Koçak et al., 2020; Adebayo and Kirikkaleli, 2021; Shahzad et al., 2021). Global warming has adverse implications for the economy, government, lifestyle, and social and geopolitical development (Bilgili et al., 2016; Adebayo and Rjoub, 2021). Global warming and climate change have caused millions of people to suffer from hunger, disease, floods, and water shortages (Escobar et al., 2009). The World Health Organization (2018) reported poor air quality levels in several cities in the low- and middle-income countries with a population of more than 100,000. An earlier assessment by the World Health Organization (2016) reported about 7 million premature deaths due to air pollution The $CO_2$ emissions are perceived as the cost of tourism due to various tourist activities. Therefore, it raised concerns about the adverse effects of energy use in the tourism industry. Therefore, it is imperative to assess the potential future effects of tourism on environmental quality, especially for the economies in which tourism has a significant contribution towards GDP.

Tourism has shown a profound positive influence on the economic growth across the globe in the last 4 decades, and this sector has emerged as an important driver in the process of economic development for both the developed and developing countries (Li and Lin, 2015; Cetin et al., 2018; Park et al., 2018; Cannonier and Burke, 2019; Chai et al., 2019; Kirikkaleli et al., 2021). Blake et al. (2006) compare the effects of the productivity of various tourism sectors on economic development and found that the tourism sector has a significant positive effect on economic development. Liu et al. (2018) employ the exogenous economic growth theory by assuming that productivity is exogenous with a diminishing return to the capital. They presented tourism activity as an exogenous tourism productivity shock to economic growth using the case of Mauritius under the dynamic stochastic general equilibrium (DSGE) model. Their findings posit that tourism creates employment opportunities; brings foreign capital inflow; improves infrastructure; provides significant contributions to the development of manufacturing, agriculture, and service sectors; increases the revenue of hotel business; and thus has an overall positive impact on the economy (Zaman et al., 2017; Zhou et al., 2018; Koçak et al., 2020). Despite the benefits of tourism for the economy, it also has some adverse effects, for instance, the pollution issue. Due to escalated economic activities and energy consumption, tourism significantly contributes towards the $CO_2$ emissions in an economy. Hence, tourism is an important factor that directly or indirectly affects the local as a well global ecosystem. According to the UNWTO Tourism statistics, international tourist arrivals recorded a 7% growth and international tourism receipts increased by 4.9% in 2017. Tourism contributed towards revenues from international passenger transport services by 240 billion USD. In addition, tourism ranks third in the global export earnings category after chemicals–fuels and the automotive sector in 2017 (UNWTO, 2018; Shahzad et al., 2020). Tourism epitomized approximately 3.5% of economic growth and approximately 3.5% of total employment in Brazil's economy in 2014 (WTTC, 2018). While tourism is not a recent phenomenon in Brazilian society, mass tourism certainly is.

Previous studies have explored the negative impacts of tourism activities on the host country's environment for different countries including France, Spain, the United States, China, Italy, Mexico, the United Kingdom, Turkey, Germany, and Thailand. Their findings suggest that tourism has an adverse effect on the environment quality (Lee and Brahmasrene, 2013; Tang et al., 2014; Aziz et al., 2020). Though it boosts the transportation, catering, and accommodation businesses in the host country (Nepal, 2008; Howitt et al., 2010; Rosselló-Batle et al., 2010; Scott et al., 2010; Lee and Brahmasrene, 2013). The environmental degradation is a complimentary phenomenon with the development process, industrialization, and economic growth. Extant literature also pointed out some other factors responsible for the environmental degradation, including population growth, urbanization, trade, energy consumption, foreign direct investment, and financial development (Li and Lin, 2015; Cetin et al., 2018; Dong et al., 2018; Nasrollahi et al., 2018; Park et al., 2018; Kirikkaleli and Adebayo, 2021).

Tourism in Brazil is a growing sector that has a significant contribution to the development of the economy. In 2018, 6.589 million tourists visited Brazil. In addition, Brazil ranks as the third top tourist destination in Latin America after Mexico and Argentina. This study investigates the association between economic growth, tourism, and $CO_2$ emissions to assess the implications of economic and tourist activities on the environmental quality using the case of Brazil. Brazil is a very significant BRICS economy, whose substantial economic growth, tourism, and GDP together lead to a high level of energy consumption and $CO_2$ emissions. Therefore, it is essential to explore the nexus between tourism, GDP, and $CO_2$ in Brazil. This study contributes to the existing literature from the following aspects: firstly, there are a few studies that explore tourism for GDP and $CO_2$ emissions for Brazil. However, they used linear methods of analysis; this study provides a more detailed analysis by using nonlinear Autoregressive Distributed Lag (ARDL) tools, which are capable of capturing the nonlinear relationship between tourism, $CO_2$ emissions, and GDP. Secondly, most of the studies did not capture the short-run and long-run relationship between tourism, GDP, and $CO_2$ emissions; the nonlinear ARDL approach provides a comprehensive analysis for both short-run and long-run relationships among the variables. The application of nonlinear models is particularly important because it captures dynamic relationships among the variables and is closer to reality. Most of the variables have dynamic trends and conventional linear models do not accurately capture the actual association between the variables, but the nonlinear model provides a reasonable prediction. The rest of the paper is organized as follows. *Literature Review* entails the detailed review of literature, *The Case of Brazil: Stylized Facts* presents the stylized facts of Brazil, *The Case of Brazil: Stylized Facts* and *Methodology* presents the methodology and empirical results, and *Empirical Analysis* concludes the study.

## LITERATURE REVIEW

### Tourism and Economic Growth

The impact of tourism on economic growth can be elaborated through the tourism-led growth hypothesis, which posits that the development of tourism leads to economic growth (Gwenhure and Odhiambo, 2017). Various theoretical frameworks supported this hypothesis; Dornbusch et al. (2014) follow the endogenous growth model by introducing the tourism factor in terms of technological investment and skill development, which stimulate economic growth in an economy. In addition, tourism provides employment opportunities for unemployed, low, and unskilled labor, which leads to economic development (van der Schyff et al., 2019). Various studies have investigated the relationship between tourism and economic growth. Akama (2016) used tourism and economic growth data from 1980 to 2013 in Kenya; they reported that economic development can be achieved by improving local tourism. Bento (2016) confirmed the tourism-led hypothesis for economic growth in Portugal. Similarly, Arslanturk et al. (2011) used the input–output method and exhibited that tourism contributes to economic growth in Turkey. Likewise, Shahzad et al. (2017) examined the tourism-led hypothesis in Mexico and found that the development of tourism has positive impact on economic growth.

The findings from a majority of the research related to tourism impact on economic growth can be subdivided into three groups. The first group of studies concludes that there is a unidirectional association between tourism development and economic growth. Khoshkhoo et al. (2017) using the input–output model revealed that the development of tourism industry in Iran significantly promoted local economic development. Likewise, a study reported a long-run positive association between tourism, economic growth, and employment in Pakistan (Manzoor et al., 2019). Govdeli and Direkci (2017) used data of 34 OECD countries from 1997 to 2017 and found that development of tourism opportunities enhances economic growth in these countries. The second group of researchers contend, though, that development in the tourism industry and economic growth reinforce each other due to a bidirectional causal relationship. For example, the study of Roudi et al. (2019) used Granger causality analysis and observed that development of tourism creates economic development in small island states. Likewise, economic growth also positively impacts tourism growth. Similarly, Besel and Uğur (2017) employed time-varying causality analysis and Fourier co-integration techniques and found a bidirectional causal linkage between tourism development and economic development in Turkey. Notwithstanding, the third group of studies assert that tourism development does not affect economic growth. As shown by the work of Arslanturk et al. (2011) and Kokotovic (2017) using vector error correction mechanism for Turkey, Croatia, and Czech Republic, respectively, they rejected the tourism-led economic growth hypothesis for these countries.

## Tourism and the Environment

Tourism is a fast-growing economic activity. In 2017, tourism contributed 10% of the world's total GDP. Besides, it assumes one-tenth of total jobs and has 7% share in global trade (UNTWO, 2018). Globally, tourism industry has exhibited tremendous growth in the last few decades despite the socio-political instability and economic crisis (Paramati et al., 2017). Although tourism contributes to economic growth and job creation, at the same time, it deteriorates the eco-system by increasing the environmental waste and escalating carbon emissions (Shi et al., 2019). Policymakers are also under immense pressure for the ongoing and ever-increasing environmental problems of global warming and climate change caused by an extremely high level of carbon emissions. The world development indicator on carbon emissions states that carbon emissions in 2014 have increased 300% as compared to the emissions in 1968. Perhaps it is due to these severe issues that the discussion of sustainable and low carbon emission economies has emerged to reduce the level of emissions, which is causing significant damage to the ecological system.

Various studies have investigated the impact of tourism activities on environmental degradation and pollution in different countries using a variety of methods. The studies by Lee and Brahmasrene (2013), Tang et al. (2014), and Tang et al. (2017) found that tourism has adverse effects on environmental quality due to increasing levels of carbon emissions while transportation activities constitute a major portion of the total carbon emissions. The study of Gössling (2002) revealed that land degradation and the use of fossil fuel have further magnified environmental problems including global warming and climate change. Transportation and accommodation activities are directly linked to tourism and contribute 4.4% towards the total carbon emissions (Peeters and Dubois, 2010). It is, therefore, asserted that higher energy consumption and deterioration of the environment is a major cause of carbon emissions caused by tourism development (Zhu et al., 2021). Hall et al. (2013) argued that tourism not only boosts economic activity, but also increases carbon emissions; hence, its further effects on climate change are an important challenge for policymakers.

## Economic Growth and the Environment

The most essential factor for achieving sustainable development is the preservation of environmental quality (Kyoto Protocol to the United Nations, 1997). Higher energy consumption for achieving fast-paced economic growth causes significant degradation in environmental quality. Economic growth is characterized by urbanization, industrialization, and improvement in transportation infrastructure, causing a higher level of energy consumption that ultimately compounds carbon emissions. Various studies have been carried out for examining the relationship between economic growth and carbon emission from a single-country and multi-country perspective. Using the case of China and employing cointegration and causality analysis, the results show that $CO_2$ emissions lead to an upsurge in the current as well as future economic growth (Lv et al., 2019). Likewise, Abid (2015) examined the relationship between economic growth and carbon emissions for Tunisia from 1980 to 2009. The Granger causality test and vector error correction mechanism were used for empirical investigation. The results confirmed a unidirectional causality between economic growth and carbon emissions and found a monotonically growing relationship between these two aspects in Tunisia. Yang et al. (2015) tested the causal relationship between tourism and carbon emissions among 71 countries from 1971 to 2010. The association among various variables was found to be dynamic in nature because of various patterns of development and region-specific characteristics. The developing countries show monotonically aggregate models and inverted U-shaped curves. On the other hand, developed countries show inverted M-shaped and N-shaped models to depict this association. Ahmad et al. (2017) examined the environmental Kuznet Curve (EKC) from 1992 to 2011 in Croatia. The VECM and ARDL models were used to test the relationship between carbon emissions and economic growth. A bidirectional causality based on VECM was reported in the short run and a unidirectional causality was observed in the long run. Besides, an inverted U-shaped association between economic growth

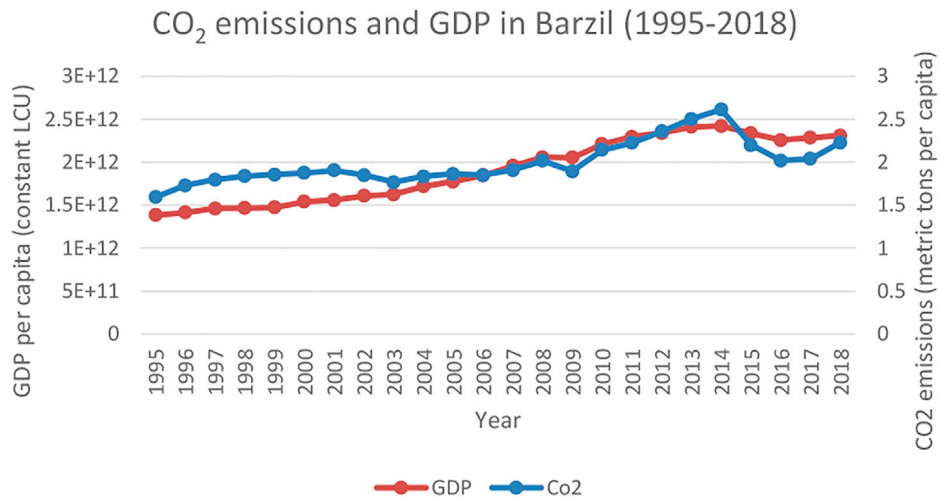


**FIGURE 1 |** $CO_2$ emissions and GDP. Source: World Development indicators.

and carbon emission was found in the long run, hence validating the EKC hypothesis. Bano et al. (2018) studied the impact of economic growth and human capital on carbon emissions in Pakistan from 1971 to 2014 using VECM and ARDL techniques. Results of the Granger causality suggest no short-run relationship between economic growth and carbon emissions, whereas carbon emission causes economic growth in the long run. Jardón et al. (2017) carried out research on 20 Caribbean and Latin American countries to test the relationship between economic growth and carbon emissions using data from 1971 to 2011. Results of EKC hypothesis exhibited an inverse U-shaped relationship with a carbon emission and economic growth. The research on exploring the nexus between $CO_2$ emissions and economic growth has mainly concentrated into two streams. The first stream of literature suggests an inverted U-shaped relationship between environmental pollutants and economic growth, which is known as the Environment Kuznets Curve (EKC), though recent studies on EKC revealed that there exists an inconsistent association between $CO_2$ emissions and economic growth (Fang et al., 2019). However, results from these studies are highly contingent upon regional and country-level specific dynamics. The second stream of literature examines the relationship between energy consumption and economic growth such as Grossman and Krueger (1995). The empirical findings of their study postulate varying linkages between energy consumption and economic growth. This dynamic association can be attributed to the choice of datasets, model specifications, and the econometric technique involved.

## THE CASE OF BRAZIL: STYLIZED FACTS

### $CO_2$ Emissions and GDP

**Figure 1** depicts a graphical trend between carbon emissions and growth in GDP per capita in Brazil. GDP growth posts an upward movement from 1995 to 2014 and a downward trend afterward up to 2016. Subsequently, GDP again reveals a growth trend up to 2018. Similar variations can be observed in carbon emissions during the same period. Carbon emissions in Brazil increased between 2008 and 2014 and a visible decreasing trend is observed afterward up to 2017, though a sudden rise is exhibited in 2018. Overall, the movement of $CO_2$ and GDP suggests a direct association between these two variables in the context of Brazil. This pattern conjectures that the Brazilian government is not deploying green technology; therefore, the country is experiencing a higher level of pollution emissions. Hence, the government should encourage the use of eco-friendly technologies to reduce the amount of emissions without a slump in the GDP growth. However, the nexus between economic growth and the environment needs to be explored further to ensure sustainable economic growth and development.

### GDP and Tourism

**Figure 2** shows the co-movement between GDP and tourism in Brazil. It depicts an upward trend for both the GDP and tourism in Brazil. Though GDP is increasing steadily as compared to tourism growth, various shocks can be observed in the number of tourism arrivals in Brazil. Nevertheless, tourism activities have posted an upward growth from 1995 to 2000, which is attributed to the incentives and rebates offered by the government to entice more tourist inflow. However, a decreasing trend in tourism arrivals can be observed from 2000 to 2003, which is mainly due to the various taxes levied by the government. The period between 2010 and 2018 shows a marked increase in tourism arrivals in Brazil. Overall, the graph suggests that GDP has an indirect positive co-movement with tourism. Tourism revenues boost government revenues, household income, and increase employment opportunities, therefore leading to economic growth and prosperity for a country.

### Tourism and $CO_2$ Emissions

**Figure 3** demonstrates the trend between tourism and carbon emissions in Brazil. Carbon emissions show an upward

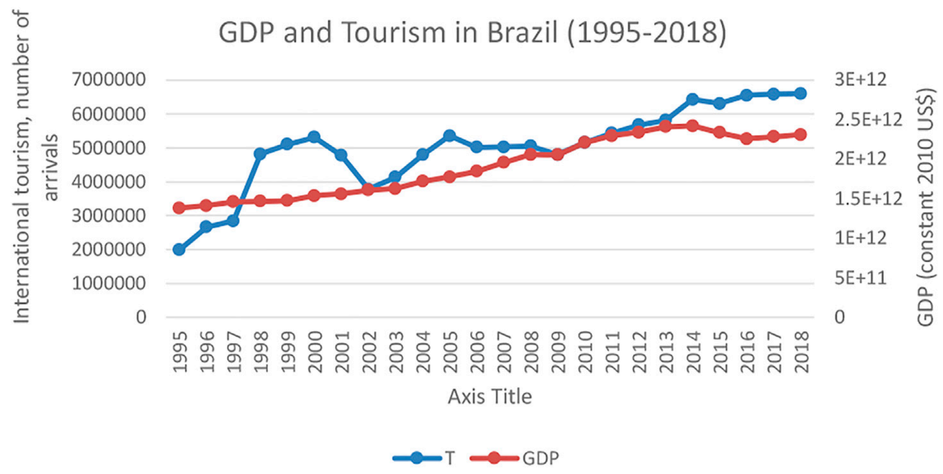


**FIGURE 2 |** GDP and tourism in Brazil (1995–1918). Source: World Development indicators (2020).

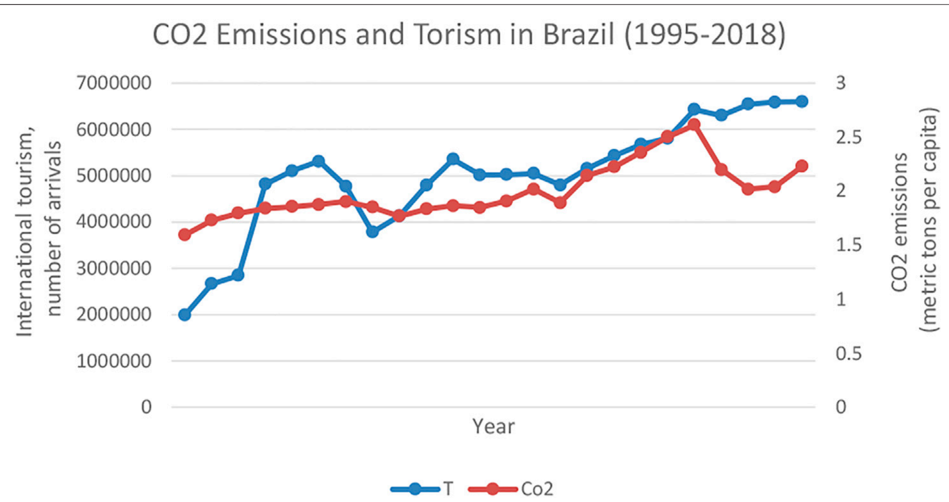


**FIGURE 3 |** $CO_2$ emissions and tourism in Brazil (1995–1918). Source: World Development indicators (2020).

movement from 1995 to 2014 and a visible decrease can be observed from 2014 to 2017. Tourism arrivals post an upward trend from 1995 to 2000 and a downward trend can be observed from 2000 to 2003. Tourism activities in Brazil as shown in the figure increased from 2003 to 2006, showing a decreasing trend up to 2010 and then onward have shown a visible increase in tourist activities in Brazil. The overall trend suggests that a huge increase in tourism volume brings a slight upward increase in the amount of $CO_2$ emissions, which confirm somehow a direct link between tourists' arrivals and $CO_2$ emissions. Tourism plays an important role in economic growth, but at the same time, tourism has its share of environmental concerns as tourist activities are among the major cause of carbon emissions. The environmental concerns from tourism and its allied economic benefits need to be balanced in the form of low carbon emission and high income for the tourism industry.

## METHODOLOGY

The study used the following econometric model for the empirical estimation:

$$CO_2 = \beta_0 + \beta_1 GDP_t + \beta_2 T_t + e_t \tag{1}$$

Where the error term $\mu_t \sim \text{n.i.i.d}(0, \sigma^2)$, and $CO_2$ is the $CO_2$ emission.

GDP = Gross Domestic Product.

T = Tourism (total number of arrivals).

*e* = Normally Distributed Error Term.

The model entails $CO_2$ emissions as the dependent variable to proxy the environmental quality, GDP per capita is an independent variable, and gross domestic product is a measure of the aggregate economic activity in the economy. T represents tourism; we take the number of tourists arrival in the country. Since, theoretically, both tourism and GDP have a perceived positive association, coefficients like $\beta_1$ and $\beta_2$ are assumed to have a positive expected sign. The error term is assumed to be uncorrelated with the explanatory variables (World Bank, 2021). The data for all induced variables are obtained from the World Bank database from 1995 to 2019. GDP is taken at Constant US dollar; T is the number of tourist arrivals and $CO_2$ emissions are taken as the emissions per metric ton. Before proceeding with the non-ARDL estimation, we first start with the linear ARDL framework to show the long-run and short-run association between the variables. **Eq. 1** presents the mathematical expression for the linear ARDL framework as follows.

$$\Delta Co_{2t} = \beta_0 + \sum\nolimits_{i-1}^{n1}\beta_{1i}\Delta Co2_{t-1} + \sum\nolimits_{i-0}^{n2}\beta_{2i}\Delta GDP_{t-1} + \sum\nolimits_{i-0}^{n3}\beta_{3i}\Delta T_{t-1} + \sum\nolimits_{i-0}^{n4}\beta_{4i}\Delta TL_{t-1} + \lambda e_{t-1} + \mu_t \tag{2}$$

If the outcomes reveal cointegration among the variables like in our case "$CO_2$ emissions, GDP, and Tourism," then any short-run deviation will adjust to the long-run equilibrium. In other words, the short-run deviation will ultimately achieve the long-run equilibrium. The "$e_{t-1}$" (i.e., $\lambda$) shows the short-run dynamics, which assumes to hold a negative and significant coefficient. The Engle and Granger (1987) and Johansen (1995) cointegration assumed that all variables must have the same order of integration for instance in the order of 1. Pesaran et al. (2001) purposed the ARDL method for the long-run estimation, which does not strictly require the same order of integration and cointegration and thus could be performed even if the variables do not hold the same order property. In addition, the "$e_{t-1}$" in **Eq. 2** is replaced by the linear combination of lagged level variables in the model. Thus, we can rewrite **Eq. 2** as follows.

$$\Delta Co2_t = \rho_0 + \sum\nolimits_{i-1}^{n1}\rho_{1t}\Delta Co2_{t-1} + \sum\nolimits_{i-0}^{n2}\rho_{2t}\Delta GDP_{t-1} + \sum\nolimits_{i-0}^{n3}\rho_{3t}\Delta T_{t-1} + \rho_4 CO2_{t-1} + \rho_5 GDP_{t-1} + \rho_6 T_{t-1} + \mu_t. \tag{3}$$

In **Eq. 3**, the coefficients of the variables use "Δ" parameters for the short run while the lag values are presented by using $\rho_4$, $\rho_5$, and $\rho_6$. The optimal lag is the necessary step before proceeding to the estimation; Akaike information criterion (AIC) may provide an appropriate lag length. Most of the previous studies employ linear association between variables like "$CO_2$ emissions", GDP, and T, which is not a realistic approach as asymmetry could be observed in the graphical illustration among the variables. Therefore, to investigate the asymmetric impact of GDP and Tourism arrivals on $CO_2$ emissions, Shin et al. (2014) introduced the nonlinear ARDL technique using the linear model framework for the short-run and long-run estimations. The variations in $CO_2$ emissions, GDP, and tourism are decomposed into positive and negative partial sum as follows:

$$GDP_t^+ = \sum_{j-1}^{t}\Delta GDP_j^+ = \sum_{j-1}^{t}\max\left(\Delta GDP_j, 0\right)$$

$$GDP_t^- = \sum_{j-1}^{t}\Delta GDP_j^- = \sum_{j-1}^{t}\min\left(\Delta GDP_j, 0\right)$$

$$T_t^+ = \sum_{j-1}^{t}\Delta Tax_j^+ = \sum_{j-1}^{t}\max\left(\Delta Tax_j, 0\right)$$

$$T_t^- = \sum_{j-1}^{t}\Delta Tax_j^- = \sum_{j-1}^{t}\min\left(\Delta Tax_j, 0\right)$$

The above equations show positive and negative shocks of the GDP and T (i.e., $GDP^+$ and $GDP^-$, and $T^+$ and $T^-$). The negative–positive components show the increasing and decreasing effects of each variable. The fact that there are two time series, one being positive and the other being negative in the Granger framework, suggests a hidden cointegration in this case. In order to test the long-run relationship, Pesaran et al. (2001) used the following equation:

$$\begin{aligned}\Delta P_t = {} & \gamma_0 + \sum\nolimits_{i-1}^{n1}\gamma_{1i}\Delta P_{t-1} + \sum\nolimits_{i-1}^{n2}\gamma_{2i}\Delta GDP_{t-1}^+ + \sum\nolimits_{i-1}^{n3}\gamma_{3i}\Delta GDP_{t-1}^- \\ & + \sum\nolimits_{i-1}^{n4}\gamma_{4i}\Delta Tax_{t-1}^+ + \sum\nolimits_{i-1}^{n5}\gamma_{5i}\Delta Tax_{t-1}^- + \sum\nolimits_{i-1}^{n6}\gamma_{6i}\Delta TL_{t-1}^+ \\ & + \sum\nolimits_{i-1}^{n7}\gamma_{7i}\Delta TL_{t-1}^- + \gamma_8 P_{t-1} + \gamma_9 GDP_{t-1}^+ + \gamma_{10} GDP_{t-1}^- \\ & + \gamma_{11} Tax_{t-1}^+ + \gamma_{12} Tax_{t-1}^- + \gamma_{13} TL_{t-1}^+ + \gamma_{14} TL_{t-1}^- + \mu_t\end{aligned} \tag{4}$$

**TABLE 1** | ADF unit root.

| | At level | 1st difference |
|---|---|---|
| GDP | −1.276559 (−2.893589)[b] | −6.988356 (−2.893956)[b] |
| $CO_2$ | −1.832508 (−1.944487)[b] | −2.042878 (−1.944487)[b] |
| T | 0.592283 (−1.944487)[b] | −2.262092 (−1.944530)[a] |

[a]*Significant at 1%.*
[b]*Significant at 5%.*
[c]*Significant at 10%.*

## EMPIRICAL ANALYSIS

This section provides the detailed outcomes of nonlinear ARDL. **Table 1** shows the ADF unit root results by using the stationarity analysis. Although the same order of stationarity is not prerequisite for the long-run relationship, it helps to understand the order of integration. We used the Schwarz information criterion (SIC) for the optimal lags selection including the constant and trend term in the ADF unit root equation. The ADF unit result shows that all the variables are not stationary at level and become stationary at first level. Therefore, we can proceed to use the bound test.

The long-run estimations are sensitive to the optimal lag selection in estimations. Bahmani-Oskooee and Bohl (2000)

**TABLE 2** | Bound test.

| Test statistic | Value | K |
|---|---|---|
| *F*-statistic | 22.37819 | 4 |
| Critical Value Bounds | | |
| Significance | I0 Bound | I1 Bound |
| 10% | 1.9 | 3.01 |
| 5% | 2.26 | 3.48 |
| 2.5% | 2.62 | 3.9 |
| 1% | 3.07 | 4.44 |

**TABLE 3** | Short-run estimations.

| Variable | Coefficient |
|---|---|
| D (CO23(−1)) | 1.8003740[a] (0.087359) |
| D (CO2(−2)) | −1.303515[a] (0.192234) |
| D (CO2(−3)) | 0.370801[a] (0.228695) |
| D (CO2(−4)) | −0.770552[a] (0.221590) |
| D (CO2(−5)) | 1.115004[a] (0.174679) |
| D (CO2(−6)) | −0.561129[a] (0.071531) |
| D (GDP_POS) | 0.115260[a] (0.015651) |
| D (GD_POS(−1)) | −0.399175[a] (0.074615) |
| D (GDP_POS(−2)) | 0.243940[a] (0.052521) |
| D (GDP_POS(−3)) | −0.064272[b] (0.015427) |
| D (GDP_NEG) | 0.132721[a] (0.021530) |
| D (GDP_NEG (−1)) | −0.414651[a] (0.096442) |
| D (GDP_NEG (−2)) | 0.223980[a] (0.070371) |
| D (GDP_NEG (−3)) | −0.050885[b] (0.022231) |
| D (T_POS) | 0.000328 (0.001950) |
| D (T_POS(−1)) | −0.008389[c] (0.004640) |
| D (T_POS(−2)) | 0.006623[a] (0.001829) |
| D (T_NEG) | 0.002448[a] (0.000303) |
| CointEq (−1) | 0.003765[a] (0.000646) |

[a]*Significant at 1%.*
[b]*Significant at 5%.*
[c]*Significant at 10%.*

and Stock and Watson (2012) indicate that fewer lags are not capable to capture full information from the model. Contrary to this, higher lags lead to "over-fits" of the model. Therefore, optimal lag selection is one the prerequisite for the accurate results. SIC criteria are used for the optimal lags for our model. **Table 2** reports the bound test results, which contains the *F*-statistics and the relevant lower and upper bound values. The table results presented in **Table 2** show that *F*-statistics values for both linear and nonlinear model are higher than the upper value, which indicates the existence of cointegration in the model.

We estimated equation (12) by using the general AIC lag criteria for optimal lag length. We drop those variables that were not significant to avoid inaccurate analysis as such results can create noise in the dynamic multipliers. **Table 3** shows the initial ARDL outcomes; the model has been tested through various diagnostic tests for the validity of outcomes. The diagnostic results included the Breusch/Pagan heteroscedasticity test, Ramsey RESET test, and Jarque-Bera test on normality, which reported no issue of heteroscedasticity, serial correlation, and normality in the error term or residuals.

**TABLE 4** | Long-run estimations.

| Variable | Coefficient |
|---|---|
| GDP_POS | −1.36511[a] (0.17148) |
| GDP_NEG | −0.87433[b] (0.28167) |
| T_POS | 0.44563[a] (0.03467) |
| T_NEG | −0.65022[b] (0.12343) |

[a]*Significant at 1%.*
[b]*Significant at 5%.*
[c]*Significant at 10%.*

**TABLE 5** | Pairwise Granger causality tests.

| Null hypothesis | *F*-statistic | Prob |
|---|---|---|
| GDP does not Granger Cause $CO_2$ | 2.6668[a] | 0.0752 |
| $CO_2$ does not Granger Cause GDP | 5.4836[b] | 0.0057 |
| T does not Granger Cause $CO_2$ | 6.4112[b] | 0.0025 |
| $CO_2$ does not Granger Cause T | 7.1079[b] | 0.0014 |
| T does not Granger Cause GDP | 0.97047 | 0.3830 |
| GDP does not Granger Cause T | 4.31065[c] | 0.0164 |

[a]*Significant at 10%.*
[b]*Significant at 1%.*
[c]*Significant at 5%.*

The long-run estimations are reported in **Table 4**, which contains both positive and negative shocks of the explanatory variables. The positive shocks indicate a negative relationship between $CO_2$ emissions and GDP; this implies that due to the development of new low-carbon technologies in the boom period, the output that emits less $CO_2$ is provided; this association is in line with Kasperowicz (2015). However, in the long run, during the recession period when GDP is declining, an increase in GDP increases the $CO_2$ emission, which indicates that GDP growth is a significant source. The positive shocks of tourism hold positive, and significant implications on $CO_2$ emissions imply that the number of tourist arrivals leads to high energy consumptions, which leads to $CO_2$ emissions. The negative shocks lead to a decrease in $CO_2$ emissions, which implies that a decrease in the number of tourists reduces $CO_2$ emissions.

The Granger causality test in **Table 5** reports the casual linkages between $CO_2$ emissions, GDP, and T. The results show bivariate causality between $CO_2$ emissions and GDP. There is a univariate causality from $CO_2$ emissions to T, though no causality is found from the T to $CO_2$ emissions. Likewise, there is a univariate causality from GDP to T. The Granger causality outcomes further verify the baseline NARDL model estimations; as the GDP causes $CO_2$ emissions due to high level of economic activities, tourism also causes $CO_2$ emissions due to a high level of energy use and increase in the aggregate consumption in the economy. The results of this study resemble those of Lee and Brahmasrene (2013), Jardón et al. (2017), Govdeli and Direkci (2017), Chengcai Tang et al. (2017), and Zhu et al. (2021).

## CONCLUSION

Brazil is the largest economy in Latin America and has a substantial contribution towards $CO_2$ emission in the region, which has far-reaching effects on social and environmental indicators. Besides the sluggish performance in some years, the tourist inflows to Brazil have increased continuously during the study period. Being a rapidly growing economy and having a huge influx of tourists have serious repercussions for the environmental quality in the country. Therefore, this study investigates the relationship between $CO_2$ emissions, tourism (T), and economic growth in Brazil. We employ time series data from 1995 to 2018 and employ the nonlinear ARDL method of estimation, which provides more realistic empirical outcomes as compared to the conventional liner estimation methods like linear ARDL. The nonlinear ARDL model is capable of capturing the realistic scenario regarding the association between the variables. The empirical results depict the long-run and short-run association between $CO_2$ emissions, GDP, and tourism. Besides, both GDP and tourism contribute to the $CO_2$ emissions through either negative or positive shocks as exhibited by the nonlinear ARDL estimations. This implies that tourist activities increase the energy consumption in the economy, which leads to higher $CO_2$ emissions. Moreover, the aggregate increase in demand also leads to higher consumption in the economy. Likewise, GDP growth is predominantly fueled by the energy consumption during the production process, which is also a leading contributor towards the $CO_2$ emissions in the economy.

Based on these findings, the study suggests that the government shall support the carbon-neutral policies of the UNWTO (2018) at the national level. In this context, Brazil may roll out various policies to reduce the pollutant emissions in the economy. (1) The transportation sector is the major producer of $CO_2$ emissions as the basic fuel needs of transportation vehicles (air, road, railroad, and water) mainly depend on fossil energy sources (Sharma and Ghoshal, 2015; Koçak et al., 2020). Therefore, the government may encourage the use of alternative fuels and hybrid technologies particularly in the transport services (Raza et al., 2017). (2) The government can implement well-defined environmental quality rules; for example, tourist spots with more adverse effects on the environment should allocate sufficient funds for environmental restoration in order to preserve environmental quality. (3) The public sector may promote renewable and clean energy production in the economy particularly in the tourist destinations by using subsidies or tax exemptions. (4) Environment quality can be enhanced by implementing certified carbon credit policies and encouraging projects such as tree plantation drives, renewable energy production, and energy savings, and through effective environmental education and awareness. The implementation of these strategies can substantially improve the ecosystem and help to reduce $CO_2$ emissions in Brazil. The study is not without limitations, though, as it only focuses on a single country. Besides, it only covers the period 1995–2018 due to data unavailability for the preceding years. This research can be extended to various dimensions. It will be interesting to see the impact of $CO_2$ emissions in tourist destinations on the health of the native population living in these regions. Nevertheless, it would be interesting to use forecasting techniques such as the neural network to predict the long-term impact of tourism on the environmental quality of a country. The current study has certain limitations; in the future, researchers should consider developed and developing regions and may include other important variables such as globalization and culture influences to better explain this relationship.

## DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: https://databank.worldbank.org/source/world-development-indicators.

## AUTHOR CONTRIBUTIONS

Conceptualization: MHS. Methodology and software: AR. Formal analysis: MZ. Data collection: MZ. Writing-original draft preparation: LS. Writing-review and editing: IU. Supervision: AA. All authors have read and approved the manuscript.

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