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The Intricate Impression of Tourism, Patent, And Renewable Energy on Environmental Sustainability

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Abstract

The growing global attention to indicating climate conversion and plummeting carbon dioxide (CO_2) emanations has spurred researchers to examine the influence of several factors on promoting environmental sustainability. This research examines the intricate role of tourism, patent applications, rent from natural resources, and utilization of renewable power in carbon dioxide secretions in Bangladesh. For this purpose, data has been collected from 1995 to 2019 from World Development Indicators (WDI). Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) and the ARDL bound cointegration procedures are employed to determine the existence of stationary data and cointegration among variables respectively. The Autoregressive Distributive Lag (ARDL) procedure is used to consider the effects of the chosen variables on CO_2 emissions over the short and long run. VIF test, White's test, and the Breusch-Godfrey test are employed to check multicollinearity, homoscedasticity, and autocorrelation respectively. The research discloses that it is vital to expand the usage of renewable energy sources while simultaneously decreasing natural resource rent by limiting natural resource extraction for a sustainable environment. Although the statistical insignificance of the long-term coefficient of tourism has been observed, the study reveals a negative coefficient for tourism, suggesting the possible efficacy of sustainable tourism practices for mitigating CO_2 emissions. The findings also demonstrate the long-term contribution of innovation activities to environmental degradation through the positive coefficient of patent applications. The research results offer significant insights for policymakers and stakeholders involved in the pursuit of a sustainable and ecologically conscious future in Bangladesh.

Keywords: Environmental sustainability, Tourism, Patent, Renewable energy, Natural resource rent, CO_2 emissions, Bangladesh, ARDL model

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INTRODUCTION

Across national boundaries and in local communities, climate change is one of the most significant problems we face today. Continued releases of greenhouse airs, especially carbon dioxide (CO2), into the environment have made this already complex problem even more severe. Every country must deal with its carbon footprint and make the switch to sustainable practices that cut down on emissions. According to the United Nations' Sustainable Development Goals (SDGs) 7, 9, and 13, affordable and clean energy, as well as technology innovation, are highlighted as urgently required solutions to combat climate change. Bangladesh, a country located in South Asia, has achieved noteworthy advancements in terms of economic growth and the reduction of poverty. These achievements have garnered international acclaim, acknowledging the country's endeavors in promoting development. Nevertheless, it occupies a prominent position among countries that are very susceptible to the consequences of climate change, characterized by a rising frequency of flood events, cyclonic disturbances, and the encroachment of sea-level rise. Bangladesh has been positioned as the seventh most impacted nation by climate change in the Global Climate Risk Index 2021 (Raihan et al., 2022; Sadekin, 2023). From 2000 to 2019, climate change-related problems cost Bangladesh almost USD3.72 billion (Islam, 2021). These persistent ecological problems are terrible news for global biodiversity as a whole and for the people living there (Nosheen et al., 2021).

The tourism industry in Bangladesh is a significant contributor to the nation's overall economic expansion and development. Bangladesh is well-known for its verdant landscapes, rich biodiversity, and rich cultural legacy, and the country has been making tremendous progress in the promotion of tourism. The number of tourists coming to the nation has been mounting consistently at the current time as a direct result of the country's growing investment in tourism-related infrastructure and facilities. It not only provides employment prospects but also generates revenue, which in turn stimulates regional prosperity. However, the expansion of the tourism industry has unwittingly resulted in increased energy consumption, increased garbage output, and alterations in land use, all of which add to the existing environmental issues. In the present era of globalization, the economic sectors of tourism and travel have experienced rapid growth and are closely intertwined with the phenomenon of climate change (Nazneen et al., 2023). It has been estimated by the UNWTO that the tourist industry is responsible for around 5% of world emissions, with 75% of those

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emissions coming from the transportation sector and 20% coming from the accommodation industry (IPCC, 2014). Travelers are always searching for well-developed tourist locations that offer a variety of accommodations, including places to dine, travel, and shop. The greater the number of arrivals of tourists, the greater the environmental deterioration and pollution caused by GHG emissions (Aslan et al. 2020). For Bangladesh's future to be sustainable, it is essential to find a way to strike a balance between enjoying the benefits of tourism while also minimizing its negative effects on the environment. It is essential to implement effective planning, laws, and management techniques to assist tourism progress in a manner that is both sustainable and less detrimental to the environment. (Chong and Balasingam, 2019). Bangladesh's government recognizes the difficulty of weighing tourism's financial benefits against its negative effects on the environment. Eco-friendly lodgings and other forms of sustainable tourism are becoming increasingly popular.

The filing of patents and the development of new technologies are frequently cited as indications of a nation's economic development. The remarkable growth that Bangladesh has seen in the number of patent applications is a reflection of the country's goals for economic and technological progress. These patents have progressively incorporated green technologies and innovations in renewable energy. Nevertheless, it is of the utmost importance to investigate the wide-ranging effects that this technological advancement may have on the environment in the long run.

Revenue from the exploitation of natural resources, sometimes known as "natural resource rent," is crucial to Bangladesh's economy. Natural resources such as coal, gas, and minerals abound throughout the country. Economic expansion and government revenue are both boosted by the extraction of these resources in developing economies (Li et al., 2022). However, the extraction of natural resources often has disastrous effects on ecosystems (Bilgili et al., 2023). For instance, the energy industry's high reliance on natural gas and coal results in significant depletion of finite resources and significant emissions of greenhouse gases. The combustion of natural resources, such as fossil fuels, has been found to have detrimental effects on the climate and seems a substantial donor to environmental alteration (Balsalobre-Lorente et al., 2019). When assessing the value of natural resources to the economy, it is important to factor in the negative environmental impacts associated with their exploitation. Bangladesh faces a difficult trade-off between maximizing the benefits of rent from natural resources and protecting the environment. Long-term economic and social

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consequences of environmental deterioration caused by resource extraction require vigilant control.

Renewable energy, which does not release greenhouse gases into the atmosphere, has the potential to reduce the risks associated with energy security (Murshed, 2020; Bekun, 2022). As a global priority in the ongoing struggle against climate change, switching to renewable energy sources is crucial. The emergence of photovoltaic plants, wind turbines, and other clean power sources is signaling an evolution to more environmentally friendly and sustainable energy generation. In 1997, after the Infrastructure Development Company Limited (IDCOL) first started financing key infrastructure and renewable energy initiatives in Bangladesh, the country began actively promoting technological innovation. To fulfill the fundamental electricity demand of the off-grid rural communities of Bangladesh, IDCOL's solar home system (SHS) was established as the most prominent technological innovation initiative (Murshed & Dao, 2020; Zaid, Alqatrani & Alasadi, 2023). It is crucial to assess the effect of the switch to renewable energy on CO2 emissions. The big question is whether or not focusing more on renewable energy will reduce the nation's carbon footprint by enough to compensate for emissions in other industries. The adoption of renewable energy sources is a significant milestone in the direction of environmental sustainability, but it is not without its difficulties. Transitioning to renewable energy sources requires coordination of technological and infrastructure improvements as well as rigorous analysis of the financial viability of such moves. Potential challenges, such as land use and wildlife conservation, must also be considered when assessing the favorable environmental impacts of renewable energy. This study examines Bangladesh's path toward renewable energy adoption, its accompanying regulatory frameworks, and its effects on carbon dioxide emissions. It investigates whether or not this shift is significant enough to significantly contribute to a decrease in carbon emissions.

The trends of CO2 emissions, tourism, patent applications, renewable energy, and natural resource rents are given below (Figures 1, 2, and 3). Here, we see that carbon dioxide emissions in Bangladesh are steadily rising over time while the use of renewable energy gradually falls. Bangladesh's increased CO2 emissions may be due, in part, to the country's declining use of renewable energy. The year 2008 witnessed the biggest influx of tourists. Following that, a declining trend in tourism has been observed. In Bangladesh, the number of tourist arrivals began to increase again after the year 2015. The fact that the total amount of

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resource rents has been going down over the past few years is encouraging news for the preservation of environmental quality.

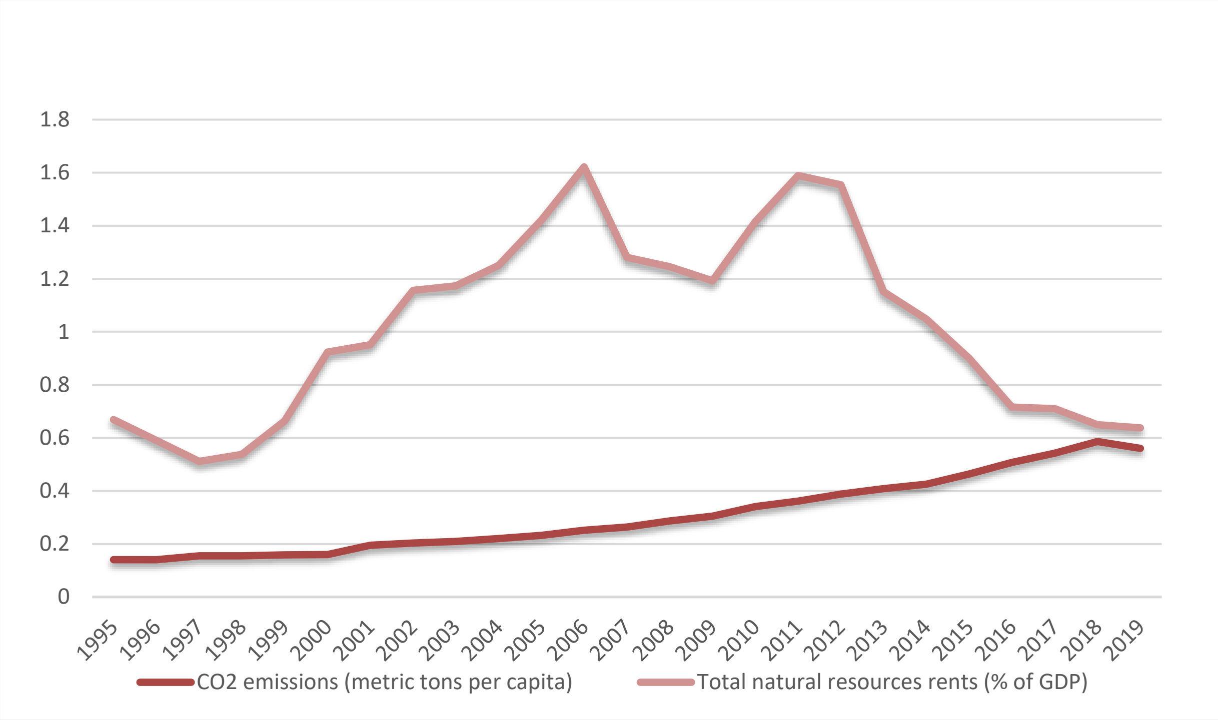

Figure 1: Trend of CO_2 emission and total natural resources rents from 1995 to 2019
Source: WDI (2023)

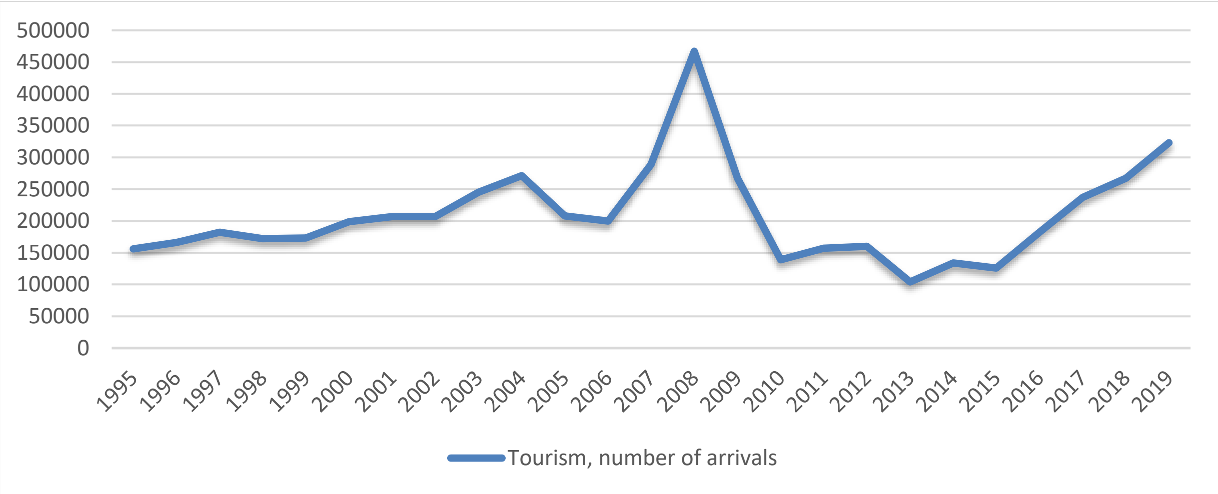

Figure 2: Trend of tourism from 1995 to 2019

Source: WDI (2023)

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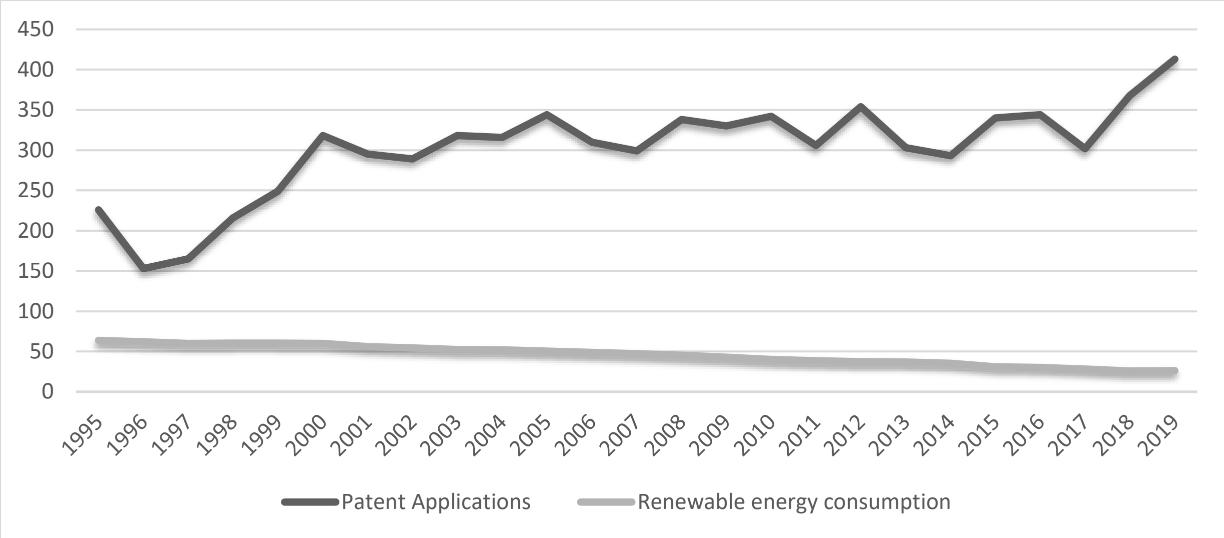

Figure 3: Trend of patent applications and renewable energy consumption from 1995 to 2019
Source: WDI (2023)

This study aims to dissect the complex interplay between tourism, patent activity, natural resource rent, renewable energy usage, and CO2 emissions in Bangladesh. The ultimate objective is to create a thorough understanding of these relationships and to provide insights into policy proposals that will aid the country's efforts to reduce its carbon footprint while supporting sustainable growth. This paper's investigation of these dimensions is driven by the following aims:

i. To measure the impact of CO2 releases that result from Bangladesh's rapidly expanding tourist industry to assess the consequences on the environment.
ii. To analyze how technological origination influences environmental degradation.
iii. To measure the effect of natural resource rent on CO2 releases.
iv. To investigate the implications of switching to renewable power cradles for the preservation of the atmosphere in Bangladesh by cutting down on CO2 emissions.

Therefore, the contributions of the paper are fourfold – the paper introduces new combinations of regressors to examine their impact on environment, applies unique techniques to find the results, opens new research opportunity to protect environment of Bangladesh and emphasize on the importance of tourism, natural resources rent and patent for the country. The rest of the paper is designed with literature assessment, data and methods utilized, outcome and argument, and conclusion and policy recommendations.

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LITERATURE REVIEW

In modern environmental economics, assessing the influence of tourism, innovations in technology, natural resource rent, and the utilization of renewable power cradles on CO2 discharges is of paramount importance. This segment compiles the existing body of knowledge and literature on these interconnected topics and their effect on CO2 discharges.

Working on data from Uruguay from 1990 to 2020, Raihan (2023) conducted ARDL short-run and long-run investigations, demonstrating how economic expansion, natural resource rents, and international trade increase Uruguay's CO2 emissions. Adebayo et al. (2023) utilized the CS-ARDL model to examine BRICS countries' data from 1990 to 2019, finding that the utilization of new technologies and renewable energy sources can lessen CO2 discharges in shorter and longer periods. Aydin et al. (2023) used a panel cointegration test covering the years 1995-2018 to demonstrate that rents from natural resources contribute to environmental pollution in Austria, Poland, and Slovakia. Using the CS-ARDL model from 1995 to 2018, Ullah et al. (2023) demonstrated the positive and significant effects of technological advancement, natural resource availability, and expansion of the economy on CO2 emanations, while also demonstrating that tourism would lead to a reduction in emissions in shorter and longer periods in BRICS nations. Thi et al. (2023), utilizing the FMOLS, DOLS, and GMM System estimation techniques to analyze data from 1990–2019, exhibited that the usage of reproducible energy sources, increased trade openness, and technological advancement all contribute to lower emissions, but international tourism has been shown to promote damage to the environment in 53 countries. Using data from 2000 to 2020 and a variety of regression models (including the feasible generalized least squares, Driscoll-Kraay, and Non-Parametric Kernel representations), Farrukh et al. (2023) demonstrated that natural resource rent and innovation contribute to environmental degradation, whereas tourism has the opposite effect, leading to lower CO2 emissions in low-income countries at higher tourist arrivals. Sadiq et al. (2023) examined ten Asian countries' data from 2006 to 2020 and found that carbon emissions and methane emissions have a positive association with natural resource rents. Using Panel Quantile Regression, Esquivias et al. (2022) demonstrated that the patent application and the exploitation of natural resources have significantly increased CO2 emissions in emerging Asia from 1990 to 2019, whereas the use of renewable energy has improved environmental quality by reducing carbon dioxide emission. Using data from 1996-2018, Liu et al. (2022) used the feasible generalized least

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square (FGLS) and panel quantile regression (PQR) methods to conclude that improvements in renewable power usage, technical innovation, and institutional excellence lead to lower carbon releases in E-**7** countries. Erdogan et al. (2022) demonstrated, employing panel quantile regression over the years 1995-2018, that while carbon emissions from international travel rise at the highest quantiles, the deleterious impression of travel on the atmosphere in the most visited nations is mitigated by advancements in environmentally friendly transportation technologies. According to Ali et al. (2022), the application of the autoregressive distributed lag (ARDL) technique revealed that technical advancements, economic development, energy consumption, and urbanization have contributed to the rise in carbon dioxide (CO2) emissions in Pakistan between the years 1990 and 2019. Between 1990 and 2019, Rahaman et al. (2022) analyzed the effect of FDI, tourism, power depletion, and economic progress on CO2 releases in Bangladesh. Long-term, positive impacts on CO2 emissions have been found in the case of foreign direct investment, electricity usage, and economic progression while tourism tends to have a negative impact. According to Raihan et al. (2022), economic expansion helps to raise CO2 emissions while renewable power and technological innovation decline CO2 emissions in Bangladesh. They utilized the ARDL bound test approach and backed it with DOLS, FMOLS, and CCR techniques on data from 1980 to 2019 to find the outcomes. Chishti et al. (2020) applied the NARDL procedure to inspect the years 1980-2019 and found that while positive tourism shock improves environmental excellence by lowering carbon emanations in Nepal and Sri Lanka, it has the opposite effect in Bangladesh, India, and Pakistan. Using an augmented mean group estimate, Zuo et al. (2021) looked at data from 1991-2018 to demonstrate the severe negative effects of natural resource rents on the environmental quality of BRI Economies**.** Yue et al. (2021) demonstrated, through the utilization of the bootstrapping ARDL causality model, that the implementation of green innovation and the promotion of tourism in Thailand result in a notable reduction of environmental harm, specifically in terms of diminished CO2 emissions. Using quarterly data for China between 1995Q1 and 2017Q4, Razzaq et al. (2021) applied a QARDL technique to demonstrate that increases in both tourism and technical invention significantly shrink long-term CO2 emanations at lesser-upper (0.05-0.95) and upper-uppermost (0.7-0.95) emanations quintiles, correspondingly. By employing the ARDL model to analyze data between 1990 and 2017, Kumail et al. (2020) demonstrated that while technological progress reduces CO2 emissions, the benefits to the tourism sector come at the expense of Pakistan's environmental quality. A connection between tourism and carbon emissions in Cyprus has been established by Katircioglu et al. (2020). The study revealed that

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tourism is associated with worsening environmental conditions. According to the discoveries of research accompanied by Paramati et al., (2018), which examined annual data from EU countries from 1990 to 2013, it appears that investments in tourism not only improve tourism earnings but also cut CO_2 emissions.

There is a dearth of studies on matters of sustainable tourism, prudent natural resource management, and switching to renewable energy sources in Bangladesh. Besides, the existing literature largely dissects carbon emissions into its constituent parts, discussing factors like tourism's effect, natural resource rent, and renewable energy usage independently. There is a clear lack of research that provides an in-depth examination of the interplay between all of these variables and their effect on carbon dioxide emissions in Bangladesh. This study sets out to fill the gap by providing a comprehensive analysis of these factors and how they interact within the specific context of Bangladesh's economy, society, and natural environment.

DATA, MODEL, AND METHODOLOGY

3.1 Data and Model

This paper utilizes the time series data of Bangladesh through the period of 1995-2019, which was chosen and constructed on the accessibility of the numerical information to analyze the aforementioned objectives. Data for all variables are collected from the World Development Indicators (WDI, 2023).

The details of the variables' names, as well as their log forms and the names of the indicators, are presented in Table 1. To ensure the dependability and consistency of the findings, we convert all series into their respective natural logarithmic forms. Table 2 presents an inclusive overview of the indicators evaluated in the model, utilizing descriptive statistics as the basis for this analysis. lnTourism has the largest mean value of all variables, whereas $lnCO_2$ has the lowest. After that, we calculate the variance inflation factor, also known as the VIF, to govern whether or not there exists multicollinearity among the explanatory indicators. Values of the VIF in Table 3 that are less than five imply that there exist no multicollinearity difficulties.

Table 1: *The names of the variables and their relevant information*

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Indicator's Information	Logarithmic format	Particulars of the indicators
CO2 emanation	lnCO2	CO2 emanations (metric tons per capita)
Tourism	lnTourism	International tourism, number of arrivals
Patent	lnPatent	Patent applications (residents + nonresidents)
Renewable power	lnREN	Renewable power usage (% of entire concluding power usage)
Natural resource rents	lnNR	Total natural resources rents (% of GDP)

Source of the Data: WDI (2023)

Table 2: *Descriptive Statistics*

Indicator	Obs	Average	Std. Dev.	Min	Max
lnCO2	25	-1.288	0.470	-1.964	-0.534
lnTourism	25	12.198	0.330	11.552	13.054
lnPatent	25	5.685	0.233	5.03	6.023
lnREN	25	3.788	0.288	3.25	4.156
lnNR	25	-0.039	0.365	-0.671	0.484

Source: Writer's calculation by Stata 16

Table 3: *Assessment for Multicollinearity*

Indicator	VIF	1/VIF
lnPatent	3.78	0.264543
lnREN	2.43	0.411403
lnNR	1.94	0.514582
lnTourism	1.24	0.808960

Source: Writer's calculation by Stata 16

In this investigation, we use Eq. (1) to evaluate our hypotheses regarding the factors that determine Bangladesh's CO2 emissions.

$$\mathbf{CO_{2t}} = f\ (\mathrm{Tourism_t},\ \mathrm{Patent_t},\ \mathrm{REN_t},\ \mathrm{NR_t}) \tag{1}$$

This functional equation can be transformed into Eq. (2) to perform the calculation for elasticity.

$$\mathrm{lnCO_{2_t}} = \alpha_0 + \alpha_1\ \mathrm{lnTourism_t},+\ \alpha_2 \mathrm{lnPatent_t} + \alpha_3 \mathrm{lnREN_t} + \alpha_4\ \mathrm{lnNR_t} + \varepsilon_t \tag{2}$$

Here, CO_2 denotes carbon dioxide emissions, Tourism means the number of tourist arrivals, Patent indicates patent applications, REN denotes renewable energy sources, NR means natural resource rents and t is time epoch. Moreover, α_0 represents the intercept value; α_1,

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α_2, α_3, and α_4 represent the co-efficient of lnTourism, lnPatent, lnREN, and lnNR respectively.

3.2 Econometric methodology

3.2.1 Unit Root Assessments

In this research, we apply two standard methods of stationarity testing procedure to guarantee that our time series indicators are stationary. These include the Phillips-Perron (PP) procedure (Phillips and Perron, 1988) and the Augmented Dickey-Fuller (ADF) procedure (Dickey and Fuller, 1981).

3.2.2 The ARDL Approach

The lagged value (or values) of the dependent variable are incorporated into an autoregressive distributed lag (ARDL) technique, together with the lagged values of the explanatory variables. The ARDL model is used in this investigation to guesstimate both the shorter time span crescendos and the longer time span link between the regressors. In Equation (2), the ARDL structure proposed by Pesaran et al. (2001) can be expressed in the following way:

$$\Delta \mathrm{lnCO_2}_t = \gamma_0 + \sum_{i=1}^{p} \gamma_{1i} \Delta \mathrm{lnCO_2}_{t-i} + \sum_{i=1}^{q1} \gamma_{2i} \Delta \mathrm{lnTourism}_{t-i} + \sum_{i=1}^{q2} \gamma_{3i} \Delta \mathrm{lnPatent}_{t-i} + \sum_{i=1}^{q3} \gamma_{4i} \Delta \mathrm{lnRen}_{t-i} + \sum_{i=1}^{q4} \gamma_{5i} \Delta \mathrm{lnNR}_{t-i} + \delta_1 \mathrm{lnCO_2}_{t-1} + \delta_2 \mathrm{lnTourism}_{t-1} + \delta_3 \mathrm{lnPatent}_{t-1} + \delta_4 lnRen_{t-1} + \delta_5 \mathrm{lnNR}_{t-1} + \mu_t \quad (3)$$

The symbol Δ is the first difference operator, while the constant term is denoted by γ_0. On the contrary, p, q1, q2, q3, and q4 demonstrate the optimal lag lengths, whereas $\gamma_1, \gamma_2 \gamma_3 \gamma_4, and$ γ_5 outline the short-run parameters. The parameters $\delta_2, \delta_3, \delta_4,$ and δ_5 represent the long-term effects, which have been normalized by δ_1. Additionally, μ_t denotes the white noise error term.

The ARDL bound procedure for cointegration is employed to ascertain the existence of a longer time span link among the regressors and regressand. In the instance that the indicators exhibit cointegration, it becomes possible to establish both shorter and longer time span models. Conversely, if cointegration is absent, only a short-run model can be formulated. The null hypothesis positing no cointegration is represented as H_0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 =$

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$\delta_6 = 0$, whereas the alternative hypothesis suggesting the presence of cointegration is denoted as $H_1: \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq 0$. If the assessed F value is greater than the acute value of the higher bound, then it is possible to reject the null hypothesis. Contrariwise, in the instance that the assessed F value is less than the acute value of the lesser bound, it will not be possible to reject the null hypothesis. If the estimated F value stands anywhere between these two limits, the outcome cannot be considered conclusive. The shorter and longer time span dynamic associations can be assessed if cointegration exists. Therefore, the representation of the error-correction model can be defined as,

$$\Delta \ln CO_{2_t} = \gamma_0 + \sum_{i=1}^{p} \gamma_{1i} \Delta \ln CO_{2_{t-i}} + \sum_{i=1}^{q1} \gamma_{2i} \Delta \ln Tourism_{t-i} + \sum_{i=1}^{q2} \gamma_{3i} \Delta \ln Patent_{t-i} + \sum_{i=1}^{q3} \gamma_{4i} \Delta \ln Ren_{t-i} + \sum_{i=1}^{q4} \gamma_{5i} \Delta \ln NR_{t-i} + \varphi ECT_{t-1} + \nu_t \quad (4)$$

Where φ represents the speed of the adjustment factor and ECT represents the error correction term. The results of ECM reveal both the timing of a short-term shock and the subsequent time required for the system to return to its long-term equilibrium state. The ECM incorporates all the coefficients about both the shorter and longer time span dynamics, ensuring that no long-run information is omitted. The error correction coefficient (ECT) serves as an important indicator of negative causality in the long term, whereas the remaining coefficients pertain to the short-term dynamics (Rahman and Mamun 2016).

There should be no autocorrelation between the error terms in Eq. (4). The "Breusch-Godfrey Serial Correlation LM test" by Godfrey and Breusch (1978) is used to detect the autocorrelation problem. The examination of heteroscedasticity is conducted through the utilization of White's General Heteroscedasticity procedure, which was established by White in 1980.

EMPIRICAL RESULT AND ARGUMENT

4.1 Unit Root Test Result

Table 4 offers the outcomes of the Augmented Dickey-Fuller (ADF) procedure and the Phillips-Perron (PP) procedure. In both procedures, we can observe that all of our explanatory variables are stationary at first difference while our dependent variable lnCO2 is stationary at level. Hence, it should be noted that the order of integration is not consistent across all variables. Given the prevailing circumstances, the Autoregressive Distributed Lag (ARDL) technique can yield superior outcomes.

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Table 4: *Outcomes of the Augmented Dickey-Fuller (ADF) test and the Phillips–Perron (PP) Assessment*

Variable	at Level		at First Difference		Status	
	ADF	PP	ADF	PP	ADF	PP
lnCO2	-3.656**	-3.618**	---	---	I(0)	I(0)
lnTourism	-1.897	-2.012	-4.045**	-3.985**	I(1)	I(1)
lnPatent	-2.337	-2.411	-6.147***	-6.429***	I(1)	I(1)
lnREN	-1.738	-1.663	-4.518***	-4.374**	I(1)	I(1)
lnNR	-0.418	-0.640	-3.771**	-3.724***	I(1)	I(1)

Note: ***, **, and * specify the elimination of the null hypothesis at 1%, 5%, and 10% significant levels respectively.
Source: Writer's calculation by Stata 16

4.2 ARDL Bound Test Result

Table 5 displays the outcomes of the ARDL-bound assessment for cointegration. Even at a significant level of 1%, the calculated F value of 5.40 surpasses the higher bound critical rate in the current instance. Thus, the null hypothesis that cointegration does not exist can be rejected in favor of the inference that a longer time span association exists between the indicators.

Table 5: *ARDL Bound Assessment of Cointegration*

H_0: No Cointegration F-Statistics=5.400***		
Critical Value	Lower Bound Value	Upper Bound Value
10%	2.45	3.52
5%	2.86	4.01
1%	3.74	5.06

Notes: ∗∗∗ specifies the elimination of the null hypothesis at a 1% significant level.
Source: Writer's calculation by Stata 16

The present study has utilized the Autoregressive Distributed Lag (ARDL) technique to examine the interrelationships between variables, encompassing both shorter and longer time span dynamics. Grounded on the long-term estimates shown in Table 6, the coefficients of lnRen and lnNR are highly statistically significant even at a 1% significant level. The longer

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period coefficient of lnPatent is significant at 10%. According to the long-run coefficient of lnRen, in the long run, CO2 emissions will fall by about 1.451% for every 1% rise in the use of renewable energy, with other things remaining constant. The outcome is reliable with the outcomes of Adebayo et al. (2023) for BRICS countries, Thi et al. (2023) for 53 countries, Esquivias et al. (2022) for emerging Asia, and Liu et al. (2022) for E-7 countries. Reproducible powerhouses, comprising sun, air, water, and geothermal energy, are widely acknowledged for their ecologically favorable attributes and sustainable nature. In contrast to fossil fuels, these sources exhibit a notable absence of carbon emissions during the process of energy generation. Consequently, the heightened adoption of renewable energy sources serves as a direct replacement for the consumption of fossil fuels, resulting in a subsequent decrease in carbon dioxide emissions. The long-run coefficient of lnNR indicates that a 1% increase in natural resource rents leads to about a 0.134% increase in carbon dioxide emissions in the long-run, remaining other things the same. This outcome is supported by the results of Aydin et al. (2023) for Austria, Poland, and Slovakia, Farrukh et al. (2023) for low-income countries, and Sadiq et al. (2023) for ten Asian countries. Bangladesh, similar to several developing nations, potentially exhibits businesses characterized by a significant reliance on resources. These sectors encompass manufacturing, building, and energy generation, which frequently depend on raw materials and energy sourced from natural resources. The augmentation of resource rents has the potential to incentivize the growth of those sectors, hence resulting in elevated levels of emissions. Rents from natural resources, especially those associated with fossil fuels like coal and natural gas, can have a major effect on the energy sector. More of these resources being made available means more potential for increasing electricity production. This growth in energy production may increase carbon dioxide emissions if the energy mix is strongly dependent on fossil fuels. Potential infrastructure expansion initiatives may be funded by rising resource rents. Building new power plants, highways, or factories are all examples of infrastructure projects that can increase demand for energy and the number of pollutants released into the atmosphere. The long run coefficient of lnPatent is 0.131 meaning that 1% enhancement in patent applications leads to about 0.131% increase in carbon dioxide emissions in the long run. Esquivias et al. (2022) also obtained the same outcome for emerging Asia. The filing of patent applications and the development of new technologies may foster economic diversity and the emergence of new industries. In the beginning phases of their growth, new industries or expanding sectors may require a great deal of energy resources, which in turn may boost industrial activity and consequently, emissions. An uptick in patent applications may indicate a

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flourishing innovation scene and an expanding economy. When the economy expands, more products and services are produced and consumed, which can increase energy use and greenhouse gas emissions. Although statistically insignificant, the long-run coefficient of tourism is negative. Ullah et al. (2023) for BRICS countries, Farrukh et al. (2023) for low-income countries, Rahaman et al. (2022) for Bangladesh, Chishti et al. (2020) for Nepal and Sri Lanka, Yue et al. (2021) for Thailand also obtain the negative coefficient of tourism in affecting CO2 emissions. The kinds of energy sources that are employed in the tourism industry directly influence the industry's overall carbon footprint. It is possible that emissions related to tourism activities may be reduced if the tourism industry switched to more environmentally friendly forms of energy or adopted renewable sources of energy.

In the short run, patent applications help to improve environmental quality in Bangladesh. In ARDL models, a negative adjustment coefficient is expected to represent the tendency of variables to return to their long-term equilibrium state after being exposed to shocks or deviations. According to the findings of our study, a rapid convergence of the variables towards equilibrium can be inferred from the magnitude of -1.023 that was found.

Table 6: *Outcomes of the assessed shorter and longer period Coefficients*

Long run estimates				
Regressor	Coefficient	Std. Error	t-Statistic	Prob. values
lnTourism	-0.039	0.023	-1.710	0.115
lnPatent	0.131*	0.072	1.830	0.094
lnRen	-1.451***	0.055	-26.510	0.000
lnNR	0.134***	0.028	4.700	0.001
ECM_{t-1}	-1.023***	0.239	-4.270	0.001
Short run estimates				
Regressor	Coefficient	Std. Error	t-Statistic	Prob. values
ΔlnTourism	0.004	0.023	0.190	0.852
ΔlnTourism(-1)	-0.002	0.028	-0.050	0.958
ΔlnPatent	-0.150**	0.057	-2.640	0.023
ΔlnREN	0.063	0.329	0.190	0.852
ΔlnNR	-0.144	0.049	-2.930	0.014
ΔlnNR(-1)	-0.141**	0.060	-2.330	0.040

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*Note: a) The Akaike information criterion, often known as AIC, is applied when selecting the optimal lag length (1 2 1 1 2). b) Note: ***, **, and * specify the elimination of the null hypothesis at 1%, 5%, and 10% significant level respectively.*

Source: Writer's calculation by Stata 16

In this study, we explore serial correlation and homoskedasticity validation tests as a means of checking the validity of the ARDL analysis. By using White's test, we can figure out whether the variance of the residuals in our regression model is constant. As can be seen in Table 7, our p-value, 0.1146 is higher than 0.05. Therefore, our regression model does not have a heteroskedasticity issue; rather, the variance of the residuals is homoskedastic. The Breusch-Godfrey test checks for the presence of autocorrelation between the error terms in a regression model. We are unable to reject the null hypothesis because our p-value is 0.7733 which is greater than 0.05. Therefore, our regression model does not suffer from an autocorrelation problem.

Table 7: Validation Test

$\chi2_{WT}$	$\chi2_{BG-LM}$
20.52 (0.1146)	0.083 (0.7733)
Ho: homoskedasticity	H0: no serial correlation

Note: WT :White's test ,BG- LM Breusch: Breusch-Godfrey LM test for autocorrelation
Source: Author's calculation using Stata 16

CONCLUSION AND POLICY RECOMMENDATIONS

This study sheds light on the dynamic relationship between tourism, patent applications, natural resource rent, renewable power usage, and their impact on Carbon Dioxide (CO_2) emanations in Bangladesh, which is an essential aspect in the country's determinations to convert more sustainable and compassionate toward the environment. This research, which made use of modern econometric tools and diagnostic tests, has uncovered important insights that could significantly influence the policy framework and initiative for a greener future. This study makes use of data spanning the years 1995 to 2019 and implements an ARDL framework to investigate the long-period and short-period associations of our selected regressors on the release of carbon dioxide (CO_2). The value of VIF ensures that our variables are free from the Multicolinearity problem. Besides, White's test and BG- LM test confirm that our regression model does not suffer from heteroscedasticity and autocorrelation

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problems, respectively. The major findings of our study reveal that the usage of renewable energy plays a crucial role in preserving the environment by downlifting carbon dioxide emanations over a longer period. Our outcomes also suggest that an increase in natural resource rents and innovation activities as represented by patent applications are responsible for long-term environmental degradation in Bangladesh, while patent applications can reduce CO2 emissions only in a short time span. Although the longer time span coefficient of tourism is not statistically significant, the negative coefficient suggests that tourism can facilitate the promotion of environmentally friendly environmentally friendly operations.

To enhance the environmental quality of Bangladesh, we propose the subsequent policy recommendations derived from our research findings:

i. Incentivizing the long-term adoption of renewable powerhouses, for example, the sun, air, and water, is deemed vital. It is recommended to implement subsidies and tax incentives for both industries and individuals engaged in the adoption of renewable energy technologies.
ii. Strong laws and monitoring programs are required to reduce carbon emissions from resource extraction and a holistic plan for managing natural resource rents should be developed to ensure that extraction is carried out in a sustainable and ecologically sound manner.
iii. Patent applicants are required to carry out an environmental impact assessment, with a focus on the possible consequences of their innovations on carbon emissions, and this is particularly crucial for those seeking patents in industries with high levels of carbon emissions.
iv. Sustainable tourism practices, such as eco-friendly accommodations, proper disposal of garbage, and conservation of natural resources, should be developed and enforced by the government of Bangladesh. Additionally, eco-certification programs for environmentally friendly tourism businesses must be established.

LIMITATIONS AND FUTURE SCOPE OF THE STUDY

Although the paper has tried to explain the topics critically, it has limitations like data unavailability before 1995 for all of the variables. Furthermore, it cannot reveal the sector-wise impact of explanatory variables on CO2 emission for the same reason. Micro-based work relating to the topics is also ignored due to maintaining the main focus of the topics.

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However, future researchers can mitigate these gaps from this research and also, they have a scope of doing further works increasing or changing the data range, variables, regions, and technique applied.

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