





Article

A Novel Investigation to Explore the Impact of Renewable Energy, Urbanization, and Trade on Carbon Emission in Bhutan

Abdul Rehman ^{1,*}, Mohammad Mahtab Alam ², Magdalena Radulescu ^{3,4,*}, Rafael Alvarado ⁵, Daniela Mihai ⁶ and Madalina Brutu ⁶

¹ College of Economics and Management, Henan Agricultural University, Zhengzhou 450002, China

² Department of Basic Medical Sciences, College of Applied Medical Science, King Khalid University, Abha 62561, Saudi Arabia; mmalam@kku.edu.sa

³ Department of Finance, Accounting, Economics, University of Pitesti, Str. Targu din Vale, No. 1, 110040 Pitesti, Arges, Romania

⁴ Institute of Doctoral and Post-Doctoral Studies, University Lucian Blaga of Sibiu, Bd, Victoriei, no. 10, 550024 Sibiu, Romania

⁵ Esai Business School, Universidad Espíritu Santo, Samborondon 091650, Ecuador; rafaalvaradolopez@gmail.com

⁶ Department of Management and Business Administration, University of Pitesti, Str. Targu din Vale, No. 1, 110040 Pitesti, Arges, Romania; daniela.mihai@upit.ro (D.M.); madalina.brutu@upit.ro (M.B.)

* Correspondence: abdrehman@henau.edu.cn (A.R.); magdalena.radulescu@upit.ro (M.R.)

Abstract: The present study explores the impact of renewable energy usage, economic progress, urbanization, and trade on carbon emissions in Bhutan. The stationarity among the variables was tested by employing the two unit root tests by taking the annual data series variables from 1982–2020. A symmetric (ARDL) technique was utilized to analyze the associations among variables with short- and long-run estimations. In addition, the cointegration regression method using FMOLS and DOLS was used in this investigation to discover the robustness of the study variables. Findings showed that via long-run assessment the variables renewable energy consumption, urbanization, and trade have adverse connections with CO₂ emission, while the variable economic progress shows a constructive linkage with carbon emission. However, the short-run assessment showed that the variable economic growth has a positive impact on carbon emissions. Further, the variables renewable energy consumption, urbanization, and trade have an adverse relation to carbon emissions in Bhutan. The consequences of both FMOLS and DOLS also mean that the variable renewable energy usage, urbanization, and trade have an adverse influence on carbon emission, while economic growth has a constructive linkage with CO₂ emission. Greenhouse gas emissions are undeniably an increasing global issue. This problem can only be handled by prudent legislation and funding. Despite having fewer greenhouse gas emissions than industrialized economies, Bhutan's government needs to develop new rules to address this issue in order to ensure environmental sustainability and economic growth.

Keywords: renewable energy; trade; urbanization; carbon emissions; economic growth



Citation: Rehman, A.; Alam, M.M.; Radulescu, M.; Alvarado, R.; Mihai, D.; Brutu, M. A Novel Investigation to Explore the Impact of Renewable Energy, Urbanization, and Trade on Carbon Emission in Bhutan. *Energies* **2022**, *15*, 2984. <https://doi.org/10.3390/en15092984>

Academic Editor: Amela Ajanovic

Received: 21 March 2022

Accepted: 18 April 2022

Published: 19 April 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Global warming has grown in importance as a result of the dramatic rise in atmospheric concentrations of greenhouse gases (GHGs) over the last several decades. Carbon dioxide emissions, the main cause of global warming, are expected to rise as a result of rapidly rising energy usage. Clean energy sources including renewable energy have emerged as viable alternatives to conventional fossil fuels in the light of the growing environmental and health risks associated with carbon dioxide emissions. To fight global warming and decrease carbon dioxide emissions, renewable energy has become an essential aspect of global energy strategy by integrating renewable energy into the global energy mix [1–3]. Economic and environmental sustainability has been a worldwide priority

for the last two decades. Technological impacts on energy and industrial developments, such as environmental deterioration, mass communication and urbanization as well as the clearance of highways and railroads, may be unexpected. For a region, energy may be a strategic asset, since long-term economic growth frequently relies largely on the usage of oil in the current technological period [4,5].

The world's challenges and difficulties originate from a country's overwhelming dependence on nonrenewable energy sources, including the eventual depletion of non-renewable fossil fuels, energy security considerations, and environmental concerns. Energy instability may have significant economic ramifications, since economic production and maintaining a sufficient standard of living for people are heavily dependent on energy use. Ultimately, the use of fossil fuels contributes significantly to GHG emissions that cause climate change. Increasing energy consumption is a key concern for the global economy in terms of fostering long-term growth and development. It is predicated on the pessimistic assumption that conventional energy sources, such as fossil fuels, are depleting. Conventional energy, on the other hand, has a massive environmental effect. Because of the wide disparity between demand and supply, the growing cost of imported fossil fuels, and rising air pollution, an urgent search for economical, efficient, and ecologically acceptable energy sources is necessary [6–8]. Global warming is universally accepted to be a severe environmental danger. Several economies are striving to decrease carbon dioxide emissions through reducing energy use. Economic growth may suffer as a consequence of reduced energy usage. Energy has a key role in improving economic circumstances for the benefit of civilization and modern economies. Long-term energy policies are required to ensure energy supply and availability for long-term economic development [9].

Energy availability is crucial for both economic development and environmental conservation. However, in order to achieve long-term development that is not harmful to the environment, we must first boost economic prosperity. Economic progress in developing countries is often delayed by a range of impediments. The use of fossil fuels by developed countries to meet the expanding demand for power to manufacture more commodities is made possible by failing infrastructure. These economies have grown increasingly polluted as a result of the stalling of their economic growth and the increased creation of harmful gases, over-consumption of fossil fuels, and deteriorating environmental degradation. The global population consumes both renewable and nonrenewable energy. Traditional economic development models are being supplanted by the sustainable growth paradigm, which seeks to diversify the economy's energy requirements. In classic economic growth models, petroleum, bioenergy, and natural gas are all important fossil fuels. Alternative energy sources such as wind, solar, and geothermal have begun to take the role of the sustainable development plan [10–12]. Energy is required for both production and consumption. The basic sources of inputs for production, according to the traditional neoclassical growth model, are land, labor, and capital. Economic development is strongly reliant on the supply of energy during this age of liberalization, privatization, and globalization. The potential of energy to create money and employment is critical to economic advancement and job creation. Renewable energy sources have attracted a lot of interest due to their many advantages, and renewable energy is growing increasingly popular for a variety of reasons, including rising worldwide demand for oil and the environmental harm caused by carbon emissions [13,14].

The fundamental issue of recent times is sustainability, so that future generations might have access to a better natural environment than the one we have now. Numerous empirical studies have been conducted to investigate the influence of urbanization on environmental quality. The findings of Mahmood et al. (2020) [15] reveal that both industrialization and urbanization harm the environment, with industrialization having inelastic impacts and urbanization having elastic effects on emissions. The results of Ahmed et al. (2019) [16] on urbanization and carbon emissions imply that urbanization increases CO₂ emissions but has a negative influence on emissions after a certain threshold. Furthermore, Salahuddin et al. (2019) [17] found that long-term coefficients indicate that urbanization causes CO₂ emissions, but globalization has only a minor long-term influence on emissions.

Zhang et al. (2021) [18] investigated urbanization, energy intensity, and CO₂ emissions, discovering that urbanization ratios were negatively related to CO₂ emissions, whereas energy intensity, per capita floor area, and per capita drainage pipe lengths of urban residential buildings were positively related to CO₂ emissions. According to Yao et al. (2021) [19], there is a non-linear connection between the various characteristics of urbanization and CO₂ emissions. Similarly, the results of Balsalobre-Lorente et al. (2022) [20] demonstrate that urbanization aids in the reduction of carbon emissions, and that energy usage is a major contributor to rising carbon emissions. The availability of energy is essential to both economic progress and environmental sustainability. It is imperative first to boost economic progress in order to achieve long-term growth that does not harm the environment. The present study has a novel contribution in the existing literature regarding renewable energy consumption, urbanization, and CO₂ emission in Bhutan, and yet no study has been conducted to highlight this vital issue in the directive to achieve sustainable growth and development. We employed the ARDL technique on annual data to encounter the impact of renewable energy usage, urbanization, and trade on CO₂ emission in Bhutan with short- and long-run estimations. For more robustness in the analysis, we also utilized the cointegration regression technique to expose the variable linkages.

After the introduction, the rest of the paper is organized as follows. Section 2 focuses on the existing review of literature related to the topic. Section 3 goes into further depth on the methods and data, as well as the specification of the study model. Section 4 gives the empirical findings, while Section 5 sums up the findings and provides key policy recommendations.

2. Literature Review

Human activities and rising carbon dioxide emissions are recognized as the key reasons of the planet's warming trend. Increased energy use and economic advancement both contribute to increased greenhouse gas emissions. Because of the link between emissions, energy consumption, and economic progress, sustainability in economic development is a global issue. This is often seen as a particular connection in theoretical and empirical settings. It is also dynamic, which is why there has been an increase in interest in this sector [21–23]. Urbanization contributes significantly to environmental pollution, due mainly to urban land use and population density. Another source of pollution is the usage of energy, which has a direct impact on economic growth which is dependent on energy. Energy supply and demand have a tremendous influence on the global economy. Firms are more likely to establish and thrive as a consequence of development. It improves both personal and social well-being. Energizing homes and companies is critical for both personal and commercial endeavors. An industrial activity that utilizes energy is neither unpleasant nor deceitful. Many believe that growing oil and gas energy production is contributing to rising CO₂ emissions and global warming [24–27].

One of the most urgent issues of our day is global warming, which has an impact on our economy, society, and natural environment. Fossil fuel usage has risen steadily since the Industrial Revolution, contributing significantly to the current state of global warming and climate variation. CO₂ emissions are a proxy for environmental deterioration in various empirical studies. Because carbon emissions have traditionally been connected to economic development, this is the explanation. It is possible to attribute economic development and economic structure to the progress of urbanization. While urbanization is a relatively new phenomenon, it is considered an advanced stage of contemporary economic growth because of its rapid expansion. Determining whether economic development is the result of urbanization or the other way around is difficult despite the strong correlation [28–31]. Consumption of fossil fuels has expanded dramatically as a result of rising worldwide output and a growing global population. Fossil fuel usage rises in tandem with sustainable economic growth, environmental sustainability, and health concerns. In the light of the aforementioned trends, nations are increasingly reverting to sources of renewable energy to meet their energy needs. A sustainable, producible, and lower-carbon energy source is renewable energy, which includes wind, solar, water, geothermal, biomass, and marine sources [32–34].

Climate change issues have gained international attention and have become a more important problem for society. Global warming has had a tremendous effect on society, politics, and the economy over the last several decades. Numerous studies have shown that carbon dioxide (CO₂) emissions are the major driver of global warming. Climate warming has been considerably accelerated by human activity, which has resulted in a wide range of negative impacts on the Earth's natural ecological habitat. In the energy-led paradigm of economic development, persistent economic expansion and its environmental effects have received growing attention. Since carbon dioxide is the initiator according to common sense, it is the primary driver of global warming. GHGs affect the natural environment, food, water, health, and even social security. In order to prevent global warming, nations must work together to cut their emissions of the pollutant carbon dioxide [35–37]. While the usage of non-renewable sources has accelerated economic expansion, the environment and biological life in the region are negatively impacted by the residue left behind after the burning of fossil fuels. Non-renewable energy sources, which are widely accessible and cheaper in less developed nations, must be used in the name of economic progress even when such usage exacerbates environmental deterioration. Environmental quality is the least desired; therefore these countries are unwilling to quit the utilization of non-renewable energy sources in order to eradicate poverty, food insecurity, and economic development [38–40].

Carbon dioxide emissions have lately received a lot of attention as a result of worldwide trade. The majority of past trade and emissions studies, on the other hand, investigated carbon emissions based on territory rather than emissions based on consumption and compensated for international trade. Because consumption-based emissions are easier to aggregate, they are also more relevant in defining who is responsible for carbon storage and in evaluating the effect of international mitigation measures [41,42]. Investment and other economic development drivers, such as access to trade, urbanization, and energy consumption, use a lot of energy sources. Carbon dioxide emissions are exacerbated and the environment as a whole is polluted when fossil fuels are used. Global manufacturing is boosted by foreign investment and trade. The deterioration of the global environment has been exacerbated by the spread of industries around the globe. Even if investment and greater trade openness contribute to carbon emissions, they may also reduce the negative effects of carbon emissions via the use of renewable energy [43,44]. Trade and investment have played a significant role in the fast expansion of the economy as a whole. In addition, environmental pollution has been linked to an increase in foreign investment and external trade [45]. The quantity of carbon dioxide emitted into the atmosphere increases as international trade expands. Greater trade is considered as boosting economic efficiency, yet some analysts see global trade as a technique employed by wealthier nations to cut emission levels [46,47]. Further, economic development is aided by trade liberalization because it allows nations to make use of their comparative advantages in moving resources. A variety of effects may be seen on the surroundings, depending on where this ends up. Due to inadequate environmental restrictions, which typically attract pollution-intensive firms, this detrimental effect is mostly to blame. Trade, on the other hand, might draw some businesses to nations where knowledge spillovers encourage cleaner manufacturing and consequently cleaner environments, which is a positive outcome [48,49].

There is no doubt that climate change is a serious issue, and there is a growing interest in how energy use and carbon emissions are linked to population dynamics. Renewable energy is essential for a world free of the threat of catastrophic global warming. Energy is essential for economic progress and societal well-being. Energy's significance as a manufacturing component has long been acknowledged. The upgrading of manufacturing processes requires a sufficient and constant supply of energy, which is essential for economic progress [50,51]. The city's emissions are aided by an ageing urban population and shifting age patterns, while smaller households and an influx of urban migrants worsen the problem. The strongest driver of growing city emissions is an increase in economic activity. Advanced technologies, particularly in the energy sector, are the primary tools for reducing emissions, while industrial restructuring and changes in energy consumption patterns are key tools

for limiting emissions growth. Other factors include urbanization and erratic shifts in urban patterns. Natural and economic factors such as air circulation and industrial transfer may extend CO₂ emissions to neighboring areas, making them more than a simple urban environmental concern [52–55]. As a result, the carbon dioxide emissions of a city are influenced not only by the city’s own energy use, but also by the cities around it. Urban emissions have distinctive geographical correlations and aggregations due to the rising dependency on external force trends, which are more dependent and correlated to urban regions as a result of proximity to one another [56,57]. Table 1 exposes the previous published literature on renewable and non-renewable energy consumption, economic growth, urbanization, foreign investment, and carbon emission linkages. However, no investigation found has shown the nexus for Bhutan’s renewable energy usage, economic progress, urbanization, and trade on carbon emission. That is why our study shows a novel contribution by utilizing the ARDL bounds testing technique with the cointegration regression analysis to encounter variable linkages.

Table 1. Previous literature shows the connection between different variables and carbon emissions.

Name of Authors	Study Variables	Data Range	Methods	Study Findings
Menyah & Wolde-Rufael (2010) [58]	RE, NE, GDP, CO ₂ e	1960–2007	Granger causality test	NE → CO ₂ e Re ≠ CO ₂ e
Al-Mulali (2011) [59]	OC, EG, CO ₂ e	1980–2009	Panel model with cointegration	OC → CO ₂ e EG → CO ₂ e
Arouri et al. (2012) [60]	EC, EG, CO ₂ e	1981–2005	Bootstrap panel unit root tests and cointegration techniques	EC → CO ₂ e EG ≠ CO ₂ e
Lee (2013) [61]	FDI, EG, EC, CO ₂ e	1971–2009	Cointegration tests	FDI → EG FDI ≠ CO ₂ e FDI ≠ EC
Shafiei & Salim (2014) [62]	UR, NRE, RE, CO ₂ e	1980–2011	STIRPAT model	UR → CO ₂ e NRE → CO ₂ e RE ≠ CO ₂ e
Zhang et al. (2015) [63]	UR, PCEC, CO ₂ e	1980–2013	ARDL approach	UR → CO ₂ e PCEC ≠ CO ₂ e
Farhani & Ozturk (2015) [64]	RGDP, EC, FD, TO, UR, CO ₂ e	1971–2012	ARDL and error correction method	RGDP → CO ₂ e EC → CO ₂ e TO → CO ₂ e UR → CO ₂ e FD → CO ₂ e
Ali et al. (2016) [65]	UR, EG, EC, TO, CO ₂ e	1971–2011	ARDL approach	UR & TO ≠ CO ₂ e EG & EC → CO ₂ e
Sulaiman & Abdul-Rahim (2017) [66]	EC, EG, CO ₂ e	1975–2015	ARDL and vector error correction model	EC & EG → CO ₂ e
Cetin et al. (2018) [67]	EG, EC, TO, FD, CO ₂ e	1960–2013	ARDL and VECM Granger causality	EG, EC, TO & FD → CO ₂ e
Rehman et al. (2019) [68]	EPC, REO, RE, FFEC, EC, GDPPC, CO ₂ e	1990–2017	ARDL bounds testing approach to cointegration	EPC, REO & CO ₂ e → GDPPC RE, FFEC & EC ≠ GDPPC
Khan et al. (2020) [69]	EC, EG, CO ₂ e	1965–2015	ARDL technique	EC & EG → CO ₂ e
Rehman et al. (2021) [70]	INDS, EI, CI, EG, GCF, CO ₂ e	1971–2019	Quantile regression analysis	INDS, EI, CI and GCF → CO ₂ e EG ≠ CO ₂ e

Note: → indicates positive impact, ≠ indicates negative impact; RE indicates renewable energy consumption; NE represents nuclear energy; GDP indicates gross domestic product; CO₂e expresses carbon dioxide emission; OC shows oil consumption; EG shows economic growth; EC indicates energy consumption; FDI indicates foreign direct investment; UR shows urbanization; NRE indicates non-renewable energy consumption; PCEC indicates per-capita energy consumption; RGDP indicates real GDP; FD indicates financial development; TO shows trade openness; EPC indicates electric power consumption; REO indicates renewable electricity output; FFEC indicates fossil fuel energy consumption; GDPPC indicates GDP per capita; INDS indicates industrialization; EI indicates energy imports; CI shows carbon intensity; GCF indicates gross capital formation.

3. Methods and Study Data

In this analysis, we used annual time series data from Bhutan for the variables of urbanization, renewable energy consumption, trade, economic progress, and carbon emission. The data ranges from 1982–2020, and this data is gathered from the World Bank (World Development Indicators). Furthermore, Table 2 shows the description of the study variables with their units of measurements and their log-forms. In addition, the trends for the analyzed variables are presented in Figure 1 with the data range 1982–2020.

Table 2. Description of variables for the investigation.

Study Variables	Log-Form	Unit of Measurements	Data Sources	URL Links
CO2 emission	LnCO2e	In kt (kiloton)	WDI	https://data.worldbank.org/country/bhutan (accessed on 20 January 2022)
Renewable Energy Consumption	LnRECO	In % of total final energy consumption	WDI	
Economic Growth	LnECGR	In annual %	WDI	
Urbanization	LnURBA	In annual %	WDI	

Model for the Variables

We explored the impact of renewable energy consumption, economic growth, urbanization, and trade on carbon emission by taking the annual series data and in the directive to check the association among these variables the following model can be demonstrated as:

$$CO2e_t = \theta_0 + \theta_1 RECO_t + \theta_2 ECGR_t + \theta_3 URBA_t + \theta_4 TRAD_t + \varepsilon_t \tag{1}$$

Equation (1) can further be extended as:

$$LnCO2e_t = \theta_0 + \theta_1 LnRECO_t + \theta_2 LnECGR_t + \theta_3 LnURBA_t + \theta_4 LnTRAD_t + \varepsilon_t \tag{2}$$

where $CO2e_t$ measures the carbon emission, $RECO_t$ specifies the renewable energy consumption, $ECGR_t$ indicates the economic progress, $URBA_t$ designates the urbanization, and $TRAD_t$ displays the trade. The time dimension is indicated through t and ε_t specifies the error term. The model coefficients are demonstrated through θ_1 – θ_4 . Furthermore, this study employed the ARDL technique which is provided by Pesaran et al. (2001) [71] to encounter the association among the study variables. When a long-run relation exists among the variables, the ARDL models may be utilized to analyze the data. As a result, the constraint is no longer applicable in the situation where the variable is stationary at $I(0)$ and $I(1)$. Similar to this, it was discovered that the ARDL model provides an effective solution to false regressions caused by missing or omitted variables. The motive of this study was to observe the long- and short-run associations amid carbon emission and other variables. Whenever we look for cointegration in our model, it is necessary to provide an autoregressive distributed lag model with an error correction term. The following is how we may specify an autoregressive distributed lag model as:

$$\begin{aligned} \Delta LnCO2e_t = \beta_0 &+ \sum_{f=1}^f \pi_f \Delta LnCO2e_{t-f} + \sum_{f=0}^f \lambda_f \Delta LnRECO_{t-f} \\ &+ \sum_{f=0}^f \tau_f \Delta LnECGR_{t-f} + \sum_{f=0}^f \delta_f \Delta LnURBA_{t-f} \\ &+ \sum_{f=0}^f \psi_f \Delta LnTRAD_{t-f} + \gamma_1 LnCO2e_{t-1} + \beta_2 LnRECO_{t-1} \\ &+ \beta_3 LnECGR_{t-1} + \beta_4 LnURBA_{t-1} + \beta_5 LnTRAD_{t-1} + \varepsilon_t \end{aligned} \tag{3}$$

In Equation (3) f displays the order of the lags. Similarly, the dynamics of the short-run among the variables can be explored with an error correction model and can be stated as:

$$\begin{aligned} \Delta \text{LnCO2e}_t = & \beta_0 + \sum_{r=1}^r \pi_r \Delta \text{LnCO2e}_{t-r} + \sum_{r=0}^r \lambda_r \Delta \text{LnRECO}_{t-r} \\ & + \sum_{r=0}^r \tau_r \Delta \text{LnECGR}_{t-r} + \sum_{r=0}^r \delta_r \Delta \text{LnURBA}_{t-r} \\ & + \sum_{r=0}^r \psi_r \Delta \text{LnTRAD}_{t-r} + \text{ECM}_{t-1} + \varepsilon_t \end{aligned} \tag{4}$$

Equation (4) shows the short-run estimation among carbon emission, renewable energy consumption, economic progress, urbanization, and trade, where d is the lags order.

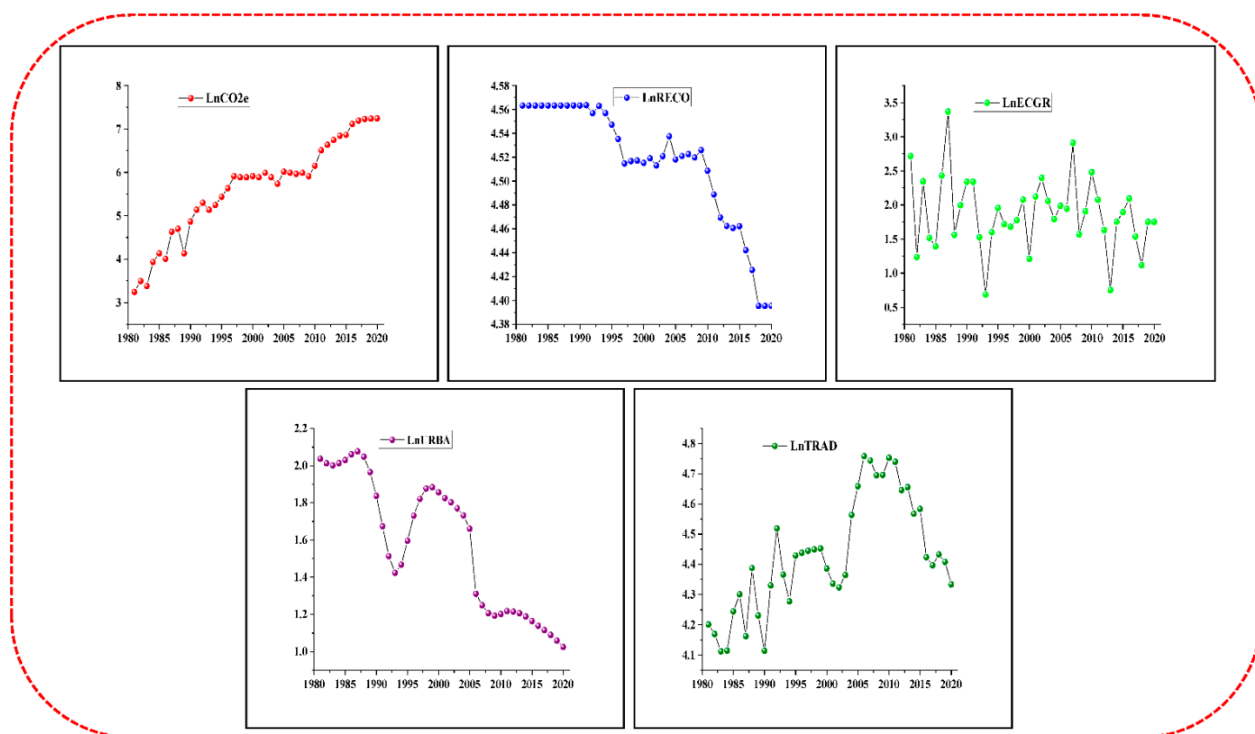


Figure 1. Variable trends.

4. Results and Discussion

4.1. Descriptive and Correlation Analysis

A statistical analysis was carried out as in Table 3 to encounter the statistics of Skewness, j -Bera, and Kurtosis. Table 1 also expresses the outcomes of correlation among dependent and independent variables. In accordance with statistical values, all variables demonstrated a correlation.

4.2. Multicollinearity Test Using Variance Inflation Factor (VIF)

The multicollinearity of data was checked using the variance inflation factor (VIF) which causes an increase in the estimated coefficients' variance. This test attempts to determine the strength to which the variance is inflated. In a multivariate regression model, multicollinearity occurs when the correlation between more than two explanatory variables is extremely substantial. Multicollinearity is characterized as the capacity to have a correlation between two independent variables. The variance inflation factor (VIF) for multicollinearity can be stated as for the j th predictor as:

$$\text{VIF}_j = \frac{1}{1 - R_j^2} \tag{5}$$

Table 3. Descriptive analysis and variable correlation.

	LnCO2e	LnRECO	LnECGR	LnURBA	LnTRAD
Mean	5.629	4.515	1.875	1.582	4.430
Median	5.886	4.520	1.843	1.666	4.416
Maximum	7.244	4.563	3.369	2.076	4.758
Minimum	3.245	4.395	0.686	1.025	4.112
Std. Dev.	1.113	0.050	0.531	0.358	0.191
Skewness	−0.491	−1.062	0.257	−0.108	0.150
Kurtosis	2.474	3.193	3.782	1.447	2.097
Jarque–Bera	2.071	7.590	1.463	4.093	1.508
Probability	0.354	0.022	0.481	0.129	0.470
LnCO2e	1.000				
LnRECO	−0.865	1.000			
LnECGR	−0.216	0.237	1.000		
LnURBA	−0.825	0.769	0.240	1.000	
LnTRAD	0.629	−0.363	−0.093	−0.663	1.000

Table 4 exposes the outcomes of the variance inflation factor (VIF) which demonstrates that the data did not contain multicollinearity. The entries in the table demonstrate that there is no connection between the predictors which means the variance of the variables is not inflated.

Table 4. Outcomes of variance inflation factor (VIF) (multicollinearity testing).

Variables	Coefficient Variance	Uncentered VIF	Centered VIF
LnRECO	4.997	21,965.20	2.722
LnECGR	0.018	14.770	1.073
LnURBA	0.157	89.449	4.262
LnTRAD	0.258	1095.222	1.983
C	85.609	18,452.44	NA

4.3. Stationary Test among Variables

The PP and ADF [72,73] tests may be utilized to encounter the unit root qualities for the variables before starting regression analysis. Both tests of empirical findings are shown in Table 5. This study reveals a number of variables that have a long-term horizontal stability, such as I(0). After the I(1), these variables develop to stationary. When it comes to the integration order, the model contains both I(0) series variables as well as those with the I(1). We used the ARDL method to perform empirical research after receiving positive findings from the unit root testing, because ARDL allows for the inclusion of integrated variables in the cointegration. If the variables do not exhibit the unit root, we reject the assumption and accept the alternative of no unit root.

4.4. Optimal Lag Length Criteria

It is important to choose a lag length that accurately represents the dynamic properties of the model. The Akaike information criterion (AIC) is a widely used method for evaluating the appropriate lag order in data analysis. On the basis of such criteria, we employed the Akaike information criterion (AIC) to identify the appropriate lag lengths for variables to be included in the ARDL model (see Table 6).

Table 5. Unit root tests results.

[ADF-Tests (at the Level)] I(0)					
	LnCO2e	LnRECO	LnECGR	LnURBA	LnTRAD
Test statistics and <i>p</i> -values *	−1.702 (0.422)	1.584 (0.999)	−4.896 (0.000)	−1.243 (0.645)	−1.973 (0.296)
[At the first difference] I(1)					
Test statistics and <i>p</i> -values *	−7.687 (0.000)	−4.790 (0.000)	−7.166 (0.000)	−3.075 (0.037)	−6.009 (0.000)
[P-P-test (at the level)] I(0)					
Test statistics and <i>p</i> -values *	−1.785 (0.382)	1.519 (0.999)	−6.000 (0.000)	−0.848 (0.793)	−1.862 (0.345)
[At the first difference] I(1)					
Test statistics and <i>p</i> -values *	−7.687 (0.000)	−4.790 (0.000)	−18.332 (0.000)	−3.075 (0.037)	−6.371 (0.000)

* indicates the one sided probability values of MacKinnon (1996).

Table 6. Outcomes of optimal lag length criteria.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	49.062	NA	6.36×10^{-8}	−2.381	−2.164	−2.305
1	194.632	243.927	9.53×10^{-11}	−8.899	−7.592 *	−8.438
2	228.717	47.903 *	6.31×10^{-11}	−9.390	−6.995	−8.545 *
3	258.568	33.885	6.00×10^{-11}	−9.652 *	−6.169	−8.424

* signifies the selected lag order through criteria.

4.5. Bounds Testing in Directive to Confirm the Cointegration

Table 7 displays the results of the ARDL bound test for the cointegration. The findings show that the variables are interdependent. These findings are corroborated by F-statistic values that are greater than or equal to the upper limit at significance levels of one percent and five percent. We may infer from the findings that the variables used in this study are linked over the long term.

Table 7. Bounds test to cointegration.

[F-Bounds Test Statistics]		F-Bounds No Relationship at Levels		
T-Stat.	Value	Significance	At I(0)	At I(1)
F-Stat.	[5.075]	[10%]	[2.2]	[3.09]
k	4	[5%]	[2.56]	[3.49]
		[2.5%]	[2.88]	[3.87]
		[1%]	[3.29]	[4.37]

Johansen cointegration technique also was utilized in this investigation with test statistics and max-eigen values and the outcomes are presented in Table 8.

Table 8. Johansen cointegration test statistics.

N-Hypothesis	T-Test Values	C-Values at 0.05	p-Values	N-Hypothesis	M-Eigen Values	C-Values at 0.05	p-Values
$r \leq 0^*$	71.002	69.818	0.040	$r \leq 0^*$	30.210	33.876	0.128
$r \leq 1$	40.791	47.856	0.195	$r \leq 1^*$	18.216	27.584	0.477
$r \leq 2$	22.575	29.797	0.267	$r \leq 2$	16.463	21.131	0.198
$r \leq 3$	6.111	15.494	0.682	$r \leq 3$	6.100	14.264	0.600
$r \leq 4$	0.011	3.841	0.916	$r \leq 4$	0.011	3.841	0.916

Note: * indicates the denial of hypothesis at significance level (0.05).

4.6. ARDL Technique Outcomes

The estimated outcomes of the short- and long-runs are explored in Table 9. Panel A results of the short-run exposed that variable renewable energy consumption, urbanization, and trade have negative coefficients (−0.923), (−0.205), (−0.182) with probability values (0.608), (0.276), and (0.563) which demonstrate the adverse impact on the carbon emissions in Bhutan. Similarly, the variable economic growth has a positive coefficient (0.209) with p-value (0.029) exposing the constructive linkage to carbon emission.

Table 9. Short- and long-runs.

Panel A: Short-Run Outcomes				
Variables	Coefficients	S-Error	t-Stat.	Prob-Values
C	5.716	7.536	0.758	0.453
LnCO2e(−1)	−0.132	0.087	−1.516	0.139
LnRECO(−1)	−0.923	1.782	−0.517	0.608
LnECGR(−1)	0.209	0.091	2.286	0.029
LnURBA	−0.205	0.185	−1.106	0.276
LnTRAD	−0.182	0.312	−0.583	0.563
D(RECO)	−9.929	3.574	−2.778	0.009
D(ECGR)	0.094	0.063	1.491	0.145
CointEq(−1)	−0.132	0.028	−4.628	0.000
Panel B: Long-Run Outcomes				
LnRECO	−6.959	10.154	−0.685	0.498
LnECGR	1.578	1.332	1.184	0.005
LnURBA	−1.550	1.730	−0.896	0.376
LnTRAD	−1.377	3.015	−0.456	0.651
C	43.083	37.857	1.138	0.263
R-squared	0.971	M-dependent var		5.690
Adj-R ²	0.964	SD-dependent var		1.058
S.E. of regression	0.198	AIC		−0.217
S-squared resid	1.218	SC		0.123
Log-likelihood	12.248	HQC		−0.095
F-stat.	150.211	D-Watson stat		2.407
Prob(F-stat.)	0.000			

Moreover, the findings of Panel B show the variable renewable energy consumption, urbanization, and trade have negative coefficients (−6.959), (−1.550), (−1.377) with probability

values (0.498), (0.376), (0.651) that demonstrate the adverse influence to carbon emission, while the variable economic growth has a positive coefficient (1.578) with probability values (0.005) that expose the productive relation to carbon emission. Countries throughout the globe have been attempting to mitigate global warming and avert its adverse repercussions for the last two decades. There has been a great deal of focus on the role that carbon dioxide emissions from fossil fuel combustion play in global warming. In order to guarantee that safe and inexpensive energy is accessible, it is vital to improve the supply sector and minimize greenhouse gas emissions. There must be an examination of alternatives to fossil fuels as part of every endeavor. There are several ways in which nuclear and renewable energy sources may be used to address both energy security and climate change. Fossil fuel consumption, which contributes to greenhouse gas emissions, has lately surged in importance, particularly in emerging countries. Because of their rapid economic growth and large populations, certain economies have energy consumption and production patterns that may have a global influence. Prior to increasing energy use, it is important to think about how it will affect the environment, especially in the early stages [74–77].

Industrial progress has been fuelled by the use of non-renewable fuels, resulting in hazardous leftovers that threaten the environment and human civilization. For regions with fewer emerging countries, the use of widely accessible non-renewable energy sources accelerates the loss of ecosystems, which is detrimental to economic progress. Some economies have not chosen to avoid the use of non-renewable energy sources, because environmental conservation is the least appealing option when it comes to ending poverty, addressing food shortages, and growing the economy [78–80]. A good knowledge of the links among carbon emissions, energy usage, and financial development is critical in both developed and developing nations. The usage of energy and carbon dioxide emissions will rise as a result of policies that support industrial growth. Fiscal incentives, therefore, might boost economic production, which with opportunity could lead to an increase in efficiency of oil and CO₂ emissions, taking into consideration the capacity of the economy. Concern over rising CO₂ emissions is a major problem for policymakers because of climate change concerns [81–83].

While economic development and energy consumption are inextricably connected, environmental concerns are also essential. Local environmental factors are partially to blame for the significant environmental impact caused by traditional energy sources such as charcoal. Humans mostly depend on coal, oil, and gas for energy. Because the bulk of our energy originates from fossil fuels, this adds to the already-stressed environment. Concerns regarding the usage of fossil fuels are growing as a result of climate change and the consequences of greenhouse gases. By employing renewable energy sources, carbon dioxide emissions may be minimized while also protecting the environment. Even if they have the potential to be resourced for a long time, it is possible that fossil fuels will become extinct in the near future. Renewable energy use has grown to the point where it may help alleviate growing concerns about global warming, the geopolitics of fossil fuels, high energy costs, energy insecurity, and reliance on foreign energy supplies, among other issues [84–86]. In addition, the rising demand for fossil fuels as a result of the intense use of energy leads to the depletion of natural resources, a rise in carbon dioxide emissions, and an overall deterioration of the environment. As a result, considerations of energy consumption must include consideration of environmental quality. Economic development is being fueled by an ever-increasing amount of energy commerce. The industrial process relies heavily on energy since it transforms raw resources into finished goods, and finished goods contribute to global trade. Economic development and energy usage are inextricably linked. Environmental worries about climate change have sparked a rise in interest in renewable energy in the literature. Recent decades have seen an upsurge in public and intellectual interest in global warming. One of the primary causes of global warming is the use of fossil fuels [87,88].

4.7. Cointegration Regression Analysis

This investigation also utilized the cointegration regression technique with the estimation of FMOLS and DOLS to encounter the linkages among the variables and outcomes as reported in Table 10. The FMOLS consequences show that urbanization, renewable energy consumption, and trade have negative coefficients (−15.134), (−0.088), (−2.043) with prob-values (0.000), (0.878), and (2.783) which expose the adverse influence to carbon emission, while economic growth has the coefficient (0.034) with probability value (0.861) which shows the constructive association to carbon emissions in Bhutan. Similarly, the findings of DOLS also show that renewable energy consumption, urbanization, and trade have an adverse linkage, while economic progress has a positive association to carbon emissions. The statistical values of R-squared, Adj-R², and Long-run variance for both FMOLS and DOLS are (0.876), (0.924); (0.861), (0.864); (0.383), (0.336) respectively.

Table 10. Outcomes of the cointegration regression analysis.

(FMOLS—Fully Modified Least Squares)				(DOLS—Dynamic Least Squares)			
Variables	Coefficients	t-Stat.	p-Values	Variables	Coefficients	t-Stat.	p-Values
LnRECO	−15.134	−4.709	0.000	LnRECO	−16.229	−3.102	0.005
LnECGR	0.034	−0.176	0.861	LnECGR	0.601	−1.109	0.280
LnURBA	−0.088	−0.154	0.878	LnURBA	−0.401	0.373	0.712
LnTRAD	−2.043	2.783	0.008	LnTRAD	−2.477	2.232	0.037
C	65.143	4.896	0.000	C	68.471	3.168	0.004
R-squared (0.876)		M-dependent var (5.690)		R-squared (0.924)		M-dependent var (5.707)	
Adj-R ² (0.861)		S.D. dependent var (1.058)		Adj-R ² (0.864)		S.D. dependent var (0.990)	
S.E. of regression (0.393)		S-squared resid (5.257)		S.E. of regression (0.364)		S-squared resid (2.663)	
Long-run variance (0.383)				Long-run variance (0.336)			

Figure 2 presents the plots of CUSUM and its square for the explored variables at the 5% level of significance.

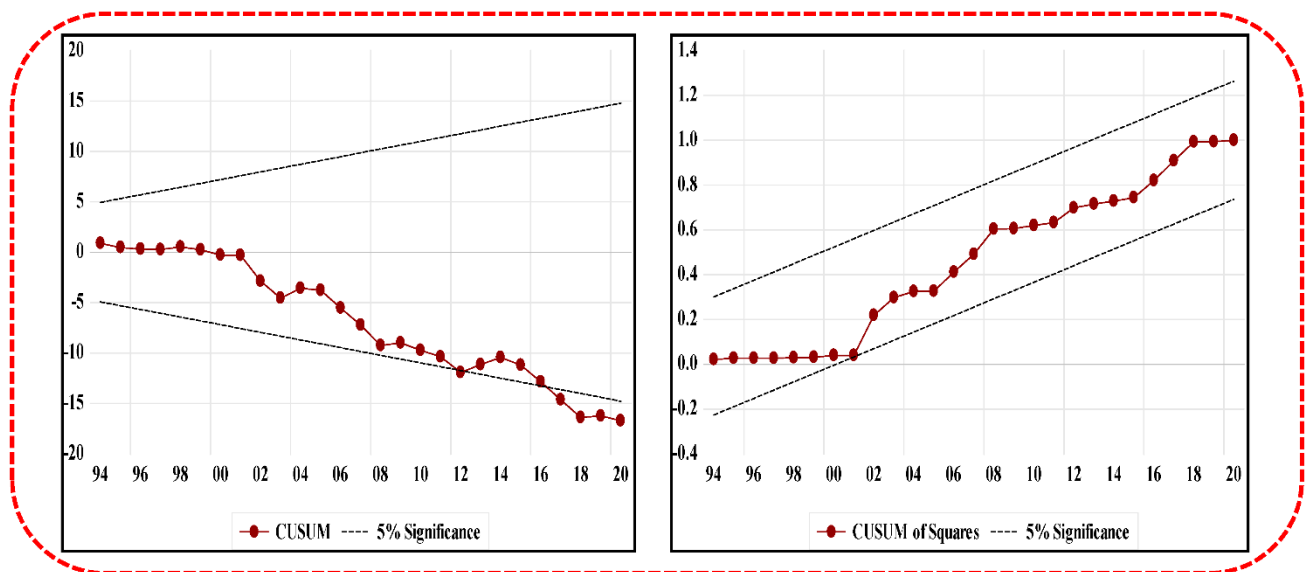


Figure 2. CUSUM–CUSUM square plots.

In addition, Figure 3 shows an inset of the partial regression leverage graphs that reveal the relationship between carbon emissions and all other factors (RECO, ECGR, URBA, TRAD). Using a leverage plot, the regression model's significant data is highlighted. The partial regression leverage plot shows how the model's parameters have a unique influence on the model.

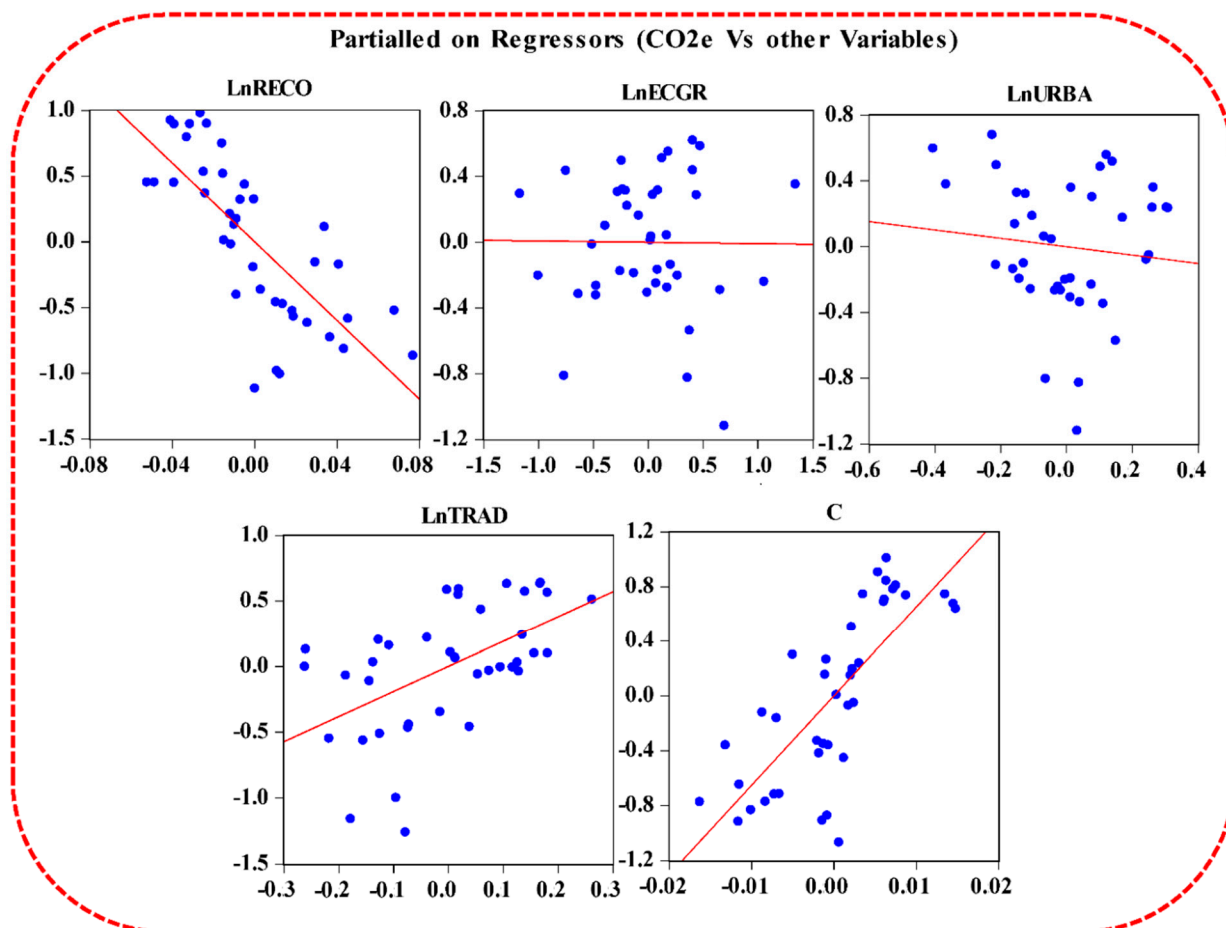


Figure 3. Partial regression leverage plots.

5. Conclusions and Policy Recommendation

The present analysis explored the impact of urbanization, renewable energy consumption, economic progress and trade on CO₂ emissions in Bhutan by taking the annual series data. By employing two-unit root testing the stationarity was tested. A symmetric (ARDL) technique was utilized to analyze the variable connections with short- and long-run estimations. The cointegration regression method with FMOLS and DOLS was used in this investigation to discover the robustness of the various variables. The consequences showed that the variable renewable energy use, urbanization, and trade have negative connections with CO₂ emission via the long-run analysis, while the variable economic progress shows the constructive linkage to CO₂ emission. Furthermore, the short-run analysis exposed the fact that variable economic growth has a constructive relation to carbon emission. Renewable energy consumption, urbanization, and trade have an adverse relation to carbon emissions in Bhutan. The consequences of the cointegration regression technique (FMOLS and DOLS) are that the variables renewable energy usage, urbanization, and trade have an adverse linkage to CO₂ emission, while the variable economic growth has a constructive association to CO₂ emission in Bhutan.

Bhutan is a growing economy with a low contribution of carbon emissions to the environment, yet feasible efforts to minimize carbon emissions in order to increase economic

growth are necessary. To remedy this problem, the government should introduce a new set of conservative policies. Conventional strategies of all nations should be concentrated on reducing CO₂ emissions in order to avoid future depletion of the planet's natural resources. An aim is to reduce the carbon intensity by enacting new environmental laws that have unintended implications. Another strategy to reduce carbon emissions is via the use of clean energy. The use of renewable energy sources like solar panels, wind turbines, and geothermal heat pumps reduces our dependency on fossil fuels and other natural resources while also lowering carbon emissions. The government emphasizes the setting of objectives and is striving to reduce CO₂ emissions and increase the use of alternative fuels. By addressing the environmental implications of urbanization, globalization, and greenhouse gas emissions, this study lays the groundwork for future research and has no limitations.

Author Contributions: Conceptualization, A.R.; methodology, A.R. and R.A.; software, A.R. and D.M.; validation, M.R., M.B. and M.M.A.; formal analysis, A.R. and M.R.; investigation, D.M. and M.B.; data curation, A.R. and M.B.; writing—original draft preparation, A.R. and M.R.; writing—review and editing, M.R., D.M. and R.A.; visualization, M.M.A.; supervision, M.R.; project administration, A.R. All authors have read and agreed to the published version of the manuscript.

Funding: The authors are thankful to the Deanship of Scientific Research, King Khalid University, Abha, Saudi Arabia, for financially supporting this work through the General Research Project under Grant no. R.G.P.2/160/43.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Wang, Z.; Zhang, B.; Wang, B. Renewable energy consumption, economic growth and human development index in Pakistan: Evidence from simultaneous equation model. *J. Clean. Prod.* **2018**, *184*, 1081–1090. [\[CrossRef\]](#)
2. Zoundi, Z. CO₂ emissions, renewable energy and the Environmental Kuznets Curve, a panel cointegration approach. *Renew. Sustain. Energy Rev.* **2017**, *72*, 1067–1075. [\[CrossRef\]](#)
3. Hanif, I.; Aziz, B.; Chaudhry, I.S. Carbon emissions across the spectrum of renewable and nonrenewable energy use in developing economies of Asia. *Renew. Energy* **2019**, *143*, 586–595. [\[CrossRef\]](#)
4. Al Asbahi, A.A.M.H.; Gang, F.Z.; Iqbal, W.; Abbass, Q.; Mohsin, M.; Iram, R. Novel approach of principal component analysis method to assess the national energy performance via Energy Trilemma Index. *Energy Rep.* **2019**, *5*, 704–713. [\[CrossRef\]](#)
5. Baloch, Z.A.; Tan, Q.; Iqbal, N.; Mohsin, M.; Abbas, Q.; Iqbal, W.; Chaudhry, I.S. Trilemma assessment of energy intensity, efficiency, and environmental index: Evidence from BRICS countries. *Environ. Sci. Pollut. Res.* **2020**, *27*, 34337–34347. [\[CrossRef\]](#)
6. Abbasi, K.; Jiao, Z.; Shahbaz, M.; Khan, A. Asymmetric impact of renewable and non-renewable energy on economic growth in Pakistan: New evidence from a nonlinear analysis. *Energy Explor. Exploit.* **2020**, *38*, 1946–1967. [\[CrossRef\]](#)
7. Kahia, M.; Aissa, M.S.B.; Lanouar, C. Renewable and non-renewable energy use-economic growth nexus: The case of MENA net oil importing countries. *Renew. Sustain. Energy Rev.* **2017**, *71*, 127–140. [\[CrossRef\]](#)
8. Rahman, M.M.; Velayutham, E. Renewable and non-renewable energy consumption-economic growth nexus: New evidence from South Asia. *Renew. Energy* **2020**, *147*, 399–408. [\[CrossRef\]](#)
9. Rehman, A.; Ma, H.; Ozturk, I.; Radulescu, M. Revealing the dynamic effects of fossil fuel energy, nuclear energy, renewable energy, and carbon emissions on Pakistan's economic growth. *Environ. Sci. Pollut. Res.* **2022**, 1–11. [\[CrossRef\]](#)
10. Alper, A.; Oguz, O. The role of renewable energy consumption in economic growth: Evidence from asymmetric causality. *Renew. Sustain. Energy Rev.* **2016**, *60*, 953–959. [\[CrossRef\]](#)
11. Jamel, L.; Derbali, A. Do energy consumption and economic growth lead to environmental degradation? Evidence from Asian economies. *Cogent Econ. Financ.* **2016**, *4*, 1170653. [\[CrossRef\]](#)
12. Adewuyi, A.O.; Awodumi, O.B. Biomass energy consumption, economic growth and carbon emissions: Fresh evidence from West Africa using a simultaneous equation model. *Energy* **2017**, *119*, 453–471. [\[CrossRef\]](#)
13. Aneja, R.; Banday, U.J.; Hasnat, T.; Koçoglu, M. Renewable and non-renewable energy consumption and economic growth: Empirical evidence from panel error correction model. *Jindal J. Bus. Res.* **2017**, *6*, 76–85. [\[CrossRef\]](#)
14. Ito, K. CO₂ emissions, renewable and non-renewable energy consumption, and economic growth: Evidence from panel data for developing countries. *Int. Econ.* **2017**, *151*, 1–6. [\[CrossRef\]](#)

15. Mahmood, H.; Alkhateeb, T.T.Y.; Furqan, M. Industrialization, urbanization and CO₂ emissions in Saudi Arabia: Asymmetry analysis. *Energy Rep.* **2020**, *6*, 1553–1560. [[CrossRef](#)]
16. Ahmed, Z.; Wang, Z.; Ali, S. Investigating the non-linear relationship between urbanization and CO₂ emissions: An empirical analysis. *Air Qual. Atmos. Health* **2019**, *12*, 945–953. [[CrossRef](#)]
17. Salahuddin, M.; Gow, J.; Ali, M.I.; Hossain, M.R.; Al-Azami, K.S.; Akbar, D.; Gedikli, A. Urbanization-globalization-CO₂ emissions nexus revisited: Empirical evidence from South Africa. *Heliyon* **2019**, *5*, e01974. [[CrossRef](#)]
18. Zhang, S.; Li, Z.; Ning, X.; Li, L. Gauging the impacts of urbanization on CO₂ emissions from the construction industry: Evidence from China. *J. Environ. Manag.* **2021**, *288*, 112440. [[CrossRef](#)]
19. Yao, F.; Zhu, H.; Wang, M. The impact of multiple dimensions of urbanization on CO₂ emissions: A spatial and threshold analysis of panel data on China's prefecture-level cities. *Sustain. Cities Soc.* **2021**, *73*, 103113. [[CrossRef](#)]
20. Balsalobre-Lorente, D.; Driha, O.M.; Halkos, G.; Mishra, S. Influence of growth and urbanization on CO₂ emissions: The moderating effect of foreign direct investment on energy use in BRICS. *Sustain. Dev.* **2022**, *30*, 227–240. [[CrossRef](#)]
21. Wang, Y.; Xiao, W.; Wang, Y.; Zhao, Y.; Wang, J.; Hou, B.; Song, X.; Zhang, X. Impact of China's urbanization on water use and energy consumption: An econometric method and spatiotemporal analysis. *Water* **2018**, *10*, 1323. [[CrossRef](#)]
22. Al-Mulali, U.; Fereidouni, H.G.; Lee, J.Y.; Sab, C.N.B.C. Exploring the relationship between urbanization, energy consumption, and CO₂ emission in MENA countries. *Renew. Sustain. Energy Rev.* **2013**, *23*, 107–112. [[CrossRef](#)]
23. Wang, Q.; Zeng, Y.E.; Wu, B.W. Exploring the relationship between urbanization, energy consumption, and CO₂ emissions in different provinces of China. *Renew. Sustain. Energy Rev.* **2016**, *54*, 1563–1579. [[CrossRef](#)]
24. Liang, W.; Yang, M. Urbanization, economic growth and environmental pollution: Evidence from China. *Sustain. Comput. Inform. Syst.* **2019**, *21*, 1–9. [[CrossRef](#)]
25. Lin, B.; Ahmad, I. Analysis of energy related carbon dioxide emission and reduction potential in Pakistan. *J. Clean. Prod.* **2017**, *143*, 278–287. [[CrossRef](#)]
26. Sun, J.; Wang, J.; Wang, T.; Zhang, T. Urbanization, economic growth, and environmental pollution: Partial differential analysis based on the spatial Durbin model. *Manag. Environ. Qual. Int. J.* **2019**, *30*, 483–494. [[CrossRef](#)]
27. Rehman, A.; Ma, H.; Chishti, M.Z.; Ozturk, I.; Irfan, M.; Ahmad, M. Asymmetric investigation to track the effect of urbanization, energy utilization, fossil fuel energy and CO₂ emission on economic efficiency in China: Another outlook. *Environ. Sci. Pollut. Res.* **2021**, *28*, 17319–17330. [[CrossRef](#)]
28. Naradda Gamage, S.K.; Hewa Kuruppuge, R.; Haq, I.U. Energy consumption, tourism development, and environmental degradation in Sri Lanka. *Energy Sources Part B Econ. Plan. Policy* **2017**, *12*, 910–916. [[CrossRef](#)]
29. Zhang, C.; Lin, Y. Panel estimation for urbanization, energy consumption and CO₂ emissions: A regional analysis in China. *Energy Policy* **2012**, *49*, 488–498. [[CrossRef](#)]
30. Çetin, M.; Ecevit, E. Urbanization, energy consumption and CO₂ emissions in Sub-Saharan countries: A panel cointegration and causality analysis. *J. Econ. Dev. Stud.* **2015**, *3*, 66–76. [[CrossRef](#)]
31. Zhang, N.; Yu, K.; Chen, Z. How does urbanization affect carbon dioxide emissions? A cross-country panel data analysis. *Energy Policy* **2017**, *107*, 678–687. [[CrossRef](#)]
32. Bayar, Y.; Sasmaz, M.U.; Ozkaya, M.H. Impact of trade and financial globalization on renewable energy in EU transition economies: A bootstrap panel granger causality test. *Energies* **2020**, *14*, 19. [[CrossRef](#)]
33. Manisalidis, I.; Stavropoulou, E.; Stavropoulos, A.; Bezirtzoglou, E. Environmental and health impacts of air pollution: A review. *Front. Public Health* **2020**, *8*, 14. [[CrossRef](#)] [[PubMed](#)]
34. Banday, U.J.; Aneja, R. Renewable and non-renewable energy consumption, economic growth and carbon emission in BRICS: Evidence from bootstrap panel causality. *Int. J. of Ener. Sec. Manag.* **2019**, *14*, 248–260. [[CrossRef](#)]
35. Fan, J.L.; Wang, Q.; Yu, S.; Hou, Y.B.; Wei, Y.M. The evolution of CO₂ emissions in international trade for major economies: A perspective from the global supply chain. *Mitig. Adapt. Strateg. Glob. Chang.* **2017**, *22*, 1229–1248. [[CrossRef](#)]
36. Wen, M.; Li, M.; Erum, N.; Hussain, A.; Xie, H.; ud din Khan, H.S. Revisiting environmental kuznets curve in relation to economic development and energy carbon emission efficiency: Evidence from Suzhou, China. *Energies* **2021**, *15*, 62. [[CrossRef](#)]
37. Zandalinas, S.I.; Fritschi, F.B.; Mittler, R. Global warming, climate change, and environmental pollution: Recipe for a multifactorial stress combination disaster. *Trends Plant Sci.* **2021**, *26*, 588–599. [[CrossRef](#)]
38. Hanif, I. Impact of economic growth, nonrenewable and renewable energy consumption, and urbanization on carbon emissions in Sub-Saharan Africa. *Environ. Sci. Pollut. Res.* **2018**, *25*, 15057–15067. [[CrossRef](#)]
39. Mohsin, M.; Kamran, H.W.; Nawaz, M.A.; Hussain, M.S.; Dahri, A.S. Assessing the impact of transition from nonrenewable to renewable energy consumption on economic growth-environmental nexus from developing Asian economies. *J. Environ. Manag.* **2021**, *284*, 111999. [[CrossRef](#)]
40. Zafar, M.W.; Shahbaz, M.; Hou, F.; Sinha, A. From nonrenewable to renewable energy and its impact on economic growth: The role of research & development expenditures in Asia-Pacific Economic Cooperation countries. *J. Clean. Prod.* **2019**, *212*, 1166–1178.
41. Dar, M.R.; Azeem, M.; Ramzan, M. Impact of energy consumption on Pakistan's economic growth. *Int. J. Hum. Soc. Sci. Invent.* **2013**, *2*, 51–60.
42. Khan, M.K.; Teng, J.Z.; Khan, M.I. Effect of energy consumption and economic growth on carbon dioxide emissions in Pakistan with dynamic ARDL simulations approach. *Environ. Sci. Pollut. Res.* **2019**, *26*, 23480–23490. [[CrossRef](#)] [[PubMed](#)]

43. Yang, Y.; Zhao, T.; Wang, Y.; Shi, Z. Research on impacts of population-related factors on carbon emissions in Beijing from 1984 to 2012. *Environ. Impact Assess. Rev.* **2015**, *55*, 45–53. [[CrossRef](#)]
44. Wang, S.H.; Huang, S.L.; Huang, P.J. Can spatial planning really mitigate carbon dioxide emissions in urban areas? A case study in Taipei, Taiwan. *Landsc. Urban Plan.* **2018**, *169*, 22–36. [[CrossRef](#)]
45. Zhou, Y.; Shan, Y.; Liu, G.; Guan, D. Emissions and low-carbon development in Guangdong-Hong Kong-Macao Greater Bay Area cities and their surroundings. *Appl. Energy* **2018**, *228*, 1683–1692. [[CrossRef](#)]
46. Han, F.; Xie, R.; Fang, J.; Liu, Y. The effects of urban agglomeration economies on carbon emissions: Evidence from Chinese cities. *J. Clean. Prod.* **2018**, *172*, 1096–1110. [[CrossRef](#)]
47. Wang, B.; Sun, Y.; Wang, Z. Agglomeration effect of CO₂ emissions and emissions reduction effect of technology: A spatial econometric perspective based on China's province-level data. *J. Clean. Prod.* **2018**, *204*, 96–106. [[CrossRef](#)]
48. Yu, Y.; Du, Y. Impact of technological innovation on CO₂ emissions and emissions trend prediction on 'New Normal' economy in China. *Atmos. Pollut. Res.* **2019**, *10*, 152–161. [[CrossRef](#)]
49. Fan, J.L.; Zhang, X.; Wang, J.D.; Wang, Q. Measuring the impacts of international trade on carbon emissions intensity: A global value chain perspective. *Emerg. Mark. Financ. Trade* **2021**, *57*, 972–988. [[CrossRef](#)]
50. Adebayo, T.S.; Awosusi, A.A.; Rjoub, H.; Panait, M.; Popescu, C. Asymmetric impact of international trade on consumption-based carbon emissions in MINT nations. *Energies* **2021**, *14*, 6581. [[CrossRef](#)]
51. Kihombo, S.; Vaseer, A.I.; Ahmed, Z.; Chen, S.; Kirikkaleli, D.; Adebayo, T.S. Is there a tradeoff between financial globalization, economic growth, and environmental sustainability? An advanced panel analysis. *Environ. Sci. Pollut. Res.* **2022**, *29*, 3983–3993. [[CrossRef](#)] [[PubMed](#)]
52. Lu, W.C. The impacts of information and communication technology, energy consumption, financial development, and economic growth on carbon dioxide emissions in 12 Asian countries. *Mitig. Adapt. Strateg. Glob. Change* **2018**, *23*, 1351–1365. [[CrossRef](#)]
53. Huang, Y.; Chen, X.; Zhu, H.; Huang, C.; Tian, Z. The heterogeneous effects of FDI and foreign trade on CO₂ emissions: Evidence from China. *Math. Probl. Eng.* **2019**, *2019*, 9612492. [[CrossRef](#)]
54. Hasanov, F.J.; Liddle, B.; Mikayilov, J.I. The impact of international trade on CO₂ emissions in oil exporting countries: Territory vs. consumption emissions accounting. *Energy Econ.* **2018**, *74*, 343–350. [[CrossRef](#)]
55. Yuping, L.; Ramzan, M.; Xincheng, L.; Murshed, M.; Awosusi, A.A.; BAH, S.I.; Adebayo, T.S. Determinants of carbon emissions in Argentina: The roles of renewable energy consumption and globalization. *Energy Rep.* **2021**, *7*, 4747–4760. [[CrossRef](#)]
56. Dauda, L.; Long, X.; Mensah, C.N.; Salman, M.; Boamah, K.B.; Ampon-Wireko, S.; Dogbe, C.S.K. Innovation, trade openness and CO₂ emissions in selected countries in Africa. *J. Clean. Prod.* **2021**, *281*, 125143. [[CrossRef](#)]
57. Hu, H.; Xie, N.; Fang, D.; Zhang, X. The role of renewable energy consumption and commercial services trade in carbon dioxide reduction: Evidence from 25 developing countries. *Appl. Energy* **2018**, *211*, 1229–1244. [[CrossRef](#)]
58. Menyah, K.; Wolde-Rufael, Y. CO₂ emissions, nuclear energy, renewable energy and economic growth in the US. *Energy Policy* **2010**, *38*, 2911–2915. [[CrossRef](#)]
59. Al-Mulali, U. Oil consumption, CO₂ emission and economic growth in MENA countries. *Energy* **2011**, *36*, 6165–6171. [[CrossRef](#)]
60. Arouri, M.E.H.; Youssef, A.B.; M'henni, H.; Rault, C. Energy consumption, economic growth and CO₂ emissions in Middle East and North African countries. *Energy Policy* **2012**, *45*, 342–349. [[CrossRef](#)]
61. Lee, J.W. The contribution of foreign direct investment to clean energy use, carbon emissions and economic growth. *Energy Policy* **2013**, *55*, 483–489. [[CrossRef](#)]
62. Shafiei, S.; Salim, R.A. Non-renewable and renewable energy consumption and CO₂ emissions in OECD countries: A comparative analysis. *Energy Policy* **2014**, *66*, 547–556. [[CrossRef](#)]
63. Zhang, Y.J.; Yi, W.C.; Li, B.W. The impact of urbanization on carbon emission: Empirical evidence in Beijing. *Energy Procedia* **2015**, *75*, 2963–2968. [[CrossRef](#)]
64. Farhani, S.; Ozturk, I. Causal relationship between CO₂ emissions, real GDP, energy consumption, financial development, trade openness, and urbanization in Tunisia. *Environ. Sci. Pollut. Res.* **2015**, *22*, 15663–15676. [[CrossRef](#)]
65. Ali, H.S.; Law, S.H.; Zannah, T.I. Dynamic impact of urbanization, economic growth, energy consumption, and trade openness on CO₂ emissions in Nigeria. *Environ. Sci. Pollut. Res.* **2016**, *23*, 12435–12443. [[CrossRef](#)]
66. Sulaiman, C.; Abdul-Rahim, A.S. The relationship between CO₂ emission, energy consumption and economic growth in Malaysia: A three-way linkage approach. *Environ. Sci. Pollut. Res.* **2017**, *24*, 25204–25220. [[CrossRef](#)]
67. Cetin, M.; Ecevit, E.; Yucel, A.G. The impact of economic growth, energy consumption, trade openness, and financial development on carbon emissions: Empirical evidence from Turkey. *Environ. Sci. Pollut. Res.* **2018**, *25*, 36589–36603. [[CrossRef](#)]
68. Rehman, A.; Rauf, A.; Ahmad, M.; Chandio, A.A.; Deyuan, Z. The effect of carbon dioxide emission and the consumption of electrical energy, fossil fuel energy, and renewable energy, on economic performance: Evidence from Pakistan. *Environ. Sci. Pollut. Res.* **2019**, *26*, 21760–21773. [[CrossRef](#)]
69. Khan, M.K.; Khan, M.I.; Rehan, M. The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. *Financ. Innov.* **2020**, *6*, 1. [[CrossRef](#)]
70. Rehman, A.; Ma, H.; Ozturk, I. Do industrialization, energy importations, and economic progress influence carbon emission in Pakistan. *Environ. Sci. Pollut. Res.* **2021**, *28*, 45840–45852. [[CrossRef](#)]
71. Pesaran, M.H.; Shin, Y.; Smith, R.J. Bounds testing approaches to the analysis of level relationships. *J. Appl. Econom.* **2001**, *16*, 289–326. [[CrossRef](#)]

72. Phillips, P.C.; Perron, P. Testing for a unit root in time series regression. *Biometrika* **1988**, *75*, 335–346. [[CrossRef](#)]
73. Dickey, D.A.; Fuller, W.A. Distribution of the estimators for autoregressive time series with a unit root. *J. Am. Stat. Assoc.* **1979**, *74*, 427–431.
74. Jin, T.; Kim, J. What is better for mitigating carbon emissions—Renewable energy or nuclear energy? A panel data analysis. *Renew. Sustain. Energy Rev.* **2018**, *91*, 464–471. [[CrossRef](#)]
75. Vo, D.H.; Vo, A.T.; Ho, C.M.; Nguyen, H.M. The role of renewable energy, alternative and nuclear energy in mitigating carbon emissions in the CPTPP countries. *Renew. Energy* **2020**, *161*, 278–292. [[CrossRef](#)]
76. Azam, A.; Rafiq, M.; Shafique, M.; Zhang, H.; Yuan, J. Analyzing the effect of natural gas, nuclear energy and renewable energy on GDP and carbon emissions: A multi-variate panel data analysis. *Energy* **2021**, *219*, 119592. [[CrossRef](#)]
77. Rehman, A.; Ma, H.; Ozturk, I.; Ahmad, M.; Rauf, A.; Irfan, M. Another outlook to sector-level energy consumption in Pakistan from dominant energy sources and correlation with economic growth. *Environ. Sci. Pollut. Res.* **2021**, *28*, 33735–33750. [[CrossRef](#)]
78. Tugcu, C.T.; Ozturk, I.; Aslan, A. Renewable and non-renewable energy consumption and economic growth relationship revisited: Evidence from G7 countries. *Energy Econ.* **2012**, *34*, 1942–1950. [[CrossRef](#)]
79. Inglesi-Lotz, R. The impact of renewable energy consumption to economic growth: A panel data application. *Energy Econ.* **2016**, *53*, 58–63. [[CrossRef](#)]
80. Yildirim, E.; Saraç, Ş.; Aslan, A. Energy consumption and economic growth in the USA: Evidence from renewable energy. *Renew. Sustain. Energy Rev.* **2012**, *16*, 6770–6774. [[CrossRef](#)]
81. Ouyang, Y.; Li, P. On the nexus of financial development, economic growth, and energy consumption in China: New perspective from a GMM panel VAR approach. *Energy Econ.* **2018**, *71*, 238–252. [[CrossRef](#)]
82. Ehigiamusoe, K.U.; Lean, H.H. Effects of energy consumption, economic growth, and financial development on carbon emissions: Evidence from heterogeneous income groups. *Environ. Sci. Pollut. Res.* **2019**, *26*, 22611–22624. [[CrossRef](#)]
83. Salahuddin, M.; Alam, K.; Ozturk, I.; Sohag, K. The effects of electricity consumption, economic growth, financial development and foreign direct investment on CO₂ emissions in Kuwait. *Renew. Sustain. Energy Rev.* **2018**, *81*, 2002–2010. [[CrossRef](#)]
84. Ahmad, N.; Du, L.; Lu, J.; Wang, J.; Li, H.Z.; Hashmi, M.Z. Modelling the CO₂ emissions and economic growth in Croatia: Is there any environmental Kuznets curve? *Energy* **2017**, *123*, 164–172. [[CrossRef](#)]
85. Chen, Y.; Wang, Z.; Zhong, Z. CO₂ emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. *Renew. Energy* **2019**, *131*, 208–216. [[CrossRef](#)]
86. Rasoulinezhad, E.; Saboori, B. Panel estimation for renewable and non-renewable energy consumption, economic growth, CO₂ emissions, the composite trade intensity, and financial openness of the commonwealth of independent states. *Environ. Sci. Pollut. Res.* **2018**, *25*, 17354–17370. [[CrossRef](#)] [[PubMed](#)]
87. Siddique, H.M.A.; Majeed, D.M.T.; Ahmad, D.H.K. The impact of urbanization and energy consumption on CO₂ emissions in South Asia. *South Asian Stud.* **2020**, *31*, 745–757.
88. Gao, J.; Zhang, L. Does biomass energy consumption mitigate CO₂ emissions? The role of economic growth and urbanization: Evidence from developing Asia. *J. Asia Pac. Econ.* **2021**, *26*, 96–115. [[CrossRef](#)]