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Urbanization, Economic Development, and Environmental Degradation: Investigating the Role of Renewable Energy Use

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Abstract: The current study explored the impact of renewable energy use, urbanization, economic growth and trade in services on CO_2 emission in Maldives by using annual data series ranging from 1990 to 2020. We have checked the variables influences by utilizing the nonlinear autoregressive distributed lag (NARDL) method with long-run and short-run connections. Findings via long-run and short-run showed that the variables renewable energy use and economic growth has positive and negative coefficients via positive and negative shocks that uncover the constructive and adverse linkage to CO_2 emission in Maldives. Similarly, trade in services showed an adversative and positive connection to CO_2 emission via positive and negative shocks. During the analysis, the variable urbanization uncovered a negative linkage to CO_2 emission. It is imperative that Maldives implement new policies and strategies aimed at reducing CO_2 emission in order to avert the environmental devastation.

Keywords: CO_2 emission; urbanization; energy utilization; environment; trade

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1. Introduction

Global warming and climate change have captured the attention of people all around the world. Over the last two decades, substantial research has been conducted into the relationships between economic growth and carbon dioxide emissions, as well as energy utilization. Economic development has been shown to harm the environment and jeopardize environmental sustainability since it is inextricably tied to energy use. Because fossil fuels are a limited natural resource, cities and economies worldwide are finding it increasingly difficult to grow. As advanced countries continue to urbanize, developing economies are projected to have the largest urbanization expansion. If urbanization is shown to have a large and negative influence on CO_2 emissions, it will be simpler to meet the sustainable development goals (SDGs) [1,2]. Energy consumption in urban areas is likely to be driven by environmentally harmful economic activities based on fossil fuels (i.e., transportation and industrial manufacturing). As a consequence of globalization, significant urban density and urbanization may be projected in the coming years. Many emerging countries are undergoing economic transformations that are expanding the urban population. People relocate from rural to urban areas for a number of reasons, including new housing, family size, changes in industrial structure, distribution of city size, and public infrastructure. More people living in cities increases CO_2 emissions and energy consumption [3,4]. The diversification of the economy caused by urbanization leads to an increase in industrial and household energy consumption. It is seen as a means of transitioning from agriculture to a technological, industrial production sector that is strongly dependent on energy and, as a consequence, releases CO_2 emission [5,6].

The impact of global warming on the economy, population and environment is one of the most pressing concerns of our era. Since the Industrial Revolution, our increased dependence on fossil fuels has worsened both global warming and climate change [7]. It is feasible to connect the rise of urbanization to both economic growth and the structure of that growth. Extensive urbanization, on the other hand, is a relatively recent phenomenon and one of the most sophisticated economic growth processes. Although there is a substantial association between urbanization and economic growth, it is difficult to identify whether economic development drives urbanization or the contrary. Urbanization, on the other hand, may result in an increase in commercial energy use and CO_2 emissions. Urbanization has been related to deteriorating environmental conditions in both developing and advanced economies. In terms of the environment, urbanization has both positive and negative consequences. It is determined by the extent to which urbanization has impacted the environment [8–10]. Energy sufficiency is important to every country's economic development. It is a trump card that improves a country's global standing by improving capital and worker productivity and generating alternative energy sources. Because natural resources are seen as one of the primary drivers of economic growth, empirical study on the relationships between different types of energy and economic development has grown in recent decades. Natural gas, oil, coal, nuclear power, and other kinds of energy are being investigated as potential economic drivers in both developed and emerging economies [11–13].

Several researchers have come to different conclusions on the influence of international trade on CO_2 emissions due to a lack of consensus on the link between foreign trade and CO_2 emissions. Environmental issues have a direct influence on trade patterns, industrial sites, trade gains, international relations, and manufacturing costs. The pollution haven hypothesis is a theory that investigates the relationship between international trade and CO_2 emissions. According to this theory, when nations with severe environmental regulations open their markets to foreign corporations, enterprises in the developed world may now relocate their operations to the developing world. Trade openness has greatly exacerbated already-existing environmental concerns as a consequence of the accompanying increase in global energy use. CO_2 emissions will rise as a result of the growth of international trade, which necessitates the use of technology that emits CO_2 [14–16]. Energy availability is essential to both economic growth and environmental sustainability. To achieve long-term sustainable development, economic growth must first be accelerated. This research investigates the Maldives' use of renewable energy in the context of sustainable growth and development for the first time, making it a novel addition to the literature. In this analysis, time series data were used, and unit root tests were performed to verify stationary properties. To examine the influence of renewable energy usage, economic growth, trade in services, and urbanization on CO_2 emissions, we utilized asymmetric techniques to estimate the long-run and short-run dynamics.

Following the introduction, the remainder of the article is structured as follows: Section 2 is devoted to a review of relevant literature that has already been published on the subject. Detailed discussion of the data and methodology is provided in Section 3, which also includes the model specification for the study. Section 4 provides the study findings and discussion, and Section 5 uncovers a summary of the findings as well as important policy suggestions.

2. Literature Review

Global warming is a severe threat to the health and well-being of people all around the world. Increasing usage of fossil fuels has led in grown global warming, and CO_2 emissions have increased dramatically in recent years [17,18]. The Industrial Revolution offered new economic possibilities, but it also gave rise to the well-known phenomena of global warming and climate change. The Industrial Revolution was one of the most major events in human history, transitioning from an organic economy driven by people and animals to one powered by fossil fuels. Climate change is a direct effect of greenhouse gas emissions to the atmosphere caused by the usage of fossil fuels. Climate change and global warming are occurring as a result of this process [19]. SDGs will be more difficult to achieve if energy and environmental policies do not take into consideration the impact of urbanization on CO_2 emissions. If urbanization is shown to have a negative and statistically significant impact on CO_2 emissions, meeting the Sustainable Development Goals (SDGs) may become easier [20].

CO_2 emissions from fossil fuel burning are widely agreed to be the primary cause of human-induced climate change [21]. Different urbanization processes and mechanisms have a significant impact on urban structures and human behaviour, and hence on energy consumption in both established and emerging economies, as well as within impoverished countries. Rural labour is increasingly concentrated in the city's industrial and service sectors as a consequence of the industrialization process, which benefits economic development. Massive emissions from human activities, especially the usage of fossil fuels, are emerging as a main source of global warming and the possible cause of a global climate crisis. Emerging countries' economic progress indicates that they will generate the majority of the world's future emissions [22–24]. Many people feel that urbanization will help the economy and enhance people's quality of life; however, it also raises our energy demand since it increases our need for more energy. The startling rise in CO_2 emissions over the last three decades may be attributable to urbanization, for experts in the area of climate science have given particular emphasis to the connection between urbanization, economic progress, energy utilization, and CO_2 emissions [25,26].

Carbon emission reductions have emerged as a critical policy goal in the battle against global warming. Environmental policy interaction does not exclude trade-related economic activities and foreign direct investment. The link between environmental quality, economic development, and CO_2 emissions is one of the most contentious issues confronting politicians, researchers, and the many developing economies. It's a complicated link that must be addressed if carbon dioxide emissions are to be reduced. Income increases cause a rise in emissions [27,28]. The quantity of CO_2 released is closely related to a country's total energy consumption and energy mix. Urbanization may have varying effects on both. While urbanization is associated with increased per capita income and landscape changes, it also has the potential to increase world energy consumption. Although looking at cities in isolation might give the impression of efficiency gains due to economies of scale, which is due to use of misleading efficiency metrics rather than absolute GHG emissions along the supply chain. Furthermore, the level of human capital is often associated with urbanization [29,30].

Ecosystems that provide food, water, energy, leisure, and clean air are in danger from human activities. Natural carrying capacity has been surpassed by human use of the earth's resources. As a result of our increasing reliance on water, infrastructure, energy, and food, the environment may be subjected to environmental stressors such as increased emissions and resource depletion. When looking at global warming in a broader perspective, it is important to keep track of the consequences of greenhouse gas emissions, land usage, and deforestation. The ecological footprint may be used to assess environmental sustainability, resource consumption, and management. In addition to being a resource accounting technique, the ecological footprint may be used to assess a country's natural resources [31–33]. Energy consumption is a significant driver of economic growth and development since it is a vital component of the industrial process. People's living standards are often higher in countries with higher levels of energy consumption. However, the use of energy results in the release of GHGs emissions such as CO_2 and SO_2. Despite the fact that energy consumption has been a difficult and sensitive topic among environmental economists and policymakers for the last three decades, economic progress and its connection to

CO_2 emissions remain the most contentious and delicate issues among policymakers and environmental economists [34,35]. Economic development and urbanization, as well as environmental challenges and climate change, have all increased. As a consequence, governments should coordinate their efforts to promote economic development with measures to protect the environment and battle global warming. In a theoretical paradigm that may be summarized as follows, economics and environmental quality are interwoven. Pollution and degradation increase as the economy develops in its early phases. In contrast, when a specific threshold is achieved, further economic development reduces environmental constraints while improving environmental quality [36,37].

The beginning of the Great Industrial Revolution brought about two of the most significant and long-lasting social transformations: urbanization and industrialization. The great desire of economists to seek high economic growth and well-being underpins this connection between urbanization and industrialization. This interdependence, on the other hand, is both an advantage and a burden for both established and developing economies. To counteract this, growing energy consumption in industry and households has resulted in environmentally polluting outputs such as CO_2 emissions and other greenhouse gases. Urbanization and industrialization have major health repercussions, although the benefits of modernity and better living conditions exceed the dangers [38–40]. Growing urbanization has been proved to generate economic progress and enhance people's living standards throughout the globe, but it also has the potential to spark a future energy crisis. Because of the current fossil energy problem, fossil energy is becoming an increasingly scarce natural resource. Furthermore, considerable increases in energy use may accelerate global warming and climate change, two of the most pressing issues confronting our world today [41–43].

Global warming is produced by the release of greenhouse gases, which is also a major concern. Greenhouse gases raise global temperatures by trapping too much heat in the atmosphere. Climate change is caused by both human activities and natural disasters. Burning fossil fuels, releasing extreme pollution from factories, and depleting forests have all contributed to the expansion of greenhouse gas levels in our outer climate, which, in turn, contributes to the phenomenon of global warming by retaining extreme heat inside the environment and increasing global temperatures. When compared to other forms of greenhouse gases, CO_2 emission is the most significant contribution to global warming [44,45]. The concerns have been raised regarding the limited supply of fossil fuels, energy security, and environmental degradation that comes with them. The combustion of fossil fuels is a significant contributor to growing greenhouse gas emissions, which are the principal driver of climate change and global warming. Carbon dioxide emissions may be lowered by using renewable energy. Renewable energy can be promoted to replace fossil fuels in order to achieve sustainable development and safeguard the environment. It will also benefit the economy by generating employment and decreasing dependency on foreign resources by expanding the usage of renewable energy [46,47].

3. Data and Methods

This investigation utilized the nonlinear autoregressive distributed lag (NARDL) technique to demonstrate the impact of renewable energy usage (% of total final energy consumption), urbanization (in numbers), economic growth (annual %), and trade in services (% of GDP) on CO_2 emissions (metric tons per capita) in Maldives. We collected data from the World Bank (https://data.worldbank.org/country/maldives (accessed on 17 May 2022) for all variables from 1990 to 2020. Figure 1 depicts the annual trends of the variables.

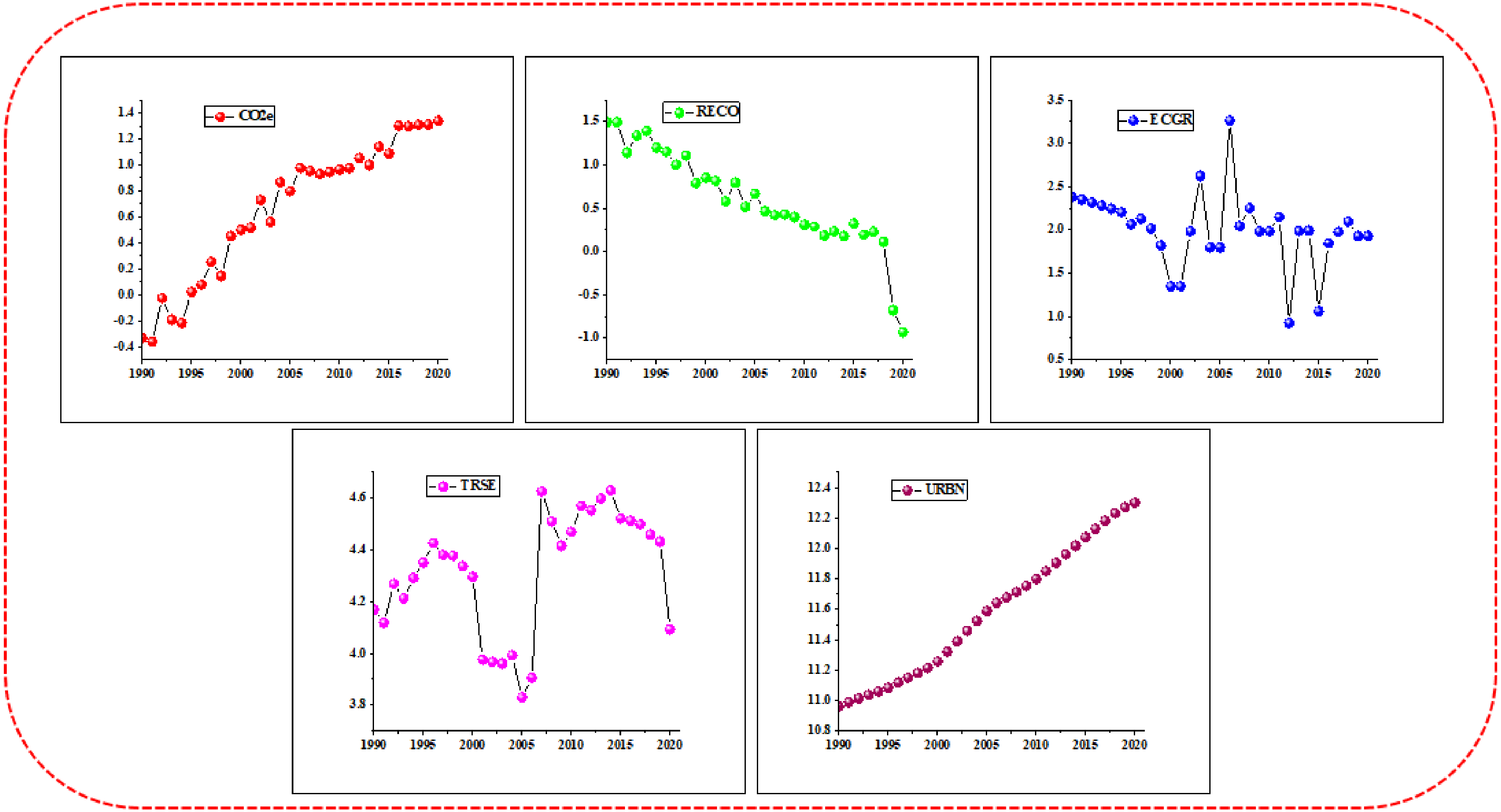

Figure 1. Variables trend (CO2e, RECO, ECGR, TRSE, URBN).

3.1. Specification of the Model

In this exploration, we have estimated the following model to verify the association among CO_2 emission, renewable energy consumption, economic growth, trade in services and urbanization:

$$CO2e_t = f(RECO_t, ECGR_t, TRSE_t, URBN_t) \tag{1}$$

Equation (1) may be rewritten as follows:

$$CO2e_t = \xi_0 + \xi_1 RECO_t + \xi_2 ECGR_t + \xi_3 TRSE_t + \xi_4 URBN_t + \varepsilon_t \tag{2}$$

where, as shown in Equation (2), $CO2e_t$ represents carbon dioxide emissions, $RECO_t$ denotes renewable energy use, $ECGR_t$ indicates economic growth, $TRSE_t$ represents trade in services, and $URBN_t$ symbolizes the urbanization. The time length is calculated via t, and the model coefficients are signified by the ξ_{1}–ξ_4. Furthermore, in the analysis first we will specify the autoregressive distributed lag (ARDL) technique with long-run and short-run which is developed by the Pesaran et al. (2001) [48] to encounter the linkages amid the variables. It is possible to describe the specification of the ARDL model as follows in the direction to encounter the association between variables:

$$\begin{aligned}\Delta CO2e_t = \beta_0 &+ \sum_{e=1}^{1} \lambda_e \Delta CO2e_{t-e} + \sum_{e=0}^{1} \gamma_e \Delta RECO_{t-e} + \sum_{e=0}^{1} \vartheta_e \Delta ECGR_{t-e} + \sum_{e=0}^{1} \tau_e \Delta TRSE_{t-e} + \sum_{e=0}^{1} \varphi_e \Delta URBN_{t-e} \\ &+ \vartheta_1 CO2e_{t-1} + \vartheta_2 RECO_{t-1} + \vartheta_3 ECGR_{t-1} + \vartheta_4 TRSE_{t-1} + \vartheta_5 URBN_{t-1} + \varepsilon_t\end{aligned} \tag{3}$$

When utilizing this approach, Equation (3) offers the dynamic connection for the specified variables.

3.2. Asymmetric Technique

It is more altered to measuring certain important factors in small samples than most traditional methods and has a positive effect on participants. When certain effects of long-term parameter combinations are expected, the F-test, according to Pesaran et al. (2001), may be used to verify predictions over the longer period. Long-term elasticities are computed using ϑ_2–ϑ_5 and then regularised by using ϑ_1 after cointegration is verified. In order to decompose the variables renewable energy usage, economic growth and trade in services, study will use the method of Shin et al. (2014) [49] with taking the positive and negative shocks ($RECO^{+}{}_{m}$; $ECGR^{+}{}_{m}$; $TRSE^{+}{}_{m}$); ($RECO^{-}{}_{m}$; $ECGR^{-}{}_{m}$; $TRSE^{-}{}_{m}$) can be demonstrated as:

$$RECO^{+}{}_{m} = \sum_{a=1}^{m} \Delta RECO^{+}{}_{m} = \sum_{a=1}^{m} \max\left(\Delta RECO^{+}{}_{m}, 0\right) \tag{4}$$

$$RECO^{-}{}_{m} = \sum_{a=1}^{m} \Delta RECO^{-}{}_{m} = \sum_{a=1}^{m} \min\left(\Delta RECO^{-}{}_{m}, 0\right) \tag{5}$$

$$ECGR^{+}{}_{m} = \sum_{a=1}^{m} \Delta ECGR^{+}{}_{m} = \sum_{a=1}^{m} \max\left(\Delta ECGR^{+}{}_{m}, 0\right) \tag{6}$$

$$ECGR^{-}{}_{m} = \sum_{a=1}^{m} \Delta ECGR^{-}{}_{m} = \sum_{a=1}^{m} \min\left(\Delta ECGR^{-}{}_{m}, 0\right) \tag{7}$$

$$TRSE^{+}{}_{m} = \sum_{g=1}^{m} \Delta TRSE^{+}{}_{m} = \sum_{g=1}^{m} \max\left(\Delta TRSE^{+}{}_{m}, 0\right) \tag{8}$$

$$TRSE^{-}{}_{m} = \sum_{m=1}^{m} \Delta TRSE^{-}{}_{m} = \sum_{m=1}^{m} \min\left(\Delta TRSE^{-}{}_{m}, 0\right) \tag{9}$$

By following Equations (4)–(9), the positive and negative shocks for the variables can be demonstrated as:

$$\Delta CO2e_t = \theta_0 + \sum_{y=1}^{P}\tau_y \Delta CO2e_{t-y} + \sum_{y=0}^{P}\lambda_y \Delta RECO^{+}{}_{t-y} + \sum_{y=0}^{P}\omega_y \Delta RECO^{-}{}_{t-y} + \sum_{y=0}^{P}\beta_y \Delta ECGR^{+}{}_{t-y} + \sum_{y=0}^{P}\psi_y \Delta ECGR^{-}{}_{t-y} + \sum_{y=0}^{P}\delta_y \Delta TRSE^{+}{}_{t-y} + \sum_{y=0}^{P}\omega_y \Delta TRSE^{-}{}_{t-y} + \pi_1 CO2e_{i-1} + \pi_2 RECO^{+}{}_{i-1} + \pi_3 RECO^{-}{}_{i-1} + \pi_4 ECGR^{+}{}_{i-1} + \pi_5 ECGR^{-}{}_{i-1} + \pi_6 TRSE^{+}{}_{i-1} + \pi_7 TRSE^{-}{}_{i-1} + \varepsilon_t \quad (10)$$

The asymmetrical shocks for the variables renewable energy consumption, economic growth, and trade in services are explored in Equation (10). Further, the representation of error correction model (ECM) can be exhibited as:

$$\Delta CO2e_t = \theta_0 + \sum_{y=1}^{P}\tau_y \Delta CO2e_{t-y} + \sum_{y=0}^{P}\lambda_y \Delta RECO^{+}{}_{t-y} + \sum_{y=0}^{P}\omega_y \Delta RECO^{-}{}_{t-y} + \sum_{y=0}^{P}\beta_y \Delta ECGR^{+}{}_{t-y} + \sum_{y=0}^{P}\psi_y \Delta ECGR^{-}{}_{t-y} + \sum_{y=0}^{P}\delta_y \Delta TRSE^{+}{}_{t-y} + \sum_{y=0}^{P}\omega_y \Delta TRSE^{-}{}_{t-y} + \pi_1 CO2e_{i-1} + \pi_2 RECO^{+}{}_{i-1} + \pi_3 RECO^{-}{}_{i-1} + \pi_4 ECGR^{+}{}_{i-1} + \pi_5 ECGR^{-}{}_{i-1} + \pi_6 TRSE^{+}{}_{i-1} + \pi_7 TRSE^{-}{}_{i-1} + \varphi ECM_{t-1} + \varepsilon_t \quad (11)$$

The positive and negative shocks among variables with error correction model are reported in Equation (11).

4. Study Findings and Discussion

Tables 1 and 2 demonstrate the outcomes of the summary statistics and correlations for the variables. Other than that, we discovered that all of the variables were comparable. Based on the statistical significance of the Jarque–Bera statistic for the various study variables, no semi-distribution concerns were detected. A correlation analysis revealed a significant connection between the responding variable and the explanatory variable. The NARDL analysis may be utilized when a model variable integrates across levels, at the first difference, or a combination of the two; however, this analysis cannot be used when a model variable integrates at the second difference.

Table 1. Descriptive analysis for the variables.

	CO2e	**RECO**	**ECGR**	**TRSE**	**URBN**
Mean	0.657	0.596	2.003	4.314	11.576
Median	0.866	0.514	1.991	4.377	11.588
Maximum	1.339	1.494	3.262	4.630	12.300
Minimum	−0.361	−0.932	0.923	3.830	10.962
Std. Dev.	0.538	0.569	0.435	0.233	0.437
Skew.	−0.526	−0.549	−0.110	−0.552	0.150
Kurt.	1.988	3.508	5.028	2.119	1.672
Jarque-Bera	2.755	1.893	5.376	2.575	2.392
Probability	0.252	0.387	0.067	0.275	0.302

Table 2. Correlation amid variables.

	CO2e	**RECO**	**ECGR**	**TRSE**	**URBN**
CO2e	1.000	−0.919	−0.283	0.299	0.950
RECO	−0.919	1.000	0.256	−0.257	−0.927
ECGR	−0.283	0.256	1.000	−0.283	−0.265
TRSE	0.299	−0.257	−0.283	1.000	0.391
URBN	0.950	−0.927	−0.265	0.391	1.000

4.1. Unit Root Testing

This study employed unit root testing to monitor variables over a long period of time. The results of the unit root testing are shown in Table 3. Two unit root techniques, Dickey–Fuller (DF-GLS) and Philips–Perron (PP), were used to evaluate the order of integration for each variable [50,51]. The test statistics and variable probability values reveal a stationary trend for a series. One step of the integral adjustment at leads the model's variables to transition from non-stationary to stationary I(1). The variables are presumed to be stationary and cannot be removed sequentially based on a stationarity measurement.

Table 3. Unit root testing results.

			[DF-GLS Tests (at the Level)]		
	CO2e	**RECO**	**ECGR**	**TRSE**	**URBN**
Test statistics and *p*-values	−0.741 (0.467)	0.828 (0.414)	−4.457 (0.000)	−2.000 (0.054)	−2.061 (0.057)
			[At the first difference]		
Test statistics and *p*-values	−2.588 (0.016)	−2.312 (0.032)	−7.703 (0.000)	−4.830 (0.000)	−2.152 (0.040)
			[P-P test (at the level)]		
Test statistics and *p*-values	−1.830 (0.359)	0.374 (0.978)	−4.715 (0.000)	−2.031 (0.051)	2.318 (0.164)
			[At the first difference]		
Test statistics and *p*-values	−10.965 (0.000)	−6.259 (0.000)	−8.296 (0.000)	−4.997 (0.000)	−1.429 (0.027)

4.2. Bounds Testing with Cointegration

The NARDL method was utilized in this investigation to expose the connection among the research variables, which included CO_2 emission, renewable energy usage, trade in services and urbanization. To complete the bounds testing to the cointegration evaluation, the AIC (Akaike Information Criterion) demands that the F-statistic be determined in a sufficient period of time. Statistics such as the F-statistic provide statistically significant results, as seen in Table 4.

Table 4. Bounds testing to cointegration outcomes.

		N-Hypothesis: Founds No Levels Relationship		
		Significance Level	**I(0)**	**I(1)**
F-statistic	4.777	10%	1.92	2.89
K	7	5%	2.17	3.21
		2.5%	2.43	3.51
		1%	2.73	3.9

As with the usage of bounds testing approach, we have also utilized the Johansen cointegration test [52] in preparation to confront the variables' resilience. Table 5 displays the outcomes of trace statics and max-eigenvalue with 0.05 critical levels.

Table 5. Johansen cointegration test outcomes.

		Trace Test		
H-No. of CE(s)	Eigen-Values	T-Statistics	0.05 C-Value	*p*-Values **
None *	0.727	91.457	69.818	0.000
At most 1 *	0.700	53.748	47.856	0.012
At most 2	0.304	18.787	29.797	0.508

Table 5. *Cont.*

Trace Test				
At most 3	0.220	8.244	15.494	0.439
At most 4	0.035	1.033	3.841	0.309
Maximum Eigenvalue				
H-No. of CE(s)	Eigen-Values	M-Eigen Statistics	0.05 C-Value	*p*-Values **
None *	0.727	37.709	33.876	0.016
At most 1 *	0.700	34.960	27.584	0.004
At most 2	0.304	10.543	21.131	0.692
At most 3	0.220	7.2104	14.264	0.464
At most 4	0.035	1.033	3.841	0.309

Note: * indicates hypothesis denial at 0.05 level; ** show the probability values of MacKinnon-Haug-Michelis (1999).

4.3. Long-Run and Short-Run Consequences

Table 6 is uncovering the results of the asymmetric analysis for the CO_2 emission, renewable energy usage, economic growth, trade in services and urbanization. The results of the short-run (Panel A) determine that renewable energy usage and economic growth has coefficients (0.348), (−0.227), (0.047), and (−0.070) with prob. values (0.026), (0.068), (0.410), and (0.283) that demonstrate the constructive and adversative interaction with CO_2 emission through positive and negative shocks. Trade in services has coefficients (−0.096) and (0.195) with prob. values (0.458) and (0.016), showing the productive and negative relation with CO_2 emission via positive and negative shocks. Further, urbanization has negative coefficient during short-run analysis with coefficient (−0.481) with probability value (0.457) that exposed the negative interaction with CO_2 emission in Maldives.

Similarly, the outcomes of the long-run (Panel B) show that the variables renewable energy use and economic growth has positive and negative coefficients (0.625), (−0.408), (0.086), (−0.126) with prob. values (0.040), (0.071), (0.447), (0.344), respectively, that exposed the productive and adversative connection to the CO_2 emission. Further, the variable trade in services has negative and positive coefficients (−0.173), (0.350) with prob. values (0.516), (0.049) showed an adversative and positive connection to CO_2 emission. The variable urbanization exposed a negative linkage to CO_2 emission having coefficient (−0.864) with prob. value (0.479).

To minimise greenhouse gas emissions and other pollutants, renewable energy is generally recognised. Renewable energy has great theoretical potential to reduce emissions, but the expense of shifting to renewable energy technology is a significant impediment to state regulation. The energy intensity of the technology in this sector is also viewed as a significant aspect in the battle against pollution and climate change, in addition to the usage of renewable energy [53,54]. The intermittency of production and the real rise in energy usage is a basic difficulty for power networks that employ a significant amount of renewable energy. To build a sustainable socioeconomic system, the usage of fossil fuels must be phased out in favour of renewable types of energy. Renewable energy unpredictability has become a big concern when it comes to strengthening power infrastructure. Renewable energy sources have progressively grown their role to meeting social and economic energy demands. Carbon dioxide emissions have reduced as the share of renewable energy in power generation has grown owing to environmental constraints, technological and economic challenges, or social ramifications [55,56].

In developed and developing economies, globalization, and economic trends, urbanization has a substantial impact on the growth of energy usage, human life, and the environment [57]. Economic development and environmental degradation are becoming more intertwined issues for countries. In the current debates over environmental preservation and sustainable development, CO_2 emissions are being closely monitored. Urbanization and industrialization, the primary ways of modernizing the economy and society, grew throughout this age of technological and productivity advancement. Industrial expansion has damaged the atmosphere as a consequence of over-exploitation of the world's primary energy sources, and CO_2 emissions are the primary driver of anthropogenic climate change. A stable climate requires stable levels of greenhouse gases, but the widespread use of nonrenewable fossil fuels has altered atmospheric carbon levels, rendering it incapable of sustaining the heat that causes global warming and climate change on the earth's surface [58–61]. A significant reliance on fossil fuels such as oil, coal, and natural gas is contributing to a lack of economic advancement in many developing countries by causing a range of problems. The burning of fossil fuels, which has spurred productivity increase, has had a severe influence on the ecosystem and natural life in this area [62].

Table 6. Asymmetrical outcomes (long-run and short-run).

Short-Run Results (Panel A)				
Variables	Coefficients	S-Error	*t*-Stat.	Prob.
C	5.137	6.943	0.739	0.468
CO2e(−1)	−0.556	0.186	−2.977	0.008
RECO_POS(−1)	0.348	0.278	1.253	0.026
RECO_NEG	−0.227	0.117	−1.936	0.068
ECGR_POS	0.047	0.056	0.842	0.410
ECGR_NEG	−0.070	0.063	−1.104	0.283
TRSE_POS	−0.096	0.127	−0.758	0.458
TRSE_NEG	0.195	0.189	1.029	0.016
URBN(−1)	−0.481	0.633	−0.759	0.457
D(RECO_POS)	−1.020	0.384	−2.653	0.016
D(URBN)	5.362	1.684	3.184	0.005
CointEq(−1)	−0.556	0.070	−7.880	0.000
Long-Run Results (Panel B)				
RECO_POS	0.625	0.406	1.540	0.040
RECO_NEG	−0.408	0.213	−1.917	0.071
ECGR_POS	0.086	0.110	0.776	0.447
ECGR_NEG	−0.126	0.130	−0.970	0.344
TRSE_POS	−0.173	0.263	−0.661	0.516
TRSE_NEG	0.350	0.364	0.959	0.049
URBN	−0.864	1.197	−0.721	0.479
C	9.226	13.151	0.701	0.491

R^2—(0.985). Adj-R^2—(0.977). Prob(F-statistic)—(0.000). Durbin-Watson stat—(2.124). Log likelihood—(41.742). F-statistic—(121.387).

Unemployment has decreased dramatically over the world as a result of enormous economic improvement in recent decades. Despite all of this success, there remain questions about the trajectory's long-term sustainability. The increased competition for economic development in key developing countries is projected to increase energy consumption [63,64]. The availability of energy is critical to human and industrial existence. In some ways, the economic well-being and sustainability of modern civilizations are dependent on a stable, abundant, and conveniently accessible energy supply. Economic development has no influence on it here. Furthermore, energy is essential to a country's capacity to establish and maintain an economy [65,66]. Energy development and commercialization in transition economies should prioritize environmental sustainability and environmental improvement. The goal of balancing social, economic, and viable settings to fulfill present demands may therefore be realized without jeopardizing the ability of the next generation to meet its own needs via negotiations. Renewable energy sources that are environmentally friendly are becoming increasingly significant in the economies of many economies. It is because the large-scale use of renewable energy sources is cost-effective and reduces rivalry with non-renewable fossil fuel energy sources [67–69]. Globally, experts and governments are paying particular attention to the rise in greenhouse gas emissions. The principal cause of rising greenhouse gas emissions is the burning of fossil fuels, particularly in emerging economies. If greater investment is made in technology, people should be encouraged to import new technologies to reduce carbon emissions. Governments should also establish suitable policies to encourage the development of renewable energy and innovative methods of mitigating environmental damage [70,71]. The statistical values of R^2, Adj-R^2, F-statistic and Durbin–Watson stat are (0.985), (0.977), (121.387) and (2.124). Furthermore, Figure 2 explores the multipliers shocks of renewable energy usage, economic growth, and trade in services.

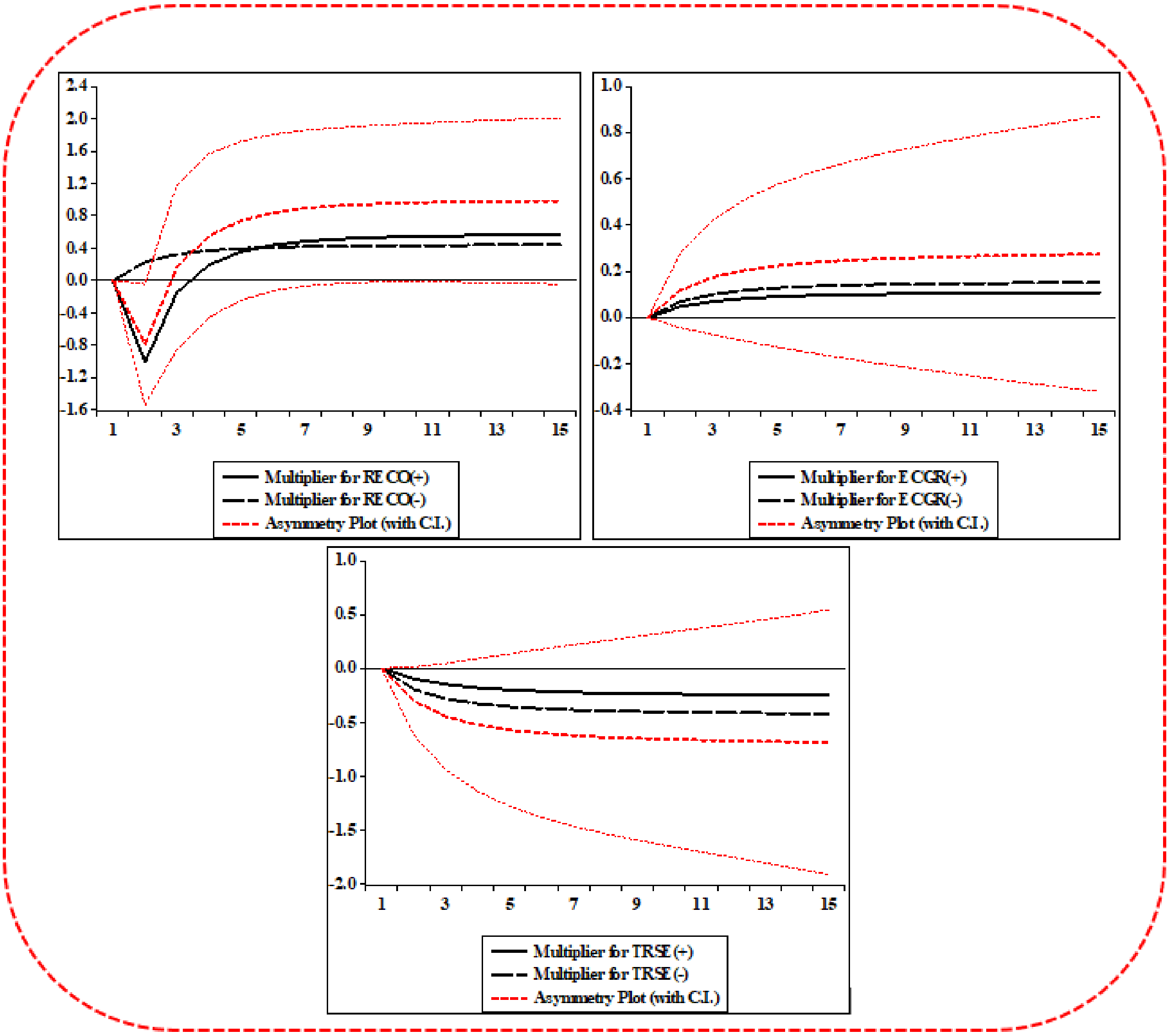

Figure 2. Multiplier positive and negative shocks of RECO, ECGR, and TRSE.

5. Conclusions and Policy Implications

In this analysis, we used yearly data from 1990 to 2020 to examine the influence of renewable energy consumption, economic growth, trade in services and urbanization on CO_2 emission in the Maldives. We have checked the variables influences by utilizing the NARDL technique with long-run and short-run connection. The study outcomes indicate that via long-run and short-run that the variables renewable energy usage and economic growth has positive and negative coefficients via positive and negative shocks that show the constructive and adverse linkage to CO_2 emission in Maldives. Similarly, trade in services showed an adversative and positive connection to CO_2 emission via positive and negative shocks. The variable urbanization exposed a negative linkage to CO_2 emission. To reduce CO_2 emissions in the Maldives, new policies and initiatives must be implemented.

Consequently, new policies and measures for lowering CO_2 emissions from the Maldives must be implemented in order to prevent environmental degradation. Global warming has resulted in climatic changes, which is wreaking havoc on the planet at an alarming rate. The Maldivian government is aware of the need to reduce emissions. Solar energy has the potential to help combat global warming, reduce the reliance on imported oil, and, most importantly, reduce energy costs. Rather than waiting for the rest of the world, it is time for the Maldives to take action on climate change immediately. The Maldivian government has begun modernizing its dispersed, inefficient, and carbon-based power generating capacity as part of its efforts to achieve carbon neutrality and reduce the threat of climate change. While the Maldives recognizes that enhanced regulation, renewable energy, and energy efficiency technologies are needed for the island economy, it lacks the skills to build an effective regulatory framework and encourage investment in these technologies. The government lays a great focus on setting and achieving targets in order to reduce CO_2 emissions and increase the use of alternative fuels. This study, which tackles the environmental repercussions of renewable energy use, urbanization, and CO_2 emissions, serves as a foundation for future research and has no limitations.

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