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Investigating the Impact of Transport Services and Renewable Energy on Macro-Economic and Environmental Indicators

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A global shift toward renewable energy has proved to be a major constituent in drifting toward climate change. Given the context, the present research study focuses on the nexus between renewable energy, transport services, and performance on economic and environmental fronts. The study has employed an ARDL time series approach to test the effects of hypothesized relationships for the period from 1989 to 2020. The results of the study divulge that the consumption of RE is inversely and significantly coupled with the economic and environmental performance indicators, validating the notion that Romania has emerged as a leading renewable energy user. Foreign direct investment inflows in Romania are significantly and positively associated with the economic and environmental performance indicators. However, the impact of foreign direct investment inflows tends to be smaller than that of the forest area and renewable energy. All the exogenous variables appear to affect the economic and environmental performance indicators significantly in the short run. Furthermore, the forest area is negatively linked with the economic and environmental performance indicators in the Romanian economy. Based on the outcomes of the research, policy prescriptions are suggested to safeguard against environmental degradation and support growth in the much-needed forest resources.

Keywords: renewable energy, forest resources, transport services, foreign direct investment, economic growth

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1 INTRODUCTION

Renewable energy (RE) directly impacts the growth of an economy (Bhattacharya et al., 2016), while the role of transport services cannot be overlooked either. Both components are equally critical in sustainable production and distribution of goods and services and also for sustainable economic growth. The global population is growing enormously, leading to a surge in demand for energy resource usage which has become a serious cause of concern for health experts, environmentalists, state authorities, and other stakeholders as these energy resources have been among the major sources of growth in pollution, environmental degradation, and health hazards (Abbasi and Riaz, 2016; Zhang et al., 2018; Li et al., 2019; Mardani et al., 2019; Amin et al., 2020a; Adedoyin et al., 2020; Ding et al., 2020; Shayanmehr et al., 2020; Amin and Dogan, 2021; Piłatowska and Geise, 2021). The transportation sector is considered a major contributor to globalization by facilitating the flow of trade, financial resources, and human power among various regions and economies (Amin et al., 2020b; Umar et al., 2021). Energy sources have abundant usage in the transport sector over the globe and as such cause huge levels of CO_2 emissions (Bai et al., 2018; Ali et al., 2019; Engo, 2019; Marousek et al., 2019; Solaymani, 2019; Giannakis et al., 2020; Liu et al., 2020; Saidi and Omri, 2020; Tiwari et al., 2020). While the environmental degradation caused by the transport sector significantly contributes to climate change and becomes an increasing threat to global warming, it becomes necessary to draw the attention of policymakers toward a sustainable zero-emission transportation system (Ozkan et al., 2019). In this regard, the most effective way to safeguard the environment is to use renewable energy sources (Sharif et al., 2019). The researchers mostly studied non-renewable energy/aggregate energy consumption (for instance, Saboori et al., 2014; Shafiei and Salim, 2014; Yin et al., 2015; Alshehrya and Belloumia, 2016; Danish et al., 2018; Fan et al., 2018; Nasreen et al., 2018; Bekun et al., 2019; Chen et al., 2019; Nathaniel and Iheonu, 2019; Peng and Wu, 2019; Sharif et al., 2019; Gkisakis et al., 2020; Koengkan et al., 2020; Suwanmanee et al., 2020; Anwar et al., 2021; Khan et al., 2021a; Khan et al., 2021b; Khan et al., 2022), but the RE-transportation-CO-economic growth nexus has not been empirically investigated. It is empirically reported that CO_2 emissions can be reduced if renewable/clean energy is produced with sustainability (Danish et al., 2017; Pata, 2018; Marousek et al., 2019; Tiwari et al., 2020; Khan et al., 2021c); biodiesel mitigates carbon emission levels Quirin et al.,(2004), and it mitigates about 75% of CO_2 in comparison with petroleum diesel. The woods and natural gasses produce methanol, which significantly contributes to decreased CO_2 emissions by about 60% compared to petroleum-based substances (Aßmann and Sieber, 2005; Yu et al., 2021a; Khan et al., 2021d). Few researchers suggested that CO_2 emissions from the transport sector can be reduced by using alternative fuels and utilizing the alternative modes of transportation (Robertson, 2016; Fotis and Polemis, 2018; Sharif et al., 2019). A roadmap comprising 40 concrete initiatives to reduce CO_2 emissions by about 60% by the end of 2050 has been launched by the European Commission in order

- to enhance social stability;
- to enhance economic development;
- to establish a sustainable transport system;
- to promote employment opportunities;
- to eliminate the intercity barriers; and
- to improve resource mobility.

This study adds to previous studies' literature examining the RE-transportation-CO-economic growth nexus in the Romanian context from 1989 to 2020 employing the autoregressive distributed lag (ARDL) time series technique.

The study has a dual dimension of contributions. First, it focuses on the Romanian economy, which is located at the crossroads of Central, Eastern, and Southeastern Europe. It is an economy with high-income levels, and by nominal GDP standards, it stands as the 45th largest economy globally (IMF, 2019). The Romanian economy is predominantly based on services, has a more significant attraction for tourism, and produces and exports machines and electrical energy equipment. Given this background, the Romanian economy is an important choice for research examining the nexuses of renewable energy, transport services, and performance on economic and environmental fronts. Second, the study contributes to the methodological dimension whereby the autoregressive distributed lag (ARDL) time series approach was adopted to test the effects of different hypothesized relationships over 22 years. ARDL is a version of the OLS model that is suitable for the time series variables with a mixed order of integration (Pesaran and Shin, 1995). The ARDL-bound testing approach was chosen due to some advantages. First, the estimates acquired from ARDL are unbiased and give consistent and efficient results when the sample is small (Akinwale, 2020). Second, ARDL is appropriate when the variables are stationary at the level of l I (0) or the first difference I (1). Still, it cannot be used when the variables are stationary at the second difference I (2) (Pesaran and Shin, 1995). Third, when applying the ARDL technique, the dynamic unrestricted error correction model (UECM) can be developed by a simple linear transformation from the ARDL-bound testing at once (Saudi et al., 2019).

The main motive behind the study is to observe the vibrant links across environmental vis-à-vis economic factors in the Romanian economy. The study applies the autoregressive distributed lag (ARDL) time series approach of Pesaran and Pesaran (1997) and Pesaran et al. (2001) to achieve the following objectives:

1) To explore the impact of forest areas on the performance of economic and environmental indicators.
2) To assess the impact of FDI on the performance of economic and environmental indicators.
3) To re-investigate the impact of RE on the performance of economic and environmental indicators.
4) To assess the effect of trade on the performance of economic and environmental indicators.
5) To assess the impact of the transport service sector on the performance of economic and environmental indicators.

This study provides contemporary insights on the determinants of Romanian environment degradation to achieve sustainable development goals (SDGs). It is significant to study from the Romanian perspective by establishing the nexus between renewable energy, forest area, transportation services, FDI, and trade. Romania has the challenge to achieve the renewable energy usage target of 30.7% by 2030 from the current contribution of 24% of the total energy, although the European Commission recommends a target of 34% by arguing that Romania has a great unused renewable energy potential.

Following is given the sequence of the remaining discussion: **Section 2** reflects upon a brief debate in the form of a literature review. The next component is methodology covered in **Section 3**, while **Section 4** covers the findings of output through the discussion of empirical simulations. The final and fifth section concludes this study with a plan for future research.

2 LITERATURE REVIEW

A wide range of literature studies are available to assess the causal relationship between RE and transport services across both macro-economic and environmental indicators globally to understand the academic and empirical strands of research. The dependence of macro-economic and environmental performance on RE and transport services seems to be of vital importance. Various scientific investigations have been performed to measure the impact of renewable vis-à-vis non-RE and transport services in different regions of the globe. The empirical studies have generated mixed and diverging results on regional differences, methodological contrasts, and theoretical probes.

Zeiger et al. (2019) attempted to develop an evaluation framework to gauge the success of efforts toward achieving environmental goals in the context of the sustainable development issues using Germany as a case study. They have evaluated the dual facets of environmental performance: the quality of the ecological planning system (EPS) and environmental outcomes (EOs), which appears to be a novel idea. Given the ease and transparency of methodology, the study was able to identify the strengths and weaknesses of a country's environmental performance. Since there is a need for further improvement, the present study, among other things, comes up with a wide-ranging and dependable approach to evaluating the environmental performance of an economy. Although the study is notable in terms of its novelty, the results can be further improved by expanding the relevance to a larger sample of countries at similar stages of development and enriching the social and economic dimensions of sustainability.

Xu et al. (2019) made a noteworthy contribution to energy sources and environmental pollution from a regional vis-à-vis national perspective of the Chinese economy. It is comprehensive in its scope and coverage as it provides a panel data analysis of 30 provinces from 1997 to 2015. Their findings reveal that controlling fossil fuel–based CO-based emissions is essential for sustainable development because of their environmental outcomes, support to the EKC hypothesis regarding CO-based emissions in China, and revelation that the growing use of coal and petroleum consumption significantly stimulates CO_2 emissions. The study offers practical policy implications for the fossil fuel–based economies that how a country like China needs to develop and use the alternative sources of energy, alter the energy consumption pattern, and successfully cope with the CO-based emissions for the country in question to be on the trajectory of sustainable development.

Faridi et al. (2018) explored the relationship between EG, urbanization, and poverty with environmental damage in Pakistan using a time series data ranging from 1972 to 2015 by employing a co-integration technique. It was observed through the analysis that EG and urbanization drives require an extensive use of energy and many other natural resources causing damage to the natural environment. The release of carbon dioxide was considered the leading source of greenhouse gas emissions, resulting from the EKC hypothesis. The ecological modernization theory proved to be valid in a developing country like Pakistan. It was further suggested that environmental-friendly tools could be used for EG, and urban facilities could be provided to the public as these are not harmful to the environment. Moreover, the study also proposes that the government rely on alternative sources of energy, for example, solar energy, being abundant in the country. Danish et al. (2019), Vargas-Hernández and López-Lemus (2021), and Shah et al. (2022) also extend some practical policy implications to achieve sustainable development goals for BRICS and the countries at a similar stage of development.

Shabir et al. (2021) studied the relationship between RE sources and EG in Sri Lanka, Pakistan, Nepal, India, Maldives, Bhutan, Bangladesh, and Afghanistan using data covering from 1995 to 2018. The study employed the fixed-effect and panel vector error correction models using geothermal, wind, and hydropower as RE sources. The study reveals that hydroelectricity is insignificantly related to sustainable EG while the other two means of RE sources impact EG directly and significantly. The study provided policy guidelines for SAARC and other countries having similar economic situations. The authors suggested that RE sources should be promoted through tax reduction and subsidies. Moreover, the use of RE eases the pressure on policymakers to improve the environment and enhance economic opportunities because these sources are environmentally friendly and promote growth.

Vargas-Hernández and López-Lemus (2021) have recently examined the effects of international trade, renewable energy, FDI, and tourism on CO-based emissions for a large sample of developed countries of Europe and developing countries of Asia Pacific employing panel data analysis from 2000 to 2020. Using the system GMM, fully modified OLS, and dynamic OLS models, they discovered that tourism is positively associated with carbon discharge. However, the REC plays an essential role in increased carbon releases. Models like FMOLS and DOLS were preferred to the OLS model for deriving unbiased results. The findings of the research allude to various policy implications across developed and developing countries over the globe. Governments need to fetch much more FDI to improve the legal framework and boost the tourism sector. Business-related expenses should be restricted to promote the travel and tourism industry. The role of RE policies surfaces out to be an important area to improve the ecological balance in various parts of the world.

Basar and Tosun (2021) examined the relationship between EG and environmental pollution in 28 OECD economies from 1995 to 2015. Over and above its contribution to literature, their research positively contributes to enhancing the consciousness of the environmental pollution risk essential for sustainable development. The study suggests that environmental concerns need to be addressed while formulating economic policies since pollution has emerged as a threat to financial stability vis-à-vis efficient resource utilization. Both the states and governments ought to devise policies so that neither EG nor environmental concerns are compromised. They suggest that balanced policies and global cooperation among countries are a *sine qua non* in this regard.

Balsalobre-Lorente et al. (2021) and Gbadegesin and Olayide (2021) analyzed the asymmetric impact of air transport on EG in

Spain using the data from 1970 to 2015 and using an asymmetric ARDL approach. The effects of RE and urbanization on EG were also deliberated, revealing that air transportation, urbanization, and social globalization were positively related to EG, while RE appeared to be negatively associated with EG. The study suggested that the government shift from non-RE sources to RE as a fossil fuel use causes air pollution and health hazards. The study also leads to environmental implications for the tourism-growth economy induced by the non-renewable, green, and clean energy sources.

Qingquan et al. (2021) and Khan et al. (2021e) presented an unprecedented standpoint on environmental economics research by associating carbon dioxide–based emissions and monetary policies. Using a novel analytical framework, they analyzed the impact of economic policies on CO_2-based emissions coupled with control variables, that is, fossil fuels, urbanization, income, remittances, and human capital for selected Asian economies throughout 1990–2014. Data analysis was based on the co-integration tests of Pedroni (1999), Pedroni (2004), and Kao and Chiang (1999) vis-à-vis a panel fully modified (PFM-LS) and panel dynamic least square (PD-LS) techniques. The results of the study revealed a significant long-term positive association between loose monetary policy and CO_2-based emissions. On the contrary, a tight monetary policy appeared to work as a compelling recipe to attenuate the CO_2-based emissions and releases. Likewise, fossil fuels and remittances surfaced as the key predictor of CO_2-based emissions, also magnifying the positive impact of the human capital on reducing CO_2-based emissions. The study tends to offer some helpful policy connotations to develop effective policies for controlling the reducing CO_2-based emissions. It also underlines the opportunities for future research both on theoretical and methodological fronts.

Li et al. (2021) studied the relationship between RE sources and EG in Sri Lanka, Pakistan, Nepal, India, Maldives, Bhutan, Bangladesh, and Afghanistan using data covering from 1995 to 2018 taking geothermal, wind, and hydropower as the major three of the largest RE sources. The results demonstrate a significantly positive impact of all three renewable sources of energy on the economic development of countries in the sample. However, the effects of hydropower RE tend to excel the influences upon EG than those upon RE alternatives, that is, geothermal and wind. The study alludes to promoting alternate energy sources through governments' intervention in the SAARC countries by offering incentive-based schemes like tax rebates and subsidies to the business entities.

Amir et al. (2021) found significant relationships between environmental degradation and economic growth along with an increase in tourism demand in Pakistan over the period from 1995 to 2020. Their study prefers to apply the ARDL and causality research methods based on the unit root and other tests concluding that tourism demand negatively impacts the environment; however, it positively impacts Pakistan's economic growth. Furthermore, they find a uni-directional relationship between tourism demand and environmental degradation in both the short and long run. Bekun et al. (2021) find significant relationships between tourism, CO_2, and real income nexus in E-7 states from 1995 to 2016. They used different econometric techniques to test the environmental Kuznets curve (EKC) theory in the E-7 economies. The tests of causality analysis, CCEMG, and Driscoll–Kraay revealed that the consumption levels of energy in tourism and transport industries have significant impacts on global climate change.

Can et al. (2022) studied the OECD regional economies by focusing on the green products to test how green products minimize environmental degradation for the OECD and report that the climate changes are mostly driven by environmental degradation. The novelty of the aforementioned research work is the development of the green trade openness index to measure the role of green products to promote the open trade environment among OECD countries from 2007 to 2017. They applied the FMOLS and DOLS techniques. They observed that the green product index reduces the ecological footprint eventually and that the increase in energy consumption causes to increase the carbon emission. The green openness among the OECD countries reduces the significant negative impact on the environment, but the green product index is insignificant in the short run.

Mehmood and Mansoor (2021) studied the impacts of urbanization in the East Asian and Pacific economies on carbon emission. Their study concerns the sample period from 1980 to 2014. Their study concerns the other variables economic growth, and trade openness to test the nexus between carbon emission levels and urbanization. They applied the ARDL method to test the hypotheses. The sample countries are promoting renewable energies in their urban area which leads to a decrease in the emission of CO_2 in the sampled regions. They observed interesting results. In China, they found that urbanization negatively impacts carbon emission levels, but it is reverted in Singapore, Japan, and South Korea. Lund et al. (2021) studied the renewable energy that sustains in the future. Their study mainly focuses on controlling and checking the energy system and the investments in renewable energy sources for the returns. But their main focus is on renewable energy to reduce the adverse impacts of the energy resources on the environment thereby reducing carbon emissions.

Khan and Ahmad (2021) empirically find the impacts of renewable energy, international trade, foreign investment, and tourism on carbon emission levels in the Asia Pacific and European developed countries from 2000 to 2020. They used the FMOLS, GMM, and DOLS methods and conclude that foreign investment, international trade, and tourism activities with sustainability by encouraging renewable energy can control carbon emissions. Simionescu et al. (2022) empirically found the association of the quality of governance with environmental pollution. They applied the ARDL approach and concluded that the increased usage of renewable energy and better quality of governance reduced the carbon emissions in the Central and Eastern European countries from 1990 to 2019.

Lee et al. (2022) empirics focused on the tourism and economic complexity impacts on the environmental footprint. They applied the quantile regression to test the EKC hypotheses for the sample of 91 worldwide economies from 2006 to 2017. They found that the environment is polluted due to the carbon

TABLE 1 | Description of variables and the data source.

Abbreviation	Variable	Source	Period
CO	The emissions are based primarily on CO_2 (measured in metric tons per capita).	WDI	1989–2020
FA	Forest area (% of the total land area)	WDI	1989–2020
FDI	The net inflows of foreign direct investment by foreign firms (measured as % of GDP)	WDI	1989–2020
RE	The consumption of renewable energy (measured as % of the total energy consumption)	WDI	1989–2020
TRADE	Trade (measured as % of GDP)	WDI	1989–2020
TrpServ	Transport services (measured as % of service imports, BoP). Not clearly measured	WDI	1989–2020

emission levels from economic and other tourism activities. They concluded that carbon emission levels are increasing due to the development of the tourism industry and the decline in the cultivation area.

Andlib and Salcedo-Castro's (2021) empirics concern the effects of tourism and governance on carbon emission levels for the sampled South Asian economies from 1995 to 2019. Tourism, technological advancement, and international connectivity are increasing in the region. They applied DOLS, FMOLS, and FEOLS methods to analyze the data and concluded that carbon emissions are adversely affecting the environment but may be controlled by the effective implementation and governance of the environmental policies. Guo and Meng (2019) studied the different factors that are demanding more transportation services in the Beijing–Tianjin–Hebei region, China, from 1995 to 2016. They found that in the coming days, the development in significant sectors is growing and demanding more transportation for their smooth operation in the Beijing–Tianjin–Hebei region, causing to increase in carbon emissions.

Zahoor et al. (2020) study finding shows that carbon emissions are increasing because of the economic activities in different economic sectors and affecting the environment of India. Their study concerns the sampled data from the year 1980 to 2015. The significant factor that is contributing to the highest carbon emission levels is the usage of petroleum products which constitute about 90%. The other significant factors are urbanization, rapid increase in population, and increasing the capacity of the different industries, and economic growth has a positive relationship with CO_2 emissions in India.

Simionescu (2021) examined the European Green Deal and considers the pollution and the environmental degradation due to climatic changes, suggesting the adaptations of different ways to reduce the GHG emissions in the Central European and Eastern countries (CEECs). The author worked on the data from the years 1990 to 2019 by applying the renewable energy Kuznets curve (RKC) and environmental Kuznets curve (EKC) hypotheses and concluded that European countries are working to achieve zero GHG emissions before 2050. Solaymani (2018) studied the characteristics of transport-related carbon emissions. This issue arises due to the use of fossil fuels which has a significant role in affecting the economy and natural eco-system. The author used the log-mean Divisia index (LMDI) from 2000 to 2015 and concluded that in the sampled countries, the transport sector has a significant role to enhance carbon emissions and causing the environment adversity.

Giannakis et al. (2020) empirics found that carbon emission levels are becoming the cause of many climate problems including a temperature rise. Their study concludes that this century has caused CO_2 emissions in larger quantities that are causing a rise in temperature from 4.5 to 5.0° in Cyprus. Land transport is playing a significant role to increase CO_2 emissions and reach an increase of 22% by the year 2030. Salahodjaev and Isaeva (2021) conducted an empirical study of 20 post-Soviet Union states to investigate the impacts of FDI, trade, GDP, and energy from 1995 to 2017. They applied DOLS and FMOLS regressions. They found that FDI and trade positively impact carbon emissions. They concluded that carbon emission levels increases in the transition country as in the sample case of the Soviet Union with the rise in the economic activities, FDI, trade, and energy consumption.

Zubair et al. (2020) investigated the impacts of FDI, trade, GDP, energy, and capital on Nigeria's CO levels from 1980 to 2018. They applied the VAR and ARD estimation techniques. They found the long-run relationship among them. Furthermore, they found that GDP, FDI inflows, and capital reduced the carbon emission levels in Nigeria. Essandoh et al. (2020) investigated the difference in impacts of FDI and trade on carbon-based emission levels for developing and developed countries from 1991 to 2014. They reported that trade negatively impacts CO_2 in the long-run relationship for developed countries, and FDI has a positive long-run relationship impact on CO_2 for the developing countries.

They concluded that developed countries have better technologies, adequate policies, and legislation to cope with carbon emissions than developing countries. Furthermore, FDI in the developing countries is less in green technologies. He et al. (2020) empirics investigated the relationship between the carbon emission, trade, and FDI from 2006 to 2018 for BRICS (Brazil, Russia, India, China, and South Africa) countries. They applied ARDL regression and reported that trade dependency positively impacts carbon emissions. Assis at el. (2020) investigated the deforestation impact on the environment from 2006 to 2016 in the Brazilian Amazon region. They found that deforestation increases the carbon content in the environment. The regeneration of degraded forest areas absorbs CO_2. Furthermore, they found that CO_2 emission is more significant in deforestation than that in forest degradation.

Setiani et al. (2021) investigated the relationship between forest fires due to the increasing Earth's temperature and carbon emissions. They found that forest fire is one of the major contributors to increase carbon emissions, and there is an increase in the probability of forest fire events due to climate change. Waheed et al. (2018) investigated the impacts of RE,

TABLE 2 | Descriptive statistics.

	CO	FA	FDI	RE	Trade	TrpServ
Mean	4.6559	28.57572	2.80348	16.9536	64.43982	32.87774
Median	4.3613	27.97100	2.5735	17.5422	61.2325	32.9740
Maximum	9.2456	32.4850	9.02011	26.5820	87.1366	78.4000
Minimum	3.58682	26.4500	0.0000	3.35576	39.13517	16.15150
Standard deviation	1.1893	1.3474	2.3716	7.16586	14.5119	14.6555
Skewness	2.26195	1.38995	1.15805	-0.50306	0.14473	1.13749
Kurtosis	8.7093	4.27959	3.8506	2.1102	1.8851	4.46498
Observations	32	32	32	32	32	32

Source: *EViews estimations.*

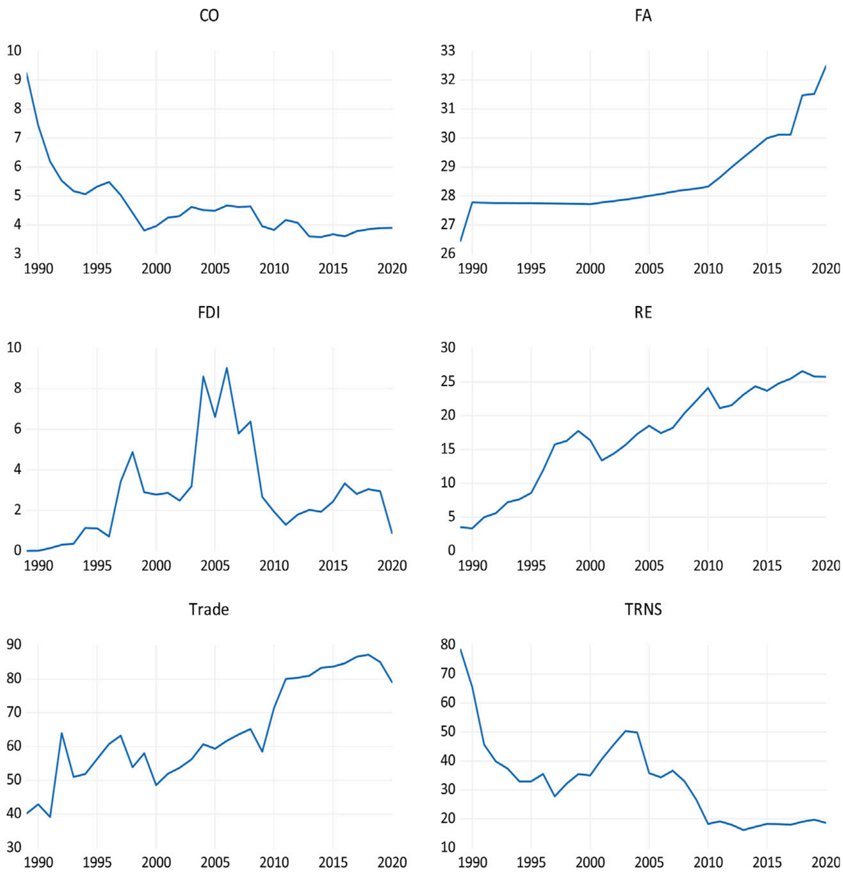

FIGURE 1 | Graph of level data from 1989 to 2020 (Source: The World Bank, 2021).

agriculture production, and forest area on carbon emission levels from 1990 to 2014 in Pakistan. They applied the ARDL regression. They found a negative relationship between the RE and forests, implying that an increase in RE and forests can cause a reduction in CO_2.

Islam, Abdul Ghani, and Mahyudin (2017) investigated the impacts of energy consumption, GDP, population, poverty, and forest on carbon emissions for Malaysia, Indonesia, and Thailand from 1991 to 2010. They found that forest areas and poverty have negative impacts on carbon emission levels. Making et al. (2019) investigated the impact of clear-cutting on carbon emissions, energy, and water vapors in the European parts of Russia. They found that clear-cutting causes to increase the carbon emissions and radiation. In this research study, we examined the impact of RE, transport services, trade, forest area, and FDI on the environmental indicator CO_2 in the context of Romania.

Mahmood et al. (2022) estimated the impacts of urbanization, oil prices, and economic growth of the GCC economies on carbon emission. They used linear and nonlinear ARLD regressions. They found that increase in oil prices positively impacts the

TABLE 3 | Correlation matrix.

	CO	FA	FDI	RE	Trade	TrpServ
CO	1					
FA	–05552	1				
FDI	–0.33415	–0.031132	1			
RE	–0.821,800	0.746,619	0.35577	1		
Trade	–0.6769	0.81958	0.95329	0.852,717	1	
TrpServ	0.8428	–0.68372	–0.05889	–0.79912	–0.832,749	1

Source: EViews estimations.

carbon emission levels in Qatar, Saudi Arabia, and Oman whereas it negatively impacts carbon emission levels in Kuwait and UAE. Urbanization positively impacts the GCC economies and economic growth and has asymmetric impacts across the GCC economies.

3 METHODS AND EMPIRICAL STRATEGIES

In this research study, we focused on the impact of RE and transport services on the macro-economic and environmental indicators in the context of Romania. After an adequate literature review and employed methodologies, the ARDL methodology was considered appropriate for time series data compiled from World Development Indicators to achieve robust and reliable empirical results. **Table 1** presents a detailed description of our study variables.

3.1 Data Source and Sample

The overall data were retrieved from the online sources available by the World Bank. We used renewable energy, transport services, foreign direct investment, trade, and FA as influence variables for analysis. The period of sampled data collected is restricted to the availability of data. The information for FA, foreign direct investment, and trade was compiled from WDI. Based on the literature review, the conceptual framework, and the study objectives, the model employed in this study used the variables, shown as follows in **Table 1**.

3.2 The Research Model

$$CO_t = f\,(TRPSERV_t + TRADE_t + RE_t + FA_t + FDI_t). \qquad (1)$$

REt shows the consumption level of RE, FDIt denotes the foreign direct investment inflow, FAt shows the forest area as a percentage of total land, and trade represents the level of trade. All the aforementioned variables are converted from a simple form to natural logarithmic form to consider heteroscedasticity and compute the concerned variables' growth rate using the log differences. In addition, this conversion gives more consistent and efficient results. The following **Eq. 2** shows the modified model:

$$LNCO_t = \beta_0 + \beta_1 LNFDI_t + \beta_2 LN\mathrm{TRADE}_t + \beta_3 LN\mathrm{RE}_t + \beta_4 LNFA_t + \beta_5 LN\mathrm{TRPSERV}_t + \varepsilon_{it}, \qquad (2)$$

where t is the timeframe, β_0 is the slope-intercept, and εit represents the error term, while β_1, β_2, β_3, β_4 and β_5 are the coefficients of the influence variables, respectively. All the variables are used in the natural logarithmic form. As the title signifies, the transportation volume, RE sources, forest area, trade, and FDI are the predictors, and environmental indicator CO-based emission levels will be the dependent ones. However, the model may also be developed to examine bi-directional effects.

It is necessary to check the integration order of each variable first and then the ranking of integration through the unit root test. Haseeb et al. (2018) stated that stationary data could give unbiased results. So to check the stationary properties, augmented Dickey–Fuller (ADF) and Philips–Perron (PP) tests were employed. In addition, formal diagnostic test statistics were used for preliminary analysis of the variables' stability, trend, and variability.

To check the long-run equilibrium relationship between the dependent variable (the quantum of carbon dioxide emissions) and the independent variables such as transport services (% of service imports, BoP), FDI (as % of GDP), the annual % growth in the trade level (as % of GDP), renewable energy consumption (REC), value-added by the sectors of agriculture, forestry, and fishing, the autoregressive distributed lag (ARDL) modeling approach is used. The ARDL bound testing approach was chosen due to some advantages. First, the estimates acquired from the ARDL are unbiased and give consistent and efficient results when the sample is small (Akinwale, 2020). Second, the ARDL is appropriate when the variables are stationary at the level of l I (0) or the first difference I (1). Still, it cannot be used when the variables are stationary at the second difference I (2) (Pesaran and Shin, 1995). Third, while applying the ARDL technique, the dynamic unrestricted error correction model (UECM) can be developed by a simple linear transformation from the ARDL-bound testing at once (Saud et al., 2018). The ARDL model is expressed as follows:

$$\mathrm{LNCO_t}+ = \beta_0 + \theta_0 LNCO_{t-1} + \theta_1 LNFDI_{t-1} + \theta_2 LNTRPSERV_{t-1} + \theta_3 LNFA_{t-1} + \theta_4 LNRE_{t-1} + \theta_5 LNTRADE_{t-1} + \sum_{i=1}^{a} \beta_i \Delta LNCO_{t-i} + \sum_{i=0}^{b} \gamma_i \Delta LNFDI_{t-i} + the \sum_{i=0}^{c} \delta_i \Delta LNTRNS_{t-i} + \sum_{i=0}^{d} \lambda_i \Delta LNFA_{t-i} + \sum_{i=0}^{e} \vartheta_i \Delta LNRE_{t-i} + \sum_{i=0}^{f} \psi_i \Delta LNTRADE_{t-i} + \nu_t, \qquad (3)$$

where Δ indicates the first difference operator, β_0 is the slope-intercept, and ε_t represents the error term. The extended strands of the influence variables are as follows:

TABLE 4 | Unit root test.

Variable	ADF unit root test			Phillips–Peron unit root test		
	Level	First difference	Order	Level	First difference	Order
lnCO	1.831 (0.9697)	−7.3499 ***	I (1)	03.101 (0.784)	−6.0337***	I (1)
lnFA	0.5698 (0.74583)	−3.4175 ***	I (1)	0.0478 (0.369)	−2.4785***	I (1)
lnRE	-1.47855 (0.68757)	−4.44178 ***	I (1)	−2.745 (0.368)	−5.745***	I (1)
lnTrade	-3.47853 ***	−7.8745 ***	I (0)	−4.1236 ***	−7.412***	I (0)
lnTRNS	-02.4589 (0.308)	−5.5236 ***	I (1)	−3.845 (0.017)**	−11.896***	I (0)
lnFDI	-01.74582 (0.954)	−3.7856 *	I (1)	4.787 (0.148)	−6.6385***	I (1)

*Source: EViews estimations. *** indicate 1%, ** indicate 5%, and * indicate 10% level of significance.*

TABLE 5 | Long-run and short-run estimations.

Dependent variable (CO), lag(3, 2, 3, 2, 3, and 3)

Long run				*Short run*			
Variable	Coefficient	T-ratio	*p*-Value	Variable	Coefficient	T-ratio	*p*-Value
lnFA	−1.38245	−2.1811	0.0810*	ΔlnFA	−1.1174	−3.17848	0.0246**
lnRE	−0.52591	−7.05792	0.0009***	ΔlnRE	−0.9650	−0935,952	0.0001***
lnTrade	0.28801	0.88263	0.41758	ΔlnTrade	0.66740	9.27143	0.0002***
lnTRNS	0.09312	0.80571	0.4570	ΔlnTRNS	0.11102	3.6278	0.01051**
lnFDI	0.1315	3.03698	0.0164**	ΔlnFDI	0.09923	7.301,845	0.0001***
Constant	6.7869	5.7308	0.0023***	ECM(-1)	−0.9848	−8.0200	0.0000***

R-square 0.9600; adjusted R-square 0.8937.
**** indicates 1%, ** indicates 5%, and * indicates 10% level of significance.*
Source: EViews estimations.

TABLE 6 | Results of ARDL co-integration.

F statistics	Significance level (%)	Critical values for the bound test	
		Lower bound	Upper bound
11.3, K =5 (lag: 3, 2, 3, 2, 3, and 3)	10	2.08	3.00
	5	2.39	3.08
	2.5	2.70	3.73
	1	3.06	4.15

Source: EViews estimations.

$$\begin{aligned}\theta_0 LNCO_{t-1} &+ \theta_1 LNFDI_{t-1} + \theta_2 LNTRPSERV_{t-1}\\ &+ \theta_3 LNFA_{t-1}\theta_4 LNRE_{t-1} + \theta_5 LNTRADE_{t-1}\\ &+ \sum\nolimits_{i=1}^{a}\beta_i \Delta LNCO_{t-i}\\ &+ \sum\nolimits_{i=0}^{b}\gamma_i \Delta LNFDI_{t-i}\sum\nolimits_{i=0}^{c}\delta_i \Delta LNTRPSERV_{t-i}\\ &+ \sum\nolimits_{i=0}^{d}\lambda_i \Delta LNFA_{t-i} + \sum\nolimits_{i=0}^{e}\vartheta_i \Delta LNRE_{t-i}\\ &+ \sum\nolimits_{i=0}^{f}\psi_i \Delta LNTRADE_{t-i}. \end{aligned} \tag{4}$$

4 ANALYSIS OF RESULTS AND DISCUSSION

This study has extracted the data from the World Development Indicators (WDI, 2021) covering the period from 1989 to 2020. The descriptive statistics are presented in **Table 2** as follows, which reveals the lack of significant difference between the mean and median of all the variables, indicating that the data are symmetrical.

The time series plots of these variables are presented in **Figure 1** as follows. A dramatic decline can be observed between the years 1989 and 2000 and onward while the CO_2-based emissions remain around the same level (4 metric tons per capita). The correlation matrix (**Table 3**) replicates the fact that the carbon emissions (CO) appear to be negatively correlated with FA, FDI, RE, and trade while positively correlated with the Trns variable. Romania seems to have observed an improvement in foreign direct investment flows until the start of the global financial crisis (GFC) with a sharp decline afterward. In addition, there has been a steady growth in the forest area from the years 1990 to 2010 with a sudden spurt afterward. The figure further reveals that the share of renewable energy amplified consistently over the sampled period, comprising around 25% of the total energy usage in 2020. The trade to GDP ratio has intensified over

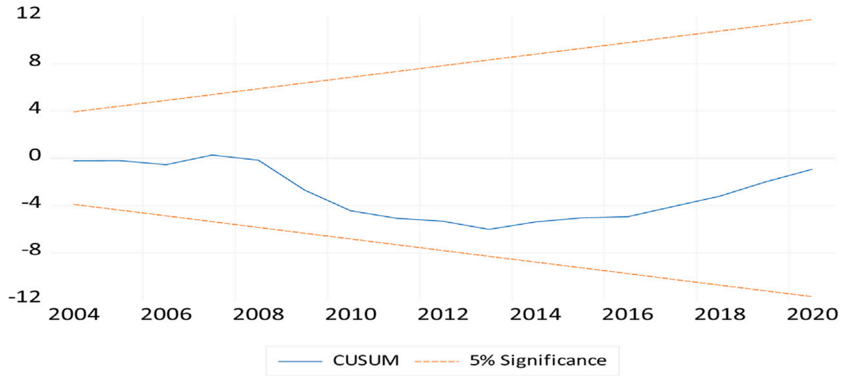

FIGURE 2 | Cumulative sum of recursive residuals. Source: EViews estimations.

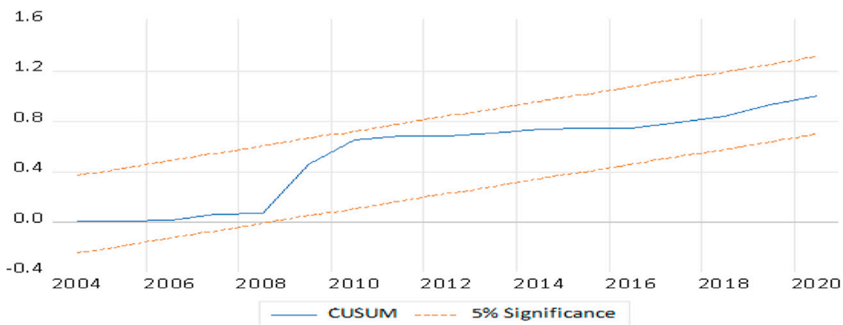

FIGURE 3 | Cumulative sum of squares of recursive residuals. Source: EViews estimations.

TABLE 7 | Diagnostics tests.

Test	F statistics and *p*-Value
A) Breusch–Godfrey serial correlation LM test	F statistics = 4.782 and *p*-value = 0.187
B) Normality	Jarque–Bera = 3.47824 and *p*-value = 0.4576
C) Heteroscedasticity test	F statistics = 2.2337 and *p*-value = 0.28413

Source: *EViews estimations.*

time while the transport services dwindled below 20% from 80% at the start of the sampled period.

The results of the unit root tests are reflected in **Table 4**, indicating that all the variables have a unit root at level but are stationary at first difference except for trade and Trns as per the Phillips–Peron test. Based on the mixed order of integration, we decided to apply the autoregressive distributed lag (ARDL) model to test the hypotheses formulated in our research. Before estimating the model based on the ARDL approach, we conducted the test for the existence of a long-run relationship among variables employing the bond co-integration test, attributed to Pesaran et al. (2001). The results of the bond test, in **Table 5**, divulge that the calculated value of the F statistic of the bond test (11.3) is greater than that of the upper bound values which supports the presence of nexus among carbon emission levels and the set of exogenous variables in the long run. Having found the co-integration among CO and the exogenous variables, the lag for each of the variables in the ARDL model was selected using the Akaike information criterion (AIC) and Schwarz information criterion (SC). According to these information criteria, the suitable lags for CO, FA, RE, trade, trans, and FDI are determined as 3, 2, 3, 2, 3, and 3, respectively (**Table 6**).

As evident from **Table 5**, trade and TrpServ variables tend to end up with zero association with CO in the long run in the case of Romania as these results have insignificant coefficients. However in the short run, both trade and TrpServ variables appear to have a significantly positive impact on environmental degradation. Hence, the short-run findings are inconsistent with those of the long-run ones. Our empirical evidence in the long-run is in contrast with those of Ertugrul et al. (2016), Jamel and Maktouf (2017), and Udeagha and Ngepah (2019), whereby trade contributes to environmental degradation but improves the environmental indicators in the short run. Jamel and Maktouf (2017) reported a significantly positive bi-directional relationship between trade and CO in the context of European countries, including Romania.

Regarding the impact of RE across the CO, an inverse connection is noticed since the coefficient is statistically significant at a 1% significance level. This result is inconsistent with the findings by Saidi and Omri (2020) as they traced no causal association between CO_2-based releases and RE in the long run for a group of 15 leading renewable energy–intensive countries and empirically supported by Salim and Rafiq's (2012) study in the context of the emerging economies but contrasts with those of Chen et al. (2019) for China. Adebayo et al. (2021) and Ummalla and Goyari (2021) also confirmed that RE helps to reduce CO_2 emissions. The inverse connection of RE with the CO is supportive of the fact that Romania is emerging as a leading renewable energy user where the increase in RE tends to be associated with fewer air-polluting emissions. The presence of an inverse connection between renewable energy and carbon emissions invalidates the feedback hypothesis, which portrays that RE and CO are symbiotic. Yu et al. (2022b) find that renewable energy negatively impacts the import of crude oil in Germany and positively impacts trade. It means that the consumption of energy from other renewable sources reduces the demand for crude oil and trade increases the demand for crude oil in Germany.

The forestry sector has gradually taken an essential position in policy and academic dialog (Mamkin et al., 2019). The variable is being examined to untangle the less visible and often difficult-to-establish association between forest area and carbon emissions. As expected, the association between the CO and FA stands as unfavorable at 1% in the long run. It insinuates that an expansion of the forest area tends to help in controlling the carbon-based emissions.

An analysis of long-run ARDL results reveals that FDI inflows in Romania are significantly and positively associated with CO. This discloses that the FDI inflows have intensified the carbon emissions in Romania, alluding to the fact that foreign firms have been striving to augment their ecological reflection through the implementation of green practices. Our findings on the role of FDI, toward CO, tend to validate the existence of the "*pollution haven hypothesis*[1]." Hence, switching toward renewable energy consumption also supports the findings to attract FDI inflows (Zaman and Shamsuddin, 2017; Yu et al., 2021b; Khan et al., 2021f; Yu and Khan, 2021) and improve other macro-economic indicators (Yu et al., 2022a; Yu et al., 2022b). The result demonstrates that the Romanian economy is better positioned to gravitate the FDI than its counterparts in Europe through the espousal of renewable energy usage. The policies toward improving environmental quality practices as implemented by the state and government agencies in the country are also endorsed by the findings of Mahmood et al. (2021), Khan et al. (2021g), Khan et al. (2021h), and Zhu et al. (2007) and also confirm the results reported by Giovanni and Esposito (2012) in the case of EU economies.

In the short run, all the exogenous variables significantly affect CO at the conventional significance level (5%). The coefficient associated with the FA coefficient is negative (-1.1174). In the case of Romania, it is expected that an increase in FA and RE is likely to reduce CO. The variable FDI tends to affect the dependent variable CO positively, yet the impact of FDI is smaller than that of the FA and RE.

The results of diagnostic tests (**Table 7**) reveal that the residuals of the model are neither auto-correlated nor heteroscedastic as the Jarque–Bera test concludes that the residuals are normal. In terms of the stability check, CUSUM tests of recursive residuals and square residuals have been performed, and the output is reported in **Figure 2** and **Figure 3**, whereby the model is validated and confirmed as stable.

5 CONCLUSION AND POLICY IMPLICATIONS

Romania is placed fourth amongst EU countries that are contributing to the carbon emission levels per capita. Our study concerns the carbon emission levels factors for Romania from 1989 to 2020 by applying the ARDL estimation technique. The variables of trade and TrpServ appear insignificant determinants in the long run, whereas in the short run, both variables significantly augment the carbon dioxide–based emissions, implying that the Romanian government has taken a broad spectrum of strategic programs to mitigate the climate change impacts on the transport sector. A gradual transition from the conventional sources of energy dependency to the RE sources causes minimization in the carbon emission levels in Romania in the short and long run. Planted and forest areas in Romania play a vital role in mitigating the impacts of carbon emissions, and a higher planted area in Romania reduces the effects of carbon emissions both in the long and short run. FDI in Romania appears to augment the variable CO over the sampled period; the FDI increases the economic activities in Romania and produces carbon and other greenhouse gases that adversely impact the environment.

5.1 Policy Implications

Our study presents several vital policy implications for the Romanian government, private institutions, and policymakers based on the results. The transport sector is accounted for as the third most significant contributor to carbon emissions in Romania. So there is an urgent need to shift the transport sector to RE energy sources. In this regard, the Romanian government should take radical steps in formulating the environmental policy and legal framework to mitigate carbon emissions in the transport sector, for instance, as enumerated in the following:

1) The incentive policy should be encouraged to switch vehicles from fossil fuels to renewable ones. The incentives policies may include subsidies and tax exemptions to promote eco-design vehicles. The implementation of discourage action plans should be made to reduce the consumption of fossil fuels by imposing heavy import duties and taxes and financial penalties on polluted transport systems, whether water or inland. Supportive financial programs should be

[1]The pollution haven hypothesis is based on the notion that polluting industries will reposition to jurisdictions with less stringent environmental regulations.

introduced with lower interest rates to promote environmentally friendly industrial and trade technology.

2) Romania is already committed to reducing the adverse impacts of climate change. Still, it lags behind the targets set for 2014–2020 in six sectors: transport, agriculture and forestry, energies, urban, and water. So the Romanian government ought to initiate adequate steps to set the benchmarks of the significant sectors for the growth of the green economy in the future and emphasize raising the level of mass awareness about the benefits of moving toward RE to mitigate the CO impacts.
3) The FDI and international trade with green products should be endorsed for a green economy to sustain economic growth. FDI with renewable sources needs to be encouraged with tax exemption and facilitate global investors toward Romania.
4) Likewise, the government needs to adopt aggressive environmental-friendly strategies that could help diminish environmental degradation through the adoption of renewable energy sources. There is also a need to cut down the freight transport services and trade cycle activities and target subsidies to encourage renewable energy and ecological traditions.
5) The forest area is negatively associated with CO in Romania, revealing that an increase in the forest area is expected to lessen the carbon-related contents in the environment. Thus, the government of Romania needs to bank upon the policies targeted toward the expansion of forest areas to ensure biodiversity and a much cleaner environment for the nation.
6) In the short run, the significance of trade and transport variables highlights the need for planning at the local vis-à-vis national levels to assist in trade and tourism promotion in the Romanian economy. This can be achieved gradually by executing the clean energies, endorsing the growth of under-developed areas, and civic society's inclusion in a tourism-led evolution drive.
7) From a policy standpoint, energy policies can be designed in the context of economic development in Romania, improvement in an environmental growth situation, and diversified use of energy sources over there. In addition, the advocacy for renewable energy sources leads toward gains from the environmental upgradation but is also valuable for the country's economic uplift.
8) There stands a need to encourage investors to invest in projects of clean energy from renewable sources which are expected to stimulate economic growth without any costs to the environmental quality.
9) The EU states may resort to the modern technology along with RE-based resources for controlling pollution. Appropriate taxation policies can be adopted to encourage environment-friendly industries while imposing excessive penalties on those who contribute to pollution.
10) A greater focus is required by policymakers to adopt green FDI in Romania coupled with investment in energy-efficient technologies. Thus, FDI attracted through the green investment can enhance the environmental feature and tourism in Romania. This further alludes to the case of FDI in areas like forestry, trade, transport, and tourism through RE-based initiatives. Hence, FDI could be used as the catalyst for improving the environmental quality in Romania.

5.2 Study Limitations and Future Research

This study has some limitations. It focuses on the Romanian environmental degradation nexus with other macro-economic indicators only. Romania has specific economic and environmental attributes with a distinct political, legal, and investment framework. So the findings of the study may apply only to Romania's economic and environmental perspective. The other limitation may be due to the results of the study being based on the symmetric methodology of the ARDL approach. So the coefficients of the relationship among the study variables may be different in magnitudes and directions in other non-symmetrical methodologies. The third limitation is based on the sampled period in the context of Romania. The incentive scheme in the future to promote renewable energy with the new investments in transport services and industries to respond to the environment degradation may limit the application of the results of the study. Given the findings of the present research study, there still stands a need for further research that could analyze the policy limitations and critical masses at which renewable energy could enhance economic growth without compromising the environmental standards. The impact of investment in green technologies, green logistics infrastructure, and climate change policies along with legislation on carbon emission levels may be incorporated into future research works. The potential research may also compare carbon emission levels before and after implementing adaptation and mitigation policies in Romania to test the effectiveness of climate change strategies and programs. Another novel research for the future could be used to incorporate the impact of COVID-19, along with macro-economic and environmental indicators, across the leading sectors of the economy among a panel of EU countries. This might assist in developing broad-based geographical policies for the EU countries at large.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material; further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

Conceptualization: JL, MQ, and MA; writing—original draft: MA, ZY, and LJ; writing—review and editing: MQ, MA, and LJ; methodology: ZY and LJ; project administration: ZY, MQ, and MA.

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