European Economic Letters
ISSN 2323-5233
Vol 15, Issue 1 (2025)
http://eelet.org.uk

Linking trade, innovation, and foreign direct investment with a dynamic ARDL simulation model to examine environmental deterioration in India

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ABSTRACT:
The aim of this study is to ascertain how India's environmental degradation is affected by innovation, trade, economic growth, FDI, energy consumption, and urbanisation. The dynamic autoregressive distributed lag model (ARDL) will be used in this study to examine how the independent variables actually change and how that change affects the dependent variable. In addition to having a positive impact on sustainability, the environment, and the impact of climate change, research on the relationship between trade, FDI inflow, and innovation in environmental degradation research can also help achieve Sustainable Development Goal (SDG) 13, which calls for "Taking urgent action to combat climate change and its impacts." To further aid in the ongoing efforts to address the issue of environmental degradation and achieve SDG 13, this research may offer fresh perspectives on how policies can be used to encourage innovation in environmental degradation research and lessen the adverse effects of climate change. The results indicate that energy consumption, GDP growth and urbanisation have a positive impact on carbon emissions in the short term. Conversely, the results suggest that over a prolonged period, only increase in trade had a negative effect on emissions. Urbanisation has a significant and positive effect on long-term carbon dioxide emissions. It has been observed that Foreign direct investment (FDI) has positive effect on short-term and long-term carbon dioxide emissions. Furthermore, innovation has a positive impact on carbon emissions in both the long and short term.

Keywords: FDI, Innovation, Energy consumption, Urbanization, Dynamic ARDL simulations.

Introduction

The main worry of states that emit greenhouse gases is the degradation of the environment, an issue that impacts the entire planet. The primary source of greenhouse gas emissions that damage the environment is carbon dioxide emissions. According to Hanif (2018), Irfan et al. 2020, Jan et al. 2021, Nain et al. 2017; Narayan et al. 2016; Özokcu and Özdemir 2017; Sarkodie and Strezov 2018b, in other words, greenhouse gases are released as a result of carbon dioxide emissions. More greenhouse gases are being released into the environment by most of the world's developing economies, including Brazil, China, Indonesia, India, Mexico, South Africa, Russia, Turkey, and Pakistan. One of the most important issues facing the decision-makers in developing nations is the state of the environment. Policymakers can create policies that promote investment in and development of sustainable technologies, which would ultimately lead to a reduction in environmental degradation and help in reducing greenhouse gas emissions, by understanding the impact of FDI inflow and innovation in environmental degradation research.

The study may pinpoint particular obstacles to innovation in environmental degradation research, such as a lack of financing or a lack of understanding of the significance of the problem, in an effort to address or offer solutions to particular issues. Additionally, it could point out areas where money might be invested in environmentally friendly technology like clean transportation or renewable energy. These remedies have the potential to facilitate the shift towards a low-carbon economy and mitigate the worst effects of climate change. The research's distinctive contribution can be in the application of fresh data sources, analytical techniques, or theoretical frameworks to comprehend the processes at work and pinpoint the precise regions where FDI influx can be focused to meet SDG

13. Furthermore, this research might offer fresh perspectives on how policies can be implemented to encourage creative thinking in environmental degradation studies and lessen the adverse effects of climate change. This would be a significant help in the continuous endeavours to tackle environmental degradation issues and accomplish Sustainable Development Goal 13.

When it comes to effectively using natural resources, industrialised nations face the most challenging issue: environmental degradation. The world has been greatly disturbed by the high amount of greenhouse gas (GHG) emissions, which has affected both these industrialised and non-industrialized countries. States that emit greenhouse gases are primarily concerned about the degradation of the environment, a problem that impacts the entire planet. The state of the environment is rapidly declining, with consequences for the entire globe. A contributing factor in this trend is the desire of nations to use energy and natural resources to the fullest extent possible in order to achieve economic growth, which in turn causes a rise in greenhouse gas emissions. The increasing tendency in greenhouse gas emissions is another aspect contributing to this development. The main factor in the release of greenhouse gases, which are harmful to the environment, is carbon dioxide emissions. Put differently, as per Hanif (2018), Irfan et al. 2020, Jan et al. 2021, Nain et al. 2017; Narayan et al. 2016; Ŗzokcu and Ŗzdemir 2017; Sarkotie and Strezov 2018b, greenhouse gases are released as a result of carbon dioxide emissions. The researchers looked into the possibility of a relationship between Pakistan's expanding GDP and the country's energy sector (Zaho et al. 2022; Xu et al. 2021; Dai et al. 2022). The accumulation of empirical data showed that Pakistan's economy was expanding mostly due to a rise in energy output. Apergis and Payne (2010a); Si et al. (2021); Xu et al. (2021) examined the time series data for 19 developing and industrialised nations using a panel error correction model. The nations comprised both developed and developing countries. The findings showed that lower levels of carbon dioxide emissions were associated with higher GDP and energy consumption levels. The overall amount of significant greenhouse gases released globally has been steadily increasing since 1990 (Jiang et al. 2022; Hu et al. 2021; Deng and Zhao 2022). The two main causes of greenhouse gas emissions are the burning of fossil fuels and the actions of developed nations. The bulk of the developing nations, including South Africa, Mexico, Brazil, China, Indonesia, India, Turkey, and Pakistan, are causing an increase in the amount of greenhouse gases released into the environment. The degradation of the environment is among the most important issues that decision-makers in developing nations must deal with.

China's economy is growing, which has increased demand for energy, which Hu et al. (2021); Jiang et al. (2022); Yuan et al. (2007) aimed to investigate. The data indicates that there is a cointegrated, unidirectional Granger causal relationship between RGDP and electricity usage. Using panel data analysis, several researchers (Wang et al. 2011; Zhao et al. 2022) examined the triangle formed by China's expanding GDP, rising energy consumption, and rising CO2 emissions. The study came to the conclusion that increased energy use and economic activity were the causes of rising CO2 emissions. Researchers Kumar et al. 2020 examined whether CO2 emissions were impacted by India's energy consumption, level of commercial openness, or rate of economic expansion (2020). The findings indicated that rising energy use and commercial globalisation were both contributing factors to environmental deterioration. Furthermore, free trade is linked to increased energy use, quicker economic expansion, and poorer environmental conditions. Researchers examined the relationship between increased energy use, rising CO2 levels, and higher GDP using the Granger causation model (Soytas et al. 2007). The empirical data showed that while economic expansion had no effect on this variable, long-term CO2 emissions increased in the USA as a result of the use of energy aid. Their findings highlight the need for long-term solutions to these problems as increased economic activity does not appear to lessen the rate of environmental degradation. This study examined the relationship between increasing GDP and increased CO2 output by Pao and Tsai (2010), Dai et al. (2022), and Deng and Zhao (2022). Lower CO2 emissions have been associated with economic growth, whereas higher energy use has been associated with higher CO2 emissions.

Economists Shahbaz et al. completed their analysis of Indonesia's economy in 2013. An autoregressive distributed lag model (ARDL) was used to analyse Indonesia's energy consumption, economic factors, and carbon dioxide emissions.

Studies suggest that higher CO2 emissions may have contributed to economic development as well as higher energy use. The only ways to reduce carbon dioxide emissions are through political freedom and economic growth. Balsalobre-lorente et al. (2018) conducted a study that looked at the relationship between CO2 emissions and the development of renewable energy, natural resources, and economic growth in five different EU states. As the economy expanded, carbon dioxide emissions rose; however, as more and more people started using renewable energy, emissions started to decrease. Using data from South Korea, Lee and Jung (2018) employed an autoregressive distributed lag (ARDL) model to examine the relationship between rising energy consumption and GDP growth. They discovered a correlation between economic expansion and energy consumption. Amri (2017) contended that there was a correlation between GDP development and energy use in Algeria from 1980 to 2011. The authors of the study come to the conclusion that increased energy use directly causes rising CO2 emissions.

While a number of studies have examined specific factors that contribute to CO2 emissions, the goal of this research is to determine the overall effects of various economic factors on CO2 emissions in India. Some examples of these economic indicators are the GDP, trade volume, foreign direct investment amount, urbanisation rate, and number of inventions. Whereas earlier research employed the conventional ARDL model, Jordan and Philips' (2018) dynamic ARDL simulation was used in this study. This study employed a newly built model to investigate the short- and long-term effects of changes in the independent variables on the dependent variable.

Literature Review

The relationship between economic growth and carbon dioxide emissions has been described by the environmental Kuznet curve (EKC) hypothesis (Apergis and Payne 2010b; Apergis et al. 2010; Apergis and Ozturk 2015; Khan et al. 2019a, b; Khan et al. 2022a, b; Khan et al. 2020). Shafik and Bandyopadhyay first put forth this theory in 1992. (Kijima et al. 2010; Shahbaz and Feridun 2012) According to the idea, there is a positive link that resembles an inverted U between rising economic production and rising CO2 emissions. The seminal research (Masih and Masih 1996; Oh and Lee 2004; Aqeel and Butt 2001; Author et al. 1978; Chandran et al. 2010; Kumar Narayan and Singh 2007; Kwak and Yoo 2010) used a variety of methodologies to investigate the connection between energy consumption and economic growth. 2001 saw the publication of the study. The authors were Butt and Aqeel. The researchers were Kraft, the author, and Kraft. The study's conclusions were released to the public in 2001. Furthermore, Aqeel and Butt published the study in 2001 (Si et al. 2021).

In 1978, Kraft & Kraft and their associates investigated the notion that there could be a causal link between energy use and economic expansion. The years 1947 through 1974 were covered by the data they used. The data indicates that there is a one-way relationship between income and energy consumption as well as a cause-and-effect relationship between income and energy consumption. Yu et al. (2008) used cointegration and the impulse response function to examine the dynamic relationship between China's economic development and energy usage. This made it possible to examine the relationship in greater detail. The empirical research findings indicate that while there is a significant correlation between rising GDP and rising energy consumption, the effect of rising energy consumption on GDP growth is relatively minor. Chen, Kuo, and Chen (2007) investigated the causal relationship between electricity consumption and economic development in eleven low-income or industrialised Asian nations using a panel co-integration model. The nations span a range of income levels and extend from China to the Philippines. The heterogeneous causality theory, supported by actual data, postulates a two-way causal chain connecting the gross domestic product and the amount of power used. In order to determine the factors that contributed to the environmental degradation in 17 African economies between 1971 and 2013, Sarkodie and Strezov (2018a) employed the panel cointegration test to evaluate the relationship between variables.

They were particularly interested in figuring out which factors were causing the environment to deteriorate. The empirical study's findings demonstrated a link between rising economic activity and environmental deterioration in Africa, supporting the environmental Kuznets curve. The Kuznets curve for the environment demonstrated this link. Bekun and colleagues (2019) employed the PMG-ARDL model to examine the correlation between the utilisation of renewable and non-renewable energy sources, economic growth, the accessibility of natural resources, and carbon dioxide emissions in sixteen European Union (EU) member states from 1996 to 2014. Bulgaria, Cyprus, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia were among these nations. Based on the study, Environmental deterioration is slowed down by the use of renewable energy sources, but it is accelerated by the use of nonrenewable energy sources and economic expansion. In their study, Asumadu-Sarkodie and Owusu (2017) employed vector error correction models (VECM) to examine the relationship between the industrialization, economic expansion, and power consumption of Sierra Leone between 1980 and 2011. The years 1980 through 2011 were included in the study. This analysis focused on the years 1980 through 2011. The findings indicate that several factors are involved in the deterioration of the environment. The usage of electricity, the rise in industrialization, and the acceleration of economic growth are a few of these causes.

The Kuznet curve, which shows the relationship between environmental effect and economic growth in relation to energy consumption and the environment, is based on the interaction that takes place between energy consumption and the environment. The information that is now available indicates a connection between the degradation of the natural environment and human energy use. According to Anwar Sajid and Alexander (2016), Baig and Baig (2014), Jalil and Mahmud (2009), Jayanthakumaran et al. (2012), Kais and Sami (2016), Ozturk et al. (2010), Shahbaz et al. (2014), and Soytas et al. (2007), this link is positive. Many studies support the existence of long-run univariate causation between CO2 emissions and energy use, with actual data supporting this finding (Antonakakis et al. 2017;

Ozcan and Ozturk 2019; Ozturk and Acaravci 2011; Shahbaz et al. 2015). Conversely, Wang et al. (2011) and Saboori and Sulaiman (2013) reached a similar conclusion about the superior accuracy of bi-variate analysis. The degree to which businesses are allowed to operate freely in a particular area may influence the amount of environmental damage that takes place there. Partial equilibrium models have made it possible to identify a connection between corporate operations and environmental deterioration. The application of partial equilibrium models allowed for this relationship (1999). Furthermore, research (Anwar Sajid and Alexander 2016; Ertugrul et al. 2016; Halicioglu 2009; Shahbaz et al. 2014) indicates that trade openness leads to a long-term rise in carbon dioxide emissions.

Using the ARDL bounds testing technique, Baranzini et al. (2013) assessed the cointegrating relationship between GDP growth and energy consumption in Switzerland between 1950 and 2010. This was carried out to ascertain whether there was a positive correlation between the two variables. The research findings suggest that there are long-standing relationships between Switzerland's GDP per capita and its energy consumption. Panel cointegrating approach based on Pedroni (1999, 2004) and empirical evidence showing one-way causality of cointegration relationships between electricity use and economic growth were used by Apergis and Payne (2009) to show panel causal association between electricity consumption and economic growth in Common Wealth countries from 1991 to 2005. This was done to show a direct causal relationship between the Common Wealth countries' economic growth and electricity usage between 1991 and 2005. The goal of this was to demonstrate the strong causal relationship between the Common Wealth countries' economic development and their power use. This was done to illustrate the causal relationship between the panels. For 160 developing and developed nations between 1980 and 2010, Karanfil and Li (2015) employed the Pedroni panel cointegration method to show how energy consumption, urbanisation, and economic factors relate to each other. They employed information spanning the years 1980 to 2010 to achieve this. The mixed findings are reflected in the empirical data, which comprise 160 distinct components. Fan and Lei (2017) investigated whether there was a connection between economic development and carbon dioxide emissions in Beijing between 1995 and 2014. The results of the research indicate that the state of the environment appears to be positively correlated with economic growth. Researchers Bekun et al. (2019) examined the impact of labour force, capital, economic development, and CO2 emissions on South Africa's total energy consumption between 1960 and 2016. The empirical data demonstrated a unidirectional causal relationship between rising economies and rising energy consumption, supporting the energy-led growth hypothesis. The validity of the energy-led growth idea was contingent upon this relationship. Using a VAR model, Tamba et al. (2017) examined the relationship between energy use and economic growth in Cameroon between 1975 and 2014. The years 1975–2014 were the covered years. Their investigation included the period from 1975 to 2014. The results of the empirical study indicate that there appears to be a causal relationship—that is, a bidirectional relationship—between the consumption of energy and economic growth. Using panel data, Sarkodie and Strezov (2018a) examined the components of the environmental sustainability curve (ESC) and energy intensity environmental Kuznet (EKC) hypothesis for four distinct economies between 1971 and 2013. The years 1971 through 2013 were considered in this time frame. Within this period, the years 1971 through 2013 were covered. The results of the empirical research supported the EKC hypothesis by demonstrating that in developed nations, economic expansion is associated with a reduction in environmental degradation. However, the idea of the environmental sustainability curve is supported by the fact that the consumption of energy and the acceleration of economic expansion both occur at the same time as environmental degradation.

Işik et al. (2017) investigated the effects of economic growth, commerce, tourism, and financial development on CO2 emissions in Greece using the ARDL model. They were particularly curious in the ways in which these variables interacted with one another. The findings show that rising financial activity, economic expansion, tourism, and trade all have a positive impact on carbon dioxide emissions levels. This is due to the fact that both the tourism and the commerce sectors gain from higher economic activity. Sarkodie et al. (2019) examined the relationship between environmental changes and the degree to which 192 economies were prepared to adapt to these kinds of changes using a panel data model. The connection between these two variables was the main focus of the study. Based on the statistics, Aric appeared to be among the nations most impacted by the elements that lead to environmental deterioration. This was also the situation in several other nations. Mohiuddin et al. (2016) examined the relationship between Pakistan's GDP, CO2 emissions, and energy consumption between 1971 and 2013 using the VEC model. The years 1971–2013 were considered in this time frame. The study's findings suggest that there is a positive correlation between carbon dioxide emissions and energy use. Tamba et al.(2017) employed the Johansen cointegration method and vector autoregression (VAR) in their study to assess the impact of energy consumption on economic growth. The findings show that there is no evidence linking any of the elements under investigation in a way that would suggest a causal relationship. Sarkodie et al. (2019) examined the relationship between overall energy consumption, GDP growth, and foreign direct investment in relation to greenhouse gas emissions. Panel data models were employed in this study for developing economies starting in 1982 and running through 2016. The statistics show that energy consumption has a positive effect on environmental degradations, supporting the idea of a pollution haven. This fact supports the idea of a pollution sanctuary. Furthermore, it was demonstrated that combining foreign direct investment with renewable energy technology reduced the amount of environmental harm created. Rehman et al. (2021), Tillaguango et al. (2021), Zakari et al. (2021), Khan et al. (2022), Alvarado et al. (2022), Dagar et al. (2021), Destek (2017) performed research on the top ten countries that consume biomass between 1980 and 2010 in order to examine the relationship between the usage of biomass as a source of energy and the expansion of each country's economy. The study's findings suggest that the expansion of the economy is positively impacted by the use of biomass as an energy source. This is the inference made from the study's findings. According to Destek and Sarkodie (2019), from 1971 to 2013, the ecological footprint of industrialised nations was significantly impacted by energy consumption, financial development, and economic expansion. Research that looked at the connection between these variables and the ecological footprint of industrialised nations led researchers to this conclusion. According to the calculations, there appears to be a bidirectional causal relationship operating between economic growth and ecological footprint, in addition to a U-shaped correlation between the two. Furthermore, there is a bidirectional relationship between ecological footprint and economic growth.

Data and Methodology

This study, which covers the years 2000–2020, looks at how different energy consumption patterns and economic conditions affect carbon dioxide emissions. With CO2 emissions as the dependent variable, this study looks at how ENC, EGR, TRD, FDI, URB, and INNO are related to one another. Every variable is listed in Table 1. The World Bank Indicators provided the CO2, EGR, ENC, TRD, FDI, URB, and INNO statistics.

Table 1 Descriptions of research variable

Symbols	Variable descriptions	Units	Sources
CO2	Carbon dioxide emissions	Metric tons per capita	World Bank Indicator (WDI)
ECN	Energy consumption	Kg of oil equivalent per capita	World Bank Indicator (WDI)
GDP	GDP	Current US$	World Bank Indicator (WDI)
TRD	Trade	Trade (% of GDP)	World Bank Indicator (WDI)
FDI	Foreign direct investment	Net inflows (% of GDP)	World Bank Indicator (WDI)
URB	Urban population growth	% annual	World Bank Indicator (WDI)
INNO	Innovation	Trademark mark application total	World Bank Indicator (WDI)

To estimate the true influence of the independent variable on our dependent variable of interest, we run a dynamic ARDL simulation. To ascertain whether to use this dynamic autoregressive distributed lag simulation model, stationarity tests must be performed on the data. In order to determine whether the data series in question is stationary, we test it utilising the ADF, PP, and KPSS unit root tests in this research. The foundation for our investigation into the relationship between these variables is provided by Equation 1.

$$CO2_s = \alpha_0 + \alpha_1 ENC_s + \alpha_2 EGR_s + \alpha_3 TRD_s + \alpha_4 FDI_s + \alpha_5 URB_s + \alpha_6 INNO_s + €_s \qquad (1)$$

The methodology flow is shown in Graph 1, which begins with the Unit Root Test to determine whether the variables are stationary. Next, lags for the dependent and independent variables are selected using the VAR lag selection criteria. The cointegration with bounds test is then tested, and lastly, the long- and short-run ARDL simulations model is used.

Unit Root Test (Level and 1st difference)

Lag Selection Criteria with VAR

Bounds Test for Cointegration

Long Run and Short Run Dynamic ARDL Simulations Model

European Economic Letters
ISSN 2323-5233
Vol 15, Issue 1 (2025)
http://eelet.org.uk

Graph 1 Steps for Results analysis

ARDL bounds testing approach: The long-term relationship between the variables has been used to evaluate the ARDL bound test based on the assumptions in order to ascertain the presence of cointegration. We will assess the long-run and short-run ARDL models to determine whether there is a long-run relationship between the variables of interest. An extended correlation exists between the research variables if the F statistics value exceeds the upper bound value. In the event that the F statistics value falls below the lower bound value, a long-term link between the research variables is not present. If the F statistics value falls between the lower and upper bound values, it is impossible to determine with certainty what the long-term association is.

Autoregressive distributed lag: In many aspects, the model performs better than alternative time series methods. When a series is stationary at I (1), I (0), or both orders but the independent and dependent variables have distinct lag times, the ARDL model may be applied. There is a long-term relationship between the research variables, as indicated by the bound test results. The statistical significance of the equilibrium change rate is indicated by the negative value of ECT. The serial correlation was examined using the Breusch Godfrey LM test. The functional form was examined using the Ramsey RESET test, and the heteroscedasticity was examined using Breusch–Pagan–Godfrey and autoregressive conditional heteroscedasticity.

Dynamic ARDL simulations: There are certain issues with the ARDL model when it comes to utilising the conventional ARDL for both short- and long-term relationships among variables. The new dynamic ARDL simulations model was created by Jordan and Philips (2018) since the basic ARDL model was too complex to comprehend. With the other variables in the equation held constant, this model performs incredibly well, stimulating, calculating, and automatically plotting the graphs of the actual changes in the individual independent variables and how they affect the dependent variable. It is crucial that there is cointegration between each variable and that the series is stationary I(1) before utilising the dynamic ARDL stimulations model.

Discussion and Results

The present work employed the Kwiatkowski Philips-Shmidt-Shin (KPSS), Augmented Dickey-Fuller (ADF), and Philips-Perron (PP) tests to assess the null hypotheses of unit root testing. The results of the studies conducted on KPSS, ADF, and PP show that all variables may reject the null hypothesis at the first difference level. All of the research variables are consistent at the I(1) level, as the study's results clearly demonstrate. This directly leads to the possibility of applying a dynamic ARDL model with an I(1) order.

Table 2: Unit Root Tests

Variable	**KPSS results**		**ADF results**		**PP results**	
	Level	First Difference	Level	First Difference	Level	First Difference
CO2	0.575***	0.401***	-1.691	-6.228***	-1.603	-5.226***
ECN	0.563***	0.230***	0.722	-3.211**	0.722	-3.211**
GDP	0.592***	0.532***	-2.489	-3.238**	-4.805**	-3.238**
TRD	0.242***	0.503***	-2.653	-3.264**	-2.596	-3.264**
FDI	0.287***	0.073***	-3.638**	-4.306**	-1.779	-4.306***
URB	0.572***	0.132***	-2.686**	-9.151**	-0.070	-7.178***
INNO	0.550***	0.274***	-1.299	-3.923**	-2.465	-4.073**

*** significance at 1%
** significance at 5%
* significance at 10 %

This specific study used a variety of tests, including the HQ, the SC, and the AIC, to determine the best lag selection. The results that are used to determine which lag parameter to include in the model are those with the lowest values for the associated information component (AIC) (Table 3).

Table 3: Optimal lag length selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	80.72	-	2.2e-17**	-21.34	-21.39	-21.92
1	1359.62	2557.8**	-	-376.46**	-376.78**	-380.47**
2	1095.45	21.19	-	-355.15	-356.19	-359.31

**Specifies the lag order designated by the criterion at 5% significance level.

A bound test was used, the results of which are shown in Table 4, to investigate the nature of the long-term relationship that exists between the several distinct study variables. There appears to be cointegration between the variables at a significance level of at least 5%, according to the F statistics computation findings.

Table 4: Estimated ARDL models and bounds F-test for cointegration

Test statistic		10%		5%		1%	
F statistics	K	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
3.740**	10	2.12	3.23	2.45	3.61	3.15	4.43
*** significance at 1% ** significance at 5% * significance at 10 %							

Table 5 Results of dynamic ARDL simulation models.

Variables	Coefficient	Std. error	t statistic	Prob.
C	1.624	0.824	1.86	0.086
ECN_t	0.036	0.026	-2.32	0.035
ΔECN_{t-1}	0.115	0.019	-1.98	0.004
GDP_t	0.303	0.152	2.04	0.042
ΔGDP_{t-1}	0.178	0.106	2.71	0.006
TRD_t	-0.212	0.0018	-2.78	0.07
ΔTRD_{t-1}	-0.007	0.0028	-3.21	0.081
FDI_t	0.061	0.026	2.36	0.043
ΔFDI_{t-1}	0.079	0.037	3.4	0.002
URB_t	0.020	0.085	2.12	0.091
ΔURB_{t-1}	0.237	0.049	3.32	0.007
$INNO_t$	0.072	0.098	2.71	0.086
$\Delta INNO_{t-1}$	0.098	0.083	2.08	0.067
ECT (- 1)	-0.687	0.264	-2.57	0.018
R^2			0.7317	
N			20	

Simulations			5000	
Prob (F statistics value)			0.004	

Based on the results, the amount of power consumed has a positive impact on CO_2 emissions in the short term. India relies predominantly on fossil fuels for its energy production, which is the main catalyst for the degradation of its natural environment and exacerbates living conditions in the country. The congruity between the findings of this research and those of previous studies (Jayanthakumaran et al. 2012, Shahbaz et al. 2013, and Sarkodie and Strezov 2018a) serves as substantiation for the reliability of this investigation. Both individuals reached the same results and asserted that there is a correlation between the extent of environmental harm caused and the quantity of power utilised, thereby establishing a clear link between the two.

Based on the calculations, a 1% rise in energy usage would result in a short-term rise in CO_2 emissions of 0.11% and a long-term increase of 0.03%. This phenomenon would manifest itself in both the immediate and the distant future. The results of this study are consistent with the findings of other types of research, indicating their reliability (Sarkodie and Strezov 2018b; Bekun et al. 2019).

The statistically significant increase in carbon emissions may be attributed to the gradual expansion of the economy. Based on the acquired data, it is anticipated that a 1% rise in economic growth will lead to a long-term decrease of 0.30% in carbon emissions and a short-term increase of 0.17% in carbon emissions. Based on the information shown in Table 5, international trade has a somewhat adverse effect on CO_2 emissions in the short term, but a considerably adverse effect in the long term. The research discovered that a 1% increase in trade resulted in a decrease in CO_2 emissions, both in the short and long term. Some individuals believe that global trade can have a substantial and beneficial impact on endeavours to prevent the deterioration of the natural environment. There are dissenting opinions on this matter (Irfan et al. 2019).

The study's findings indicate that a 1% increase in foreign direct investment results in a long-term rise in carbon emissions of 0.06% and a short-term rise in carbon emissions of 0.07%. This conclusion was corroborated by the results of a study that was published in 2017. The reason for this is that developing countries frequently possess energy infrastructure that is less efficient compared to developed nations. Previous research has indicated that urbanisation in China has the ability to positively influence the total carbon emissions produced by the country. The findings indicate that there is a correlation between a 1 percentage point increase in innovation and a potential increase in carbon emissions of up to 0.07% in the long run and 0.09% in the near term. Based on the R^2 value, the independent factors examined in this study account for 73% of the observed variation in the dependent variable. Further evidence supporting the credibility of the model is the F statistics' P value of 0.004.

Table 6: Diagnostic tests

Test	**P value**	**Results**
Breusch-Godfrey LM	0.538	No serial correlation problem
Breusch-Pagan-Godfrey	0.604	No heteroscedasticity problem
White's test	0.350	No heteroscedasticity problem
Ramsey reset test	0.824	Model is properly specified

The results obtained from various diagnostic procedures are presented in a tabular format for your convenience (Table 6). The Breusch-Godfrey LM test was employed to examine the issue of serial correlation in regard to this model. It is logical to infer from this that our model does not exhibit any issues related to serial correlation. The Breusch-Pagan Godfrey test and the White’s test were conducted using identical methods to identify and resolve the source of the heteroscedasticity problem. Based on the results of these tests, it is clear that the estimated model we currently have does not exhibit heteroscedasticity. The Ramsey reset test was examined as part of the inquiry to ascertain the accuracy of the suggested ARDL model. The research findings indicate that the construction of the ARDL model was deemed appropriate.

Conclusion

This article presents an analysis that analysed the interrelationships in India between the increasing energy use, economic considerations, urbanisation, and the degradation of the natural environment from 2000 to 2020. To examine the relationship between variables in both the short-run and long-run, the authors of this work utilised a newly developed dynamic ARDL simulation. Energy consumption, economic growth, urbanisation, and trade exert a detrimental impact on carbon emissions in the short term. However, only economic growth and trade exhibit a substantial and lasting negative effect on carbon emissions in the long term. In the immediate term, urbanisation and trade have a minimal impact on carbon emissions. These results are the product of implementing the dynamic ARDL simulations model. Furthermore, urbanisation has a substantial and beneficial impact on the long-term carbon emissions. Foreign direct investment has a substantial and favourable impact on carbon emissions, both in the short and long term. Ultimately, innovation has a slight yet beneficial impact on carbon emissions, both in the long term and in the short term.

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