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Determinants of Environmental Degradation in India: Fresh Insights

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Abstract:

This study aims to investigate the impact of electric power consumption, trade openness, urbanization, and income per capita on environmental degradation. The paper focuses on the Indian economy and employs "Autoregressive Distributed Lagged Modeling Approach (ARDL)" and utilizes data from 1991 to 2023. Findings confirm the EKC hypothesis between income and CO2 for the Indian economy where CO2 initially rise with the increase income level, but eventually higher economic growth enhanced environmental outcomes. Similarly, our results show that urbanization has improved the environment while higher electric power consumption has degraded the environment. However, evaluations on the impact of trade openness show that it has an insignificant impact on the environment. The results have implications India that could be utilized for effective policy making by the government authorities of India to address environmental challenges.

Keywords: CO_2, Trade Openness, Urbanization, India, EKC, ARDL.

1. Introduction

The growth journey of the India in recent times has been impressive both for policy makers and researchers. India performed well over the years economically (e.g., Kanjilal & Ghosh 2013). The Indian economy is leading the global growth and is accounting for about 15 % global economic growth (IMF, 2018). According to the report of World Bank, the Indian economy is the third largest economy globally by the benchmark of PPP and further its growth is turned stable, diversified recently. This remarkable growth experience has helped the economy to uplift millions of people from poverty. Higher economic performance is the prime goal of all economic activities as it is directly related to improved living standards.

Different factors played a role in the growth performance of the Indian economy. For example, Chatterji et al., (2014) reported that international trade has improved economic performance in India since 1980 and onward. The open trade policies adopted during the early 90s have also played a vital role in sustaining economic growth including attracting higher foreign direct investment and reducing restrictions on private companies in India as discussed in Sarkar and Mishra (2023). Majumdar (2023) show that economic reforms such as promoting higher privatization and trade liberalization enabled India to develop. Policy makers in India have realized the importance of outward oriented policies over the inward oriented policies though a bit lately.

Despite the satisfied growth experience of the Indian economy, it is also a fact that CO_2 emissions are also on the rise and the environmental quality is adversely affected (Udemba et al., 2021; Qayyum et al., 2021; Hossain et al., 2023). Al-Mulali et al. (2018) commented that global warming is the main challenge facing the world. Rudra and Chattopadhyay (2018) in their recent comprehensive paper demonstrated that CO_2 and PM_{10} are increasing with a steady pace in the Indian economy. Improving the quality of the environmental is indeed essential for the residents of India as bad poor environment quality is associated with numerous socio-economic problems. Managi and Jena (2008) also highlighted serious environmental issues associated with higher economic growth and reported that the Indian economy is losing $14 billion annually due to pollution.

The other contending challenge for the Indian economy is higher urban migration from rural areas. Urban migration has been on the rise in India. According to the World Bank report (2011), cities and towns have been expanded as increasing number of people migrate to cities and towns to get opportunities. Study of Study of (Nijman 2013; Raihan and Voumik, 2022) and demonstrated that the urban population increased rapidly during the last decade. Urban population is thought to be an integral part of economic growth as mentioned by the World Bank report of (2011), however it poses serious threats. Work in also (Chopra, 2016; Haldar and Sharma, 2022) showed that urbanization is mainly responsible for environmental degradation particularly in India.

Recently, environmental issues got attention from all stakeholders. Several researchers tried to study the linkages between environmental issues and their root causes. In this direction, the relationship between electric power consumption, trade, income, urbanization, and environment degradation has got the attention of researchers. There are significant number of cross-country studies on the factors of CO_2 emissions. However, cross-country studies mainly suffer from heterogeneity problems and hence their applicability to specific economies is always questionable. The Indian economy is moving towards the more liberal regime in recent years and is also facing urban migration problem. Therefore, the Indian economy is indeed very relevant to study the factors of environmental degradation. Previous empirical papers have not extensively focused on the economy of India to figure out the true determinants of CO_2 emissions. Therefore, we attempt to fill the research gap by focusing on the Indian economy. Our findings will be helpful for the government authorities of India.

This article investigates the relationship between electric power use, trade, urbanization, income level and environmental degradation for the Indian economy. The present study is also interested to test the EKC hypothesis. This examination is of crucial importance due to the rapid economic growth and the strong reliance of exhaustible energy resources that could have the potential on environmental quality. Considering the ongoing controversy on the extent to which economic development progression influences environmental quality, we expect that policy makers will find our results useful.

The outlines of the papers are as follows. Section two provides a detailed discussion on literature. Section three report descriptive statistics on the data utilized to investigate the research question. Section four explains the methodology, and Section 5 provides thorough discussions and analysis on the short- and long-term effect of income on environmental degradation. Conclusion is shown in the final section.

2. Literature Review

Several studies are carried out by researchers to investigate what are the major influencers of environmental quality in India. Kumar (2011) focused on the Indian economy and showed that CO_2 emissions impacted economic growth positively. Indeed, Shahbaz et al. (2021) show that CO_2 emissions are inevitable for economic due to the higher reliance of imported oil and fossil fuel-based energy. Bekun (2022) also confirmed significant impact of non-renewable energy and CO_2 emission on observed GDP and that there exists a one way between CO_2 emission economic growth. On the other hand, work by Udemba (2021) shows that there is a long run relationship between CO_2, trade and growth.

Kanjilal and Ghosh (2013) demonstrate evidence regarding EKC hypothesis for India. Moreover, in a recent study, Usman et al. (2019) investigated the EKC hypothesis for the Indian economy by also focusing on energy consumption and democracy. Rudra and Chattopadhyay (2018) proposed a new sustainable index for human development and reported the presence of U-shaped EKC. India is a diverse economy and hence disparities may be present. Sinha and Shahbaz (2018) focused on the Indian economy and applied ARDL bounding approach to investigate the EKC hypothesis. They proved the EKC in Indian economy and further reported that the turning point is US $ 2937.77. Uzair Ali et al. (2022) also confirm the EKC hypothesis that the relationship between

CO2 and economic development is U-shaped and a short-term causality running from economic development to CO_2.

This shows that Indian economy has not been the focus of researchers. It means that there is a need to consider the Indian economy and identify the determinants of CO_2 emissions. The Indian economy has done well recently by improving its overall economic growth. Therefore, we are interested to explore whether this remarkable growth of the Indian economy is responsible for environmental issues.

3. Data and Descriptive Statistics

We use carbon dioxide (CO2) for environmental degradation. Income (Y) is chosen to represent the economic development of the Indian economy. Urban density (UPG) is also selected to evaluate the extent to which urbanization could affect environmental degradation in India. Electric power consumption is used for energy. Finally, trade openness is utilized as explanatory of environmental degradation following (Jayanthakumaran et al., 2012; Kohler, 2013; Al-Mulali et al., 2016; Lin, 2017; Shahbaz et al., 2017; Ghazouani et al., 2020; Wen et al., 2020; Sajeev and Kaur, 2020; Jun et al., 2020; Wang and Zhang, 2021; Karedla et al., 2021).

Table 1. Descriptives Analysis

Variables	Definition	1991	2023	% Change
CO_2	“Metric tons per capita”	0.741	1.662	124.265
Y	“GDP per capita (constant US $)”	531.898	2236.313	320.439
UPG	“Urban population as % of total population”	3.067	2.245	-26.806
TRADE	“Trade as % of GDP”	16.987	45.921	170.323
ELC	“Electric power consumption (kWh per capita)”	293.317	768.334	161.946

“Source: Author Calculation from WDI Database”

In the first step, it is worthwhile describing the data to underline the behavior of the data over the years. We have reported average data from the start year 1991 and the final year 2023. Table 1 reports descriptive statistics from 1991 to 2023 of selected variables. CO_2 emissions measured in “metric tons per capita” remained 0.741 in 1991 which has raised to 1.662 in 2023. The net increase in CO2 emission is more than 124 percent, which is indeed alarming. Similarly, urban population growth for the Indian economy has declined by more than 26 percent. Urban population growth was 30.6 percent in 1991 which has decreased to 2.245 percent in 2023. It is interesting to note that urban population growth has declined consistently throughout the study period. Similarly, the Indian economy has achieved remarkable improvement in terms of trade openness. The trade openness degree has improved by more than 170 percent between 1991-2023.

Moreover, electric power consumption also exponentially raised. The statistics show that electric power consumption increased by more 161 percent between 1991-2023. percent increase in energy used in India. The Indian economy is focusing on the industrialization process recently. Hence, the increase in electric power consumption is justifiable as industrialization is dependent on the use of energy. However, alternative sources of energy use must be used. Traditional energy sources produce huge emissions which are harmful. It is also vital to show that income level has raised in India significantly. The statistics show that the income level has jumped from 531.898 US $ in 1991 to 2236.313 US $ in 2023. This enormous rise in income has helped the Indian economy to win the fight against the poverty. These statistics show that the overall performance of India is very good.

4. Modeling and Methodology

This study intends to study to model CO_2 emissions, per capita income, openness to trade, and urban population growth for the Indian economy. The following model is designed for analysis purposes.

$$lnco_{2t} = \beta_0 + \beta_1 lny_t + \beta_2 lntrd_t + \beta_3 upg_t + \beta_4 lnelc_t + \mu_t \qquad (1)$$

Model 1 demonstrates that CO_2 emissions are dependent on income, openness, urban population growth rate and electric power consumption. CO_2 emissions which are measured in “metric tons per capita”. The term Y_t stands for income measured in “constant US Dollars”. Similarly, “trade as percentage of GDP” is utilized to capture trade openness of the Indian economy while urban population is growth is used to capture urbanization. Finally, electric power consumption is measured by “Electric power consumption (kWh per capita)”. Data on the included variable in model-1 are taken from credible international data source which is known as “World Development Indicators (WDI)”. The WDI data is available for researchers freely and can be downloaded easily in several formats including Excel.

We followed the recent study conducted by Ahmad el al., (2018) and Afridi et al. (2019) They have taken income in square form to test the EKC hypothesis. We modify the function form defined in expression (1) as below.

$$lnco_{2t} = \beta_0 + \beta_1 lny_t + \beta_2 lny_t^2 + \beta_3 lntrd_t + \beta_4 upg_t + \beta_5 lnelc_t + \mu_t \qquad (2)$$

In expression 2, we have added the square term of income level. All other variables are explained above. Therefore, in the next step, we move towards the available cointegration approaches. Several techniques, “Engle Granger (1987)”, “Johansen (1988)”, and “Autoregressive distributed lag model (ARDL)” have been proposed in the literature. Among the mentioned approaches, the Engle Granger test and Johansen test work well for two and more than two non-stationary variables respectively. The autoregressive distributed lagged modeling approach (ARDL) is specifically designed by Pesaran Shin and Smith (2001) which handles both non-stationary and stationary variables and is more efficient in small sample analysis. Therefore, we will employ the ARDL modeling approach owing to the numerous benefits associated with it. We have transformed model-2 into the framework of ARDL as given below.

$$\Delta lnco_{2t} = \beta_0 + \sum_{i=1}^{n1}\beta_{1i}\Delta lnco_{2\,t-i} + \sum_{i=0}^{n2}\beta_{2i}\Delta lny_{t-i} + \sum_{i=0}^{n3}\beta_{3i}\Delta lntrd_{t-i} + \sum_{i=0}^{n4}\beta_{4i}\Delta upg_{t-i} + \sum_{i=0}^{n5}\beta_{5i}\Delta lnelc_{t-i} + \gamma_1 co_{2\,t-1} + \gamma_2 y_{t-1} + \gamma_3 trd_{t-1} + \gamma_4 upg_{t-1} + \gamma_5 lnelc_{t-1} + \varepsilon_t \quad (3)$$

The parameters $(\beta_1 - \beta_5)$ stands for the short run impacts of regressors on the dependent variable. The parameters $(\gamma_1 - \gamma_5)$ indicate long run impacts.

5. Discussion and Findings

5.1 Unit root Testing

The unit root testing is essential to choose the proper model based on the behavior of the chosen series overtime. We have therefore utilized two widely used test namely, the "augmented dickey fuller (ADF)" to find out whether the selected variable for the study exhibits unit root.

Table 2: Unit root

"Variables"	"Level"	"Difference"	"Decision"
$LNCO_2$	-0.425	-4.859***	I(1)
LNTRD	-1.139	-4.929***	I(1)
UPG	-2.912	-4.009***	I(1)
LNY	-1.546	-5.667***	I(1)
LNELC	-2.721	-5.398***	I(1)

Note: "The asterisks (***) stands for 1 percent significance level".

Results of Table 2 confirmed the unit root issue which is directly linked with all variables. Hence, the use of OLS is rejected to avoid drawing conclusions based on spurious results. By taking the first difference, the issue of unit root is addressed, and all data series become stationary. Thus, based on the unit root testing that necessitates the transformation of the results, cointegration models should be the appropriate model to utilize in investigating the impact of selected determinants on environmental degradation.

5.2 Descriptive Analysis

In Table 3, the study reports descriptives. The average value of CO2 emissions is 1.280 while the maximum value is 2.054 and minimum value is 0.731. Likewise, the electricity use in India is 556.680 with a standard deviation of 181.876. The maximum value of electricity use is 794.292 while the minimum value is 293.317. The average value of openness is 37.073 for India while the standard deviation is 12.295. The urbanization statistics show that average urbanization is 30.278 while the maximum value is 36.364 and lowest value is 25.778. The income statistics show that its average value is 1171.443 while the maximum value is 2236.313 and minimum value is 531.898.

Table 3. Descriptive Analysis

Descriptives	CO_2	ELC	TRD	UPG	Y
Mean	1.280	556.680	37.073	30.278	1171.443
Maximum	2.054	794.292	55.793	36.364	2236.313
Minimum	0.731	293.317	16.987	25.778	531.898
Std. Dev.	0.420	181.876	12.295	3.216	518.520
Observations	33	33	33	33	33

5.3 ARDL Bound Testing

Hence, the use of OLS method was not suitable. The more appropriate approach is to use the cointegration tool to obtain consistent and reliable results, ensuring robust conclusions.

Table 4: ARDL Outcome

Variable (Dependent)	Value	Decision
F CO2	11.695***	“Cointegrated”
F TRD	6.779*	“Cointegrated”
F Y	10.640***	“Cointegrated”
F UPG	3.245***	“Not Cointegrated”
F ELC	9.593***	“Not Cointegrated”
Levels	“Lower Value”	“Upper Value”

1	"3.06"	"4.15"
5	"3.12"	"4.25"
10	"2.75"	"3.79"

Note: "The asterisk (***, *) shows 1 percent and 10 percent significance level respectively".

Cointegration results are inserted in Table 4. Cointegration is accepted for all models except where urban population is used. It means that variables have joint long-term relationships among themselves. Cointegration is desirable for showing long-term relationships.

The second important analysis is to use the "error correction models (ECM)". The objective of the ECM is to study the short run impacts. The ECM models include the "error correction term (ECT)" as well. The role of ECT is important as it has some valuable advantages. For example, the ECT indicates the speed by means of which the model converts to equilibrium. All models in the short run are not in equilibrium state. However, in the long run, all models reach the level of equilibrium. The role of ECT is that it shows the speed of conversion which is important for policy analysis. Therefore, we must propose ECM models to achieve the benefits. We have designed the ECM models below.

$$\Delta lnco_{2t} = \beta_0 + \sum_{i=1}^{n1}\beta_{1i}\Delta lnco_{2\,t-i} + \sum_{i=0}^{n2}\beta_{2i}\Delta lny_{t-i} + \sum_{i=0}^{n3}\beta_{3i}\Delta lntrd_{t-i} + \sum_{i=0}^{n4}\beta_{4i}\Delta upg_{t-i} + \sum_{i=0}^{n5}\beta_{5i}\Delta lnelc_{t-i} + ECT_{t-1} + \varepsilon_t \quad (4)$$

5.3 Results and Discussions

The long run results and the short run dynamics are presented in Table 5. In the long run, income has impacted CO_2 emissions positively. Similarly, the square term of income is negatively and significantly linked with CO_2 emissions. The positive influence of income and the negative influence of its square term has confirmed the EKC hypothesis. This is consistent with earlier findings in Asongu et al. (2016) and De (2023) who show that the EKC hypothesis is present in the long run. Therefore, policies makers need to be more vigilant and keep an eye on increased income level as it improves environmental quality. Hence, individuals behave more rationally, and hence environmental quality improves. Our findings are supported by prior literature (Tahir et al. 2024; Burki and Tahir, 2023).

Moreover, the results demonstrated that electric power consumption is the primary cause of the poor quality of the environment. Increased electric power consumption positively contributes to CO_2 emissions and hence worsens the environment. Our results are supported by the research study of Chopra (2016). Moreover, urbanization has improved environmental quality in India. It means that the Indian economy has effectively controlled unplanned urbanization due to which the quality of environment has improved. Finally, trade is playing an insignificant role in explaining CO2 emissions. Trade openness is not significant statistically although it carries a negative coefficient. The insignificant impact of trade openness could be explained by the fact that the Indian economy has replaced traditional technologies with advanced technologies which produces less emissions. Also, it is possible that factors may be more responsible for CO2 emissions instead of trade openness.

The short run findings show the use of electric power is the fundamental cause of CO_2 emissions in India in the short run. Moreover, trade openness has improved environmental quality significantly. Furthermore, urbanization has lost its significance. Finally, the speed of adjustment of the model is 80 percent.

Table 5: Long run and short run results

"Variables"	"Coefficients"	"Standard Errors"	"T-test"
"Long run"			
lny_t	2.093**	1.002	2.087
lny_t^2	-0.153**	0.070	-2.174
$lntrd_t$	-0.039	0.066	-0.593
Upg_t	-0.212***	0.068	-3.108
$lnelc_t$	0.830***	0.123	6.731
Constant	-11.402	3.439	-3.315
"Short run"			
$\Delta lntrd_t$	-0.074*	0.037	-1.977
ΔUpg_t	-0.051	0.053	-0.970
$\Delta lnelc_t$	1.490***	0.110	13.543
ECT_{t-1}	-0.904***	0.090	-8.924

5.4 Validity Testing and Stability Analysis

Table 6 presents diagnostics testing of the study to assess the validity of findings. Reported diagnostics show that there is no issue of serial correlation in the model's residual; no presence of heteroskedasticity; the residuals are normal; and with no evidence of omitted variables or incorrect functional form. Thus, the diagnostics tests confirm the validity of the model. We also carried out "CUSUM test" and the "Square of CUSUM test" to evaluate the stability of the model. Figure 1 and Figure 2 illustrate the "CUSUM" and "Square of CUSUM", respectively and showing that the line of both graphs lay inside the critical limits, which confirm the stability of the model.

Table 6: Validity Testing

"Diagnostics"	"F-Statistic"	"Conclusion"
"LM Test"	1.779 (0.195)	"No serial correlation"
"Heteroskedasticity"	0.831 (0.372)	"No heteroscedasticity"
"Normality"	0.672 (0.714)	"Normal distribution"
"Ramsey Test"	0.085 (0.932)	"Correct functional form"

Fig 1. "CUSUM Test"

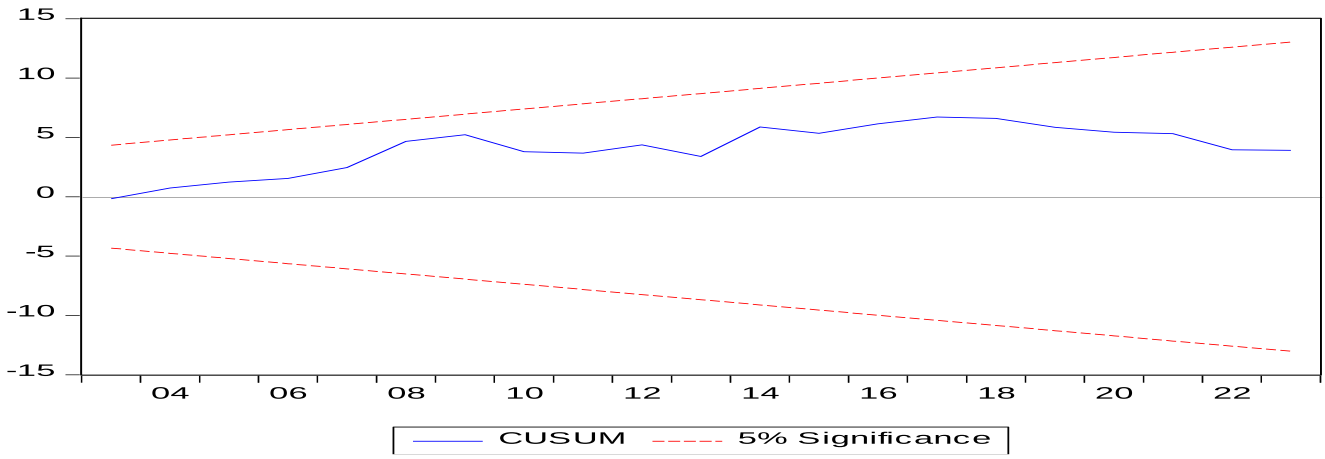
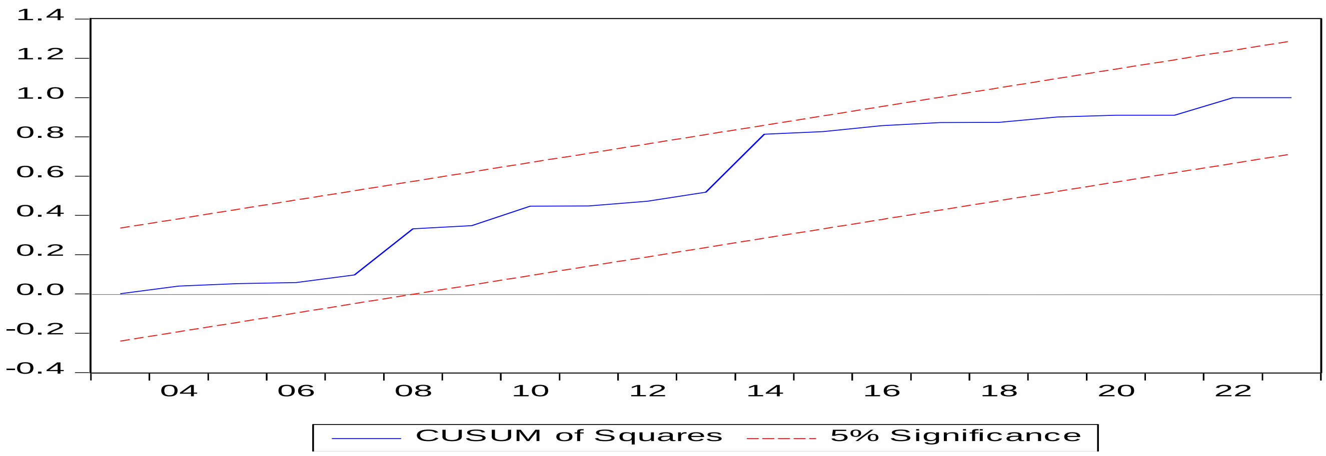


Fig 2. "CUSUM Square Test"



6. Conclusion

This paper evaluates the short-term dynamics and the potential long-term relationships between power consumption, trade, income, urbanization and environmental degradations. We have focused on the Indian economy and employed the ARDL and utilizing annual data from 1991 to 2023 to extract results.

The findings of the study have confirmed the presence of EKC hypothesis in India. It means that CO_2 initially rises with the increase income level, but eventually higher economic growth enhances environmental outcomes. Electric power consumption is the key source responsible for environmental degradation in India. Hence, policymakers must formulate policies regarding the encouragement of alternative sources of energy.

6.1 Implications

The study suggests based on the robust results that the authorities of India shall encourage the use of alternative sources of energy including renewable energy sources. The use of renewable energy sources and advanced technologies for the purpose of production will enhance the environment. Similarly, the process of urban planning needs to be carried out effectively to protect the environment from further degradation.

6.2 Limitations and Future Research Directions

Like all research study, our study has several limitations. Firstly, our study has only focused on the Indian economy and hence the results our analysis may not be applicable to other economies. Secondly, our analysis is based on only several variables while environmental quality responds to several determinants.

Future, studies are suggested to test the modeling of our paper by utilizing data of other economies. This exercise will help to determine the robustness of modeling and findings. Similarly, the inclusion of all relevant factors into the model we estimated in this paper will bring some more in-depth information about the factors of environmental quality.

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