International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2022, 12(1), 177-187.

Analysis of the Existence of Environmental Kuznets Curve: Evidence from India

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Received: 30 August 2021 **Accepted:** 14 November 2021 **DOI:** https://doi.org/10.32479/ijeep.11964

ABSTRACT

The study aims to estimate the Environmental Kuznets Curve (EKC) in the Indian context for the period of 1991-2018 by considering the role of economic growth, renewable energy, foreign direct investment, stock market size, energy intensity, and private investment in the energy sector with the help of autoregressive distributed lag (ARDL) cointegration technique. The results confirm the existence of an inverted U-shaped EKC relationship between economic growth and CO_2 emission level. However, the estimation of turnaround point shows that CO_2 levels have kept increasing past the turnaround point, indicating that income disparity is a decisive factor in determining emissions and is a better indicator than national income. Furthermore, results confirm the negative impact of economic growth and stock market size on the environment. In contrast, renewable energy, foreign direct investment, and energy intensity positively impact the environment in the long run. However, the impact of private investment is insignificant. Though the Indian economy continued to grow during the last few decades, the minimal investment towards renewable energy may not help to reduce the environmental problems. Hence, the nation's income growth alone does not solve the ecological issues in the long run. In addition, it requires an increase in private investment towards the development of India's renewable energy sector.

Keywords: EKC Hypothesis, Renewable Energy, Carbon Emission, Environmental Degradation, Turnaround Point

JEL Classifications: M41, M48, K3, Q56, Q58

1. INTRODUCTION

Increasing greenhouse gas levels have become one of the significant concerns in countries all over the world. The rapidly rising carbon emissions could lead to natural disasters and have adverse effects on the public as a whole (Diaz, 2007). Being the fastest growing economy globally, the need for energy consumption has also increased drastically in India, which cannot be compensated by using dirtier fuels. Hence, the shift towards renewable energy, which is economical and clean than non-renewable energy sources, is the need of the hour and the only solution for future energy problems. These renewable energy sources are easily managed and could improve the economy of the country. The Ministry of New and Renewable Energy (MNRE) in India set a target in 2015 to achieve 175GW of grid-interactive renewable power by 2022 (Nations, 2016). It has increased the target to 227GW in 2018 (IBEF, 2020). However, the forecast in 2020 reveals that India will miss the target and the effects of the Covid-19 pandemic also have to be seen in the coming years, which pose a challenge for the government to meet the target set (Mohanty, 2020; ANI, 2020).

India is a highly populated and developing country, and hence, fossil fuels have been the primary driver of economic growth in India. However, the government and MNRE have taken significant initiatives to employ a greener fuel mix. Since this is an ongoing and major process, a wide variety of research has been conducted on the emission levels of CO_2. One among them is the Environmental Kuznets Curve (EKC) hypothesis. EKC hypothesis suggests that as a country undergoes economic growth and the national income increases, it tends to worsen indicators of environmental degradation until the national income reaches a certain level, also known as a turn-around point beyond which the environment improves with further economic growth. Grossman and Krueger (1991) were the first to establish an inverted U-shape relationship between environmental degradation and economic development in their research paper on the North American Free Trade Agreement. A few studies have tried to find the impact of renewable energy on the carbon emission level, such as Richmond and Kaufmann (2006); Sugiawan and Managi (2016); Ben Jebli et al. (2016); Al-Mulali and Ozturk (2016); Dogan and Seker (2016); Farhani and Shahbaz (2014); Bölük and Mert (2015); Danish et al. (2017); Al-Mulali et al. (2016) and Sinha and Shahbaz (2018) in the Indian context. However, most of these studies are conducted for the study period till 2015. The objective of the present study is to improve upon if not add to the existing literature by including the extended study period. The present study analyzed the impact of Renewable Energy (RE), Foreign Direct Investment (FDI), Stock Market Size, Energy Intensity (EI), and Private Investment (PI) into the energy sector on India's carbon emissions level by using ARDL cointegration technique from 1991 to 2018.

The theoretical aspect of including the energy intensity is to measure the energy efficiency, which is the estimated amount of energy required to produce one unit of GDP. Most developed countries got the first-mover advantage and have very low energy intensity due to the highly efficient process present in their industries. However, energy intensity can vary widely depending on climate and other conditions. As a developing nation, India could not avoid using dirtier fuels. Still, it is expected to reduce gradually as and when the government moves towards clean energy and new and more efficient techniques. India has set long-term targets to reduce the country's energy intensity by 2030 to 35% of 2005 levels. As of 2020, India is on track to hit the target as already the energy intensity has reduced to 20% of 2005 levels (IANS, 2020).

The private participation investments into the energy sector are included in the study to measure the financial development and its impact on the energy sector and, consequently, the emission of pollutants. Many literature exists on the effects of financial developments, such as Dogan and Seker (2016); Shahbaz and Lean (2012); Sinha (2018). Still, to the best of our knowledge, this is the first study to consider the investment into the energy sector with the help of private participation. The ease of doing business in India has recently become better, which could attract more investments into the energy sector (Livemint, 2020). Both foreign and domestic companies can invest in existing power plants and structures or choose to start a project on their own with more efficient techniques (Roche, 2020). The expectation is that by using these investments in existing projects or new projects can make the entire energy generation process to consumption much more environmentally friendly. Hence, this study aims to find whether this private investment has a significant impact on energy efficiency and, thus, ultimately, carbon emissions.

Including stock market indicators as an explanatory variable for investigating the EKC hypothesis is not unheard of but is quite rare. Only a few literature exists that have made use of stock market indicators in this context (Sadorsky, 2011). The effect of stock markets can be multi-fold. First, they can act as an additional source of financing for businesses looking to expand. This expansion may cause consumption of more energy and an increase in CO_2. Second, a healthy stock market can also indicate a strong economy, thus promoting the production and consumption of goods and services, leading to increased emissions. Moreover, a healthy stock market is expected to be well regulated and hence, may enforce strict rules on publicly listed companies to embrace eco-friendly technology (Paramati et al., 2018). Another aspect is that the companies that are more likely to be publicly listed are more socially aware these days and acknowledge the environmental and social credentials of a company as a crucial part of its future success and growth (Vibhaw, 2020).

Despite the significant amount of literature already existing on the EKC within the context of India, this paper is an attempt to contribute to the existing work in the following ways. Firstly, it estimates the EKC for India by considering the contrasting combinations of explanatory variables such as PI into the energy sector, stock market indicators, RE as a share of primary energy supply, EI, and FDI from 1991 to 2018, using a reduced-form model. It helps create the eight cases with different variables and inspect its repercussions on India's ecological degradation during the selected years. Secondly, it aims to narrow the gap regarding the past 5 years' events as most of the previous studies have only considered the period until 2015. It is a significant flaw as renewable technology, specifically awareness about emissions, has come a long way in the last 5 years. It is recognized by Namahoro et al. (2021), and hence, they analyzed the impact of renewable energy consumption on CO_2 emission for the African countries from 1980 to 2018. Thirdly, the present study brings into the fold a new explanatory variable, PI.

Fourthly, the current study aims to find a long-run relationship among the variables and investigates the presence of the EKC and its turning points, if any. However, for all the cases, it is observed that despite the advent of turning point, the CO_2 levels are continuously rising. This finding contradicts the findings of previous studies, which state that the turning point is yet to occur and is not part of the timeline taken into consideration for the study (Sinha and Shahbaz, 2018; Sinha, 2018; Mor, 2014). The literature of EKC is categorized into two sections. The first section includes the studies that supported the inverted-U shaped EKC (Iwata et al., 2011; Baek and Kim, 2013; Sulaiman et al., 2013; Bölük and Mert, 2015). In contrast, the second section contains the studies that have given evidence against the validity of the EKC hypothesis (Pal and Mitra, 2017; Mikayilov et al., 2018; Moutinho et al., 2017; Maneejuk et al., 2020; Al-Mulali et al., 2015). However, the findings of the present study are very different from the above two categories. In the present study, the results support the EKC hypothesis, but the estimation of turnaround point gives contradictory findings. These results could be because of the lack of sufficient initiatives taken by the government and concerned authorities to impact the fuel mix significantly. The increasing CO_2 level indicates that despite the strides in India's renewable energy program to improve the carbon footprint, at this moment, not enough is being done.

At last, this paper also attempts to address the implication of the results found and suggest possible explanations for them. The study's findings are of practical value to all the stakeholders. In addition, this paper helps to understand the significance of financial development and the need for different initiatives which has to be taken by the respective authorities and the government to boost RE investment in India. It is observed that the developing countries could affect the carbon footprint if they do not have shifted their focus from harmful fuel mix to cleaner energy sources and increased the investment in the RE sector. Hence, the country does not grow faster at the cost of ecological damage but also reduces overall carbon emissions.

The rest of the paper is structured as follows. Section 2 discusses the literature related to the EKC hypothesis. Section 3 outlines the research methodology and data. Section 4 presents the main findings and analysis of the results. Section 5 includes the conclusions and policy implications.

2. LITERATURE REVIEW

There is a wide body of literature exists with regards to the EKC. They can be classified based on the methodology, the dependent and explanatory variables, and findings. A significant number of studies were carried out on pollutants other than CO_2 to investigate the EKC hypothesis, such as Cho et al. (2014) for methane and Day and Grafton (2003) for SO_2. The studies that have used CO_2 as the pollutant to investigate the EKC are: Hamit-Haggar (2012) found that there exists a significant impact of energy consumption and economic growth on CO_2 emission in Canada. Ben Jebli et al. (2016) adds onto this result with the finding that non-renewable energy consumption is also a significant factor that impacts emissions for the top 25 OECD countries. Similar findings were published by Lau et al. (2014) for the case of Malaysia, Farhani and Shahbaz (2014) for 10 MENA countries, Kasman and Duman (2015) for the EU countries, Danish et al. (2017) for the case of Pakistan, and Sinha (2018) for the Indian context.

Many of the studies on EKC also investigated the effect of different explanatory variables on environmental degradation such as financial development (Dogan and Seker, 2016; Shahbaz and Lean, 2012; Sinha, 2018; Lau et al., 2014; Ozturk and Acaravci, 2013), urbanization (Al-Mulali and Ozturk, 2016; Kasman and Duman, 2015), and trade and FDI (Ben Jebli et al., 2016; Lau et al., 2014; Hamit-Haggar, 2012; Al-Mulali and Ozturk, 2016; Dogan and Seker, 2016; Kasman and Duman, 2015). However, most of the studies showed contradictory results. Some studies found that trade and FDI positively impact emissions, whereas others found the opposite is true. These findings could be because different areas are under study, and some countries could be embracing the benefits of environmentally friendly imports, whereas some countries import highly polluting goods (Al-Mulali et al., 2015). Dogan and Karry (2019) and Shahbaz et al. (2013) investigated the impact of energy intensity on the EKC, which is a deviation from the usual proxy for the scale effect of energy consumption. They found that energy intensity positively impacts CO_2 emissions as energy intensity is a measure of efficiency. Hence, when countries become more efficient in their processes, they tend to pollute less. Despite much work done on economic growth and stock markets and their relationship, only a few exist on the stock market's impact on carbon emissions. Paramati et al.(2018) found that stock markets have a positive impact on carbon emissions for countries that are classified as developed whereas, for emerging economies and developing countries, stock markets seem to cause more harm to the environment.

Concerning the methodological aspect, two basic approaches have been used in the literature. First is the cross-country panel data analysis (Arouri et al., 2012; Narayan et al., 2016; Richmond and Kaufmann, 2006; Tsurumi and Managi, 2010; Yang et al., 2015; Iwata et al., 2011; Ben Jebli et al., 2015) and second, is the individual country time-series analysis (Bölük and Mert, 2015; Tutulmaz, 2015; Saboori and Sulaiman, 2013; Baek and Kim, 2013; Sulaiman et al., 2013; Zambrano-Monserrate et al., 2016). The current study is based on the second approach, where the ARDL cointegration technique is used to investigate the relationship. The ARDL approach is a tried and tested method in the context of EKC. Earlier studies, such as Lau et al. (2014), Bölük and Mert (2015) and Sugiawan and Managi (2016) investigated the EKC with the help of the ARDL bounds test for cointegration. In contrast, Kanjilal and Ghosh (2013) conducted a structural break analysis and confirmed the existence of a threshold cointegration relationship among the variables.

A majority of the studies tend to agree on the fact that most of the countries that show evidence for the EKC existence are from the high-income category, such as Canada (Hamit-Haggar, 2012), and the USA (Plassmann and Khanna, 2006) or upper-middle-income countries such as Malaysia (Lau et al., 2014), Turkey (B¨ol¨uk and Mert, 2015; Dogan and Karry, 2019), Pakistan (Danish et al., 2017), and India (Sinha and Shahbaz, 2018; Sinha, 2018). A minority of these studies suffer from the setback that they take into account a small timeline. Hence, not enough data was available for the inferences to be meaningful in these cases.

Based on the evidence of inverted-U shaped EKC, many studies have estimated the turnaround point and found it to be large and outside the sample (Iwata et al., 2011; Baek and Kim, 2013; Sulaiman et al., 2013; Bölük and Mert, 2015). However, few studies found the contradictory results and nullify the existence of EKC (Pal and Mitra, 2017; Mikayilov et al., 2018; Moutinho et al., 2017; Maneejuk et al., 2020; Inglesi-Lotz et al., 2014; Ben Jebli et al., 2015; Al-Mulali et al., 2015). Pal and Mitra (2017) examined the relationship between GDP per capita and CO_2 emission for India and China. Their results confirmed the N-shaped EKC, where CO_2 emission first increases with the GDP growth rate and then decreases with the expansion of economic activities, but after this, at a certain threshold level, they start increasing again. Similar evidence for the N-shaped EKC was given for Spain and Portugal by Moutinho et al. (2017). Maneejuk et al. (2020) also examined the relationship between economic growth and environmental degradation using the EKC hypothesis. They found that EKC is valid only for three out of eight international economic communities and nine out of 44 individual countries.

In the Indian context, there exist studies investigating the EKC (Mor, 2014; Sinha and Shahbaz, 2018; Sinha, 2018; Kanjilal and Ghosh, 2013). However, they provided contradictory results. Mor

(2014) given evidence for the existence of EKC. Sinha (2018) and Sinha and Shahbaz (2018) also agreed on the existence of EKC and found a cointegrating relationship among emission, growth, and energy consumption, whereas Kanjilal and Ghosh (2013) disputed the cointegration relationship.

In the current study, the objective is to verify the existence of EKC in the Indian context. Since India is an emerging and developing economy with recently implemented pro-renewable technology policies, the study set out to investigate the influence of the chosen explanatory variables on the country's emission levels. In addition, government has recently implemented a Make in India policy and welcomed private investments, making it prudent to find their impact on the EKC.

3. METHODOLOGY

The following sub-sections present the reduced-form model and ARDL methodology used in the study to verify the existence of the EKC curve.

3.1. Base Model

This study investigates the impact of different explanatory variables on the existence of the EKC for India and their effect on environmental degradation. It also attempts to find the link between the renewable energy generation of India and its effect on environmental degradation. It subjects the model to an additional analysis by measuring the impact of few more explanatory variables such as the net FDI, stock market data, and PI into the energy sector. In the current context, the equation presented by T (1993) serves the purpose as it includes a quadratic model with the provision to add other explanatory variables. Based on this logic, a reduced-form model is shown in Equation 1.

$$lnCO_{2t}=\beta_0+\beta_1 lnGDP_t+\beta_2 lnGDP^2_t+\alpha lnEI_t+\delta lnRE_t+\mu_t \quad (1)$$

Where CO_2 represents per-capita CO_2 emissions; GDP is per-capita GDP in 2015 US$, EI is the energy intensity of India measured in Kilogram oil equivalent per 2015 US$ and RE represents the share of primary energy supply from renewable sources.

For Equation 1, the coefficients β_1 and β_2 determine the geometrical relation between carbon emissions and GDP. The coefficients of income can define the five different forms of EKC.

1. $\beta_1 = \beta_2 = 0$ indicates that GDP has no impact at all on carbon emissions.
2. $\beta_1 > 0$ and $\beta_2 = 0$ indicate that GDP has a positive and linearly increasing impact on carbon emissions
3. $\beta_1 < 0$ and $\beta_2 = 0$ indicate that GDP has a positive and linearly decreasing impact on carbon emissions
4. $\beta_2 < 0$ indicates that the relationship between GDP and carbon emissions takes the form of an inverted U-shape
5. $\beta_2 > 0$ indicates that the relationship between GDP and carbon emission takes the form of a U-shape.

The rationale of including EI in the EKC hypothesis is to capture both scale effect and composition effect. In the initial phase of economic growth, developing countries like India are using fuel mix, which is comprised of fossil fuels, and the major contributor to the environmental degradation is the energy-intensive industries (Dogan and Karry, 2019). Thus, the energy intensity is expected to increase in the initial growth phase until the turnaround point is reached. Following the turnaround point, the expectation is that new and energy-efficient technologies have been adopted, thus making economic growth more efficient. Since energy intensity is also a measure of efficiency, it can capture the changes, results from a resource-intensive economy to a knowledge-technology-based economy. This stage is referred to as the composition effect, which affects the environment positively (Sugiawan and Managi, 2016). Next, the technique effect occurs when the newly adopted technologies and processes are cleaner and efficient for emissions (Grossman and Krueger, 1991). The combined role of scale, composition, and technique effect gives the inverted U-shaped relationship in the EKC.

Two variables are included in the study to capture the technique effects: FDI and PI into the energy sector. FDI is the net of inflows and outflows to the country over a certain period measured in 2015 US $. FDI can also account for the technique effect as it is a good proxy to measure the inflow of funds that can be used to produce or research better technologies. PI is the amount of investment that has been put into energy projects that directly or indirectly affect the environment. The investments can take the form of lease contracts, Greenfield projects, and divestitures. PI is also measured in 2015 US $. Additionally, stock market size is used to capture the growth and prosperity of the economy. SENSEX is the benchmark index in India and, as such, provides an excellent proxy to capture the size and prosperity of the Indian stock market. One of the reasons SENSEX is chosen over the likes of NIFTY is that this study's timeline predates establishing the National Stock Exchange (NSE).

Eight different cases are estimated to measure the impact of different combinations of variables on the CO_2 emission level, which are as follows:

- Case 1 - (*CO_2, EI, GDP, GDP^2, RE*)
- Case 2 - (*CO_2, EI, GDP, GDP^2, RE, SENSEX*)
- Case 3 - (*CO_2, EI, GDP, GDP^2, PI, RE*)
- Case 4 - (*CO_2, EI, GDP, GDP^2, PI, RE, SENSEX*)
- Case 5 - (*CO_2, EI, F DI, GDP, GDP^2, RE*)
- Case 6 - (*CO_2 EI, FDI, GDP, GDP^2, RE, SENSEX*)
- Case 7 - (*CO_2, EI, FDI, GDP, GDP^2, PI, RE*)
- Case 8 - (*CO_2, EI, FDI, GDP, GDP^2, PI, RE, SENSEX*).

The study is conducted from 1991 to 2018, and all the data has been obtained from verified sources. The data for FDI, GDP, and PI is obtained from World Development Indicators, World Bank, while CO_2 and RE data is obtained from International Energy Agency (IEA), and the EI data is retrieved from EnerData. After retroactively checking different models, Case 8 is excluded from the study as it suffers from serial correlation.

3.2. ARDL Technique

The study uses the ARDL bounds testing approach of cointegration presented by Pesaran et al. (2001). The significant advantage of using this approach is that it can handle small data samples, as is the case with the present study. Furthermore, it covers the possibility of endogeneity among the explanatory variables. It also helps to identify the long-run and short-run estimates for the models. The study shows the long-run model and the error correction term (ECT) present in the short-run model. ARDL bounds testing approach also has the inherent advantage that it does not require the variables to be of any particular order of integration as long as they are I (0) or I (1). The basic ARDL model is presented in the Equation 2.

$$\Delta lnCO_{2t} = \beta_0 + \sum_{i=1}^{p}\beta_{1i}\Delta lnCO_{2t-i} + \sum_{i=0}^{q}\beta_{2i}\Delta lnGDP_{t-i} + \sum_{i=0}^{r}\beta_{3i}\Delta lnGDP_{t-i}^2 + \sum_{i=0}^{s}\beta_{4i}\Delta lnEI_{t-i} + \sum_{i=0}^{t}\beta_{5i}\Delta lnRE_{t-i} + \sum_{i=0}^{u}\beta_{6i}\Delta lnFDI_{t-i} + \sum_{i=0}^{v}\beta_{7i}\Delta lnPI_{t-i} + \sum_{i=0}^{w}\beta_{8i}\Delta lnSENSEX_{t-i} + \lambda_1 lnCO_{2t-1} + \lambda_2 lnGDP_{t-1} + \lambda_3 ln(GDP)_{t-1}^2 + \lambda_4 lnEI_{t-1} + \lambda_5 lnRE_{t-1} + \lambda_6 lnFDI_{t-1} + \lambda_7 lnPI_{t-1} + \lambda_8 lnSENSEX_{t-1} + \varepsilon_t \quad (2)$$

Where βs represent the short-run coefficients and λs represent the long-run multiplier. For the cointegration test, the joint significance of the lagged values of the variables is estimated by using the Wald statistic. The null hypothesis for the test is stated as setting all λ values as equal and 0, which indicates no cointegration. In contrast, the alternative hypothesis states that none of these are similar, and none of them are equal to 0. The critical values for the test are interpreted in the following way. The values are present in the form of an upper bound and lower bound. If the computed statistic is greater than the upper bound, it can reject the null hypothesis. If the computed statistic is lower than the lower bound, it cannot reject the null hypothesis. If the statistic falls between the upper and lower bound, it cannot conclude anything decisively.

For ARDL, an important parameter is the lag length. The lag length should be optimal enough to take care of serial correlation and over-parameterization. In this study, Schwarz's Criterion (SC) is used to find the optimal lag length. Hence, the model with the least SC is selected for further estimation. It uses only SC as this will give parsimonious models with the least lag length.

Once the presence of cointegration among the variables is established, the long-run equation can be estimated using Equation 3.

$$lnCO_{2t} = \beta_0 + \sum_{i=1}^{p}\beta_{1i} lnCO_{2t-i} + \sum_{i=0}^{q}\beta_{2i} lnGDP_{t-i} + \sum_{i=0}^{r}\beta_{3i} lnGDP_{t-i}^2 + \sum_{i=0}^{s}\beta_{4i} lnEI_{t-i} + \sum_{i=0}^{t}\beta_{5i} lnRE_{t-i} + \sum_{i=0}^{u}\beta_{6i} lnFDI_{t-i} + \sum_{i=0}^{v}\beta_{7i} lnPI_{t-i} + \sum_{i=0}^{w}\beta_{8i} lnSENSEX_{t-i} + \varepsilon_t \quad (3)$$

The short-run model is estimated to find the ECT value, which is expected to be negative and significant. ECT estimates the speed of adjustment to the long run when there is a shock in the equilibrium. It follows some model diagnostic and stability tests such as tests for serial correlation, heteroskedasticity, and recursive estimate CUSUM and CUSUMQ.

4. ANALYSIS OF RESULTS

ARDL model requires variables to be in either I(0), or I(1) integrated, and none of the chosen variables are I(2) integrated. Hence, three different unit-root tests are used, KPSS (Kwiatkowski-Phillips-Schmidt Shin), ADF (Augmented Dickey-Fuller), and PP (Phillips-Perron). Based on the results depicted in Table 1 it is concluded that all the variables are in the I(1) form.

Before proceeding with the cointegration test, it is required to identify the optimal lag lengths. This study uses a maximum lag length of two and prioritizes models that have the least SC. The top four models suggested by minimum SC values are listed in Table 2 for all the seven cases. All the models are retroactively checked with the diagnostic statistics to ensure that they are valid. The final models selected according to the diagnostic tests and the SC are highlighted in Table 2. The next step is to establish a cointegration relationship among the variables based on Equation 2.

The tests for co-integration are conducted using the ARDL model for each case with their respective lag lengths. The results depicted in Table 3 for all the models show that the F-statistic exceeds the upper bound critical values. Hence, it is concluded that these variables in their respective models do not offer any evidence of "no co-integration" amongst themselves, and thus, the null hypothesis is rejected.

Next, the long-run multipliers and ECT are estimated for each case based on Equation 3. These results are shown in Table 4.

For Case 1, the basic model comprises only GDP, GDP^2, EI, and RE, and the results indicate that GDP and GDP^2 are insignificant. Thus, it nullifies the existence of EKC despite GDP having a positive coefficient and GDP^2 having a negative coefficient. While considering the other six models, it is observed that the coefficients of GDP are positive and significant. In contrast, the coefficients for GDP^2 are negative and significant for all the cases, indicating an inverted-U shaped relationship. Furthermore, a positive coefficient for GDP suggests that in the long run, a rise in the GDP or income will lead to an increase in carbon emissions which is consistent with the findings of (Sinha and Shahbaz, 2018; Sinha 2018; Mor, 2014). The negative sign of the GDP^2 coefficient is also as expected and is consistent with previous findings in the Indian context. According to the EKC hypothesis, the combination of GDP and GDP^2 signifies that there will be a tendency for carbon emissions to decline with an increase in income in India over the long run.

With regards to renewable energy, the long-run coefficient is positive, which is in contradiction to the previous study in the Indian (Sinha and Shahbaz, 2018) as well as foreign contexts (Sugiawan and Managi, 2016). However, this is just a case of India's

Table 1: Results of unit root tests

Variables	ADF		KPSS		PP	
	No Trend	Trend	No Trend	Trend	No Trend	Trend
Level						
CO_2	1.984	–1.404	0.6596*	0.1379*	0.0648	–1.6709
EI	0.3830	–3.1965	0.6740*	0.0744*	0.2645	–1.7796
FDI	–3.3605	–4.3790	0.6645*	0.1095*	–3.3605	–4.4437
GDP	0.2228	–1.6763	0.6575*	0.1053*	0.2073	–2.0437
GDP^2	0.5130	–2.0437	0.6659*	0.1197*	0.4946	–2.9368
PI	–2.4982	–2.8967	0.3763*	0.1175*	–2.3072	–2.9368
RE	1.9267	–0.0506	0.5474*	0.1672*	2.1570	0.0475
SENSEX	–0.8511	–3.0704	0.6539*	0.0920*	–0.6192	–3.0704
First Differences						
CO_2	–2.143551	–3.28211	0.2057	0.1012	–5.1366*	–5.2116*
EI	–4.2465*	–4.2062*	0.1082	0.0917	–4.2395*	–4.2002*
FDI	–5.7160*	–5.9344*	0.3686	0.0992	–5.8156*	–6.0066*
GDP	–4.6175*	–4.5431*	0.1533	0.1177	–4.6123*	–4.5400*
GDP^2	–4.5759*	–4.5741*	0.1985	0.1138	–4.5547*	–4.5518*
PI	–9.8665*	10.6341*	0.1101	0.0892	–9.1395*	–10.634*
RE	–4.1025*	–4.9040*	0.5554	0.1098	–4.1025*	–4.9003*
SENSEX	–6.7850*	–6.6500*	0.2848	0.2823	–8.0074*	–8.1469*

*p<0.05, **p<0.1

Table 2: Optimal lag length for each case

Case 1		Case 2		Case 3	
SC	Lag Length	SC	Lag Length	SC	Lag Length
–5.248694	2, 1, 0, 0, 0	–5.387731*	2, 1, 0, 0, 0, 0*	–5.127777	2, 1, 0, 0, 0, 0
–5.564213*	2, 1, 0, 0, 2*	–5.295421	2, 1, 0, 0, 0, 1	–5.101932*	2, 1, 0, 0, 1, 0*
–5.139896	2, 1, 0, 0, 1	–5.288332	2, 1, 0, 0, 2, 0	–5.099838	2, 1, 0, 0, 0, 2
–5.128637	2, 2, 0, 0, 0	–5.268638	2, 1, 0, 0, 1, 0	–5.036869	1, 1, 0, 0, 1, 0
Case 4		Case 5		Case 6	
SC	Lag Length	SC	Lag Length	SC	Lag Length
–5.607353*	2, 1, 0, 0, 0, 0, 0*	–5.742155*	2, 1, 0, 0, 0, 0*	–5.644514*	2, 1, 0, 0, 0, 0, 0*
–5.549714	2, 1, 0, 0, 0, 0, 1	–5.692939	2, 1, 1, 0, 0, 0	–5.575812	2, 1, 1, 0, 0, 0, 0
–5.166203	2, 1, 0, 0, 1, 0, 0	–5.660718	1, 2, 0, 0, 0, 0	–5.548066	1, 2, 0, 0, 0, 0, 0
–5.1633712	2, 1, 0, 0, 0, 2, 0	–5.634136	2, 2, 0, 0, 0, 0	–5.534328	2, 2, 0, 0, 0, 0, 0
Case 7					
SC	Lag Length				
–5.617620*	2, 1, 0, 0, 0, 0, 0*				
–5.567639	2, 1, 1, 0, 0, 0, 0				
–5.549130	2, 1, 0, 0, 0, 1, 0				
–5.541731	1, 2, 0, 0, 0, 0, 0				

*Indicates selected model

Table 3: Result of long run bounds test

	Case 1		Case 2		Case 3		Case 4	
	Value	K	Value	K	Value	K	Value	K
F-Statistic	23.22825	4	30.18469	5	22.42321	5	24.86848	6
Critical values	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
10%	2.525	3.56	2.407	3.517	2.407	3.517	2.334	3.517
5%	3.058	4.223	2.91	4.193	2.91	4.193	2.794	4.148
1%	4.28	5.84	4.134	5.761	4.134	5.761	3.976	5.961
	Case 5		Case 6		Case 7			
	Value	K	Value	K	Value	K		
F-Statistic	44.05703	5	37.35636	6	36.331201	6		
Critical values	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)		
10%	2.407	3.517	2.334	3.515	2.334	3.515		
5%	2.91	4.193	2.794	4.148	2.794	4.148		
1%	4.134	5.761	3.976	5.691	3.976	5.691		

renewable energy program, which is not significantly impacting the fuel mix. The positive coefficient is due to the increasing carbon levels despite an increase in the share of renewable energy, which indicates that despite strides are being made to improve the carbon outlook of energy production, at this moment, not enough is being done. Also noticeable is the elasticity of RE with respect to GDP. GDP has a higher magnitude, which shows that if India follows a similar trend in the long run, then the harm caused by GDP will overpower the good created by RE for the environment. As per Thompson Reuters, India had larger emission footprints. Indian public sector coal mining company, Coal India produced the highest amount of greenhouse gas among global businesses in 2016-17. Apart from Coal India, Reliance Industries, NTPC Limited, and ONGC were among the 100 highest carbon foot print global companies. According to the reports provided by the IEA, India was the 3rd highest emitter of CO_2 in the globe in the year 2015 and continued to be in the list of top 5 countries having larger emission footprints from 2000 to 2001 onward.

The results of the EI coefficient indicate the positive and significant elasticity for EI. It means that, when EI increases, the carbon dioxide emissions are also expected to increase, which is consistent with the scale effect. However, the negative sign on the coefficient can also be an indicator of the composition effect, which shows that India has started to embrace greener and cleaner technologies and make its industrial processes more energy efficient (Alberini and Segerson, 2002; Dogan and Karry, 2019; Shahbaz et al., 2013; IEA, 2021).

Regarding the cases involving the stock market indicator, results show that its coefficients are positive and significant for Cases 2 and 4 but not for Case 6. The factor that could explain the findings for Case 6 is the inclusion of FDI, which could bring just enough negative impact on the carbon emission due to the technical effect and make the stock market barely insignificant. For Cases 2 and 4, results show that the stock market index positively impacts carbon emissions, as is clear from the sign of the elasticities. This result is in accordance with the findings of Paramati et al. (2018). It can be explained by the fact that India is still a developing country and the stock market has not modernized enough to implement rules and regulations that enforce companies to become cleaner in the environmental context.

Next is to evaluate the impact of FDI on carbon emission for Cases 5, 6 and, 7. The coefficient for FDI is negative, which indicates that foreign investment could have driven technological advancements that have brought forth positive environmental impacts. This result contradicts previous findings in the international context (Lau et al., 2014). However, the magnitude of elasticity for FDI is minimal for all three cases, which indicates that the technological improvements are still not enough to overpower the degradation of the environment caused by a rise in national income and, to a smaller extent, the stock market index. The economy had faced many challenges while attracting private players to invest in the renewable energy sector during the last two decades (Sarangi, 2018). The investment in India by private players had decreased significantly from 2004 to 2008, gradually diminished during 2011-13 (Boachie et al., 2020), and remained sluggish during 2016-18 (Rooj and Sengupta, 2018).

A critical observation for Cases 3, 4, and 7 is that the PI into energy is insignificant for all three cases. This result is unexpected as in India, emphasis is being made on private players for investing in greener energy technology and production process (Roche, 2020; Livemint, 2020). However, this could be a case of delayed impact. A majority of these investments are into power plants and to make existing infrastructure more efficient. However, many of these projects could take multiple years before completion and before they significantly impact the emission levels. The global financial crisis 2008 had impacted almost all the economies and sectors, especially those in which heavy investments were proposed, including the electric power sector. The South Asian countries were already struggling from the repercussion of the food crisis and the increase in energy prices globally during that time. The impact of the crisis was fully seen on the private investments in the Indian electric power infrastructure. Projects which had achieved financial closures were not significantly affected, but the cost of debt has increased by around 75-100 basis points. Projects that were in the advanced phases of development significantly affected in achieving financial closure on time. Equity financing by PI in the power sector was adversely affected during the crisis (ESMAP, 2015).

The ECT values shown in Table 4 depict the adjustment rate after a shock to the equilibrium, and the negative sign indicates that it converges to the long-run values. The ECT terms for the seven cases are significant and negative, as expected. Since the models used for all seven cases follow the quadratic implementation of EKC hence, the turn-around point is estimated for each of the cases. The turn-around point indicates the income level at which the environmental conditions will improve with a further increase in national income. The turn-around points for each case are estimated and presented in Table 5 along with the projected years in which they are supposed to occur according to the in-sample GDP values.

Since the coefficients of GDP and GDP^2 are significant for all cases except for Case 1, that shows EKC evidence. However, for all the cases except for Case 3, it is observed that despite the turning points have already arrived, the CO_2 levels have continued to rise. This finding contradicts the majority of the literature in the Indian context, which found that the turning point is yet to occur and is not part of the timeline taken into consideration for study (Sinha and Shahbaz 2018; Sinha 2018; Mor 2014). However, a possible explanation for this has been presented in Xu et al. (2012) which stated that the GDP per capita indicator is flawed for the EKC analysis as it does not depict an actual image of income disparity. According to the IMF in 2016, India's Gini coefficient stood at 0.51 (Nair, 2016). It means that there is still a large portion of wealth owned by a minority while the majority of society earns considerably less. It means that the low-income individuals have not reached the required level of income yet, at which point they would pay attention regarding environmental protection. Similar findings were revealed by Cialani (2007) which stated that the inverted-U shape of EKC did not establish in Italy from 1861 to 2002. Their results showed that economic growth and CO_2 have a positive relationship. Zambrano-Monserrate et al. (2018) tried to analyze the relationship between GDP and CO_2 emissions in Peru during 1980-2011. They also did not support the inverted-U shaped EKC relation. The paper suggested that policies that prevent

Table 4: Long run multipliers

	Case 1	Case 2	Case 3	Case 4
	ARDL (2, 1, 0, 0, 2)	ARDL (2, 1, 0, 0, 1, 0)	ARDL (2, 1, 0, 0, 0, 0, 0)	ARDL(2, 1, 0, 0, 0, 0, 0)
ln(EI)	0.7273*	0.7221*	0.6982*	0.7173*
ln(FDI)	-	-	-	-
ln(GDP)	0.465640	0.7219*	0.9976	0.7148**
$ln(GDP)^2$	–0.027430	–0.048757	–0.0626**	–0.0483**
ln(PI)	-	-	6.74E-06	0.000317
ln(RE)	0.2782*	0.2190*	0.262607	0.2191*
ln(SENSEX)	-	0.0313**	-	0.0312**
ECT	–0.1999*	–0.2076*	–0.2809*	–0.2058*
C	–1.9489	–3.1707*	–4.0348*	–3.1528*
R^2	0.998980	0.999023	0.998853	0.999023
Adj R^2	0.998407	0.998563	0.998208	0.998474
SE	0.012124	0.011513	0.012859	0.011865
F-Statistic	1741.816	2173.041	1548.152	1818.680
DW statistic	2.510828	2.134771	2.079567	2.118749
Diagnostic tests				
Serial Correlation	0.0664	0.2437	0.1563	0.1788
Normality	0.506879	0.805116	1.475821	0.817881
Heteroscedasticity	0.9633	0.9109	0.9589	0.9597
	Case 5	**Case 6**	**Case 7**	
	ARDL (2, 1, 0, 0, 0, 0)	**ARDL (2, 1, 0, 0, 0, 0, 0)**	**ARDL (2, 1, 0, 0, 0, 0, 0)**	
ln(EI)	0.9110*	0.0629*	0.9174*	
ln(FDI)	–0.0312*	–0.0274**	–0.0313*	
ln(GDP)	1.2492*	1.1794*	1.2597*	
$ln(GDP)^2$	–0.0840*	–0.0803*	–0.0846*	
ln(PI)	-	-	–0.000375	
ln(RE)	0.3286*	0.3109*	0.3288*	
ln(SENSEX)	-	0.009547	-	
ECT	–0.1546*	–0.1467*	–0.1566*	
C	–4.4377*	–4.2557*	–4.4639*	
R^2	0.999315	0.999333	0.999315	
Adj R^2	0.998992	0.998958	0.998930	
SE	0.009643	0.009804	0.009936	
F-Statistic	3098.267	2664.789	2594.029	
DW statistic	2.346643	2.349030	2.378725	
Diagnostic tests				
Serial Correlation	0.2406	0.1465	0.1644	
Normality	1.397893	1.025821	1.422517	
Heteroscedasticity	0.9064	0.9281	0.9634	

*p < 0.01, **p < 0.05, ***p < 0.1

Table 5: Turn around point

	GDP value	Year
Case 1	4855.1102	Yet to Occur
Case 2	1642.4125	2015
Case 3	2853.5780	Yet to Occur
Case 4	1623.4864	2015
Case 5	1691.2980	2015
Case 6	1545.8833	2013
Case 7	1704.8891	2015

environmental degradation have to be established in Peru. A move towards the use of RE like solar, wind, etc., must be encouraged and promoted. Similarly, Al-Mulali et al. (2015) studied the presence of the EKC hypothesis in Vietnam from 1981 to 2011 by using the ARDL methodology. They concluded that there was a positive relationship between GDP and pollution in the country both in the short and long term, and hence, the EKC hypothesis does not exist.

Though there is a shift towards the use of RE by increasing the RE projects, India is still primarily dependent on imports of fossil fuel, crude, and petroleum products. It is one of the biggest consumers of coal globally (IEA, 2019), around 74% of energy demand is furnished through these sources. As per the Centre for Monitoring Indian Economy, India imported 171, 215, 207, 195, 213 million tons of coal in 2013-2014, 2014-2015, 2015-2016, 2016-2017, 2017-2018, respectively (Das, 2018). The rationale behind the contradiction in the present study results from the expected EKC hypothesis is the ineffectiveness and inefficiency in India's shift towards RE consumption at the earlier stages. Nevertheless, it is expected that this would not continue as India is accelerating the adaptation of RE at a faster pace. According to the NITI Aayog, the present government is looking forward to sustainable growth and structural policy reforms in electric mobility alongside other sectors. It is evident from India's second score in the clean energy investment rankings in 2018 and topped in 2019 (BloombergNEF, 2019) due to assertive RE policies and RE installed capacity.

Some diagnostic test results have been reported for each selected model in Table 4. The ideal lag lengths are determined by minimizing SC for each case, but each set of lag lengths is also checked for serial correlation, non-normality, and heteroskedasticity. Only the set of lag lengths that satisfy these criteria are then taken into consideration. Regarding the stability of the models, the CUSUM and CUSUMQ tests have been used, and all the models have plots falling within the 5% critical bounds, which signify their stability.

5. CONCLUSION AND POLICY IMPLICATIONS

The objective of this paper is to check the existence of EKC for India under the influence of various factors such as EI, RE, stock market indicators, PI into the energy sector, and FDI. In addition, the study is more relevant in India's current context as the government announces the major plan to implement 175GW of grid-interactive renewable power by 2022.

The rationale behind including the EI is to capture the composition effect and scale effect, while FDI is included to capture the technique effect. From the obtained results, it is concluded that income has a significantly negative impact on the environment in the long run, i.e., the higher the national income gets, the more the level of environmental degradation. There is also a shred of evidence that the share of renewable energy in the primary energy supply is not enough to offset the degradation brought about by the income. In addition, FDI positively impacts the environment by bringing investments into technologically cleaner and more efficient processes. Results also indicate that EI positively impacts the environment as reducing EI leads to a decrease in CO_2 emissions. According to IEA (2021), EI has declined over the period in consideration, and this could be explained due to the improving efficiency of production processes in industries across the country. In contrast, PI into the energy sector turned out to have no significant impact, but it could impact in a more extended period than in the current study period.

The study has also estimated the turning points according to the EKC hypothesis for all seven cases. Case 1 has insignificant coefficients for GDP and GDP^2, which can refute the claim for the existence of EKC. The remaining six cases show significant coefficients, and the turning-points are found to be between 2013-2015. However, the CO_2 levels are continuously increasing with an increase in wealth which indicates the fact that income inequality is the decisive factor and reducing this inequality can lead to better environmental indicators in the future.

Despite the presence of the EKC, the outlook on the Indian emission levels cannot be taken lightly and does not mean that India will soon start lowering emission levels due to the turning point. There needs to be policy implementation that backs the goal of the renewable energy target set by the government of India. One such policy could be to promote energy-efficient technologies, such as a decrease in the subsidy of fossil fuels and a shift towards more subsidies for renewable technologies. The government and authorities should also take the initiative to strengthen the environmental laws and pollution regulations to reduce the reliance on dirtier fuels such as coal, fossil fuel, etc. The government can also encourage organizations to take public initiatives to electrify rural areas with renewable energy and decrease the income disparity in these areas. A pro-trade regime can also be implemented wherein the import of funds and cleaner and greener foreign technologies can be enforced. Despite India being a developing economy, SENSEX is an extensive index with a large market capitalization. Hence, it can implement the regulations to ensure that listed companies adhere to green and clean practices, as is the precedent set by the developed economies.

The study can be extended further by considering social factors such as education, urbanization, industrialization, and political freedom. Some of these factors can play a crucial role in determining emission levels, especially education. The more educated a person is, the more socially aware they become and hence, tend to reduce the global climate crisis. Further, research can also be done with more years of data with these social factors as explanatory variables. An analysis can also be made on the impact of private investment in energy with a more extended date period. It will be interesting to see the outlook of emissions at the end of 2022, and how India will deal with the prevailing challenges in the RE sector and transform those into opportunities. Hence, an EKC analysis using a larger dataset can reveal more insights.

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