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Environmental Sustainability in India: The Effects of Financial Development and Green Energy on Ecological Footprint

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Abstract
In this study, environmental sustainability is investigated through the ecological footprint variable in India from 1965 to 2018. In this context, the impact of renewable energy use, financial development, urbanization and economic growth on India's ecological footprint is analyzed. Since all variables were stationary at the first difference, the cointegration relationship between variables was tested with Gregory-Hansen and Hatemi-J cointegration tests. Empirical findings have shown that there is a long-term relationship between the variables in the relevant period. FMOLS, DOLS, and CCR estimators were used to determine the direction and magnitude of the effect of the explanatory variables on the dependent variable. The estimation results found that while economic growth increased the ecological footprint the most, financial development decreased the most. In addition, the increase in urbanization increases environmental degradation. However, although the use of green energy is not at the desired level, it increases the environmental quality. On the other hand, the study tests the EKC hypothesis for India. Research results support that there is an inverted-u-shaped relationship between economic growth and ecological footprint. Therefore, for India, whose GDP is integrated with fossil fuels, higher growth at the beginning causes more fossil fuel use and negatively affects environmental quality. On the other hand, increasing urbanization in India, which has an underdeveloped energy infrastructure, increases environmental degradation. However, increasing renewable energy and financial development offer significant opportunities to reduce the ecological footprint.

Keywords
Environmental sustainability, ecological footprint, green energy financial development, India

Introduction

Increases in industrialization with globalization have increased global growth. Compared to 1970, industrialization increased by 262.54% in 2020, while global economic growth increased by 349.86% (UNCTADSTAT, 2022). This increase has led to high environmental degradation. Compared to 1970, global CO_2 emissions among the harmful gases released to the environment increased by 126.14% in 2020 (BP Statistic Review, 2022). Despite today's technologies, the share of fossil energy in global total energy use in 2019 was 80.88% (IEA, 2022). This shows that such a high level of fossil fuel dependency cannot be abandoned soon. There was already a need for a healthier and more livable world. This situation shows that this need will increase in severity for many years. Therefore, environmentally oriented energy policies are very important in terms of improving environmental quality.

Many factors affect environmental quality. Economic growth is among the most important factors. Higher growth causes economies to compete more and have more export ambition. This situation causes the environmental quality to be ignored in the beginning. However, insufficient and inefficient technologies in the field of energy increase environmental degradation. Therefore, higher growth initially results in more environmental degradation. However, increasing economic growth after a certain period reflects positively on the income level and welfare of the society. This situation leads to the adoption of environment-oriented policies and the increasingly effective implementation of these policies. Therefore, these situations are similar to that of the EKC. The EKC curve is a quadratic curve with a concave shape as follows.

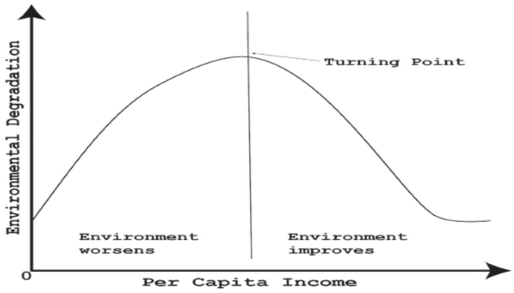

Fig. 1. The Environmental Kuznets Curve (EKC)

As can be seen in Figure 1, the EKC hypothesis examines the relationship between economic growth and environmental pollution. If we pay attention to this curve, per capita income is on the horizontal axis, and environmental degradation is on the vertical axis. Per capita income is always increasing. However, environmental degradation increases at first. However, this increase gradually increases up to a certain point. Then, at the point where the slope of the EKC is 0 (zero), the degradation remains constant. Environmental degradation then decreases rapidly. In addition, studies in the literature investigate the relationship between economic growth, environmental degradation and energy consumption (Lei et al., 2022; Vargas-Solar et al., 2022). On the other hand, there are studies investigating the effects of financial development (Anwar et al., 2022; Habiba and Xinbang, 2022) and urbanization on environmental quality (Mahmood et al., 2022; Balsalobre-Lorentevd., 2022; Kocoglu et al., 2022).

Fossil energy is the energy source that affects environmental quality the most. The use of fossil energy is generally the energy source with the highest share in the energy portfolio of developing economies. At the same time, the high fossil energy use of these economies can seriously affect the outlook for global fossil energy use. Fossil energy use, which only the economies of China and India had, had a share of 9.31% and 2.31%, respectively, in global energy use in 1990. This caused China and India to have a share of 10.18% and 2.59%, respectively, of global CO_2 emissions in the same year. However, the amount of fossil energy owned by these economies increased significantly, at 25.33% and 6.05%, respectively, in 2019. This situation caused it to be responsible for 29.38% and 6.87% of global CO_2 emissions, respectively, in 2019 (IEA, 2022). Therefore, it is seen that the global environmental quality has deteriorated approximately 3 times in only two countries in the last thirty years. These two economies are developing countries with high fossil energy use among their energy uses. However, considering that developing countries have a significant weight from a global perspective, environmental degradation raises serious concerns. Therefore, the concerns for a cleaner and healthier world future intensify even more. Therefore, economies have started to seek alternative energy sources to fossil fuel sources.

Some studies evaluate nuclear energy as an alternative to fossil fuel (Sadiq et al., 2022; Fell et al., 2022; Majeed et al., 2022). However, considering the potential safety problem of nuclear energy and the need for serious responsibility, it can be a deterrent. However, since the use of green energy reduces environmental degradation, it is thought that it can be an alternative clean energy source to fossil fuels. (Kirikkaleli et al., 2022; Yu et al., 2022; Zafar et al., 2022). Despite today's technologies, the share of fossil fuels in the global energy supply in 2019 was 80.88%. However, the share of renewable energy, which can be an alternative to fossil energy, is 4.72%, and the share of nuclear energy is 5.02% (IEA, 2022). However, these alternative energies offer significant opportunities for economies with scarce energy resources. For this reason, it is thought that using renewable energy together with nuclear energy is important in reducing environmental degradation.

On the other hand, developments in the general economy can significantly affect environmental quality. Increasing financial developments with globalization have caused capital increases in economies. The increased capital is reflected in the energy input, which brings very high costs in production. This situation leads to an increase in the use of efficient technologies in the field of energy. On the other hand, increasing environmental-oriented policies and investments are important for reducing environmental degradation (Tamazian et al., 2009). Therefore, increasing financial development can have a positive effect on environmental quality. However, in some economies, higher financial development may lead to a reduction in costs, resulting in a greater increase in competition. This situation turns into production ambition in economies and may cause environmental quality to be ignored. This situation may negatively affect environmental quality (Dasgupta et al., 2001).

Urbanization is among the factors affecting environmental degradation. Due to the increasing industrialization in countries, the fact that urban regions offer very important opportunities causes the intensification of urbanization (Börüban and Güler, 2021). Rapidly increasing industrial activities cause an increase in labour demand. This situation can lead to an increase in CO_2 emissions with the increase in energy demand. The reason for this is the insufficient energy infrastructure of developing economies and the high share of fossil fuels, especially in the housing sector. According to the 2019 Human Development Report, increasing urbanization increases CO_2 emissions (UNDP, 2019). On the other hand, it is estimated that increasing urbanization globally accounts for more than half of global energy use and causes more than 50% of energy-related CO_2 emissions (IRENA, 2016). Therefore, it is important to examine the environmental quality of urbanization and to understand energy policies in particular economies.

The Indian economy is important in terms of its high economic and social potential. India alone is responsible for 17.78% of the world's population in 2019. However, compared to 1990, its GDP increased by 479.40%, and its population increased by 56.47% in 2019 (World Bank, 2022). On the other hand, the use of fossil fuels increased by 331.24% in the same period. The highest increase in fossil energy was obtained by natural gas with 424.93%, coal with 350.78%, and oil with 285.40%. The increase in the use of fossil fuels, on the other hand, caused CO_2 emissions to increase by 335.77% in the same period (IEA, 2022). On the other hand, significant increases have been experienced in nuclear energy and renewable energy, which can be an alternative to fossil energy in India. Compared to 1990, the use of nuclear energy increased by 656.75% in 2019, while the use of renewable energy increased by 325.99%. However, while the share of nuclear energy among the total energy resources in India in 2019 was 0.57%, the share of renewable energy is 2.20%, which is not sufficient and at the desired level. On the other hand, the share of fossil fuels in 2019 was 58.66%, indicating that concerns about environmental quality will remain relevant for the Indian economy in the coming years.

CO_2 emission, which is used as an indicator of environmental quality in the literature, is a variable that only represents air pollution. However, environmental quality includes water and soil pollution as well as air pollution. Therefore, the ecological footprint has been proposed by Rees (1992) and Wackernagel (1994). The ecological footprint is an indicator that represents water and soil pollution along with air. The ecological footprint increased by 24.56% in 1973, 23.25% in 2010, and 21.49% in 2018 compared to 1961, with increasing growth, industrialization, prosperity, and changing consumption habits as an indicator of human consumption of natural resources (Global Footprint Network, 2022). Therefore, improvement in both CO_2 emission and ecological footprint indicators is important. This situation shows that there is a need for sustainable energy and environment-oriented energy policies, as well as for global production and consumption changes.

This study has many contributions to the literature. First, it will be investigated as the second-fastest growing economy globally and the fourth most energy-consuming Indian economy in the world. In addition, according to 2019 data, it is the second-largest economy in the world, with a population of over 1.3 billion. It is also the third-largest CO_2 emitter in the world by cumulative global emissions after China and the USA. Therefore, investigating environmental quality in such an economy is a matter of curiosity. The second is the use of the more comprehensive ecological footprint dependent variable instead of CO_2 emissions. Since the last data on the ecological footprint variable was in 2018, the validity of the EKC hypothesis will be investigated in India for 54 years, as shown in the current data from 1965-2018. In this way, it is desired to investigate whether the high growth rates for India are realized by sacrificing environmental quality or whether economic growth is dominant over the effects of environmental quality. Third, as far as we know, there are recent studies investigating the impact of renewable energy use on CO_2 emissions in India (Rana and Sharma, 2019; Adamu et al., 2019; Usman et al., 2019; Ozcan and Ulucak, 2021; Sultan et al., 2021; Sahoo and Sahoo, 2022; Bekun, 2022). However, this study differs from other studies in terms of both duration and use of renewable energy, as well as ecological footprint, financial development and urbanization variables. In addition, the impact of renewable energy use, financial development and urbanization on environmental quality has recently been examined within country groups, including the Indian economy (Anwar et al., 2022). In this study, it is examined specifically for India. On the other hand, the Hatemi-J test and the Gregory-Hansen test are used to investigate the cointegration relationship between the variables and structural breaks included in the model. In addition, the FMOLS long-term estimator is used. DOLS and CCR estimators were used to assess the robustness of the results.

This study investigates the impact of green energy consumption (hydro), financial development, and urbanization on the ecological footprint, which is an important indicator of environmental quality for the Indian economy. On the other hand, the validity of the EKC hypothesis for the Indian economy is tested. A literature review is given in the next section. Then, the data and model are introduced, and the empirical findings are explained. In the last section, conclusions and implications are presented.

Literature Review

Many studies in the literature investigate the relationship between environmental quality and economic growth. Mehmood (2022) found that increasing economic growth in South Asian countries, including the Indian economy, adversely affected the environmental quality up to a certain level, and then there were improvements in environmental quality. Similarly, Usman et al. (2019), Rana and Sharma (2019), Sultan et al. (2021), and Ozcan and Ulucak (2021) found that the EKC hypothesis is valid for the Indian economy. On the other hand, some studies obtain the validity of the EKC hypothesis for different country groups by using the ecological footprint variable instead of CO_2 emission. Ajmi and Inglesi-Lotz (2021) for Tunisia, Aydin and Turan (2020) for India and South African countries, Dogan et al. (2019) for Mexico, Indonesia, Nigeria, and Turkey, Bulut (2021) for Turkey, Ergun and Rivas (2020) for Uruguay and Mrabet and Alsamara (2017) for Qatar investigated the EKC hypothesis for ecological footprint and found evidence that it is valid. On the other hand, Murshed et al. (2022), in their study of South Asian countries, found that the EKC hypothesis is not valid for India. Similarly, Alola and Ozturk (2021) for the USA, Adamu et al. (2019) for India, Koc and Bulus (2020) for South Korea, and Sarkodie (2018) for Africa, found that the EKC hypothesis is not valid. On the other hand, Al-Mulali et al. (2015) for low- and low-middle-income countries and Yilanci and Pata (2020) for China, using the ecological footprint, obtained results that support the validity of the EKC hypothesis.

In the literature, there are studies in which the financial development variable is used while testing the EKC hypothesis. With globalization, production has increased in economies in recent years. This situation has revealed financial development as a driving force for the progress of economies. Increasing financial development causes a capital increase in host economies and increases the use of efficient technologies. In addition, higher financial development encourages the use of clean energy and causes an increase in renewable energy investments. Thus, higher financial development positively affects the environmental quality (Al-Mulali and Sab, 2012; Lahiani, 2020; Khan and Ozturk, 2021). On the other hand, increasing financial development unconsciously increases production and turns it into ambition. Increasing production increases the energy demand. In countries with high use of fossil fuels, the increase in energy demand increases the use of fossil fuels. In this case, it causes an increasing effect of higher financial development on CO_2 emissions (Khan et al., 2022; Anwar et al., 2022; Ling et al., 2022).

In the literature, different results have been obtained for different countries and with different methods. However, in general, the use of renewable energy has an increasing effect on environmental quality. However, this is not enough. In addition, efficient technologies and the use of alternative energy sources are also necessary for environmental quality.

Material and Method

Data and Model

In this section, the validity of the EKC hypothesis for the Indian economy in the period 1965-2018 is investigated. For this, the following model will be used:

$$\boldsymbol{EF_t = \beta_0 + \beta_1 GDP_t + \beta_2 GDP_t^2 + \beta_3 FD_t + \beta_4 GREEN_t + \beta_5 URB_t + \varepsilon_t} \qquad (1)$$

CO_2 emission, which is used as an indicator of environmental quality in the literature, is a variable that only represents air pollution. However, environmental quality includes water and soil pollution as well as air pollution. Therefore, ecological footprint, which is an indicator that represents water and soil pollution along with air, was chosen as the dependent variable. Therefore, in equation (1), EF represents the ecological footprint (gha per capita). In addition, GDP expresses GDP per capita (constant 2015 USD), FD expresses financial development (domestic credit to private sector percentage of GDP), and URB expresses urbanization (ratio of urban population to total population). Due to data constraints, GREEN is taken as hydro-green energy consumption (per capita (TWh)). GDP, FD, and URB data were obtained from the World Bank (2022), EF data were obtained from the Global

Footprint Network (Global Footprint Network, 2022) and GREEN data were obtained from the BP (2022) statistical review. The natural logarithms of all variables are taken.

(1) Equation is quadratic. For the EKC hypothesis to be valid in this equation, $\beta_1 > 0$ and $\beta_2 < 0$ must be statistically significant. This means that economic growth is constantly increasing while environmental degradation rises to its peak, then stops, and then declines rapidly. On the other hand, equation (1) shows an inverted-u-shaped concave parabola. Therefore, the vertex of this parabola is obtained as $Y^* = \frac{-\beta_1}{2\beta_2}$. Therefore, the slope at the Y^*point is zero, and after this point, the level of environmental degradation starts to decrease rapidly.

Methodology and Empirical Results

In this part of the study, the stability tests of Perron (1989) and Zivot and Andrews (1992), which allow for structural breaks, will be used. Then, Gregory and Hansen (1996) and Hatemi-J (2008) cointegration tests will be performed for the long-term relationship. Then, the Fully Modified Least Squares Method (FMOLS), Canonical Co-integrated Regression (CCR), and Dynamic Ordinary Least Squares (DOLS) estimators, in which the structural changes are included in the model as dummy variables, will be used for the short-long-term relationship.

Perron (1989) Unit Root Test

In the stagnation test brought to the literature by Perron (1989), Perron stated that the Great Depression that took place in 1929 and the Oil Crisis in 1973 would cause structural change, and under the basic hypothesis, he discussed the A, B, and C models as follows (Perron, 1989: 1364).

$$y_t = \mu + \alpha y_{t-1} + \delta_1 D(TB)_t + e_t \quad \text{(Model A)}$$
$$y_t = \mu + \alpha y_{t-1} + \delta_2 DU_t + e_t \quad \text{(Model B)}$$
$$y_t = \mu + \alpha y_{t-1} + \delta_1 D(TB)_t + \delta_2 DU_t + e_t \quad \text{(Model C)}$$

Model A, Model B, and Model C are the unit root processes in which structural break occurs at the level, respectively; slope parameter; It shows that the structural break is stable and trending. The null hypothesis for Model A is based on the existence of a unit root. On the other hand, Model C indicates that it is not stationary due to a structural break in both the level and the slope. Where $D(TB)_t$ and DU_t are dummy variables considering shocks in slope and level, respectively. Table 1 shows the unit root test results.

Tab. 1. Perron unit root test results

	Model A			Model C		
Level	Test Statistics	Lag	Break Date	Test Statistics	Lag	Break Date
EF	-3.316	0	2006	-3.747	0	1999
GDP	-1.785	4	1978	-2.170	4	1978
GDP^2	-0.882	4	1978	-1.152	4	1978
FG	-2.333	0	1989	-2.188	0	1986
GREEN	-3.724	0	1994	-4.608	0	1981
URB	-4.278	1	1990	-3.903	1	2003
1st Dif.	Test Statistics	Lag	Break Date	Test Statistics	Lag	Break Date
EF	-10.880^{***}	0	2002	-10.785^{***}	0	2002
GDP	-6.708^{***}	3	1976	-6.634^{***}	3	1977
GDP^2	-6.584^{***}	3	2002	-6.680^{***}	3	1977
FG	-7.504^{***}	0	1998	-7.704^{***}	0	1998
GREEN	-9.031^{***}	0	2004	-8.774^{***}	0	2004
URB	-4.934^{*}	1	1980	-5.438^{*}	1	1980

Note: Critical Values for Model A obtained from Perron (1989) are 1%=-5.92, 5%=-5.23, 10%=-4.92%, Critical values for Model C are 1%=-6.32%, 5%=-5.59%, 10%=-5.29%.

Table 1 shows the unit root test results of Model A and Model B. For both models, all variables have unit roots at their level values. However, in the first difference, the URB is stationary at 10%, and other variables are stationary at the 1% significance level. Therefore, the integrated degree of all variables is obtained as I(1).

Zivot and Andrews (1992) Unit Root Test

While Perron (1989) determined the structural breaks externally in the stability test, Zivot and Andrews (1992) included them internally in the model. Zivot and Andrews (1992), who internally determined the structural break dates, introduced the following three models.

$$y_t = \mu + \beta t + \alpha y_{t-1} + \theta_1 DT(\varphi) + \sum_{i=1}^{k} c_i \, \Delta y_{t-i} + e_t \qquad \text{(Model A)}$$
$$y_t = \mu + \beta t + \alpha y_{t-1} + \theta_2 DU(\varphi) + \sum_{i=1}^{k} c_i \, \Delta y_{t-i} + e_t \qquad \text{(Model B)}$$
$$y_t = \mu + \beta t + \alpha y_{t-1} + \theta_1 DU(\varphi) + \theta_2 DU(\varphi) + \sum_{i=1}^{k} c_i \, \Delta y_{t-i} + e_t \qquad \text{(Model C)}$$

Model A, Model B, and Model C are fixed, respectively, in trend; It refers to the process in which there is a structural break in the constant and trend. The null hypothesis for Model A is based on the existence of a unit root. On the other hand, Model B is a unit rooted in a change in trend. For Model C, it means that it is stable and not stationary due to a shock in the trend. Here, *DT* and *DU* are dummy variables that consider the constant term and structural breaks in the trend, respectively. Δy_{t-i} was added to the model to avoid the autocorrelation problem.

Table 2 shows the unit root test findings.

Tab. 2. Zivot and Andrews unit root test results

	Model A			Model C		
Level	**Test Statistics**	**Lag**	**Break Date**	**Test Statistics**	**Lag**	**Break Date**
EF	-2.861	1	2007	-2.961	1	2000
GDP	-1.909	4	1979	-2.101	4	1979
GDP^2	-0.979	4	1979	-1.131	4	1979
FG	-3.445	3	1990	-3.184	3	1990
GREEN	-3.869	0	1975	-4.653	0	1982
URB	-4.044	3	1991	-3.425	3	2010
1st Dif.	**Test Statistics**	**Lag**	**Break Date**	**Test Statistics**	**Lag**	**Break Date**
EF	-10.334***	2	2003	-10.286***	0	2006
GDP	-6.503***	4	1985	-6.212***	4	1985
GDP^2	-6.287***	4	1979	-6.022***	4	2004
FG	-7.535***	0	1999	-7.764***	0	1999
GREEN	-8.452***	0	2004	-8.588***	0	2004
URB	-4.560*	1	1981	-4.991*	1	1981

Note: Critical values taken from Zivot and Andrews (1992) are 1%=-5.34%, 5%=-4.93%, 10%=-4.58% for model A, and 1%=-5.57%, 5%=-5.08 for model B, 10%=-4.82%.

In Table 2, the unit root test results, which include the change in the trend with the A model and the C model, are given. According to the results of both models, the statistical values of all variables are less than the critical values in terms of absolute value. Therefore, all series have unit roots in their level values. On the other hand, the first difference of all variables is taken. It was found that the URB variable was stationary at 10% and all other variables at the 1% significance level. Therefore, the degree of cointegration of all variables is I(1).

Gregory-Hansen and Hatemi-J Cointegration Tests

Engle-Granger (1987) cointegration, Johansen (1988) cointegration, and Pesaran et al. (2001) traditional cointegration tests neglect structural breaks. Cointegration tests that do not take into account structural breaks in country economies may lead to misleading results (Seker vd., 2015). In the test introduced to the literature by Gregory and Hansen (1996), the structural break is allowed, and this break is determined internally. However, this cointegration test based on the error term allows a structural break in the cointegration vector. Similar to the structural stability tests, Gregory-Hansen (1996) suggested three different models in the cointegration test as follows. These models were used to investigate the cointegration relationship between the variables to be used in the model.

$$y_{1t} = \mu_1 + \mu_2 \varphi_{tr} + a^T y_{2t} + \varepsilon_t \qquad \text{(Model A)}$$
$$y_{1t} = \mu_1 + \mu_2 \varphi_{tr} + \beta t + a^T y_{2t} + \varepsilon_t \qquad \text{(Model B)}$$
$$y_{1t} = \mu_1 + \mu_2 \varphi_{tr} + a_1^T y_{2t} + a_2^T y_{2t} \varphi_{tr} + \varepsilon_t \qquad \text{(Model C)}$$

Here, μ_1 and μ_2 are the breaks at the constant, α_1 is the slope coefficient before the fracture occurs, and α_2 is the change in the slope coefficient after the fracture (Gregory and Hansen, 1996:103). The Philips test statistical equations are as follows (Gregory and Hansen, 1996:106).

$$Z_a^* = inf_{\tau eT} Z_a(\tau)$$
$$Z_t^* = inf_{\tau eT} Z_t(\tau)$$
$$ADF^* = inf_{\tau eT} ADF(\tau)$$

The Z_a^*, Z_t^*, and ADF^*test statistics found in these tests are compared with the critical values obtained by Gregory-Hansen (1996). In the following process, the null hypothesis of the existence of a cointegration relationship between the variables is tested (Tıraşoğlu Yıldırım, 2012:115). In the cointegration test developed by Hatemi-J (2008), another structural break is added to the three models in the Gregory-Hansen test. Thus, two structural break cointegration tests are tested.

Regime shift models for Gregory-Hansen and Hatemi-J are given in the figure below:

$$\begin{aligned} G - H \rightarrow EF_t = {} & \alpha_0 + \alpha_1 D_{1t} + \beta_{01} GDP_t + \beta_{11} D_{1t} GDP_t + \beta_{02} GDP_t^2 + \beta_{12} D_{1t} GDP_t^2 \\ & + \beta_{03} FD_t + \beta_{13} D_{1t} FD_t + \beta_{04} GREEN_t + \beta_{14} D_{1t} GREEN_t + \beta_{05} URB_t \\ & + \beta_{15} D_{1t} URB_t + \varepsilon_t \end{aligned}$$

$$\begin{aligned} H - J \rightarrow EF_t = {} & \alpha_0 + \alpha_1 D_{1t} + \alpha_2 D_{2t} + \beta_{01} GDP_t + \beta_{11} D_{1t} GDP_t + \beta_{21} D_{2t} GDP_t + \beta_{02} GDP_t^2 \\ & + \beta_{12} D_{1t} GDP_t^2 + \beta_{22} D_{2t} GDP_t^2 + \beta_{03} FD_t + \beta_{13} D_{1t} FD_t + \beta_{23} D_{2t} FD_t \\ & + \beta_{04} GREEN_t + \beta_{14} D_{1t} GREEN_t + \beta_{24} D_{2t} GREEN_t + \beta_{05} URB_t \\ & + \beta_{15} D_{1t} URB_t + \beta_{25} D_{2t} URB_t + \varepsilon_t \end{aligned}$$

Where the expression α_0 indicates that the EKC hypothesis does not start from the origin. α_1 and α_2 are the points where the first and second structural breaks intersect the vertical axis. $\beta_{01}, \dots \beta_{05}$ are the slope parameters before slippage. $\beta_{11}, \dots, \beta_{15}$ are the slope parameters at the moment of the first structural break. On the other hand, $\beta_{21}, \dots, \beta_{25}$ are the slope parameter at the second structural break. D_{1t} and D_{2t} are dummy variables. These dummy variables are defined by,

$$\boldsymbol{D_{1t}} = \begin{cases} \mathbf{1} \ \ \boldsymbol{i} \ \boldsymbol{f} \ \boldsymbol{t} > [\boldsymbol{n\tau_1}] \\ \mathbf{0} \ \ \boldsymbol{i} \ \boldsymbol{f} \ \boldsymbol{t} \leq [\boldsymbol{n\tau_1}] \end{cases}; \ \boldsymbol{D_{2t}} = \begin{cases} \mathbf{1} \ \ \boldsymbol{i} \ \boldsymbol{f} \ \boldsymbol{t} > [\boldsymbol{n\tau_2}] \\ \mathbf{0} \ \ \boldsymbol{i} \ \boldsymbol{f} \ \boldsymbol{t} \leq [\boldsymbol{n\tau_2}] \end{cases}$$

with the unknown parameters $\tau_1 \varepsilon$ (0,1) and $\tau_2 \varepsilon$ (0,1) signifies the relative timing of the regime change point, and the bracket denotes the integer part (Pata, 2018).

The null hypothesis is based on the absence of a cointegration relationship. An ADF test was performed to test this hypothesis. ADF test is calculated by the corresponding t-test for the slope of $\boldsymbol{\hat{u}_{t-1}}$ in a regression of $\Delta\boldsymbol{\hat{u}_t}$ on $\boldsymbol{\hat{u}_{t-1}}$, $\Delta\boldsymbol{\hat{u}_{t-1}}$, …, $\Delta\boldsymbol{\hat{u}_{t-k}}$ where $\boldsymbol{\hat{u}_t}$ signifies the estimated error term from regression $(\boldsymbol{H-J})$. The $\boldsymbol{Z_a}$ and $\boldsymbol{Z_t}$ test statistics are based on the calculation of the bias-corrected first-order serial correlation coefficient estimate $\boldsymbol{\hat{p}}^*$, defined as:

$$\hat{p}^* = \frac{\sum_{t=1}^{n-1} \left(\hat{u}_t \hat{u}_{t+1} - \sum_{j=1}^{B} w(j/B) \hat{\gamma}(j) \right)}{\sum_{t=1}^{n-1} \hat{u}_t^2}$$

where $w(.)$ is a function providing kernel weights meeting the standard conditions for spectral density estimators, B (itself a function of n) is the bandwidth number satisfying the conditions $B \rightarrow \infty$ and $\frac{B}{N^5} = O(1)$and $\hat{\gamma}(j)$ is an autocovariance function. The autocovariance function is defined by:

$$\boldsymbol{\hat{\gamma}(j)} = \frac{\mathbf{1}}{\boldsymbol{n}} \sum_{\boldsymbol{t=j+1}}^{\boldsymbol{T}} \left(\boldsymbol{\hat{u}_{t-j}} - \boldsymbol{\hat{\rho}\hat{u}_{t-j-1}} \right) \left(\boldsymbol{\hat{u}_t} - \boldsymbol{\hat{\rho}\hat{u}_{t-1}} \right)$$

where $\hat{\rho}$ is the OLS estimate of the effect (without intercept) of $\hat{u}_{t-1}$ on $\hat{u}_t$. The Z_a and Z_t test statistics are defined as:

$$\boldsymbol{Z_a = n(\hat{p}^* - 1)}$$

and

$$\boldsymbol{Z_t = \frac{(\hat{p}^* - 1)}{\left(\hat{\gamma}(0) + 2\sum_{j=1}^{B} w(j/B)\hat{\gamma}(j)\right)/\sum_{1}^{n-1}\hat{u}_t^2}}$$

where $\hat{\gamma}(0) + 2\sum_{j=1}^{B} w(j/B)\hat{\gamma}(j)$ is the long-run variance estimate of the residuals of a regression of $\hat{u}_t$ on $\hat{u}_{t-1}$. These three test statistics have nonstandard distributions. It should be mentioned that the asymptotic distribution of the *ADF* test statistic is identical to the distribution of the Z_t statistic (Hatemi-j, 2008).

Gregory-Hansen and Hatemi-J cointegration test findings are shown in Table 3.

Tab. 3. Cointegration results

Test	***ADF t-statistic***	***Zt***	***Za***	***ADF (Time break(s))***	***PP (Time break(s))***
Gregory-Hansen	*-8.257****	*-8.560*	*-62.376*	*2004*	*2003*
Hatemi-J	*-8.135***	*-8.213*	*-60.057*	*1982, 1999*	*1982, 1999*

Note: *(10%), **(5%) and ***(1%) are levels of significance. In the Gregory-Hansen test, for m=4, ADF and Zt critical values are 1%=-6.92, 5%=-6.41, 10%=-6.17, and Za critical values are 1%=-90.35%, 5%=-78.52, 10%=- It is 72.56. In the Hatemi-J test, for m=4, ADF and Zt critical values are 1%=-8.353, 5%=-7.903, 10%=-7.705 and Za critical values are 1%=-140.135, 5%=-123.870, 10%= It is -116.169.

When Table 3 is examined, it is seen that the *ADF* and Z_t test statistics according to the Gregory-Hansen cointegration test results are higher than the critical values at the 1% significance level. Similarly, according to the Hatemi-J cointegration test results, it is seen that the ADF and Z_t test statistics are higher than the critical values at the 5% significance level. Therefore, according to the results of both tests, there is a cointegration relationship between the variables.

According to the results of Table 4, after the oil crisis in 1973, there was an energy crisis in 1979. After this crisis, a new recession period has begun for the world. The energy crisis, which was seen as the deepest crisis until this period after the Second World War, deeply affected many developed and developing economies until the mid-1980s. This situation caused the global economy to shrink by 1.3%. Therefore, this situation has also affected the Indian economy. On the other hand, the Asian financial crisis and the Russian banking crisis that occurred in the 1997-1999 period also deeply affected the Indian economy, which has an important social and economic potential after China. On the other hand, the pace of scientific and technological development caused the monetary policies to be loosened in economies. This situation increased the bubbles that caused the crisis environment in the economy. This situation caused the housing and asset prices to bubble burst in 2003 and 2004. In addition, after 2001, the "DOT: COM" bubble burst, and this situation caused a global crisis (Çelebi, 2013:39). Therefore, the Indian economy was also affected by these crises.

Long Term Coefficient Estimation

This section will determine the magnitude and direction of explanatory variables' effect on environmental quality. FMOLS method will be used for long-term coefficient estimation. The mentioned method was proposed by Phillips and Hansen (1990). The mentioned method ensures that the structural changes are included in the model as a dummy variable. This estimator eliminates the problem of internality (Nazlıoğlu, 2010: 99). The CCR estimator developed by Park (1992) solves the problem of endogeneity in the long run (Mehmood et al., 2014: 9). Finally, the long-short-term coefficient estimation will be made with DOLS estimator developed by Stock and Watson (1993). The DOLS estimator adds a dynamic element to the process. This test eliminates the problems that may arise in static equations. In addition, it shows effective results in both heterogeneous and low numbers of observations (Mark and Sul, 2003: 654).

Estimation results are shown in Table 4.

Tab. 4. Long-run coefficient estimation results

EF	***GDP***	***GDP^2***	***FG***	***GREEN***	***URB***	***Dummy***	***C***
FMOLS	*5.092****	*-0.861****	*-0.083****	*-0.005*	*0.016*	*0.593**	*-7.533****
	(0.733)	*(0.128)*	*(0.029)*	*(0.020)*	*(0.182)*	*(0.533)*	*(0.925)*
DOLS	*4.877****	*-0.843****	*-0.151****	*-0.078***	*0.598**	*1.556**	*-8.289****
	(1.324)	*(0.231)*	*(0.041)*	*(0.032)*	*(0.321)*	*(0.761)*	*(1.715)*
CCR	*5.260****	*-0.893****	*-0.087****	*-0.006*	*0.030*	*0.551*	*-7.583****
	(0.774)	*(0.136)*	*(0.029)*	*(0.020)*	*(0.183)*	*(0.530)*	*(1.006)*

Note: *(10%), **(5%) and ***(1%) are levels of significance. The expressions in parentheses show the standard error values.

When Table 4 is examined, increases in per capita income and urbanization increase the ecological footprint of the Indian economy, while financial development and renewable energy use decrease it. However, renewable energy and urbanization were statistically insignificant in FMOLS and CCR estimators. According to the DOLS estimator, all estimators are statistically significant. However, the magnitude and sign of all variables showed similar results for all three estimators. Therefore, the DOLS estimator will be preferred for interpretation. When analyzed as a coefficient, a 1% increase in financial development and renewable energy use causes a 0.15% and 0.08% decrease in ecological footprint, respectively. On the other hand, a 1% increase in urbanization causes a 0.60% increase in ecological footprint. In addition, GDP is positive, and GDP^2 is negative for all three estimators. This shows the validity of the EKC hypothesis for the Indian economy. In other words, increasing income first increases the ecological footprint and then causes it to decrease rapidly.

Table 5 shows the short-term coefficient estimation results.

Tab. 5. Short-term coefficient estimation results

ΔEF	***ECT_{t-1}***	***ΔGDP***	***$ΔGDP^2$***	***ΔFG***	***ΔGREEN***	***ΔURB***	***C***
FMOLS	*-0.286****	*0.337*	*0.013*	*-0.078*	*0.066***	*-0.219*	*0.001*
	(0.104)	*(0.652)*	*(0.111)*	*(0.047)*	*(0.025)*	*(0.986)*	*(0.006)*
DOLS	*-0.149****	*-0.973***	*0.205****	*-0.013****	*0.092****	*-0.160*	*0.005***
	(0.039)	*(0.382)*	*(0.059)*	*(0.029)*	*(0.012)*	*(0.341)*	*(0.002)*
CCR	*-0.257***	*0.386*	*0.007*	*-0.080*	*0.063**	*-0.041*	*0.001*
	(0.120)	*(0.983)*	*(0.159)*	*(0.072)*	*(0.037)*	*(1.112)*	*(0.006)*

Note: *(10%), **(5%) and ***(1%) are levels of significance. The expressions in parentheses show the standard error values.

When Table 5 is examined, the magnitudes and signs of the variables generally showed similar results in the short term as well as in the long term. According to all three estimators, increases in financial development and urbanization in the short term reduce the ecological footprint while the use of renewable energy increases. In addition, the ECT is negative and statistically significant. Therefore, this confirms the cointegration relationship between the variables. On the other hand, the error correction mechanism works. The ECT coefficient FMOLS (-0.286), DOLS (-0.149), and CCR (-0.257) indicate that approximately 29% (FMOLS), 15% (DOLS), and 26% (CCR) of deviations on the ecological footprint will be corrected within one year, respectively.

Conclusion and Implications

In this study, the validity of the EKC hypothesis for the Indian economy in the 1965-2018 period was investigated. For this, Gregory-Hansen and Hatemi-J cointegration tests were used. FMOLS, CCR, and DOLS estimators were used for long-term coefficient estimation. In addition to GDP per capita variables, financial development, renewable energy use, and urbanization variables are used. Due to the data constraint, the energy produced from the hydro source was used for the renewable energy variable. According to all three estimators, higher financial development and the use of renewable energy reduce the ecological footprint of the Indian economy. On the other hand, the increase in urbanization negatively affects environmental quality.

Hence, the EKC hypothesis is valid for India. This result Usman et al. (2019), Rana and Sharma (2019), Sultan et al. (2021), and Ozcan and Ulucak (2021) agree with the results that the EKC hypothesis is valid for the Indian economy. On the other hand, while the increase in renewable energy use and financial development reduces the ecological footprint, urbanization increases it. These findings were found for BRICS countries in the study by Cheng et al. (2019), for Sub-Saharan African countries in the study by Acheampong et al. (2019), Chen et al. (2019) for China, Wang et al. (2021), for 25 economies along the Belt and Road, for BRIC countries in the study by Pata (2021), and in the study by Kirikkaleli et al., (2022) show that the use of renewable energy has a positive effect on environmental quality. Also, Al-Mulali and Sab (2012), Lahiani (2020), and Khan and Ozturk (2021), it is similar to the results that the increase in financial development increases environmental quality. On the other hand, according to Liu and Bae (2018), Ahmed et al. (2019), Mehmood and Mansoor (2021), and Anwar et al. (2022), it is in line with the results of the study that higher urbanization deteriorates environmental quality.

Short-term findings were similar according to all three estimators. In the short term, while financial development and urbanization increase the ecological footprint, the use of renewable energy increases. In addition, the error correction mechanism works in all three estimators. According to all three estimators, $ECT \in (-1.0)$ and statistically significant were obtained. Thus, according to the FMOLS, DOLS, and CCR models, approximately 0.29, 0.15%, and 0.26% of a variant at the t-1 period will be corrected at the t period, respectively.

According to the Gregory-Hansen cointegration test results, scientific and technological development speeds caused the monetary policies to loosen in economies. This situation increased the bubbles that caused the environmental and economic crises. In 2003 and 2004, the housing and asset prices bubble did not last long enough and eventually burst. In addition, the bursting of the "DOT: COM" bubble after 2001 revealed the global crisis. On the other hand, according to the Hatemi-J cointegration results, after the oil crisis in 1973, an energy crisis was experienced in 1979. After this crisis, a new recession period has begun for the world. The energy crisis, which was seen as the deepest crisis until this period after the Second World War, deeply affected many developed and developing economies until the mid-1980s. This situation caused the global economy to shrink by 1.3%. Therefore, this situation has also affected the Indian economy. Emerging crises caused negativities in the Indian economy and led to the revision of energy policies. Because the Indian economy is foreign-dependent in the energy field and is easily affected by any crisis, its economy is so fragile. In addition to the general economic level, the fact that India is the country that emits the most CO_2 emissions cumulatively after the USA and China shows that environmental quality is also important. Increasing CO_2 emissions intensify the threat of a livable world due to environmental degradation in India/worldwide. That is why the Indian economy signed the Kyoto Protocol in 2002. In addition, by signing the Paris Agreement in October 2016, it committed to reducing CO_2 emissions to prevent the temperature from rising above 1.5ºC. It has adopted various strategies for these goals. In line with these targets, the Indian economy increased the use of fossil fuels by 161.89% in 2019 compared to 1990, resulting in an increase of 165.84% in CO_2 emissions. However, it increased the use of nuclear energy, which can be an alternative to fossil fuel, by 446.61% in the same period. On the other hand, although not at the desired level, it increased the use of hydrorenewable energy by 21.98%. However, wind, sun, etc., managed to increase the use of renewable energy by 12453.56% (IEA, 2022).

It has been concluded that the use of renewable energy is important for sustainable economic growth and increasing environmental quality in India. Therefore, increasing the use of renewable energy is an effective policy to reduce the ecological footprint. Therefore, increasing investments and providing incentives for renewable energy provide important opportunities to increase environmental quality and reduce foreign dependency on energy. With the increase in economic growth, the preference for energy-efficient technologies is important in terms of sustainability. In addition, improving and planning the energy infrastructure in cities will increase the environmental quality.

Considering the limitations of this study, the use of renewable energy has been examined only in hydro due to data constraints. In addition, with the promotion of renewable energy, the use of nuclear energy will lead to significant developments. In addition, the study examined general environmental quality. The sectoral analysis will also provide detailed information. Finally, Fourier methods, which take into account structural breaks recently introduced to the literature, can also be used for the method.

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