Revisiting the EKC Hypothesis With Export Diversification and Ecological Footprint Pressure Index for India: A RALS-Fourier Cointegration Test

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This study assesses India's environmental problems by focusing on the ecological footprint pressure index (EFPI), which provides a simultaneous analysis of biocapacity and ecological footprint. In particular, the study examines the impact of export diversification, economic growth, and renewable energy on EFPI under the environmental Kuznets curve (EKC) hypothesis for India. To analyze the long-run relationships, the Residual Augmented Ordinary Least Squares (RALS)-Fourier cointegration test is applied to annual data from 1965 to 2014. Contrary to the EKC hypothesis, the results show a U-shaped relationship between income and EFPI. The absence of the EKC hypothesis implies that economic development does not help to ensure environmental quality; hence, other measures are required to minimize irreversible environmental problems. In this regard, the results of the study suggest that renewable energy consumption and export diversification reduce EFPI. Based on the overall findings of the study, it is recommended that the Indian government improve environmental values by changing the export structure and energy mix.

Keywords: ecological footprint, EKC hypothesis, export diversification, RALS-fourier cointegration, India

INTRODUCTION

The desire for a higher standard of living pushes countries to accomplish the objective of economic growth through the transition from the agricultural to the industrial sector, which may lead to deterioration of the environment (Li et al., 2021). The environmental quality is simply influenced by national and international economic aspects. To meet this objective, both developed and developing nations are considering various policies and strategies that address the impact of global trade on sustainable economic growth. More so, to generate sustainable revenues and curtail dependence on specific exports, the World Bank and the International Monetary Fund (International Monetary Fund, 2020) encourage both developing and advanced economies to adopt export diversification policies. Diversified exports and trade openness strategies primarily promote countries' economic development. Occasionally, however, it may also be a process that leads to environmental degradation. Clearly, diversified exports simply rely on industrialization and traditional fossil fuel-based energy consumption, which can degrade environmental quality by emitting greenhouse gas (GHG) emissions unless the portion of clean and renewable energy sources has

been inflated (Can et al., 2021; Shahzad et al., 2021). Export diversification and the impact of renewable resources on environmental quality have recently become an important research topic. The environmental indicator studied in this context is important.

Global warming is a universal concern and the whole world is facing an alarming situation due to the expansion of GHG emissions (Yang et al., 2021). In recent years, economies have also been hit by enormous disasters, such as the explosion of floods in India, Pakistan, and Australia, the tsunami in Indonesia, and the fire disaster in Russia, etc. Such disasters are the main reasons for the deterioration of the ecological environment (Dagar et al., 2021). However, carbon dioxide (CO_2) emissions do not reflect this and similar disasters. In this context, the ecological footprint proposed by Rees 1992) is a more comprehensive environmental measure. Ecological footprint includes six sub-components such as builtupland, cropland, grazingland, fishing grounds, forest area, and carbon footprint, allowing to examine environmental problems with air, land and marine ecosystems. On the one hand, an analysis covering only the ecological footprint deals with the demand side of environmental problems. On the other hand, biocapacity reflects the supply side of this demand (Pata and Isik, 2021). Ecological footprint and biocapacity should be evaluated together in order to evaluate environmental problems from both supply and demand aspects. In this context, the ecological footprint pressure index (hereafter EFPI) can be used as a proxy for environmental deterioration. Calculated by dividing the ecological footprint by biocapacity and proposed by Huang et al. (2007), the EFPI allows for a simultaneous analysis of the environmental situation with supply and demand. Hence, this will offer an opportunity to evaluate the ecological hazards from a wide ranging perspective rather than just considering environmental demand.

In this study, we examine the effects of export diversification, renewable energy consumption, and gross domestic product (GDP) on EFPI. In this study, we seek answers to three basic research questions. 1) What is the impact of export diversification on sustainable development? 2) Does the use of renewable energy promote environmental quality? 3) Is there an inverted U-shaped environmental trade-off between GDP and EFPI, as reflected in the environmental Kuznets curve (EKC) hypothesis proposed by Grossman and Krueger (1991)? We attempt to answer these questions for India.

We have chosen to analyze the determinants of environmental degradation in India for several reasons. Since the 1990s, India's GDP growth rate has been among the fastest in the world (Solarin et al., 2017). However, this growth also brings with it social, economic and environmental problems. The increasing production and consumption activities in the wake of liberalization and economic reforms in India have led to environmental problems such as climate change and depletion of the ozone layer globally (Pata and Kumar, 2021). Moreover, Indian society is exerting significant pressure on water and land resources. The fact that India has the third largest ecological footprint in the world (Global Footprint Network, 2018) is a clear indication of these pressures. For these reasons, it is important to

study the impact of export diversification, renewable energy and income on environmental quality in India, both for the country and the world.

However, few studies in the literature have adjusted export diversification to test the EKC hypothesis (Liu et al., 2019). Given this gap, our study is the first to analyze the impact of export diversification on environmental degradation in India. Moreover, we introduce and use the RALS-Fourier cointegration test to provide stronger evidence of the cointegration relationship than conventional methods by considering both the information of the high moments of non-normal residuals and smooth structural changes. Furthermore, unlike previous studies, we focus on the ecological footprint pressure index for India and thus analyze the ecological footprint and biocapacity simultaneously. With these aspects, we expect this study to contribute to the field of environmental economics. Based on the outcomes of this study, policy implications will be suggested on export diversification and economic growth for emerging countries. The regulators of these countries may benefit from these recommendations by drawing such plans to enjoy sustainable economic growth and international trading.

The remainder of the study is organized as follows. Section 2 represents the existing literature whereas Section 3 defines the materials and methods of the research. Section 4 elaborates the empirical results. Lastly, Section 5 concludes the study and provide some indispensable policy implications.

LITERATURE REVIEW

Since the seminal research of Grossman and Krueger (1991), many researchers have tested the validity of the environmental Kuznets curve hypothesis, which implies that there is an inverted-U-shaped relationship between income and environmental degradation, ultimately resulting in environmental benefits from economic growth. In the initial stages of economic development, ecological degradation becomes started to rise as the per capita income in a country increases; though, after reaching a certain point, the per capita income begins to decline by preserving the environment (Tamazian et al., 2009; Jalil and Feridun, 2011; Shahbaz et al., 2013; Ulucak et al., 2020). More so, some studies showed a mixed relation between economic growth and the environment (Destek et al., 2020; Ullah et al., 2022).

Because the EKC literature is so extensive, we briefly review studies on India. Some studies have argued that the EKC hypothesis is valid for India (see e.g., Managi and Jena, 2008; Tiwari et al., 2013; Shahbaz et al., 2015; Sinha and Shahbaz, 2018; Ahmed and Wang, 2019; Rana and Sharma, 2019; Usman et al., 2019). In contrast, the studies of Alam et al. (2016), Pal and Mitra (2017), Destek et al. (2018), Adamu et al. (2019), Sarkodie and Yadav (2019), Pata and Aydin (2020), and Bandyopadhyay and Rej (2021) do not support the EKC hypothesis. The validity of the EKC hypothesis for India is still a controversial issue in the current literature. We aim to contribute to this discussion by examining the effects of renewable energy and export diversification on the ecological footprint pressure index in India.

On the one hand, some researchers have analyzed the determinants of renewable energy (Abumunshar et al., 2020; Habesoglu et al., 2022; Samour and Pata, 2022). On the other hand, the environmental pollution-reducing effect of renewable energy consumption has been proven in many studies (see e.g., Destek and Sinha, 2020; Wang et al., 2020; Destek and Manga, 2021; Li et al., 2021; Pata, 2021; Rehman et al., 2021; Fareed et al., 2022; Rehman et al., 2022, among others). However, contrary to the general view, some studies have reported that renewable energy does not have a significant impact on environmental degradation (Apergis et al., 2010; Menyah and Wolde-Rufael, 2010; Lin and Mubarek, 2014; Pata, 2018), even that it can increase CO_2 emissions (Boluk and Mert, 2014). Al-Mulali et al. (2016) also found that renewable energy production could increase the ecological footprint by causing inefficiency in the use of water and land.

Researchers have widely used trade-related variables such as exports, imports, and trade openness when testing the EKC hypothesis. However, these variables refer to trade volume and do not provide information on the diversity of exported and imported goods. How does the diversity of exported goods affect environmental degradation? Recently, some studies have focused on this relatively new research topic compared to the EKC hypothesis and renewable energy. There is also no consensus among researchers on this topic and different results can be observed under the following parts.

The first part of the studies emphasizes the negative environmental side of export diversification. Liu et al. (2018) used the Johansen cointegration test and vector error correction (VEC) model on annual data from 1990 to 2013, and found that export diversification leads to the formation of more ecological footprint in Korea, Japan, and China. Liu et al. (2019) utilized the Driscoll-Kraay panel estimator for 125 countries from 2000 to 2015 and found that export diversification is positively linked with CO_2 emissions. Can et al. (2020) performed the autoregressive distributed lag (ARDL) model for 84 developing countries from 1971 to 2014 and concluded that export diversification increases CO_2 emissions. Wang et al. (2020) conducted the cross-sectional ARDL model for G7 countries from 1990 to 2017 and concluded that export diversification has a positive impact on CO_2 emissions. Iqbal et al. (2021) used the Augmented Mean Group Estimator for 37 OECD countries from 1970 to 2019 and noted that export diversification has a positive impact on CO_2 emissions. Khan et al. (2021) and Sharma et al. (2021) applied the cross-sectional approach for different countries and reported similar results to previous studies.

The second part of the studies emphasizes that export diversification benefits the environment. Shahzad et al. (2020) used the generalized moment method for 63 countries from 1971 to 2014 and reported that export diversification has a negative impact on CO_2 emissions. Fareed et al. (2021) conducted the Fourier quantile causality test for Indonesia from 1965q1 to 2014q4 and concluded that export diversification increases the load capacity factor and improves environmental quality. Li et al. (2021) conducted Bayer-Hanck and Maki cointegration test for annual data from 1989 to 2019 and found that export diversification reduces CO2 emissions in China. Similarly, Zafar et al. (2022) studied the relationship between export diversification and the environment in a panel of 22 countries over the period 1986–2017 by employing Westerlund and Edgerton cointegration, Cup-FM and CUP-BC long-run estimation, and generalized quantile regression techniques and found that export diversification lessens CO2 emissions.

Despite the vast literature, no study has considered export diversification in testing the EKC hypothesis for India. Also, no study has examined the ecological footprint index pressure index for India. Previous studies have generally focused on environmental degradation indicators such as CO2, nitrogen oxides and ecological footprint. These indicators only symbolize the increase in emissions or ecological footprint due to a demand, but do not provide information on nature's ability to meet human demand for environmental resources. To address these research gaps, we examine the impact of export diversification, income, and renewable energy consumption on EFPI in India.

METHODOLOGY

In the last two decades, several cointegration tests have been introduced in the literature that consider structural changes in the long-term relationship. The pioneers use dummy variables to capture structural changes and only allow for sharp breaks (see Gregory and Hansen, 1996; Carrion-i-Silvestre and Sansó, 2006; Hatemi-J, 2008, among others). But, as emphasized by Hyndman (2014), "most things change slowly over time," and dummy variables are not able to characterize such changes. To compensate for this shortcoming, Tsong et al. (2016) and Banerjee et al. (2017) suggest using a Fourier function when testing the cointegration relationship to account for multiple smooth changes. Using a Fourier function eliminates the need to determine the location and number of breaks.

Although both types of tests allow for structural changes, they do not take into account the information contained in non-normal errors because the limiting distribution of test statistics is not based on the assumption of error distribution and the parameter estimates are based on test regressions that remain consistent. Since using the information contained in non-normal errors improves the power of the test, as pointed out by Lee et al. (2014), we follow the suggestion of Im and Schmidt (2008) and employ "residual augmented least squares" (RALS) to use this information to improve the power of the Fourier Engle-Granger cointegration test introduced by Yilanci (2019). The RALS method allows the use of information in the higher moments of the residuals, and because of this advantage, a number of studies use RALS to improve the power of unit root or cointegration tests (see, among others, Im et al., 2014; Meng et al., 2014; Lee et al., 2014). Differently, we propose for the first time the use of the RALS method in a cointegration test that accounts for structural breaks in the long-run relationship.

We first explain the two-step procedure of the Fourier Engle-Granger (FEG) cointegration test. The FEG test is a residual-based test for cointegration, and the first step is to estimate **Eq. 1** as follows:

$$y_{1t} = \alpha_1 + \alpha_2 \sin\left(\frac{2\pi kt}{T}\right) + \alpha_3 \cos\left(\frac{2\pi kt}{T}\right) + \beta' y_{2t} + e_t \quad (1)$$

where y_{1t} and y_{2t} shows the dependent variable and nx1 vectors of regressors. t and T indicate the trend term and sample size, respectively. k is a particular frequency determined by the value that gives the minimum sum of squared residuals (SSR). In the second step, we investigate the null of no-cointegration by testing the unit-root characteristics of the residuals of **Eq. 1** using the Augmented Dickey-Fuller (ADF) unit root test as in **Eq. 2**:

$$\Delta \hat{e}_t = \rho \hat{e}_{t-1} + \sum_{i=1}^{p} \phi_i \hat{e}_{t-i} + \varepsilon_t \quad (2)$$

Then, we can define the τ_{FEG} test statistic to test the null hypothesis as in **Eq. 3**:

$$\tau_{FEG} = \frac{\hat{\rho}}{se\left(\hat{\rho}\right)} \quad (3)$$

where $\hat{\rho}$ denotes the ordinary least squares (OLS) estimator of ρ and $se\left(\hat{\rho}\right)$ is the standard error of $\hat{\rho}$. To illustrate the use of the information about the non-normality of the error term, we consider the following moment conditions in **Eqs 4**, **5**:

$$E\left(\varepsilon_t \otimes x_t\right) = 0 \quad (4)$$

$$E\left[\left(h\left(\varepsilon_t\right) - K\right) \otimes x_t\right] = 0 \quad (5)$$

where ε_t, x_t present the residuals, and all regressors in **Eq. 2**. $h\left(\varepsilon_t\right)$ denotes the nonlinear function of ε_t and K is defined as $E\left(\varepsilon_t\right)$. **Equation 4** shows the usual moment condition of OLS estimation, while **Eq. 5** refers to the further moment conditions based on non-linear functions of ε_t.

Following the suggestion of Im and Schmidt (2008), we augment Eq. (2) with the following term:

$$\hat{w}_t = h\left(\hat{\varepsilon}_t\right) - \hat{K} - \hat{\varepsilon}_t \hat{D} \quad (6)$$

where $h\left(\hat{\varepsilon}_t\right) = [\hat{\varepsilon}_t^2, \hat{\varepsilon}_t^3]'$, $\hat{K} = \frac{1}{T}\sum_{t=1}^{T} h\left(\hat{\varepsilon}_t\right)$, and $\hat{D} = \frac{1}{T}\sum_{t=1}^{T} h'\left(\hat{\varepsilon}_t\right)$. So, we can replace these terms into **Eq. 6** and obtain $\hat{w}_t$:

$$\hat{w}_t = [\hat{\varepsilon}_t^2 - m_2, \hat{\varepsilon}_t^3 - m_3 - 3m_2\hat{\varepsilon}_t]' \quad (7)$$

The first part of **Eq. 7** is related to the condition of homoscedasticity of the error terms, which improves the efficiency of the estimator as long as the residuals are asymmetric. The term of the second part improves the efficiency if $\mu_4 = 3\sigma^4$ not the case. Thus, as long as the error term is not normally distributed, the inclusion of $\hat{w}_t$ in the test **Eq. 2** will improve the power of the test as follows:

$$\Delta \hat{e}_t = \rho \hat{e}_{t-1} + \sum_{i=1}^{p} \phi_i \hat{e}_{t-i} + \hat{w}_t' \varphi + \xi_t \quad (8)$$

We can obtain the RALS-FEG test statistic by estimating the OLS to **Eq. 8**. We can obtain the t-statistic on $\rho = 0$ for the test the null of no-cointegration as τ_{RFEG}. The asymptotic distribution of τ_{RFEG} is given as follows:

Lemma 1: Under the null hypothesis of no-cointegration, the limiting distribution of τ_{RFEG} can be derived as

$\tau_{RFEG} \rightarrow \rho\tau_{FEG} + \sqrt{1-\rho^2}Z$, where τ_{FEG} shows the t-statistics for $\hat{\rho} = 0$ in **Eq. 2**, and Z denotes a standard normally distributed random variable and ρ gives the long-run correlation between the residuals of **Eqs 2**, **8**, which can be calculated as follows:

$$\rho^2 = \frac{\sigma_{\varepsilon\xi}^2}{\sigma_\varepsilon^2 \sigma_\xi^2}$$

Under the moment conditions of **Eqs 4**, **5**, the RALS-FEG test has the same asymptotic distribution as generalized method of moments estimators (see Lee et al., 2014). We compute the critical values of the RALS-FEG test considering **Eq. 7** with different frequency values of $k = 1, 2, 3, 4$, and 5, for different values long-run correlation of $\rho^2 = 0.1, 0.2, ..., 0.9$, and 1.0, for different sample sizes of T = 100, 500, and 2,500 with different numbers of integrated regressors (n = 1,2,3, and 4). We use 10,000 simulations to compute the critical values and have tabulated them in the Appendix (see **Supplementary Appendix Tables S1A–S8A**). The results indicate that the critical values decrease as the optimal frequency increases. Besides, we also investigate the finite small sample properties of the RALS-FEG test and report the results in the Appendix (see **Supplementary Appendix Table S9A**), which presents that the RALS-FEG test outperforms the FEG test in all cases in terms of power.

The fully modified OLS (FMOLS) method developed by Phillips and Hansen (1990) is used to obtain cointegration estimators. The FMOLS estimator remedies diagnostic problems encountered with standard estimators. This method was obtained by developing the OLS, taking into account the internality and autocorrelation problem. Moreover, the asymptotic deviation and externality assumption were used in FMOLS to eliminate the inadequacy of the OLS estimator in calculating the optimal values of the cointegrated equations (Chen and Huang, 2013).

$$\hat{A}^+ = \left(Y^{+'}X - T\hat{\Delta}_{0x}^+\right)\left(X'X\right)^{-1} \quad (9)$$

The FMOLS estimator that corrects for the deviation effect in the cointegrated equation with the help of the $\hat{\Delta}_{0x}^+$ kernel estimator is shown in **equation 9** (Phillips, 1995).

Data and Model
Data
We use annual data for the period 1965–2014 for our empirical analysis, which aims to analyze the dynamic impact of economic growth, renewable energy consumption, and export diversification on the ecological footprint pressure index under the EKC hypothesis. Since export diversification data was available until 2014, we limited our data range to 50 years. Among the variables used in the study, EFPI is the ecological footprint pressure index measured as ecological footprint (per capital, global hectares)/biocapacity (per capita, global hectares), GDP and GDP^2 are gross domestic production (per capita, constant 2010 $US) and its squared term, REC is renewable energy consumption (per capita, kWh) and EXDIV stands for export diversification

TABLE 1 | Descriptive statistics.

Variables	EFPI	GDP	REC	EXDIV
Mean	1.837	700.023	215.876	2.188
Median	1.752	568.899	203.069	2.164
Maximum	2.690	1640.181	397.351	2.843
Minimum	1.385	345.421	106.670	1.813
Std. Dev	0.378	361.702	65.979	0.247
Observations	50	50	50	50

(index, measured by Henn et al., 2020). These variables are obtained from four different data sources. EFPI data is from the Global Footprint Network (2021), GDP is from the World Bank (2021), REC is from Our World in Data (2021), and EXDIV is from the International Monetary Fund (2021). The descriptive statistics of the variables are shown in **Table 1**.

As for the mean, GDP has the highest value and EFPI has the lowest value. EXDIV is the variable with the lowest standard error. The mean value of EFPI is 1.83, and in the last 15 years, the EFPI value has been above "2", as shown in **Figure 1**.

SOURCE: Global Footprint Network (2021).

In **Figure 1**, the green area indicates pretty safe ecological status, and the blue area indicates relatively safe ecological status. According to Wang et al. (2018), EFPI values above "2" mean that the ecological situation in a country or region is completely unsafe. An EFPI greater than 1 symbolizes that humanity's demand

for ecological resources is greater than the supply of natural resources and that regional ecology is unsustainable (Wang et al., 2018). The ecological footprint pressure index in India has been greater than "1" for 50 years and in unsafe areas. Since 2001, the EFPI has crossed the threshold of "2". In other words, the people of India will not be able to sustain their current use of land and water resources in the future. This situation highlights the need to address the ecological problems of India, whose population, economy, exports and energy demand are growing rapidly.

Model

To investigate the validity of the EKC hypothesis in India, we use the following log quadratic specification:

$$LnEFPI_t = \beta_0 + \beta_1 LnGDP_t + \beta_2 LnGDP_t^2 + \beta_3 LnREC_t$$
$$+ \beta_4 LnEXDIV_t + u_t \qquad (10)$$

where ln is the logarithm, t is the time period, β_0 is the constant term, $\beta_{1,2,3}$, and β_4 are the long term elasticities with respect to the dependent variable, and u_t is the error term. The inclusion of the squared GDP in **Equation 10** helps to analyze the inverted U-shaped EKC relationship. If β_1 is positive, β2 is negative, and both coefficients are statistically significant, the EKC hypothesis is valid. If β_1 is negative and β_2 is positive, there may be a U-shaped relationship between economic growth and environmental degradation (Pata and Caglar, 2021). When β_1 and β_2 are zero, there is no relationship between pollution and
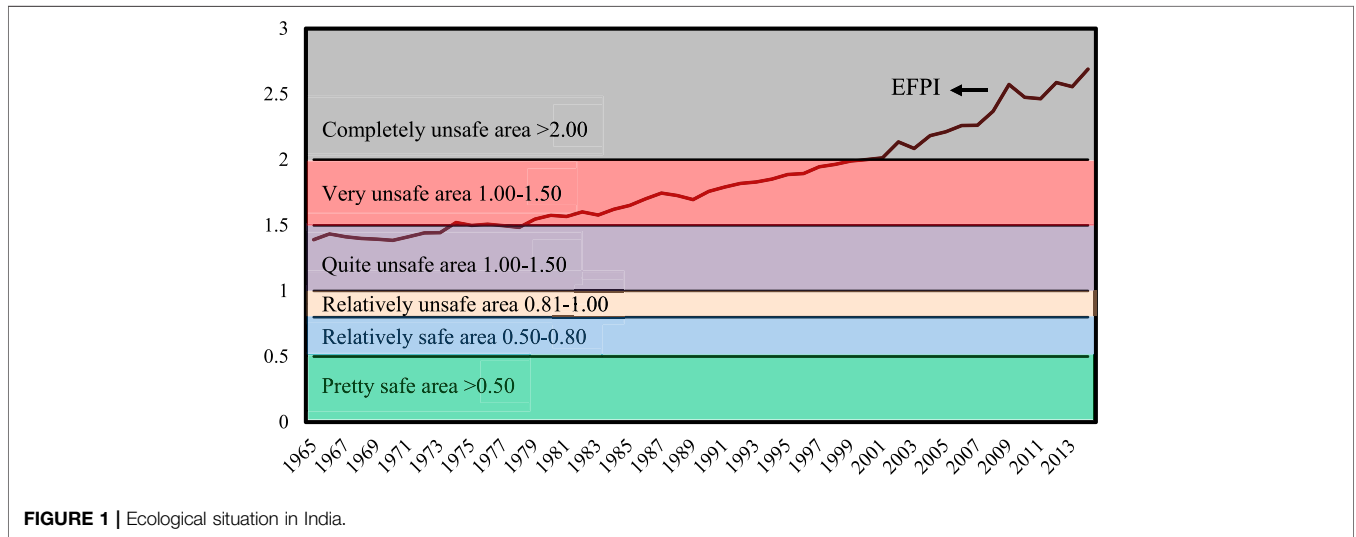

FIGURE 1 | Ecological situation in India.

TABLE 2 | Results of unit root tests.

Variable	k	F-Stat	FADF-Stat	ADF-Stat	p-value
LnEFPI	5	0.764	2.879 (9)	3.015 (9)	0.999
LnEXPD	1	1.701	-3.315 (1)	-2.562 (0)	0.108
LnGDP	5	5.762	0.473 (9)	4.360 (4)	0.999
LnGDP²	5	5.564	0.659 (9)	4.574 (4)	0.999
LnREC	1	2.132	-1.652 (1)	-1.239 (0)	0.650

Note: 10% critical value for the F test is 7.78. The numbers in the parenthesis show the optimal lag length. k denotes optimal frequency.

TABLE 3 | Results of cointegration tests.

Country	FEG Stat	RALS-FEG Stat	ρ^2	Optimal Freq	Lag Length
India	−5.482*	−5.317*	0.904	1	0

Note: * shows the significance at the 1% level. 1% critical value of the FEG, and RALS-FEG, tests are -4.906 and -4.790, respectively.

TABLE 4 | Results of long-run estimation.

	Constant	LnEXPD	LnGDP	LnGDP^2	LnREC
Coefficients	7.660**	−0.155*	−2.444**	0.218*	−0.057***
t-stats	2.409	−2.721	−2.578	3.076	−1.844

Note: *, **, and *** show the significance at the 1, 5, and 10% levels, respectively.

income. The expected value of β_3 is negative because greater use of renewable energy can help reduce anthropogenic air, water and soil pollution. However, the expected sign of β_4 can be positive or negative conditional on the type of goods exported.

Empirical Results

To investigate the long-run relationship among the variables, we first test the unit root properties of the variables under consideration. To this end, we employ the Fourier augmented Dickey-Fuller (FADF) unit root test introduced into the literature by Enders and Lee (2012). They extend the traditional augmented Dickey-Fuller (ADF) unit root test with a Fourier function to allow for multiple smooth changes. We first test the significance of the Fourier function, and in case of significance, we interpret the results of the FADF test; otherwise, we use the ADF unit root test. **Table 2** presents the results of the unit root tests:

The results show that the trigonometric terms are not statistically significant because the F-test statistics are below the critical values. Thus, instead of considering the results of the FADF test, we interpret the results of the ADF test, which show that all variables are non-stationary at the level. Therefore, we can apply the cointegration test to investigate the long-run relationship between the variables. **Table 3** presents the results of the FEG and RALS-FEG tests:

The findings of the RALS-FEG test show a cointegration relationship between the considered series. The FEG test also support these findings, as the test statistic is above the critical value of 1% (-5.482|>|-4.906|). In other words, both test statistics suggest the rejection of the null hypothesis of no cointegration. Therefore, after finding the cointegration relationship, we calculate the long-term coefficients using FMOLS method and present the results in **Table 4**.

The long run estimates divulge that all coefficients are statistically significant at the traditional levels. Since the GDP coefficient is positive and its squared coefficient is negative, there is a U-shaped relationship between income and environmental degradation, implying that the EKC hypothesis is not valid for India. In stark contrast to the opinion of Sinha and Shahbaz (2018), Ahmed and Wang

(2019) and Usman et al. (2019) that the EKC hypothesis holds for India, our result is fully consistent with the outputs of Adamu et al. (2019) and Sarkodie and Yadav (2019). It is possible that the EKC hypothesis is not valid in countries like India that have not yet completed the industrialization phase. The U-shaped relationship between income and pollution in India shows that in the initial stage of economic development, economic growth reduces pollution, but after a certain threshold, industrial production, use of polluting inputs and excessive resource consumption increase environmental degradation. As Sarkodie and Yadav (2019) point out, the validity of the U-hypothesis could mean that India's energy- and carbon-intensive industrial production is driving up pollution. So, income growth does not automatically solve environmental problems, and hence additional measures need to be taken to maintain environmental quality while the economy expands. India needs an annual economic growth of 6–8% to reduce poverty (Alam et al., 2016), and therefore, it does not seem feasible for the Indian government to take measures that limit economic development due to environmental concerns. In this context, export diversification and renewable energy use can be included in the environmental policymaking.

The coefficient of renewable energy is negative and statistically significant at 1% level, revealing that cleaner energy has a reducing impact on the EFPI. All else is same, a 1% upsurge in REC reduces EFPI by 0.057%. This outcome concurs with the results of Wang et al. (2020) for G7 economies, Iqbal et al. (2021) for 37 OECD countries, Li et al. (2021) for China, and Pata (2021) for the United States. Considering the environmental positive role of renewable resources, Indian government should invest in renewable energy technologies and expand the use of renewable energy instead of fossil fuels. Although the Indian economy is based on polluting energy sources, it may be possible to increase environmental quality without hindering economic growth by increasing the use of renewable energy types.

More so, keeping other things constant, there is 0.15% decline in EFPI due to 1% rise in export diversification. This empirical result is contradictory with Liu et al. (2018, 2019), Can et al. (2020), Wang et al. (2020), Iqbal et al. (2021), Khan et al. (2021) and Sharma et al. (2021). However, our results are in line with the findings of Shahzad et al. (2020), Li et al. (2021), and Fareed et al. (2021). Diversification of export commodities can contribute to environmental quality by reducing traditional energy consumption (Li et al., 2021). Accordingly, Shahzad et al. (2021) found that export diversification reduces energy demand in India. Moreover, the production of chemical, industrial and high-tech goods can support renewable energy adaptation by providing technological advancement through export basket

diversification. Therefore, India can reduce EFPI by diversifying export portfolios and markets.

CONCLUSION

This study contributes to the growing literature by analyzing the dynamic influence of export diversification, economic growth and renewable energy on the EFPI using time series data from India for the period 1965–2014. Following the EKC hypothesis, we applied the RALS-Fourier cointegration test to provide stronger evidence of the cointegration relationship than conventional methods by considering both the high moments information of the non-normal residuals and smooth structural changes. This technique is efficient enough to extend the power of the Fourier-Engle-Granger cointegration test. The empirical findings represent that diversified exports and greener energy consumption have a reducing effect on EFPI. Moreover, contrary to the EKC hypothesis, the results show a U-shaped association between GDP and EFPI, implying that economic development does not contribute to the maintenance of environmental quality.

The empirical results of the study suggest the following policy implications. *First*, to offset the effects of global warming, export diversification strategies should be incorporated into sustainable growth programs. Industry actors and political influencers should not influence regulators in emerging economies. *Second*, policymakers should also promote clean energy to reduce EFPI by substituting renewable resources for fossil fuels. The employment of export diversification and clean energy is expected to achieve the goal of carbon neutrality. Since these factors are closely aligned and not mutually exclusive, they would not only enable a smooth transition of the industrial energy structure, but also increase export revenues. Specifically, this study recommends that to achieve the goal of carbon neutrality and address environmental challenges, emerging economies need to consider export diversification and renewable energy sources. A country like India can enable the development of clean environmental technologies by diversifying its exports. It can also increase the efficiency of energy use by facilitating the adaptation of high technologies thanks to the specialization of the production process in export. In addition, the Indian government can support exporting companies that use renewable energy sources with measures such as tax exemptions, investment subsidies for renewable energy, and price or volume adjustments for companies that do not use renewable resources.

Finally, future studies could incorporate other comprehensive environmental indicators to arrive at more meaningful results. In addition, this article considers the cointegration nexus that can lead to worthwhile effects of export diversification and renewable energy. Including the moderation effect in the analysis could increase its explanatory power. Moreover, this study is limited to time-series data from one emerging market. Future studies can be conducted considering a region or continent to evaluate the impact of a panel data analysis.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

UP: Methodology, Software, Formal analysis, Data Curation, Conceptualization, Writing Original Draft, Writing—Review and Editing, Resources. ZF: Writing—Review and Editing, Investigation. FS: Writing—Original Draft, Writing—Review and Editing, Investigation. MR: Writing—Review and Editing, Investigation.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.886515/full#supplementary-material

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