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REVIEW ARTICLE

Attaining Environmental Sustainability Through Cashew Nut Production in India: Revisiting the Role of Energy Consumption and Economic Growth

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A R T I C L E I N F O

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A B S T R A C T

Although carbon dioxide (CO_2) emissions are the most debated topic in the current era, the solution for this is not yet reached a conclusion in the literature. Further, curbing CO_2 emissions along with maintaining the same pace of economic growth is necessary to achieve sustainable development. Being a top producing, processing and exporting country of cashew nuts in the world, India has a well-established growth effect that emanates from cashew nut production. However, the environmental effect of cashew nut production is not clear. Thus, this study aims to assess the role of cashew nut production on CO_2 emissions while endogenising energy consumption and economic growth in the environmental degradation function of India during 1975-2021. For empirical analysis, the study uses combined cointegration, cointegrating regressions, and time and frequency domain causality tests. The evolved outcome shows a long-run cointegration of the series. Further, cashew nut production significantly reduces CO_2 emissions, while energy consumption portrays a significantly increasing role in CO_2 emissions. Surprisingly, but not shockingly, economic growth significantly reduces CO_2 emissions in India. From the causality point of view, a unidirectional causality runs from cashew nut production to CO_2 emissions in both time and frequency time causality tests. Based on the findings, the study suggests a policy for sustainable development in India.

Introduction

Considerable attention has been received to climate change among scholars around the world for the last couple of decades (Vahdati et al., 2019; Mutebi *et al.*, 2022). Although plenty of pollutants are responsible for climate change, the leading role of CO_2 emissions (a contribution of three-quarters) is undeniable in the total greenhouse gases (Gokmenoglu *et al*., 2019; Karimi Alavijeh *et al*., 2022; Mahalik *et al*., 2021; Pata, 2021; Patel *et al*., 2021; Villanthenkodath & Mahalik, 2022). Given the scenario, anthropogenic factors have been identified as the responsible factors for CO_2 emissions (Ahmad & Khattak, 2020). By taking a cue from this, scholars try to examine the role of different factors responsible for CO_2 emissions while augmenting the environmental degradation function in the presence of economic growth and energy consumption (Mahalik *et al*., 2021; Villanthenkodath & Mahalik, 2022).

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Further, the evolution of economic growth is concerned; it established the role of agriculture and agro-based industries in the growth process of all countries in the world. Besides, various agricultural products bear the capacity to feed many and offer a livelihood for millions by participating in production activities (Gatahi *et al.*, 2020; Karimi Alavijeh *et al*., 2022). As a result, it is expected to have CO_2 emissions and, thereby, environmental degradation due to agriculture-related production activities (Patel *et al*., 2021; Karimi Alavijeh *et al*., 2022; Ferreira *et al*., 2021). Interestingly, the allocation of resources between agriculture and industry fosters the displacement of the traditional sector due to stages of economic development (Mahmood *et al*., 2019). However, (Karimi Alavijeh *et al*., 2022; Khan, 2020) believes that adverse or positive environmental effects on society are also possible from the agriculture sector amid the implementation of such structural transition while the developmental process is taking place in any economy.

As far as developing economies are concerned, agriculture contributes significantly to economic growth, supply of food, and livelihood through value-added products (Cetin *et al*., 2022). Although a plethora of studies empirically proved the coherence between agriculture and economic growth (Dhahri & Omri, 2020; Loizou *et al*., 2019), very few studies found a causal linkage between agricultural growth vis a vis environmental degradation. For instance, Mahmood *et al*. (2019) found that the share of agriculture reduces the emission, while (Pata, 2021) refuted this observation in the context of BRIC countries. Thus, it is evident that there are no uniform findings hold for the impact of agriculture on environmental degradation. Further, it is unfortunate that a behemoth of literature focused on the aggregate level analysis of the agriculture sector on the environment (Cetin *et al*., 2022; Gokmenoglu *et al*., 2019; Gokmenoglu & Taspinar, 2018; Pata, 2021). Thus, it implies that there is a paucity of crop-specific environmental impact studies, which necessitates an analysis as the countries are moving from food crops to cash crops.

Regarding cash crops, the focus of developing countries in terms of agriculture production is shifting toward the production of cash crops rather than food crops as it is made for profit and market (Monteiro *et al*., 2017; Vahdati *et al.*, 2018). From this transformation point of view in the agriculture sector, cashew gets a special mention in the context of developing countries in their march to inclusive growth by offering different avenues (Das *et al*., 2022; Monteiro *et al*., 2017). For instance, cashew is a cash crop, yields the highest foreign exchange source and is a large contributor to India's export basket. Besides, there are multiple by-products, such as Cashew Nut Shell Liquid (CNSL), nut and cashew apple, that can be extracted. As a main by-product of cashew, cashew nut plays important economic and health benefits like proteins, fats, minerals and sources of vitamins A, D, and E (Das *et al*., 2022). Besides, according to (Kapinga *et al*. 2010), the cashew nut is used in various food processing industries. However, it is believed that the processing of cashew nuts creates both indoor and air pollution. Thus, it damages the planet altogether that we live, which in turn is a threat to all abiotic and biotic species. But, based on the aforementioned hypothesis, no empirical testing has been conducted on the role of cashew nut production on environmental degradation to our limited knowledge.

Therefore, the present study aims to assess the role of cashew nut production on environmental quality in a developing country which is the largest producer of cashew nuts, i.e., India. As per the (DCCD 2019) estimate, it found that India has a large share (nearly 20%) in the cumulative world production of raw cashew nuts. Moreover, according to the Indian Council of Agricultural Research (ICAR, 2019), being the biggest cashew grower, exporter and processor, India has significant dominance in the world cashew sector. For cashew processing, there are nearly 1850 little-scale ventures out of 3799 total handling units across India (Tosif, 2019). India is the major exporter of cashew, accounted around fifteen per cent of global export (IBEF, 2022), amounting to the U S $ 452 million for the period of 2021-22. Besides, India is the world's largest producer of cashew nuts (Mohod *et al*., 2010). However, the studies on the Indian cashew nut industries are limited to the qualitative aspects of cashew cultivation and growth; for instance, see (Mog *et al*., 2022; Nair, 2010).

Alongside this backdrop, the contribution of this study to the literature on the environment is many folds. First, unlike previous studies, the present study incorporates cashew nut production in environmental degradation function in India. Second, many scholars augmented the environmental degradation function by using energy consumption and economic growth with varieties of modelling methods, outcomes, and frameworks. But, a combined cointegration application by incorporating cashew nut production, energy consumption and economic growth is expected to be new to the literature. Third, aligning with the Sustainable Development Goals (SDGs) of the United Nations (UN), the study uses the control variables, i.e., economic growth and energy consumption on the basis of (SDG-8) and (SDG-7), respectively, for the model assessing the impact of cashew nut production on environmental degradation in India. Four, unlike the large-scale time-domain causality application in existing studies, this study uses the frequency and time-domain causality tests to expose the causality of cashew nut production, energy consumption and economic growth with CO_2 emissions in India. Finally, this study proposes possible policy measures for improved production of cashew in India.

However**,** when looking at the prevailing literature on cashew, it is undoubted that the well-established economic growth effect of cashew production has been observed by different scholars. For example, (Lundy, 2021) for Guinea-Bissau, a nation-state in West Africa (Bassett *et al*., 2018) for Côte d'Ivoire and (Dendena & Corsi, 2014) for the cashew market review. Interestingly, these studies ended up finding an economically beneficial role played by cashew in the analysis. However, the environmental effect of cashew has not been studied in detail despite having a possible link with the environmental quality determination. Few scholars argue that cashew can protect the natural environment by offering biodiesel production from the by-product of cashew nut shells (Suwanmanee *et al*., 2020). Similarly, the production of bio-ethanol, pesticides, dyestuff, and agents for surfacing coating, among others, can be created from cashew nuts as by-products (Balgude & Sabnis, 2014; Hu *et al*., 2018). However, it is also important to note the adverse environmental consequences emanating from cashew nuts, which can cause significant environmental degradation(Scaldaferri & Pasa, 2019; Temudo & Abrantes, 2014). But, surprisingly, most of the environmental impact analysis relies on total agricultural output than focusing on specific agricultural crops.

In this regard, (Ben Jebli & Ben Youssef, 2017) explored the nexus between CO_2 emissions and agricultural output during 1980–2011 in five North African countries. The emanated outcomes reveal a reduction in CO_2 emissions due to agricultural production. Similarly, (Gurbuz *et al*., 2021) have reached the conclusion that agricultural production is capable of reducing the CO_2 in Azerbaijan during 1992–2014. The same conclusion can be observed in the studies conducted by (Cetin *et al*., 2022) for 47 developing countries, (Selcuk *et al*., 2021) for the full panel of the next 11 countries, and (Adedoyin *et al*., 2020) for Sub-Saharan African countries.

In contrast, a positive and significant role of agriculture on CO_2 emissions is observed by (Waheed *et al*., 2018) in an Autoregressive Distributed Lag(ARDL) setting, which means environmental pollution was boosted due to take placing of agriculture growth during 1990–2014 in Pakistan. A similar conclusion has been reached by applying a bootstrap ARDL approach for Turkey (Yurtkuran, 2021), (Karimi Alavijeh *et al*., 2022) by using panel quantile regression for the 15 most populous developing countries in most of the quantiles, and (Gokmenoglu & Taspinar, 2018) for Pakistan by implementing Fully Modified Ordinary Least Squares (FMOLS) approach.

In prevailing literature, factors like energy consumption and economic growth in the environmental degradation functions are much celebrated. In this vein, many studies used these factors are control variables while constructing the environmental degradation function (Agboola *et al*., 2021; Mahalik *et al*., 2021; Ssali *et al*., 2019; Villanthenkodath *et al*., 2022; Villanthenkodath & Mahalik, 2020, 2022; Wen *et al*., 2021). For instance, by executing the pooled mean group estimation, (Ssali *et al*., 2019) evidenced the increase in CO_2 emissions due to energy use and economic growth in six selected sub-Saharan African countries during 1980–2014. The same findings hold by (Agboola *et al*., 2021) while assessing the role of energy consumption and GDP growth on CO_2 emissions relying upon the application of the ARDL model in Saudi Arabia. Similarly, (Villanthenkodath *et al*., 2022) found that both economic growth and energy consumption harm the environmental quality in South Africa while implementing the ARDL model. In the context of India, (Villanthenkodath & Mahalik, 2020) documents the environment-degrading role of economic growth in India during 1980-2018. The other study conducted (Villanthenkodath & Mahalik, 2022) evidenced that environmental quality impedes the role of energy consumption, while economic growth was not significant in the determination of environmental degradation during 1985-2016. However, (Mahalik *et al*., 2021) found a positive and significant role of economic growth in environmental degradation in India. Shockingly, the study found that energy consumption reduces environmental degradation in India as the share of renewable energy is increasing in total primary energy consumption. Similarly, (MK, 2020) argued by applying the machine learning technique that fossil fuel in the energy mix is the prime cause of environmental degradation in India. Thus, the study suggests moving towards renewable energy consumption as there is no harm to the environment and economic growth. In contrast, (Sahoo *et al*., 2021) evidenced that renewable energy consumption also harms the environment along with economic growth in BRICS countries from 1990 to 2016 while considering material footprint as a proxy for environmental degradation. A study (Villanthenkodath & Arakkal, 2020) explored the environmental Kuznets curve from 1970 to 2017 in New Zealand; the evidence shows that linear economic growth term harms the environment, but the study validates the conventional environmental Kuznets curve.

The following sections are impeded in the study: section 2, materials and methods; section 3, the result; section 4, discussion; the final section concludes the study.

Materials and Methods

The dynamic impact of cashew nut production on CO_2 emissions in the presence of energy consumption and economic growth stretches the period between 1975 and 2021 in India. By following (Ben Jebli & Ben Youssef, 2017; Pata, 2021; Waheed *et al*., 2018; Hendarto *et al*., 2022), equation 1 is specified to assess the role of cashew nut production, energy consumption and economic growth on environmental pollution.

$$CO_{2t} = f(CASHEW_t, EC_t, GDP_t) \quad (1)$$

In the equation, carbon dioxide emissions are represented by using CO_2 measured in million tonnes of carbon dioxide sourced from the British Petroleum Statistical Review of World Energy, cashew nut production indicated by employing CASHEW calculated the production in tonnes obtained from Food and Agriculture Organization (FAO). Energy consumption delineated by EC is measured in million tonnes extracted from the same source of CO_2. Further, economic growth is notated by employing GDP measured in per capita (constant 2015) collected from World Development Indicators of the World

Bank. However, the model estimation was conducted after making an econometric model with the log-linear transformation of the series and represented in equation 2.

$$LNCO_{2t} = \beta_0 + \beta_1 LNCASHEW_t + \beta_2 LNEC_t + \beta_3 LNGDP_t + \mu_t \quad (2)$$

Here, β_1, β_2, and β_3 are the coefficients of the respective explanatory variables with respect to the dependent variable, while β_0 is the constant. The error term is denoted by μ_t having the assumption that is usual for the term. However, the term LN stands for natural logarithms.

In existing standard literature, different approaches have been used to model the link between variables of interest and uncertainty. Thus, this study explores the impact of cashew nut production on CO_2 emissions by controlling economic growth and energy consumption as additional determinants. Thus, this study has applied Bayer and Hanck (2013) combined cointegration analysis. Further, we estimated Fully Modified Ordinary least square (FMOLS) Dynamic Ordinary Least Square (DOLS) to understand the long-term effect. Besides, the Canonical Cointegrating Regression (CCR) technique is a robust estimation to authenticate the results of FMOLS and DOLS. In the final stage, the causality of the study variables is assessed by using both time and frequency domain causalities. However, before we estimate the techniques need to investigate the stationarity of the series.

Before proceeding with the test of cointegration and regression analysis of the series, we need to examine whether the series is stationary or not (that is, if it contains a unit root). Therefore, it employs the Dickey–Fuller's (1979) Augmented Dickey-Fuller (ADF), Phillips-Perron test. Since the ADF test is invalid in the presence of autocorrelation, the study carried out the Phillips-Perron test (1988). Philips-Perron test do the nonparametric adjustments in the error term to make the test robust against any form of heteroskedasticity and autocorrelation.

The long-run equilibrium analysis among variables is mostly tested using different cointegration techniques. Initially, Engel Granger (1987) proposed a residual-based test; later, several authors proposed different versions of the analysis, such as the system-based cointegration test of Johansen (1988). Later Boswijk (1994) and Banerjee *et al*. (1998) came up with ECM-based F-test and t-test analyses, respectively. The result produced from all these methods gives different conclusions. Moreover, each of these methods developed from a different theoretical background, which leads to differing estimates. Gregory *et al*. (2004) found that the P values for different single cointegration tests are weakly correlated. Due to the inconsistency in the previous models, Bayer and Hanck (2013) proposed a new cointegration test. Since the Bayer and Hanck (2013) cointegration model is based on the Monte Carlo Simulation, the test shows better power properties than the individual tests. An important feature of this test is that it combines various individual cointegration tests and, thus, more detailed results. Bayer and Hanck (2013) combined the probability values of all these tests. Combined probability values of individual tests can be obtained using the following formula of Fisher (1932):

$$\text{EG-JOH} = -2[[\ln(P_{EG}) + \ln(P_{JOH})] \quad (1)$$

$$\text{EG-JOH-BO-BDM} = -2[\ln(P_{EG}) + \ln(P_{JOH}) + \ln(P_{BO}) + \ln(P_{BDM}) \quad (2)$$

Where: P_{EG}, P_{JOH}, $P_{BO,}$ and P_{BDM} represent the level of significance for individual cointegration tests.

Since the variables are cointegrated, the study employs a Fully Modified Ordinary least square (FMOLS) Phillips and Hansen (1990) and Dynamic Ordinary Least Square (DOLS) Saikkonen (1992) and Stock and Watson (1993)) estimation methods. FMOLS is a semi-parametric technique to avoid the correlation problem and is asymptotically unbiased and efficient. DOLS augment regressors by adding lags and leads, making the cointegrating equation error term orthogonal to stochastic regressor innovations. FMOLS and DOLS help to eliminate the problem of serial correlation and endogeneity among the variables. We also used the canonical cointegrating regression (CCR) technique as a robust estimation to authenticate the results of FMOLS and DOLS.

By using Breitung and Candelon (2006) proposed frequency domain causality test, this study exposes the short-, medium-, and long-term causal link between study variables. Unlike other causality tests, it allows the series to distinguish non-linearity and causality. Further, the long-, medium- and short-term period-based decomposition of causality makes this test unique. Besides, whether the sample size is small or large, this test permits seasonal variations embedded in the series. Finally, the frequency domain causality test outcome emanated from the BC approach has been confirmed by using the time domain causality test.

Results

As a preliminary analysis, the descriptive statistics comprising central tendencies and dispersion measures of the study variables, i.e., carbon dioxide emissions (CO_2), cashew nut production (CASHEW), energy consumption (EC) and economic growth (GDP), are reported in Table 1. It found a high average for CASHEW, followed by CO_2, GDP, and EC, respectively. A similar trend is applicable to the median variance, maximum and minimum of the considered sample. Further, all the series are positively skewed, meaning that there is a long tail on the right side of the distribution.

Table1. Summary statistics.

Statistics	CO_2	CASHEW	EC	GDP
Mean	1048.06	438572	14.4127	858.221
Median	875.337	423915	12.0627	680.578
Maximum	2465.78	817000	34.1483	1965.54
Minimum	253.406	144254	3.49924	370.529
Std. Dev.	695.57	217147	9.46439	484.628
Skewness	0.69199	0.23068	0.6888	0.91656
Kurtosis	2.19692	1.60953	2.20971	2.60543
Observations	46	46	46	46

Further, to provide necessary information about the series, a graphical representation of the series is needed. Thus, Fig. 1 offers a visual plot of the study variable, where we found a smooth increase of all the variables except cashew nut production during 1975-2021. Although cashew nut production is fluctuating during 1995-2005 and 2010-2021, the general trend of the series is increasing. Therefore, it is vital to assess the link between carbon dioxide emissions, cashew nut production, energy consumption, and economic growth.

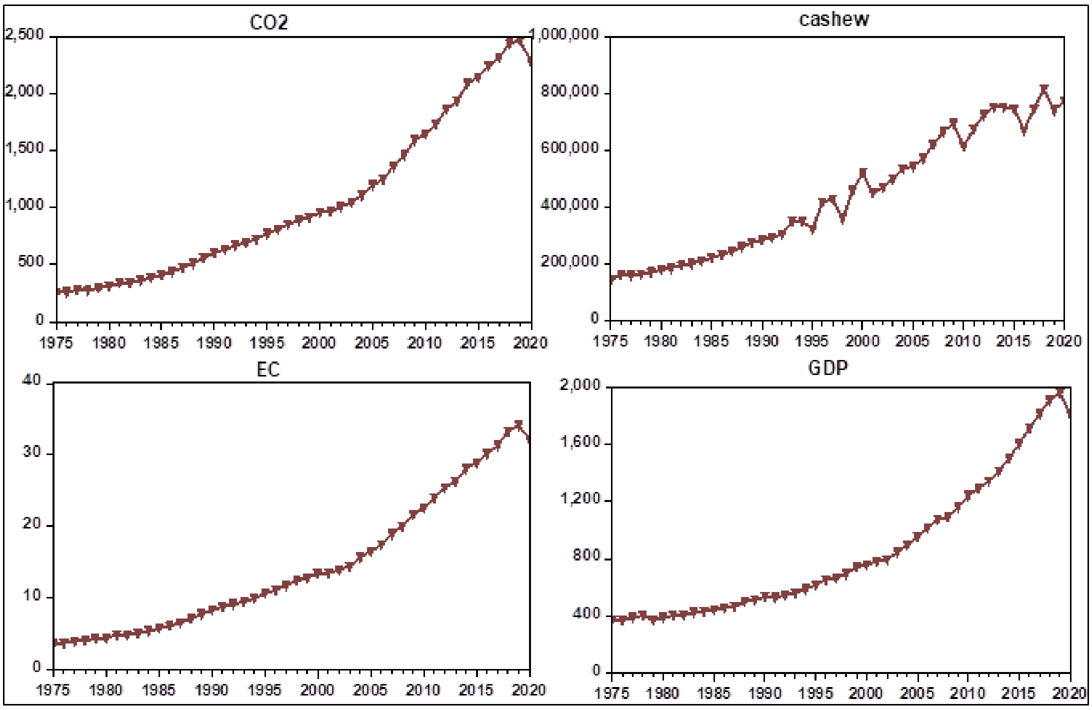

Fig. 1. The visual plot of study variables.

After understanding the trend of the study variables, the impact of cashew nut production, energy consumption, and economic growth on carbon dioxide emissions has been assessed by using the line fit graphs. The outcomes are portrayed in Fig.s 2-4. Specifically, Fig. 2 exhibit a positive relation between CO_2 emissions and cashew nut production. Similarly, energy consumption (Fig. 3) and economic growth (Fig. 4) shows a positive relationship with CO_2 emissions. In a nutshell, it observed that cashew nut production, energy consumption, and economic growth create a possible positive link with CO_2 emissions in India. Hence, it warrants a thorough examination of the series by using advanced econometric tools.

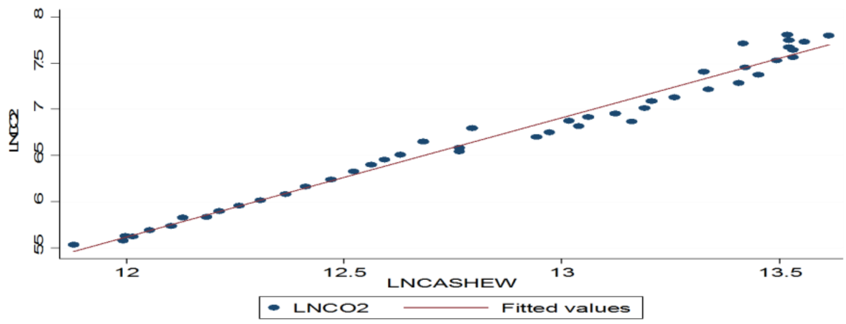

Fig. 2. Relationship between CO_2 emissions and cashew nut production.

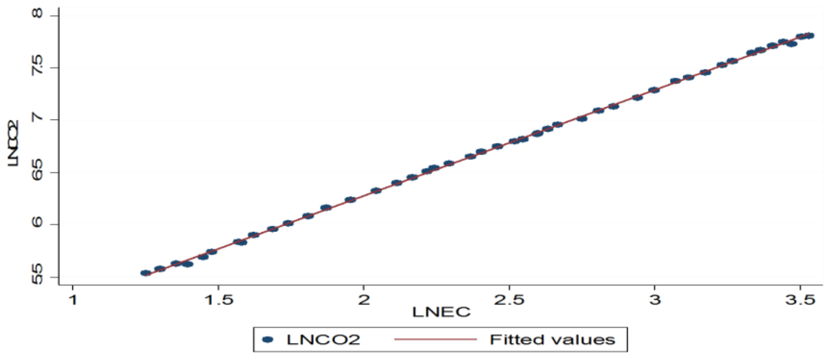

Fig. 3. Relationship between CO_2 emissions and energy consumption.

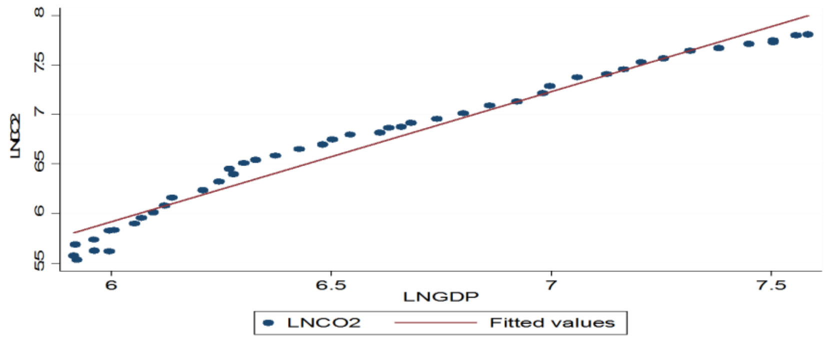

Fig. 4. Relationship between CO_2 emissions and economic growth.

In order to disseminate the long-run relationship between the series, the application of the Bayer-Hanck (2013) combined cointegration test is identified as appropriate for the empirical analysis. Thus, the series in the estimation should not exceed or falls below the integrated of order I (1). If the above condition is not satisfied, the execution of long-run cointegration estimation using the Bayer-Hanck combined cointegration test not only produces a contradictory outcome but also creates potential information loss. Hence, we decided to implement Augmented Dicky Fuller and Phillips and Perron unit root tests proposed by (Dickey & Fuller, 1979) and (Phillips & Perron, 1988), respectively. The output portrayed in Table 2 indicate with 99% confidence that the series is stationary at the first difference for all the variables, while it is not so in the levels for the variables under scrutiny.

Table 2. Unit root tests.

Variable	ADF		PP	
	Level	First difference	Level	First difference
lnCO_2	-1.6076	-3.8518*	-1.3676	-4.0340*
lnCASHEW	-2.0270	-11.4008*	-1.3658	-8.9705*
lnEC	-1.5721	-4.8122*	-1.5068	-4.9362*
lnGDP	1.3323	-4.7479*	1.3027	-4.7767*

Note: * indicates a 1% significance level.

Once the integration order has been identified for all the variables, the study implements the Bayer and Hanck method of cointegration to examine the long-run relationship among the series. The outcome reported in Table 4 shows two types of critical values, namely EG-JOH-BO-BDM and EG-JOH. Here, EG-JOH-BO-BDM is the combined Fisher statistics for the cointegration tests proposed by (Banerjee *et al.*, 1998; Engle & Granger, 1987; Johansen, 1988, 1991; Peter Boswijk, 1994), while EG-JOH is the combined Fisher statistics by using cointegration tests introduced by (Engle & Granger, 1987; Johansen, 1988, 1991). Interestingly, the estimated Fisher statistics is above the critical value at a 5% level of significance; hence, it is 95% confident that the series of variables that assess the cointegration of CO_2 emissions while considering the cashew nut production, energy consumption and economic growth as its potential determinants.

Table 3. The results of Bayer and Hanck cointegration analysis.

Model estimated	EG–JOH	EG–JOH–BO–BDM	Cointegration
CO_2=F(CASHEW,EC,GDP)	17.4754**	24.1177	Yes
5% critical value			
EG- JOH	10.637		
EG–JOH–BO–BDM	20.486		

Note: ** indicates a 5% significance level.

After verifying the cointegration of the series, the study illustrates the outcome emanating from the FMOLS, DOLS, and CCR approaches are reported in Table 4. It found a significant reduction in CO_2 emissions due to cashew nut production in India. Precisely, the long-run estimators like FMOLS, DOLS, and CCR show a reduction of CO_2 emissions of about 0.063%, -0.146%, and -0.067%, respectively, for a 1% increase in cashew nut production. In line with traditional notions, the estimated coefficient of energy consumption is positive and significant, which implies that energy consumption harms the environment by fostering CO_2 emissions. Precisely, a 1% increase in energy consumption leads to a rise in CO_2 emissions by 1.10 %(FMOLS), 1.18 %(DOLS) and 1.11% (CCR) when keeping other factors in the model constant. However, the economic growth coefficient is negative and significant across the models. It implies that economic growth is not causing environmental degradation. Specifically, keeping other factors constant, a 1% increase in economic growth leads to a decrease in CO_2 emissions by -0.052% in FMOLS, -0.078% in DOLS, -0.07% in CCR.

Table 4. FMOLS-DOLS-CCR Long-run coefficient estimates.

Variable	FMOLS		DOLS		CCR	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
LNCASHEW	-0.0630**	-2.0627	-0.1465*	-5.3231	-0.0674***	-1.6843
LNEC	1.1008*	30.0322	1.1877*	39.5887	1.1167*	24.4013
LNGDP	-0.0521***	-1.9702	-0.0785*	-4.2637	-0.0706*	-2.4274
C	5.1894*	12.8369	6.2140*	17.8376	5.3278*	10.1846
R-squared	0.9996		0.9999		0.9996	
Adjusted R-squared	0.9996		0.9998		0.9996	
S.E. of regression	0.0140		0.0093		0.0141	
Long-run variance	0.0002		0.0001		0.0003	
Mean dependent var	6.7470		6.7513		6.7470	
S.D. dependent var	0.6997		0.6761		0.6997	
Sum squared resid	0.0080		0.0026		0.0081	

Note: *, ** and ***indicate significance at 1, 5 and 10 per cent, respectively.

Fig. 5-10 depicts the B.C. frequency domain causality test spectral graphical plots explaining the causal link of variables like cashew nut production, energy consumption and economic growth with CO_2 emissions. Further, 0–1(permanent causality range), 1–2 and 2–3(temporary causality range) are frequencies in which the causal link between the variables is assessed. In Fig. 5, it found that the running of permeant causality from cashew nut production to CO_2 emissions at 1% statistical significance for at frequencies lower than 0.5 and at 5% statistical significance for at frequencies lower than 0.7. Further, a temporary causality holds at a frequency between 1.7 and 2.2 at 5% significance.

However, no causality was observed from CO_2 emissions to cashew nut production in Fig. 6. Thus, it concluded that unidirectional causality runs from cashew nut production to CO_2 emissions.

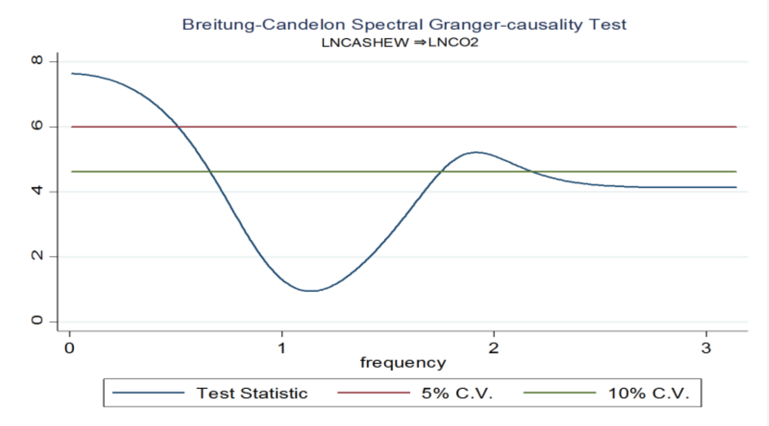

Fig. 5. Granger-causality from LNCASHEW to $LNCO_2$

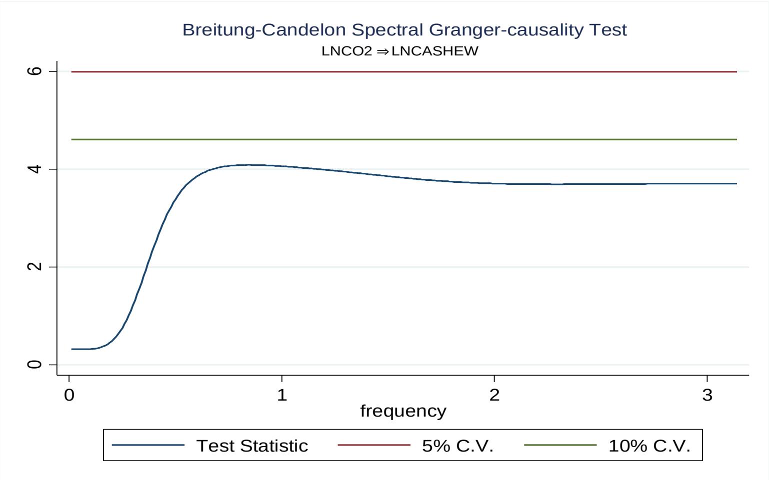

Fig. 6. Granger-causality from $LNCO_2$ to LNCASHEW.

Moreover, it is observed that no causality runs from energy consumption to CO_2 emissions in Fig. 7. But, a causal link was found from CO_2 emissions to energy consumption at a 1% significance level for frequencies between 1 and 1.3, as visible in Fig. 8. This finding is not surprising since the high accumulation of CO_2 in the atmosphere causes an increase in temperature, which in turn necessities the purchasing of energy-intensive appliances at the firm and household level to create artificial cooling to make them survive amid the rising temperature.

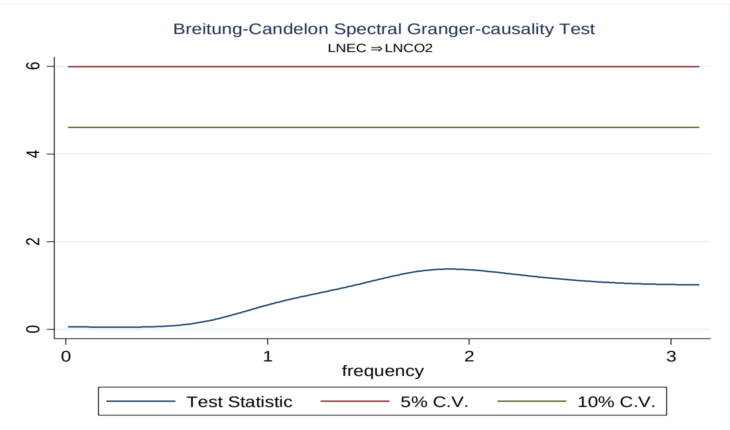

Fig. 7. Granger-causality from LNEC to $LNCO_2$.

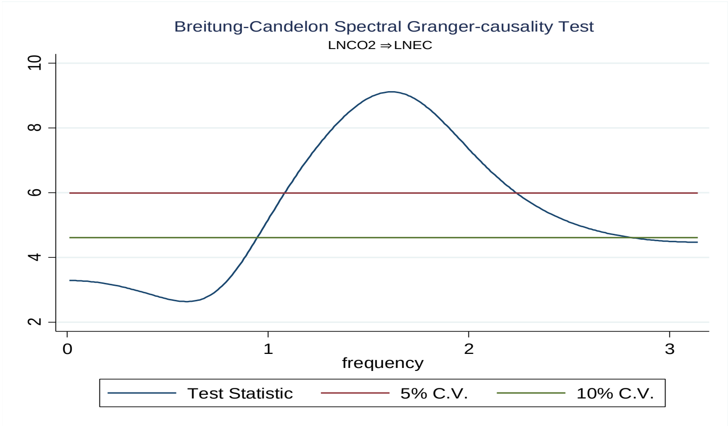

Fig. 8. Granger-causality from $LNCO_2$ to LNEC.

Besides, the study found in Fig. 9 that a casualty from CO_2 emissions to energy consumption at a 5 % significance level for frequencies between 0.9 and 2.7 and at a 1% level for frequencies from 2.8 to 3. However, in Fig. 10, there is no causal link found between CO_2 emissions to economic growth. Thus, a country like India warrants economic growth that won't create ecological grief. This finding underscores the need to promote economic growth to combat poverty, unemployment and inequality in India since the regression evidence shows that economic growth is not harming the environment. Finally, the robustness of the finding was calculated using time domain causality, and the results are reported in Table 5. It is consistent with frequency domain causality outcomes.

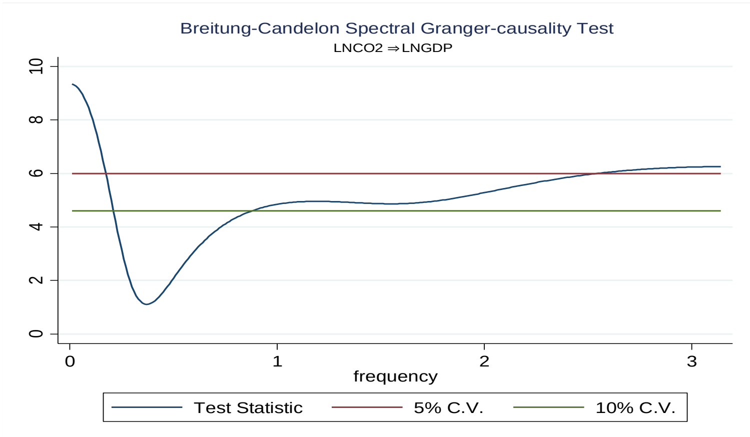

Fig. 9. Granger-causality from $LNCO_2$ to LNGDP.

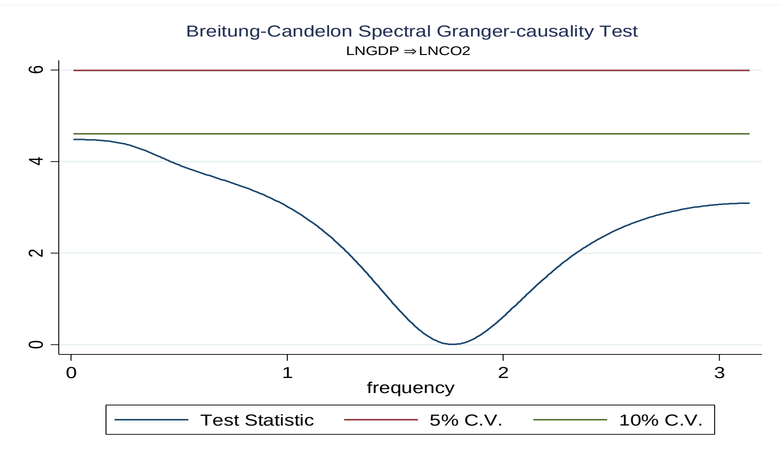

Fig. 10. Granger-causality from LNGDP to $LNCO_2$.

Table 5. Granger causality test result.

Null Hypothesis:	Obs	F-Statistic	Prob.
LNCASHEW does not Granger Cause LNCO_2	43	4.24503*	0.0115
LNCO_2 does not Granger Cause LNCASHEW		0.83080	0.4857
LNEC does not Granger Cause LNCO_2	43	0.57477	0.6353
LNCO_2 does not Granger Cause LNEC		3.11208**	0.0382
LNGDP does not Granger Cause LNCO_2	43	0.64604	0.5905
LNCO_2 does not Granger Cause LNGDP		4.53667*	0.0085
LNEC does not Granger Cause LNCASHEW	43	1.23453	0.3114
LNCASHEW does not Granger Cause LNEC		2.69589***	0.0603
LNGDP does not Granger Cause LNCASHEW	43	0.86465	0.4683
LNCASHEW does not Granger Cause LNGDP		3.29667**	0.0313
LNEC does not Granger Cause LNGDP	43	2.69619***	0.0603
LNGDP does not Granger Cause LNEC		2.19085***	0.106

Note: *, ** and ***indicate significance at 1, 5 and 10 per cent, respectively.

Discussion

Regarding the cashew nut production on CO_2 emissions, the result may be due to the participation of cashew industries in Global Supply Chains (GSCs) may be helped India reduce greenhouse gas (GHG) by offering energy-efficient processing and raw cashew nut transportation. Further, this environmentally beneficial role is attributed to India's aim to meet the health issues of locals in the cashew production area due to cashew processing and nutshells waste management. Thus, this finding is corollary with (Suwanmanee *et al*., 2020), (Cetin *et al*., 2022) for 47 developing countries, (Selcuk *et al*., 2021) for the full panel of the next 11 countries, and (Adedoyin *et al*., 2020) for Sub-Saharan African countries. However, it deviates from (Yurtkuran, 2021) for Turkey, (Waheed *et al*., 2018) for Pakistan and (Gokmenoglu & Taspinar, 2018) for Pakistan.

As far as the adverse environmental effect of energy consumption is concerned, it is possible because of the predominance of non-renewable energy in total energy consumption in India. Although meeting increased energy need with fossil fuel fosters economic growth, the environmental consequences related to it is often ignored. Moreover, the outdated and less effective technology in the energy sector also fuels environmental degradation due to energy consumption. Thus, the energy consumption finding has literature support from the studies (Ssali *et al*., 2019) for six selected sub-Saharan African countries (Villanthenkodath *et al*., 2022) for India (Villanthenkodath & Mahalik, 2022) for India, while divulges from an India based study by (Mahalik *et al*., 2021).

While the beneficial impact of economic growth on CO_2 emissions is not surprising since India is the economy that is emerging with the dominance of the service sector in the total national output, it implies that an economy growing with service sector domination needs less energy compared to the economy growing with the manufacturing sector. According to (International Energy Agency, 2015), industrial sector-led growth requires three times more energy than the service sector-led economy. Therefore, it is possible to presume that the service sector-led economic growth is more eco-friendly than the service sector-led growth. This finding is in line with the short-run finding of the study by (Villanthenkodath & Mahalik, 2022) for India. But, it contradicts the studies by (Mahalik *et al*., 2021) for India, (Ssali *et al*., 2019) for six selected sub-Saharan African countries, (Villanthenkodath *et al*., 2022) for India.

Conclusions

The present study aims to find the dynamic impact of cashew nut production on CO_2 emissions in the presence of energy consumption and economic growth, spreading the period between 1975 and 2021 in India. In order to explore the long-run relationship between the series, Bayer-Hanck combined cointegration test has been applied. The empirical evidence indicates that the cointegration of CO_2 emissions while considering cashew nut production, energy consumption and economic growth are the potential determinants. The results from FMOLS, DOLS, and CCR experiments indicate the reduction in CO_2 emissions is attributed to an increment in cashew nut production in India. The inverse relationship between CO_2 emissions vis a vis cashew nut production eventually signals India's commitment to reduce greenhouse gases by fostering efficient processing, raw cashew nut transportation and nutshells waste management.

In consonance with existing literature, a causal link found from CO_2 emissions to energy consumption followed by high temperature promulgate the requirement for an energy-efficient machine that warrants both household and firm levels. Unless otherwise, carbon emissions induced by energy consumption and the agriculture production sector controlled by an effective tax system, there exists plausible damage to the environment. The empirical examination provides policy directions to the existing literature in different directions. For instance, the connection between energy consumption, carbon emissions, and agricultural economic growth will provide sustainable practices in the agriculture sector through an efficient mechanism in cashew nut production.

An unconventional finding of a reduction in CO_2 emissions is ascribed to an increase in cashew nut production in India, suggesting different policy perspectives. First, by enhancing cashew nut production there by the economic growth of the country can be achieved since cashew nut is a major cash crop in India. Second, the reduction in carbon emissions by devising the systematic plantation of cashew nut trees and efficient use of land resources will lead to control the climate change. Third, by increasing cashew nut production, on the one hand, the firms can export cashew nut value-added products and earn foreign exchange money; on the other hand, the firms can capitalise on the local demand for cashew nut products. In fact, the majority of India's rural population is under the poverty line and is facing the issue of malnourishment, particularly among women and children. Since the cashew nut and its value-added products possess high nutritional benefits, the pressing issue of malnourishment can be addressed by providing cashew nuts at a subsidized price to the poor. Fourth, the Government of India has to provide sufficient weightage to the cashew nut industry since it accommodates a major chunk of the rural workforce, more specifically women and hence it can alleviate rural poverty.

Conflict of interests

The authors declare that there is no conflict of interest.

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