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Time Series Analysis of Environmental Degradation in India

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The purpose of this study is to explore the long-run relationships and short-run dynamic interactions between environmental degradation (proxied by carbon dioxide, CO_2 emissions) and the independent variables of consumption (proxied by income level or gross domestic product, GDP per capita) and energy use in India over the period 1975 to 2015, using time-series analysis. The multivariate cointegration methodology is applied in this study to establish the possible causal relations between the variables concerned. The cointegration test and the vector error correction model display the evidence of a positive long-run relationship between consumption and environmental degradation, while energy use is negatively related to environmental degradation. The long-term elasticity coefficients of the exploratory variables on environmental degradation display relationships that are theoretically grounded. The study concludes with an examination of policy implications of the findings.

Key words: Environment,Degradation, VECM, Co-integration, India

Globalisation has brought about changes in the production and consumption patterns in many societies, especially societies that are affluent. Nowadays, it is quite common to see an unlimited number of goods and wide ranging services being provided to consumers who are spoilt for choice. However, the over-indulging behaviour of consumers and over-zealous conduct of producers, who are out to make the best out of the demands and maximise profits do come with attendant problems to our environment. In Ger's view (1997: 112) the "consumption and production patterns of affluent countries are responsible for most transboundary problems, such as ozone layer depletion, ocean pollution and chemicalization of the habitat."

The effects of global warming can be devastating and heat waves, drought, ozone layer depletion, storms, floods and rising sea levels can cause massive economic damage to agriculture and infrastructure. The past few decades have witnessed rapid economic growth especially in developing nations, such as China, India and Russia. Economic development is often associated with higher energy consumption. However, unsustainable energy consumption triggered by rapid development creates environmental problems. For instance, increased energy consumption for fuel production can cause the greenhouse effect, which can further lead to other environmental disasters. The main cause of such problems, especially global warming is carbon dioxide (CO_2) emissions from the burning of fossil fuels (Davis and Caldeira, 2010). Hence, environmental problems such as global warming often affect the production of goods and services in a country or region. Additionally, unchecked consumer behaviour can also cause serious consequences to the environment and thus, many developing nations are concerned of the potential environmental damage that can be caused by incessant consumption spending. With this background, the main objective of this study was to investigate the dynamics of consumption, energy use and environmental degradation in India over a period of 40 years from 1975 to 2015.

Material and Methods

Annual time series data of the variables of carbon emissions (CO_2), gross domestic product per capita (GDPC) and energy use (EC) from 1975 to 2015 was used for India. The data was obtained from the World Development Indicator, to examine the influence of consumption and energy use on environmental degradation.

Environmental degradation is proxied by carbon emission (CO_2) data, while consumption is proxied by GDPC. The use of GDPC as a proxy for consumption is supported by the findings of Adrangi, *et al.,* (2004) on the accuracy of GDPC as a proxy for consumption.

The augmented Dickey-fuller (ADF) and Phillips-Perron (PP) unit root tests were used to test stationarity. Thereafter, the maximum likelihood approach for cointegration test developed by Johansen (1988) and Johansen and Juselius (1990) or better known as the JJCointegration Test was used. It provides information pertaining to whether the set of non-stationary variables under consideration is tied together by the long-run equilibrium path. In denoting X as a vector of the variables under study, the JJ test is based on the following vector error correction (VECM) representation:

$$\Delta X_t = \alpha + \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + ... + \Gamma_p \Delta X_{t-p} + \Pi X_{t-1} + u_t \quad (1)$$

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where α is an $n \times 1$ vector of constant terms, Γi (i = 1, 2,.., p) and Π are $n \times n$ matrices of coefficients, p is the optimal lag order and n is the number of variables in the model. The JJ test is based on determining the rank of Π, which depends on the number of its characteristics root (eigenvalue) that differ from zero.

As the purpose of this study is to determine the causal direction between the variables in question, the following vector error correction models (VECM) are estimated as:

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{k} \alpha_i \Delta y_{t-i} + \sum_{i=1}^{k} \alpha_j \Delta x_{t-j} + \gamma_1 ecm_{t-1} + \varepsilon_{1t} \quad (2)$$

$$\Delta y_t = b_0 + \sum_{i=1}^{k} \beta_j \Delta y_{t-i} + \sum_{i=1}^{k} \beta_j \Delta x_{t-j} + \gamma_1 ecm_{t-1} + \varepsilon_{1t} \quad (3)$$

where cm_{t-1} is the lagged residual from the cointegration between yt and xt in level.Granger (1988) points out that based on Equation (2), the null hypothesis that xt does not Granger cause ytis rejected not only if the coefficients on thex_{t-1} are jointly significantly different from zero, but also if the coefficient one cm_{t-1} is significant.

The study also applies the multivariate cointegration methodology of Johansen (1988) and Johansen and Juselius (1990) to establish the possible causal relations between environmental degradation and the variables of consumption and energy use. The cointegration test and the vector error correction model are used to find out whether there is evidence of long-run relationships between environmental degradation and the variables of consumption and energy use.

This study has also drawn ideas from Loganathan and Thirunaukarasu (2010) who used a combination of OLS-EG, DOLS, ARDL and ECM to identify the short-run elasticity between total energy consumption and economic performance for Malaysia. Belke, Dobnik and Dreger (2011) insights gained through their effort to distinguish the effects of the national and international developments as drivers of the long-run relationship are also pertinent to this study.

This study also used econometric modelling with VECM long run relationship between consumption and environmental degradation through CO_2 emissions.

Results and Discussion

The econometric findings are discussed in this section, starting with the results of the Unit Root test, followed by the discussions of the results of Johansen's Cointegration Test. Thereafter, the Vector Error Correction model results are analysed and finally, the results of the further innovation analysis using Variance Decomposition is presented.

Table 1. ADF and PP Unit Root Tests

LEVEL	AugumentedDickeyFuller		Phillips-Perron	
	Constant without trend	Constant with trend	Constant without trend	Constant with trend
$LOGCO_2$	-0.90018 (0)	-2.23153 (0)	-0.825315 [1]	-2.432273 [1]
LOGGDP	-0.66808 (0)	-1.46445 (0)	-0.257636 [3]	-1.536115 [2]
LOGEC	-1.13324 (0)	-2.43516 (0)	-0.764263 [2]	-2.345581 [3]
FIRST DIFFERENCE	AugumentedDickeyFuller		Phillips-Perron	
	Constant without trend	Constant with trend	Constant without trend	Constant with trend
$LOGCO_2$	-7.05268 (0)***	-7.05268()***	-7.86237 [1]*	-8.08981[2]***
LOGGDP	-6.72662 (0)***	-6.72662()***	-8.19688 [3]*	-8.26478[4]***
LOGEC	-7.205017(0)***	-7.20501()***	-6.83608 [4]*	-7.08553[5]***

Note: *** and ** denotes significant at 1% and 5% significance level, respectively. The figure in parenthesis (…) represents optimum lag length selected based on Schwatz Info Criterion.The figure in bracket […] representsthe Bandwidth used in the Phillips-Perron test selected based on Newey-West Bandwidth criterion.

Unit root test (order of integration)

The ADF and PP Unit root tests were performed on a 40 years period data *i.e*. from 1975 to 2015 to check whether the three variables in equation (1) were stationary in level or in first-difference. The results of this test are shown in Table 1. The constant without trend and the constant linear trend specification were included in this test equation. The lag length used is represented in the brackets as shown in Table 1. The order of integration of the relevant variables was determined prior to performing a cointegration test as only integrated variables of the same order could be co-integrated. The test for unit roots in the variables of the system was calculated through the Augmented Dickey-Fuller (ADF) test and further supported by the Phillips-Perron (PP) test as shown in Table 1 for both level and first-differenced series. Table 1 confirms the stationarity of the variables when they are first-differenced, that is, all variables used in this time series are *I*(1).

Johansen-Juselius cointegration test

The Johansen-Juselius Cointegration test was performed using non-correlated errors as the lag selection criterion. Since all variables in this time series are *I*(1), there is a likelihood of an equilibrium relationship between them. The cointegration test of Johansen (1988) and Johansen-Juselius (1990) was applied to investigate the presence of a long-run equilibrium relationship among the variables in study. Table 2 estimates the number of long run relationships that exist between environmental degradation (proxied by CO_2 emissions) and it determinants comprising consumer behaviour (proxied by GDP per capita) and energy consumption (EC). After performing the Johansen Cointegration Test, the Vector Error-correction Model (VECM) was estimated and the optimal lag length was obtained. A model with the optimum lag of 1 was chosen based on the Ljung-Box-Q statistics as the error terms of all equations in the system were found to be serially uncorrelated. The results in Table 2 show that both the trace statistics and the Maximum-Eigenvalue statistics indicate the presence of a unique cointegrating vector at 1% level. Therefore, the empirical results suggest the presence of a long run cointegration relationship between environmental degradation (proxied by CO_2 emissions) and its determinants comprising of consumer behaviour (proxied by GDP per capita) and EC.

Table 2. Results from Johansen's Cointegration Test: Unrestricted Cointegration Rank Test (Trace and Maximum Eigen value)

	Test statistics		Critical value (5%)	
	Trace	Max eigen value	Trace	Max eigen value
r = 0	182.7769***	63.79001***	125.6154	46.23142
r ≤ 1	118.9869***	48.39270***	95.75366	40.07757
r ≤ 2	62.59417	32.27059	69.81889	33.87687

Note: *** denote significance at 1%. This table shows the results from Johansen's Cointegration Test for both Trace and Maximum Eigenvalue which shows the presence of cointegration for this system of variables.

Vector error correction model (VECM)

The vector error-correction model is used to capture the long-run equilibrium dynamics in the time series. Since there is evidence of cointegration, the dynamic relationships between the cointegrated variables can be studied using an error-correction model. The cointegrating vector (normalised on the CO_2 emissions) representing the long-run relationship (with lag 1) is shown as follows:

$$\ln(CO2)_t = -15.3453 + 4.1254\ln(GDP)_t^{***} - 4.2675\ln(EC)_t^{***} + e_t \quad (4)$$

t-stat [11.21345] [8.34378]

Note: *** denotes significant at 1%

The coefficients found in the normalised cointegrating vector in equation (2) are long-term elasticity measures because the variables have undergone logarithmic transformation. Equation (2) shows that both LNGDP and LNEC are at 1% significance level. In the long run, there seems to be a positive and significant relationship between consumption (proxied by real GDP per capita) and environmental degradation (proxied by CO_2 emission), while energy consumption has a negative and significant impact on environmental degradation in India.

The positive relationship between consumption (proxied by real GDP per capita) and environmental degradation (proxied by CO_2 emission) are consistent with the empirical evidence of Tucker (1995); Adrangi et al., (2004); and Halicioglu (2009).

It is interesting to note that energy consumption in India has a negative relationship with CO_2 emissions. While this result contradicts with the findings of Ang (2007; 2009) and Jalil and Mahmud (2009), it is believed that when there is improved energy efficiency, is likely to reduce CO_2 emissions as shown in results. The plausible explanation for this puzzling relationship is the existence of safer patterns of production and consumption that does not pollute as much as before. Aside from this, national and global environment policies and cooperation between governments have provided a stronger push for improved energy efficiency and cleaner environment. Such policies include the imposition of green taxes on pollutants and subsidies for green companies, encouraging the use and further development of more sustainable energy technologies.

Policy implications

The findings of this study have important implications on issues related to sustainable development in the country. In essence, the government must put into place regulatory measures stringently to enforce green laws that will reduce carbon emission. The empirical evidence gathered in this study postulates that higher consumption is positively associated with worsening environmental degradation in the long run. Therefore, it is important for policy makers to take cognizance that higher consumption and income level inevitably leads to deteriorating environmental conditions.

The most effective way to achieve the best of both worlds is via education. People in developed countries tend to have greater environmental awareness due to better education and subsequent awareness on the effects of human activities on the environment. Indian authorities must take the cue from developed nations to incorporate environmental education in the school curriculum. Additionally, technology, such as the state-of-art waste management systems should also be utilized to curb environmental degradation.

The rise in environmental degradation may only be confined to certain sectors of the economy. As such, imposing a blanket approach in taxation on all sectors in order to deter carbon emission may not be outright effective. This selective approach may deter the "culprits" and coerce them to undertake measures that will reduce pollution, whilst the cleaner sectors will justifiably be rewarded for the efforts taken. It is also hoped that the Indian government, in its hope to achieve a sustainable "high-income nation" status, further implements and extends green policies that will assist in achieving its vision of developed status in 2020.

Conclusion

This study explored whether environmental degradation (proxied by CO_2 emissions) in India could be explained by consumption (proxied by GDP per capita) and energy consumption. The study employed vector error-correction model to gather empirical evidence to support the notion that environmental degradation is cointegrated with a pair of independent variables; namely, GDP per capita and energy consumption. The empirical results suggest the presence of long-run equilibrium relations between these variables and environmental degradation. The results lend evidence on the existence of a positive relationship between environmental degradation and consumption and a negative relationship between environmental degradation and energy use.

Based on the findings, it can be concluded that consumption patterns have caused a negative impact on the environmental in India. The findings of this study offer an insight into the damaging impact of uncontrolled consumerist lifestyle on the environment. Hence, understanding the key drivers behind India's growing consumption and its associated CO2 emissions is critical for the development of its climate policies in the future.

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