RESEARCH ARTICLE

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Econometric Analysis of Influences of Trade Openness, Economic Growth and Urbanization on Greenhouse Gas Emission in INDIA (1961-2017)

Abhay Pratap Raghuvanshi*

Assistant Professor Economics

Abstract

This paper examines the impacts of trade openness, gross domestic product (GDP) per capita, and urbanization air pollution. It takes into consideration data on India during the period 1961-2017 to see how trade openness, *GDP* per capita growth, urbanization have impacted CO_2 emissions. To test for the existence of an inverted U shaped hypothesis, U-test is used in this paper. The data is subjected to various econometric tests, including unit root test, optimal lag test before applying the Johansen test for co-integration to understand the long-run relationship between the above variable. Then the unrestricted VAR model and Wald test are used to find the short-run causality between the variables under analysis. Further, to observe variation in an endogenous variable into the component shocks to the VAR, variance decomposition of the CO_2 emission is observed.

Keywords: Carbon-dioxide emission per capita, Economic growth, Johansen test of co-integration, Trade openness, Urbanization, U-test, Vector autoregressive model.

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Introduction

The study of the relationship between pollution and income has mainly focused on investigating the Environmental Kuznets curve (EKC) (Stern, 2004). This so-called environmental Kuznets curve originated from Kuznets (1955), who hypothesized in 1954 that income inequality first rises in early years of economic growth and then falls in the curse of economic development. Kuznets's view that the early stages of income growth distribution of income become more unequal but that the distribution eventually moves back toward greater equality as economic growth continues. Grossman and Krueger's (1991) are those who set up the actual EKC concept. They point out that the level of environmental degradation and per capita income follows the same inverted U-shaped relationship, as does income inequality and per capita income in the original Kuznets curve.

This inverted U-shape curve suggests that at the early stages of economic development, pollution intensity rises with per capita income and falls as per capita income rises beyond some threshold level that could be determined from the estimated coefficients of the following equation.

Corresponding Author: Abhay Pratap Raghuvanshi, Assistant Professor Economics, e-mail: raghuvanshi0802@gmail.com

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$$\ln E_t = \alpha + \beta_1 \ln Y_t + \beta_2 \ln Y_t^2 + \varepsilon_t$$

Where E_t denotes per capita pollution, Y_t, denotes per capita income, Y_t^2 indicates square income per capita, ε_t is an error term.

The threshold point could be calculated as the exponential of the ratio β_1 over $2\beta_2$. A negative value for the coefficient β_2 along with U-test confirms the inverted U-shape of the curve. Empirically the growth-pollution literature studying the relationship between per capita income and pollution per capita (Millimet and Stengos, 2003 and Azomahou, Lasney and Van 2006) for individual countries and groups of countries has found that: (i) at the early stages of economic development pollution intensity rises with per capita

income; (ii) but pollution intensity falls as per capita income rises beyond some threshold level (Grossman and Krueger, 1995 and List and Gallet, 1999, among others)

Although several pollutants have been considered in the study of the EKC (Managi, 2006) in this paper CO_2 is used as a variable for pollution. In effect, the debate concerning the reduction of CO_2 emissions is still active both in developed nations and developing countries.

Literature Review

Environment Kuznets curve

At the initial stage of development, the level of CO_2 increases with income. After some threshold level of income, this relationship may change from positive to negative as more efficient infrastructure and energy-efficient technology are implemented during the development of the country.

Urbanization

Most cities are growing at a faster rate than the national average, as the endurance workers are migrating from rural to urban areas for better jobs, better life, better education, better treatment, etc. Thus urban populations pressure on urban resources and the environment, as a result, the environment is polluted. Although urbanization is often discussed in the context of economic modernization, it is a demographic indicator that increases urban density and transforms the organization of human behavior, thereby influencing household energy use patterns. However, the extent to which urbanization affects national energy use and CO_2 emissions has not been fully and clearly explained in a single theory. The relationship between urbanization and various environmental issues, including energy use and emissions, has been studied extensively in recent years. Some researchers show that urbanization increases energy demand, generating more emissions. Conversely, other scholars argue that urbanization and urban density improve the efficient use of public infrastructure (e.g., public transport and other utilities), lowering energy use and emissions. Previous research has shown conflicting results, suggesting that the relationship between urbanization, energy use, and emissions is complicated.

Effect of International Trade on Environment

Environmentalists have raised the topic of free trade as being the cause of environmental pollution. Their argument that the scale of economic activities increases the level of pollution, and in addition, it is possible that the production of pollution causing goods be taken over from northern countries, which have higher standards of protection by southern countries whose regulations are looser in this respect. Conversely, free trade advocates argue that the income gained through trade brings about a stricter adherence to environment protection regulations. Thus, the negative effects of free trade are compensated for. Many studies have been carried out concerning the issue, of which the empirical work of Grossman and Krueger (1993) and the theoretical work of Copeland and Taylor (1994), Yues (1996), and Dean (2000) can be mentioned.

The increasing amount of CO2, the dominant contributor to the greenhouse effect, seems to be aggravating environmental problems. India is an emerging economy and one of the important countries which has a high carbon emission in the world. India has experienced a significant rise in energy consumption and carbon emissions in recent decades.

Model Specification

For examining the Environment Kuznets Curve with data on India during 1961-2017 following regression equation is estimated:

$$\ln E_t = \alpha + \beta \ln Y + \gamma \ln Y^2 \quad (1)$$

Depending on the parameters and equation (1) may be inverse U-shaped or not. A U shape is then implied by the conditions

$$\beta + \gamma f'(x_l) > 0 > \beta + \gamma f'(x_h)$$

If either of these inequalities is violated the curve is not inverse U-shaped but

U-shaped or monotone. The individual significance of both β and γ is necessary but not sufficient. First, it is checked whether the estimated minimum point ($x_{min} = \beta/(2\gamma)$) itself is within the date range. Most works use the criterion that if both βand γare significant and if the implied extreme point is within the data range, they have found an inverted U shape. This is a sensible criterion, but it is neither sufficient nor necessary. As the noted significance of γalone is always a necessary condition in the test of a U shape. So this sufficiency condition is checked using U-test.

To study the relationship between income, trade openness and urbanization following equation is estimated.

$$\ln E_t = \alpha + \beta 1 \ln Y_t + \beta_3 T_t + \beta_4 \ln U_t + \zeta_t \quad (2)$$

Where E_t denotes per capita emissions of carbon dioxide (CO_2), Y_t denotes per capita *GDP*, T_t indicates trade openness as measured by the share of exports and

imports in *GDP*, U_t is the share of the urban population in total population, ζ_t is a stochastic error term, and *t* is a year index.

The assumptions concerning the preceding equation 2 are that while the *GDP* per capita is supposed to impact the emissions of CO_2 i.e., negatively the environment positively, the trade openness variable will impact pollution, thus positively the environment and urbanization is supposed to impact emission of CO_2thus negatively to the environment.

To observe the long-run relationship between income, pollution(emission CO2), urbanization, and trade openness, The Johansen Maximum Likelihood Procedure is applied. Based on a VAR approach to cointegration. The test relies on the relationship between the rank of a matrix and its eigenvalues or characteristic roots. In the absence of cointegation relation between the variables, the unrestricted VAR model is used. Vector auto-regression (VAR) is an econometric model used to capture the evolution and the interdependencies between multiple time series, generalizing the univariate AR models. A VAR is an equation, n variable model in which each variable is, in turn, explained by its own lagged values, plus (current) and past values of the remaining n -1 variables.

Following the VAR model is estimated in the study

$$E_t = C_1 + {}_{1i}E_{t-i} + \gamma_{1i} Y_{t-i} + \alpha_{1i} T_{t-i} + \mu_{1i} DU_{t-i}) + \varepsilon_1 \quad (3)$$

$$Y_t = C_2 + {}_{2i}E_{t-i} + \gamma_{2i} Y_{t-i} + \alpha_{2i} T_{t-i} + \mu_{2i} DU_{t-i}) + \varepsilon_2 \quad (4)$$

$$T_t = C_3 + {}_{3i}E_{t-i} + \gamma_{3i} Y_{t-i} + \alpha_{3i} T_{t-i} + \mu_{3i} DU_{t-i}) + \varepsilon_3 \quad (5)$$

$$DU_t = C_4 + {}_{4i}E_{t-i} + \gamma_{4i} Y_{t-i} + \alpha_{4i} T_{t-i} + \mu_{4i} DU_{t-i}) + \varepsilon_4 \quad (6)$$

Here urbanization is represented by the first difference of the urbanization variable (DU); all other variables are as previous.

In the end, variance decomposition and the impulse response function is shown for emission in the above unrestricted VAR model.

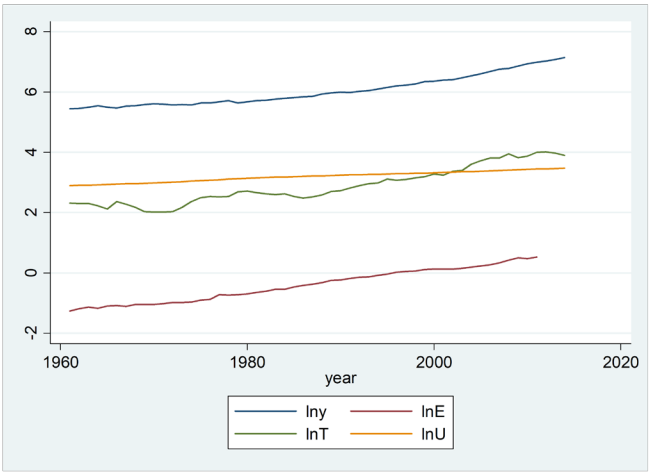


Figure 1

Data and Results

The model is estimated using data from World Development Indicators (WDI) and covering the period 1961-2017. Figure 1 shows the series in natural logarithm (Top panel) and in first difference (Bottom panel).

The variable *LNE* indicates pollution measured as CO_2 emission (metric ton per capita), *LNY* indicates Gross domestic product per capita and *LNT* indicates trade openness as measured by the share of exports plus imports in GDP.

Environmental Kuznets Curve (INDIA)

Results of Estimated equation 1 is given in table below

	Coefficients	*Std. Error*	*t-value*
lny	10.07086	.6730526	14.96
LnY^2	-.7236865	.0547595	-13.22
constant	-34.61599	2.058044	-16.82

R^2Root MSE = .06931

Number of observation = 51 F(2,48) = 1531.48

In effect from the estimated coefficients of the following Eq1

$$lnE_t = -34.61599 + 10.07086\, lnY_t - .7236865 lnY^2 \quad (7)$$

From the table above it is observed that both β and γ coefficients are significant also the coefficient of lnY_t is positive and coefficient of lnY^2 is negative and, in addition, the estimated extremum point - (β/2γ) = 6.958026 is within the data range, it is common to conclude that there is an inverse U-shaped relationship. This criteria is too weak. To test properly for the presence of a U shape on some interval of values, we need to test whether the relationship is decreasing at low values within this interval and increasing at high values within the interval, to check this we perform

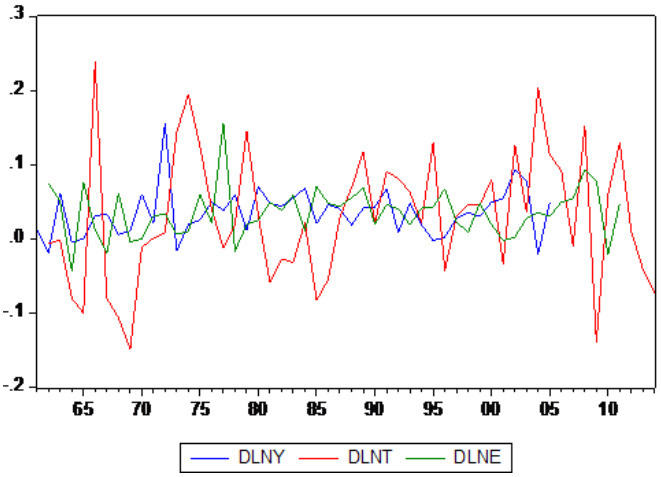


Figure 2

the U-test. The result of the U-test is given in the table below.

	Lower bound	*Upper bound*
Interval	5.447491	7.140957
Slope	2.186309	-.2647684
t-value	27.60546	-2.373303

Overall test of presence of a Inverse U shape:
t-value = 2.37
p>|t| = .0108
95% Fieller interval for extreme point: [6.8466065; 7.1081067]

From the above test, it is observed that the hypothesis of lower bound slope $\beta+\gamma f'(x_l)>o$ and at the upper bound slope is $\beta+\gamma f'(x_l)<0$ can be rejected. Also, the p-value for the overall test of the presence of inverse U shape is less than 5%, so the null hypothesis of inverse U shape is rejected.

Result suggests that using the U-test, the relation between the emission of CO_2 and income is not inverted U shape in case of India during (1961-2017). As only the necessary condition, such as the statistically significant negative value of $\beta = -.7236865$ and computed extreme point $(\beta/2\gamma)= 6.958026$, predicted turning point computed by $e^{-(\beta/2\gamma)}= 1051.55574$ to be present within the data set are satisfied but not the sufficiency condition. The relation between income and emission of CO_2 in the case of India is plotted in Figure 3.

Trade variable (T) has a negative coefficient indicating that with an openness of trade emission has gone down, the positive coefficient on the *GDP per capita* variable(lnY) indicates that with an increase in income emission increase, thus increasing the environmental degradation. The positive coefficient of urbanization variable indicates an increase in emission that is urbanization negatively impacting the environment.

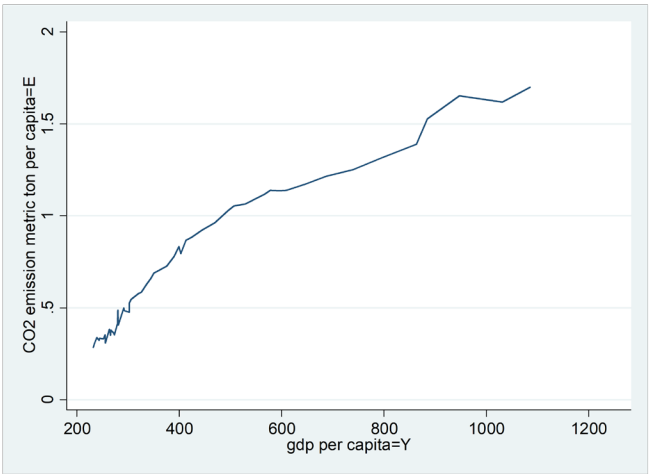


Figure 3: Environment Kuznets curve (India)

The Johansen Maximum Likelihood Procedure

The variables Et, Yt, Tt, Du are non-stationary at level, but after first difference variables become stationary. These all 4 variables are integrated of order one i.e., I(1) as suggested by the ADF test.

Step 1 The result of test can be quite sensitive to the lag length. The most common procedure is to estimate a vector autoregression. Then use the same lag length test as in traditional VAR.

Both the Trace test and Max-eigenvalue test indicates no cointegration at the 0.05 level, which means at a 5% level of significance, the null hypothesis that many cointegration equations are 0 can be rejected. When the number of cointegrating equations are zero then unrestricted VAR is used rather than a vector error correction model.

The results of estimate equation 2

lnE	*Coefficients*	*t value*
lnY	.7682724	7.65
lnU	1.971352	13.65
T	-.0955	-4.23
Constant	-11.08425	-37.63

Number of observations = 51 Adj R-squared = 0.9916
F(3, 47)= 1970.44

Note *indicate significant at 1% level of significance

Table

OPTIMAL LAG TEST	
AIC	3
LR	3
FPE	3
HQC	1
SC	1

Note: AIC = Akaike information criterion, SC = Schwarz information criterion, HQC = Hannan-Quinn information criterion, LR = sequential modified LR test statistic
Out of five selection criteria three indicate lag of 3, so 3 lag is used in the Johansen test of cointegration. Result of the test given in the table below.

Johansen Test of Cointegration Series: E, Y, T, DU

Hypothesized No of Cointegration equations	*None*	*At most 1*
Trace Statistic	43.31234(0.1251*)	22.26832(0.2839*)
Max-eigenvalue statistic	21.04402(0.2736*)	13.78736(0.3828*)

Note: (*) is the MacKinnon-Haug-Michelis (1999) p-values.
Lags interval (in first differences): 1 to 3

Estimated Vector Auto-regression(3) Model

In equation three, the joint significance of the coefficients of the lagged variable of GDP per capita is checked. At 10% level of significance null hypothesis is rejected, implying that jointly all the three coefficients of lagged gdp per capita variable influence emission that is there is short-run causality running from GDP per capita to emission. Similarly, in equation four, the joint significance of the coefficients of the lagged variable of trade openness is checked. It is observed that jointly all the three coefficients are significant; that is, there is short-run causality running from trade openness to the GDP per capita. From equation three, GDP per capita causes emission, and from equation 4 trade openness causes GDP per capita, so trade openness impacts emission through a channel called GDP per capita.

Coefficients that are significant in the equation 3,4,5,6 are

Coefficients	*t-statistic*	*p value*
β11	6.484664	0.0000
γ13	-2.455318	0.0153
α11	2.167884	0.0319
γ21	5.387959	0.0000
γ22	-1.658382	0.0995
γ23	2.405869	0.0174
α21	2.443487	0.0158
β31	-2.59734	0.0104
γ31	2.888686	0.0045
α31	3.387948	0.0009
C3	-2.133580	0.0346
α33	-1.934903	0.0550
μ31	6.814993	0.0000
μ32	-1.798656	0.0742

Test of joint significance using Wald test

Null hypothesis	*Chi-square value*	*Probability*
$\gamma_{11} = \gamma_{12} = \gamma_{13} = 0$	7.816524	0.0500
$\alpha_{21} = \alpha 22 = \alpha_{23} = 0$	7.448899	0.0589

Variance decomposition of E

Period	*Y*	*T*	*DU*
1	0.000000	0.000000	0.000000
2	0.657544	5.147560	0.020899
3	10.72532	6.668217	0.263291
4	10.39965	13.97582	0.278280
5	9.863561	17.54154	0.292827
6	69.43608	18.79259	0.858770
7	11.43747	18.29075	1.858416
8	11.85234	17.36955	17.36955
9	14.08795	15.78642	3.766949
10	16.58356	14.25776	4.486114

Variance decomposition

Variance decomposition separates the variation in an endogenous variable into the component shocks to the VAR. Thus, the variance decomposition provides information about the relative importance of each random innovation in affecting the variables in the VAR.

In short-run that is period 3, impulse or innovation or shock to Y can cause 10.73% fluctuation in E, a shock to T can cause 6.66% fluctuation in E and shock to DU can cause 0.26% fluctuation in E

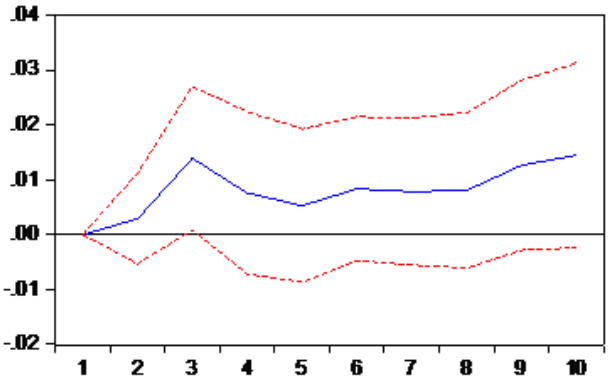
In the long run that is period 10, shock to Y can contribute 16.58% fluctuation in the variance of E, shock to T can cause 14.25% fluctuation in the variance of E, shock(impulse) to DU can cause 4.5% fluctuation in the variance of E .

In the short run to long run contribution of Y, T, DU to the fluctuation in the variance of E is increasing.

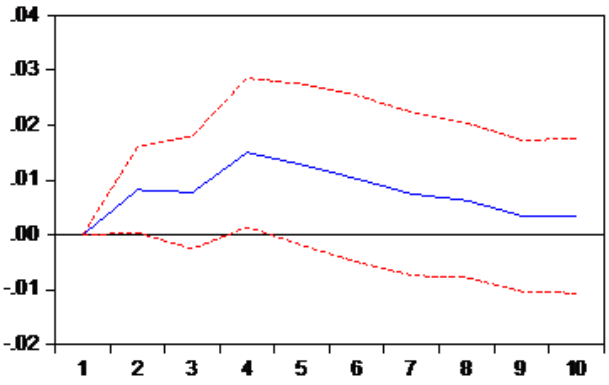
Impulse Response Function (IRF)

The impulse response function is a shock to the VAR model. An IRF measures the effect of a shock to an endogenous variable on itself or on another

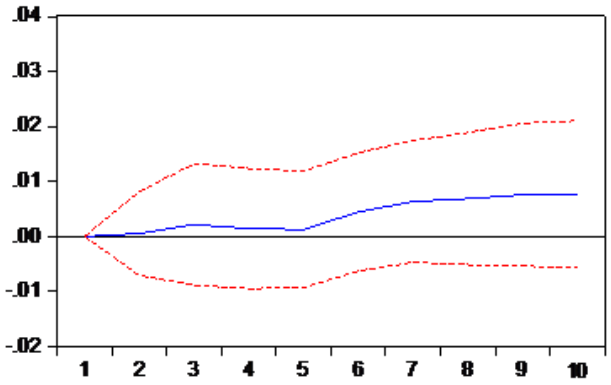
Response to Cholesky One S.D. Innovations ± 2 S.E.



Response of E to Y



Response of E to T



Response of E to DU

Residual diagnostic test

	Equation 3	*Equation 4*
Heteroskedasticity Test: Breusch-Pagan		
-Godfrey Prob. Chi-Square	0.7444	0.8178
Breusch-Godfrey Serial Correlation		
LM Test: Prob. Chi-Square	0.8616	0.1795
Jarque –Bera test probability	0.55864	0.604512
Required	0.997327	0.998281

Note: Since all the probability value more than 5%, so the null hypothesis of homoscedasticity can be rejected, no autocorrelation and errors are normally distributed in eq 3 and 4. Also regression equation 3 and 4 have high R square value

endogenous variable. In the graph below, it is observed how the emission responds shown by the blue line to the innovation/shock given to variables such as income, trade openness, and urbanization. The reaction of emission to urbanization and income is increasing, whereas a reaction to trade openness variable increases and then decreases with an increase in the period from 1 to 10. Thus if income and urbanization go up, emission will be reacting positively. When there is a shock in trade openness, the emission is some time increases, some time decreases.

Conclusion

The aim of this study was two-fold; the first aim was to test for the inverted U shaped relationship between the income and the pollution. Results show the absence of an inverted U shaped relationship using U test. A secondary aim was to determine the relation between CO_2emission, economic growth, trade openness, urbanization, and India for the period 1961-2017. With this aim, the effects of each one of these four factors on the others were studied systematically using the VAR model. Result showed that shock to income can contribute 16.58% fluctuation in the variance of emission, shock to trade openness can cause 14.25% fluctuation in the variance of emission, shock(impulse) to DU can cause 4.5% fluctuation in the variance of E. Impulse response function shows that in future period shock in income and urbanization result in increase in emission and shock in trade openness causes increase in emission for some period and decreases for some period.

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