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DECOUPLING CO_2 EMISSION PER CAPITA IN INDIA WITH GDP PER CAPITA AND OTHER DETERMINANTS

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ABSTRACT

Decoupling CO_2 emission per capita from GDP per capita is an essential property in indicating Environmental Kuznets Curve hypothesis which is empirically verified in Indian economy during 1970-2016 and in addition to that this phenomenon is also satisfied if population density, energy use, electricity consumption, foreign direct investment inflows and degree of openness are assumed to be other determinants of per capita CO_2 emission in which N shaped EKC hypothesis was verified in both cases. To examine it, the paper used semi-log and double log regression analysis, Bai-Perron Model for structural breaks, Johansen co-integration test and vector error correction model including Wald test for short run causality. The paper concludes that India's per capita CO_2 emission has been increasing at the rate of 3.49% per year during 1970-2016 significantly with four upward structural breaks. There are six co-integrating equations among those variables so that long run association exists among them. Long run causalities were found from GDP per capita, electricity consumption, FDI inflows and trade openness to the CO_2 emission per capita. There are short run causalities running from population density, energy use, electricity consumption respectively to the CO_2 emission per capita. There is bidirectional short run causality between FDI and population density. But short run causality was found from energy use to trade openness. The vector error correction model is unstable, non-stationary and non-normal.

Keywords: CO_2 Emission per Capita, GDP per Capita, Energy Consumption, Foreign Direct Investment, Trade Openness, Environmental Kuznets Curve, Co-integration, Short Run Causality, Long Run Causality.

JEL Classification Code: C32, F18, F43, O13, Q53, Q56.

INTRODUCTION

The relationship between CO_2 emissions and economic growth has concentrated on two mainstreams: (i) an inverted U-shaped relationship between environmental pollutants and economic growth; and (ii) the relationship between energy consumption and economic growth. This inverted U-shaped relationship between GDP per capita and various indicators of pollution is referred to as the Environmental Kuznets Curve (EKC) which was introduced by Kuznets (1955) that

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can be applicable to many areas. The EKC hypothesis has verified numerous empirical studies.

The relationship between economic studies of the trade openness and CO_2 emissions has undoubtedly become a major concern for economists, policymakers and the general public. The relation may be positive or negative. In economic theory, the fact is that increasing trade enhances economic growth. Similarly, increasing growth adversely affects the environment by releasing emissions into the atmosphere. It is expected that the countries affected to implement more environment friendly production techniques to enhance the quality of the environment.

A number of studies have examined the environmental consequences of trade liberalization and economic growth in recent decades. According to the EKC concept, CO_2 emissions are expected to have a positive relationship with the level of income or trade liberalization before the EKC threshold and then a negative relationship beyond the threshold. Similarly, if there is a positive relationship between CO_2 emissions and free trade, then the country is not likely to have experienced its optimal level of trade liberalization.

The view that the foreign direct investment enhances CO_2 emissions is called Pollution Haven Hypothesis. The Pollution Haven Hypothesis can occur in three ways (Aliyu, 2005). Firstly, pollution industries arise through polluting industries to countries with more loose regulations than countries with strict environmental regulations. Secondly, developed countries throw away hazardous wastes related to industrial and nuclear energy production into developing countries. Thirdly, multinational corporations should obtain unlimited sources of renewable resources such as oil and petroleum products, lumber and other forest resources, etc., in developing countries. Foreign investments can cause positive or negative environmental impacts in host countries in the form of two conditions called pollution haven and pollution hale effects. If the environmental impact of foreign direct investments is positive, it is a pollution haven hypothesis. If it is negative, it becomes pollution hale effect.

The relationship between energy consumption and economic growth has important implications for energy policy and there are four types of causalities between them such as neutral, conservative, growth and feedback hypothesis. However, rapid economic growth is usually accompanied by increased energy consumption and may cause unexpected effects on energy resources and the environment. (Shiu & Lam, 2004; Mozumder & Marathe, 2007; Ozturk, 2010). Other authors such as Keppler and Mansanet-Bataller (2010), Narayan (2010) and Pao and Tsai (2010) stated that economic growth and energy consumption are accompanied with environmental degradation in both developed and developing countries. These studies have generated an inverted U-shaped curve. Toda-Yamamoto (1995) examined that the results of causality test imply that carbon emissions and FDI, energy consumption and CO_2 emissions have bidirectional causal relationships. On the other hand, there are unidirectional causal relationships running from economic growth and energy consumption to FDI and from economic growth to energy consumption.

The contribution of globalisation, particularly trade openness, towards greenhouse gas emissions have been an important issue within the context of human induced climate change. As individual countries vary according to income levels as well as the composition of traded commodities, which have different emission intensities, the relationship between trade openness and greenhouse gas emissions can be considered as an empirical question which depends on country specific variables. Baek et al. (2009) have examined the dynamic relationship among trade, income and environmental quality, i.e., emission of sulphur dioxide (SO_2) using co-integration analysis for a sample of developed and developing countries. The results suggest that trade and income growth increase environmental quality in developed countries and the reverse is evident in most developing countries.

According to economic theories, there is a positive relationship between trade liberalization and economic growth. Since trade openness could increase production and income, it affects the emissions. But, by virtue of trade theories there is no clear relationship between environmental quality and trade openness. The similar hypothesis of EKC is applicable to the conditions of trade openness and environmental effects, and also towards the experimentation for measuring scale effect of the open economic policies.

Lastly, economic studies concluded that income per capita and population growth are the main two factors increasing carbon emissions in OECD countries, whereas the decrease in energy intensity is the main factor reducing them. In the EKC hypothesis, these studies indicate that the elasticity of CO_2 emissions and energy use with respect to population are close to unity. A few of them considered population density as an additional explanatory variable. Emissions are typically decomposed into scale, composition and technique effects. Scale effects are measured with income and population variables, composition effects refer to changes in the input or output mix and technique effects are proxied by energy intensity (the effect of productivity on emissions) and global technical progress.

In those above perspectives, the paper seeks to explore EKC hypothesis with respect to GDP per capita to consider population density, energy use, electricity consumption, foreign direct investment inflows and trade openness as other explanatory variables of CO_2 emission per capita in India from 1970 to 2016.

LITERATURE REVIEW

Zhang and Liu (2017) examined 10 newly industrialised countries during 1971-2013 and found that the results support Environmental Kuznets Curve hypothesis where trade openness negatively affects the emissions and real GDP and energy positively affects the emissions. The vector error correction model indicates long run causality from energy to emission and from trade openness to energy. Ave, Edoja and Charfedding (2017) studied 31 developing countries from 1970 to 2013 in panel data and showed that economic growth has negative effect in CO_2 emission under low growth regime but it is positive in high growth regime. The validity of EKC is inverted U shaped. Energy consumption and population exert positive and significant effect on CO_2 emission. Ameyaw and Yao (2018) studied five West African countries during 2007-2014 in panel data. The research found that the causality revealed that there exists a unidirectional causality running from GDP to CO_2 emission and from labor force to CO_2 emission and no causality was found from CO_2 emission and gross fixed capital formation. Bidirectional Long Short-term Memory Algorithm Formulation process showed that the upward surge in African’s total CO_2 emissions is a threat to human and ecological safety if past and current intricate paths in data are transmitted into future.

Pazienza (2015) examined that FDI inflows in agriculture and fishing sector of 30 OECD countries from 1981 to 2005 affected emissions negatively in panel data analysis. Peng et al. (2016) studied province level panel data in China using cross sectional dependence and homogeneity and found that there was bidirectional causality between FDI and CO_2 emissions in Neimenggu and there was unidirectional causality from FDI to CO_2 emissions in Beijing, Henan, Guizhou and Shanxi during 1985-2012. Albiman, Suleiman and Baka (2015) used causality and non-causality test, impulse response functions and variance decomposition, ADF and P.P. unit root test in Tanzania during 1975-2013 to investigate environment pollution and per capita economic growth. Economic growth rate and energy consumption per capita both being unidirectional, cause environment pollution through CO_2 emission in Tanzania. Sulaiman and Abdul-Rahaman (2017) verified empirically in Malaysia during 1975-2015 using Autoregressive Distributed Lag approach, Vector Error Correction, variance decomposition and impulse response functions respectively where energy consumption is revealed to be an increasing function of CO_2 emission which increases with energy consumption and economic growth. Kais and Mbarek (2017) used panel unit root and co-integration, vector error correction and Granger causality test during 1980-2012 in three North African countries and found that there were unidirectional causalities running from economic growth to CO_2 emission and from energy consumption to CO_2 emission. A high level of economic growth leads to high level of energy consumption. Lean and Smyth (2010) showed in 5 ASEAN countries during 1980-2006 that there is positive association between electricity consumption and emissions and a nonlinear relationship between emissions and real output consistent with EKC. There is unidirectional causality from emissions to electricity consumption in the short run. Sohag et al. (2017) investigated the impacts of real income, trade, population increase and energy consumption on CO_2 emissions using data from 82 developing nations between 1980 and 2012 using various Mean Group (MG) approaches (cross-correlated and augmented). The results showed that a percentage increase in trade (holding all of the other explanatory variables constant) reduces CO_2 pollution by 0.3%. Meanwhile, the results were inconclusive for low-income, middle-income and full sample countries.

Sun et al. (2019) studied in 49 Belt and Road high emission countries from 1991 to 2014 in panel data using panel co-integration under three income panels: high, medium and low respectively. The paper found that trade openness had both positive and negative impacts on environmental pollution but varied on different groups of countries. VEC model showed that in the long run there are causal effects between trade, economic growth, energy consumption and environmental pollution in Belt and Road countries. EKC results indicated the existence of an inverted U-shaped relationship between trade openness and carbon emissions. Naranpanawa (2011) empirically verified in Sri Lanka during 1960-2006 through ARDL approach and Johansen-Juselius co-integration test and found that there is long run relation and there exists both short run and long run causalities between trade openness and carbon emissions. Choi, Heshmati and Cho (2010) studied in China, Korea, Japan from 1971-2006 in which China showed an N shaped while Japan had U shaped curve. In Korea, it is inverted U shaped. VEC model showed that in China openness is negatively related with emission and openness square is positively related with emission. GDP and GDP square are positively related with emission significantly. In Korea, openness is positively related with emission and openness square is negatively related with emission significantly. GDP affects negatively and GDP square affects negatively in emission significantly. In Japan GDP is negatively related with emission and GDP square positively affects emission significantly while openness has positive impact with emission and negative impact with openness square insignificantly during the specified period.

Stern and Common (2001) investigated the presence of an EKC for emissions of SO_2 using a panel of 73 countries from 1960 to 1990. The results of their analysis provide evidences of a global inverted-U shaped EKC. Random effects estimation produces consistent results and again reveals an inverted-U shaped EKC for OECD countries. Many empirical studies have verified the EKC hypothesis. Bhowmik (2019) examined in Nordic countries during 1970-2016 and found the validity of EKC hypothesis where relative and absolute decoupling from GDP per capita to the CO_2 emission per capita was observed. Hettige et al. (1992); Cropper and Griffiths (1994); Grossman and Krueger (1995); Martinez-Zarzoso and Bengochea-Morancho (2004); Apergis (2016) and Bae (2018) all support the EKC hypothesis.

Dietz & Rosa (1997) and York, Rosa and Dietz (2003) studied the impact of population on carbon dioxide emissions and energy use within the framework of the IPAT1 model. The results from these studies indicate that the elasticity of CO_2 emissions and energy use with respect to population are close to unity. In a panel data context, Shi (2003) found a direct relationship between population changes and carbon dioxide emissions in 93 countries over the period 1975-1996. A similar result was obtained by Cole and Neumayer (2004). These authors considered 86 countries during the period 1975-1998 and they found a positive link between CO_2 emissions and a set of explanatory variables including population, urbanization rate, energy intensity and smaller household sizes.

OBJECTIVES OF THE PAPER

The paper endeavors to search out the absolute and relative decoupling of CO_2 emissions per capita from GDP per capita of India during 1970-2016 along with other determinants like population density, energy use, electricity consumption, FDI inflows and degree of openness and tries to verify Environmental Kuznets Curve hypothesis. Even, the paper attempts to find out the long run association between those variables and short causalities among them by applying econometric models of co-integration and vector error correction model. The paper also examined to show the structural behavior of CO_2 emission per capita of India.

METHODOLOGY AND SOURCE OF DATA

Semi-log linear regression model is used to show trend value. Bai-Perron (2003) model is applied to find out the structural breaks of emission. Double log multi-variable regression model is used to examine the relation among the variables studied here. Johansen (1988) co-integration test is applied to indicate long run association and vector error correction model is utilised to find out short and long run causalities with the help of co-integrating equations. Wald test (1943) is done for acceptance or rejection of short run causality. Hansen-Doornik (1994) VEC normality test verified the multivariate normality. The data of CO_2 emission per capita in million ton, GDP per capita in US dollar at current prices, population density per square km of land, energy use in kg of oil equivalent per capita, electricity consumption in kwh per capita of India from 1970 to 2016 were collected from the World Bank. The data of foreign direct investment inflows in million dollar and trade openness of India from 1970 to 2016 were collected from UNCTAD (trade openness=sum of export and import of goods and services/2/GDP/2).

SOME OBSERVATIONS FROM THE ECONOMETRIC MODELS

India is the third largest CO_2 emitter in this world. In India CO_2 emission per capita has been increasing at the rate of 3.49% per year from 1970 to 2016 significantly.

Log(y)=-1.1397+0.03498t

(-76.30) * (66.36)*

R^2=0.989, F=4404.42*, DW=0.66, *=significant at 5% level, y=CO_2 emission per capita in India, t=period of time.

India's CO_2 emission per capita has four upward structural breaks in 1983, 1990, 1998 and 2008, respectively, which have been determined by Bai-Perron test through applying HAC standard errors and covariance (Bartlett Kernel, Newey-West fixed bandwidth=4.00). These structural breaks are plotted in the following Figure 1.

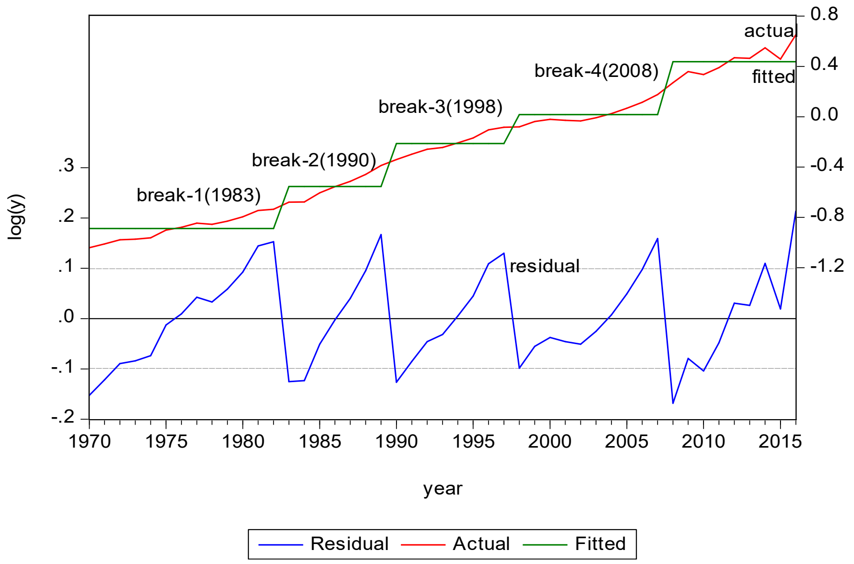

Figure 1. Structural breaks of CO_2 emission.

Source: Plotted by author

The high liberalised and speedy globalisation processes are quite helpful to decouple CO_2 emissions per capita in India where Environmental Kuznets Curve hypothesis is applicable.

Log(y)=28.307 - 16.889 log(x1) + 2.838 log(x1)^2 - 0.1524 log(x1)^3

(2.26) * (-2.58)* (2.65) * (-2.66) *

+ 2.332 log(x6) - 0.3782 log(x6)^2 + ui

(2.84) * (-2.51)*

R^2=0.954, F=171.20*, DW=0.39, AIC=-1.14, SIC=-1.17, *=significant at 5% level, x_1=GDP per capita in India, x_6=trade openness.

The estimated equation states that India's CO_2 emission per capita (y) is absolutely decoupled with x_1 and x_1^3 but not relatively decoupled with x_1^2 since $\delta\log(y)/\delta\log(x_1)<0$, $\delta\log(y)/\delta\log(x_1)^2>1$ and $\delta\log(y)/\delta\log(x_1)^3<0$. The decoupling is accelerated with higher trade openness since $\delta\log(y)/\delta\log(x_6)^2<0$ satisfying absolute decoupling condition. Thus GDP per capita with liberalisation both satisfied EKC hypothesis showing N shaped curve (Figure 2).

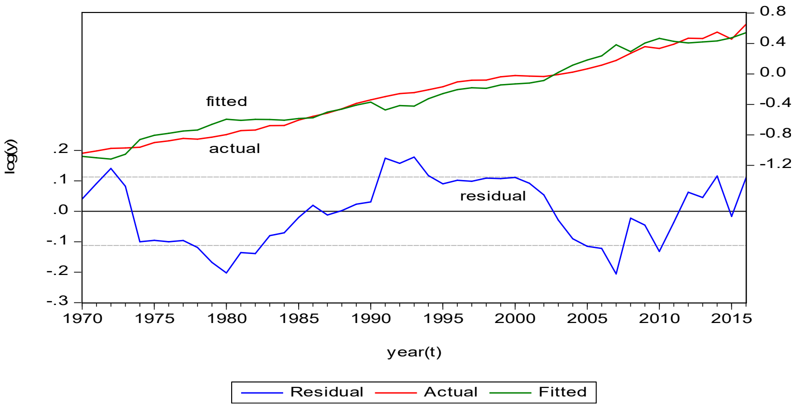

Figure 2. GDP per capita and trade openness.

Source: Plotted by author

$$\text{Log}(y)=-3.115 - 2.924 \log(x1) + 0.5559 \log(x1)^2 - 0.0347 \log(x1)^3 - 0.3953 \log(x2)$$
$$(-0.81)\ (-1.72)^* \quad (1.82)^* \quad (-1.93)^* \quad (-1.03)$$
$$+ 1.3115 \log(x3) + 0.4085 \log(x4) - 0.00055 \log(x5) + 0.0342 \log(x6)$$
$$(4.15)^* \quad (3.85)^* \quad (-0.18) \quad (1.04)$$

R^2=0.997, F=1952.15*, DW=2.44, AIC=-4.22, SIC=-3.86, *=significant at least 10% level, x_1=GDP per capita in current US Dollar, x_2=population density per square km of land, x_3=energy use in kg of oil equivalent per capita, x_4=electricity consumption kwh per capita, x_5=Foreign direct investment inflows in million dollar, x_6=trade openness (average value of total trade of goods and services by average of GDP), y=CO_2 emission per capita in million ton.

If population density, energy consumption, foreign direct investment inflows and trade openness are included with GDP per capita as the chief determinants of CO_2 emission per capita in India during 1970-2016,then the above estimated equation exemplified that EKC hypothesis is accepted for decoupling CO_2 emission per capita where energy consumption (x_3 and x_4) are positively revealed with emission significantly but negatively related with population density and FDI inflows insignificantly and also positively related with trade openness insignificantly. GDP per capita and cube of GDP per capita have been decoupling CO_2 emission per capita absolutely ($\delta\log(y)/\delta\log(x_1)<0$ and $\delta\log(y)/\delta\log(x_1)^3<0$) and square of GDP per capita has been decoupling relatively with CO_2 emission per capita ($\delta\log(y)/\delta\log(x_1)^2>0<1$) in India significantly with 10% level. In the following Figure 3, it is visible that EKC is partially N shaped during the period of study.

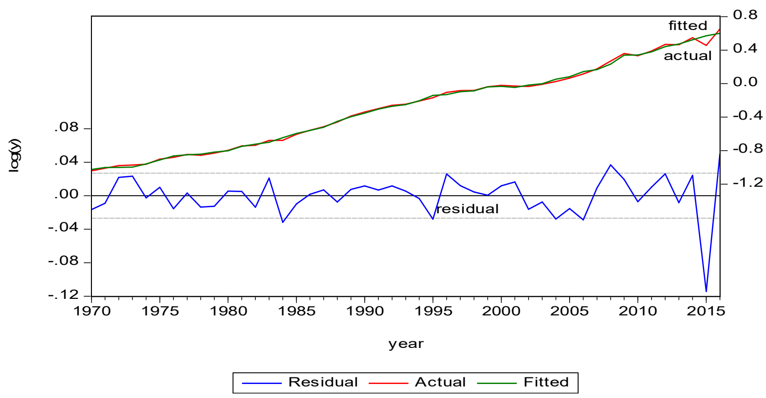

Figure 3. N shaped EKC.

Source: Plotted by author

Johansen unrestricted co-integration rank test with linear deterministic trend of first difference series of the CO_2 emission per capita, GDP per capita, GDP per capita square, GDP per capita cube, population density, energy use, electricity consumption, foreign direct investment inflows and trade openness of India from 1970 to 2016 indicates that Trace statistic contains seven co-integrating equations and Max-Eigen statistic contains six co-integration equations which mean that all the variables have long run association significantly. The values are shown in the Table 1.

Table 1. Cointegration test.

Hypothesized no. of CE(s)	**Eigen value**	Trace **Statistic**	0.05 **Critical Value**	**Probability****
None *	0.941434	400.1752	197.3709	0.0000
At most 1 *	0.765428	272.4832	159.5297	0.0000
At most 2 *	0.725885	207.2335	125.6154	0.0000
At most 3 *	0.693594	148.9942	95.75366	0.0000
At most 4 *	0.540602	95.76629	69.81889	0.0001
At most 5 *	0.490963	60.76357	47.85613	0.0020
At most 6 *	0.281937	30.37801	29.79707	0.0428
At most 7	0.210633	15.47407	15.49471	0.0504
At most 8 *	0.101783	4.830474	3.841466	0.0280
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Probability****
None *	0.941434	127.6919	58.43354	0.0000
At most 1 *	0.765428	65.24972	52.36261	0.0015
At most 2 *	0.725885	58.23926	46.23142	0.0017
At most 3 *	0.693594	53.22796	40.07757	0.0010
At most 4 *	0.540602	35.00271	33.87687	0.0366
At most 5 *	0.490963	30.38556	27.58434	0.0213
At most 6	0.281937	14.90394	21.13162	0.2957
At most 7	0.210633	10.64360	14.26460	0.1730
At most 8 *	0.101783	4.830474	3.841466	0.0280

** denotes rejection of the hypothesis at the 0.05 level, **MacKinnon-Haug-Michelis (1999) p-values*
Source: Calculated by author

The estimated VEC model states that the positive change in population density, electricity consumption, and foreign direct investment inflows induced the negative changes in the CO_2 emission per capita during 1970-2016 significantly but the positive change in energy use indicated a positive change in CO_2 emission per capita along with a relative decoupling process. The incremental change in FDI is positively related with increment in population density due to absolute decoupling and relative decoupling has been associated with the foreign direct investment inflows. Incremental change in energy use has positive influence on increment in trade openness but incremental change in CO_2 emission per capita has negative relation with the increment in trade openness significantly during the specified period. The t values of coefficients of six error corrections and all other coefficients of the variables of the VEC model are given in the Table 2 shown below.

Table 2. The estimated VECM.

Error Correction	dlogy	$dlogx_1$	$dlogx_1^2$	$dlogx_1^3$	$dlogx_2$	$dlogx_3$	$dlogx_4$	$dlogx_5$	$dlogx_6$
CointEq1	-1.007	0.876	7.557	44.353	-0.0004	-0.2706	-0.1360	9.907	1.711
t values	-3.17*	0.65	0.45	10.28*	-0.59	-1.12	-0.30	0.56	1.22
cointEq2	-5.94	-6.975	-126.56	-1591.38	0.0098	-1.896	-0.2167	-124.93	7.620
t value	-1.7	-0.49	-0.71	-0.94	1.16	-0.74	-0.045	-0.67	0.51
cointEq3	0.875	0.872	18.206	244.055	-0.0012	0.2601	-0.0376	11.623	-2.193
t value	1.41	0.33	0.56	0.79	-0.79	0.55	-0.042	0.34	-0.80
cointEq4	-0.039	-0.035	-0.883	-12.694	4.46E-05	-0.0104	0.0070	-0.1587	0.1745
t value	-1.05	-0.22	-0.45	-0.68	0.47	-0.37	0.13	-0.07	1.06
cointEq5	-0.245	2.741	29.827	238.018	-0.0031	0.0122	0.2623	94.69	4.299
t value	-0.41	1.10	0.96	0.80	-2.41*	0.02	0.31	2.89*	1.64
cointEq6	-2.618	-1.900	-15.194	-65.005	0.00207	-1.0700	-1.028	-51.531	-10.76
t value	-2.78*	-0.48	0.30	-0.13	0.88	-1.50	-0.77	-0.99	-2.60*
dlogy(-1)	-0.882	-0.931	-9.364	70.853	0.0010	0.099	0.0430	6.107	-2.565
t values	-3.56*	-0.84	-0.68	-0.54	1.52	0.49	0.11	0.42	-2.21*
dlogy(-2)	-0.570	-0.950	-11.109	-98.553	0.0008	-0.1926	-0.1036	-5.866	-1.275
t values	-2.41*	-0.96	-0.89	-0.83	1.42	-1.071	-0.30	-0.45	-1.22
$dlogx_1(-1)$	-3.068	21.848	296.789	2996.64	-0.0128	1.3531	-0.810	101.126	-17.324
t values	-0.56	0.91	0.99	1.057	-0.90	0.31	-0.10	0.32	-0.69
$dlogx_1(-2)$	7.775	-21.331	-220.576	-1719.68	-0.0063	-0.0259	4.640	644.57	-17.894
t values	1.16	-1.05	-0.87	-0.71	-0.53	-0.007	0.67	2.43*	-0.84
$dlogx_1^2(-1)$	0.563	-2.989	-41.349	-422.831	0.0021	-0.1747	0.1512	-9.262	2.732
t values	0.59	-0.75	-0.83	-0.90	0.91	-0.24	0.11	-0.17	0.65
$dlogx_1^2(-2)$	-1.274	3.663	38.359	303.368	0.00097	0.0121	-0.7319	-98.297	3.227

t values	-1.62*	1.11	0.93	0.77	0.49	0.02	-0.65	-2.27*	0.93
dlogx$_1^3$(-1)	-0.037	0.128	1.825	19.021	0.00011	0.0057	-0.0093	0.116	-0.1413
t values	-0.71	0.59	0.67	0.74	0.89	0.14	-0.12	0.04	-0.62
dlogx$_1^3$(-2)	0.068	-0.205	-2.181	-17.501	-4.91E-05	-0.0015	0.037	4.952	-0.1921
t values	1.61*	-1.16	-0.98	-0.83	-0.46	-0.04	0.62	2.12*	-1.03
dlogx$_2$(-1)	-119.57	100.937	1347.678	13748.9	1.5991	-39.114	-30.451	5360.3	-360.99
t value	-2.28*	0.46	0.49	0.52	12.22*	-0.98	-0.40	1.85*	-1.56
dlogx$_2$(-2)	89.117	-125.01	-1544.91	-14659.2	-0.737	22.933	29.80	-4386.4	334.572
t values	2.20*	-0.73	-0.72	-0.72	-7.29*	0.74	0.51	-1.96*	1.87*
dlogx$_3$(-1)	2.616	2.434	26.354	213.198	-0.0030	0.629	0.6853	36.653	8.490
t value	2.95*	0.65	0.56	0.48	-1.36	0.93	0.54	0.72	2.17*
dlogx$_3$(-2)	1.747	3.242	40.665	387.67	-0.00025	0.6508	0.8016	57.384	1.118
t value	3.28*	1.45	1.45	1.46	-0.18	1.61*	1.05	1.95*	0.47
dlogx$_4$(-1)	-1.053	2.861	36.815	359.69	0.00088	-0.1675	-0.1375	7.614	-3.048
t value	-2.51*	1.63*	1.67*	1.72*	0.84	-0.52	-0.23	0.32	-1.65*
dlogx$_4$(-2)	-0.434	0.964	10.360	80.462	-0.00011	-0.3209	-0.5994	-17.147	-1.526
t value	-1.54	0.84	0.71	0.58	-0.17	-1.52	-1.51	-1.11	-1.24
dlogx$_5$(-1)	-0.0136	0.025	0.315	2.975	3.13E-05	-0.0036	-0.0061	0.4718	-0.0186
t value	-2.92*	1.32	1.29	1.27	2.67*	-1.02	-0.92	1.82*	-0.90
dlogx$_5$(-2)	-0.0056	0.025	0.325	3.147	2.06E-05	-0.0018	0.0023	0.3638	-0.0256
t value	-1.67*	1.82*	1.84*	1.87/	2.44*	-0.72	0.49	1.95*	-1.71*
dlogx$_6$(-1)	-0.027	-0.433	-5.257	-48.484	-8.30E-05	-0.0394	0.0938	0.3637	0.2676
t value	-0.51	-1.89*	-1.83*	-1.78*	-0.60	-0.95	1.20	0.12	1.11
dlogx$_6$(-2)	0.0298	-0.266	-3.259	-30.226	-0.00018	-0.0039	0.0691	-0.653	0.3200
t value	0.56	-1.20	-1.18	-1.15	-1.36	-0.98	0.92	-0.22	1.37
c	0.655	0.330	2.164	2.430	0.0024	0.3385	0.0628	-19.215	0.6093
t value	1.96*	0.23	0.12	0.01	2.99*	1.33	0.13	-1.04	0.41

R-squared	0.932	0.664	0.656	0.601	0.999	0.734	0.634	0.895	0.747
F-statistic	10.90	1.56	1.51	1.54	17492	2.18	1.37	6.85	2.33
AIC	-5.09	-2.22	2.82	7.33	-17.07	-5.64	-4.38	2.93	-2.12
SC	-4.07	-1.21	3.83	8.34	-16.06	-4.62	-3.37	3.94	-1.10

*Source: Calculated by Author; *=significant at 10% level*

In the system equations of the VECM, the Wald test proved that there are short run causalities running from population density, energy use, electricity consumption and foreign direct investment inflows to the CO_2 emission per capita in India. In addition to that there are short run causalities from foreign direct investment inflows to population density, from GDP per capita to foreign direct investment inflows and from energy use to trade openness respectively. Null hypothesis H0 and all the Chi-square values of the coefficients with their probabilities of the Wald test have been incorporated in the Table 3.

Table 3. Short run causality.

H0=No causality	Chi-square(2)	Probability	Accepted/rejected	Causality-yes/no
Causalities from dlogx_2(-1), dlogx_2(-2) to dlog(y)	5.215	0.07	Rejected at 10%	yes
Causalities from dlogx_3(-1), dlogx_3(-2) to dlog(y)	11.482	0.003	rejected	yes
Causalities from dlogx_4(-1), dlogx_4(-2) to dlog(y)	6.358	0.04	rejected	yes
Causalities from dlogx_5(-1), dlogx_5(-2) to dlog(y)	10.074	0.006	rejected	yes
Causalities from dlogx_5(-1), dlogx_5(-2) to dlog(x_2)	7.375	0.025	rejected	yes
Causalities from dlogx_1(-1), dlogx_1(-2) to dlog(x_5)	6.530	0.030	rejected	yes
Causalities from dlogx_3(-1), dlogx_3(-2) to dlog(x_6)	7.271	0.026	rejected	yes

Source: Calculated by Author

With the help of the estimated system equations, the paper found six significant co-integrating equations which are shown in the Table 4 from which it is clear that the equation 1 has been converging significantly towards the equilibrium since all the t values of the coefficients are significant and $c(1)<0$ and is significant which indicates that apart from the decoupling there are long run causalities running from electricity consumption, foreign direct investment inflows and trade openness to the per capita CO_2 emission in India during 1970-2016. Moreover, the equations 5 and 6 have been approaching to the equilibrium but they are not significant and other equations are divergent.

Table 4. Co-integrating equations.

	$Logy_{t-1}$	$Logx_{4t-1}$	$Logx_{5t-1}$	$Logx_{6t-1}$	Constant
1]Z_{1t-1}	-1.007	-0.277	-0.132	-0.238	3.382
t value	-3.17*	-3.11*	10.82*	2.70*	
2]Z_{2t-1}	0.877	2.699	-0.869	-1.72	-10.792
t value	0.66	4.12*	-9.66*	2.65*	
3]Z_{3t-1}	7.599	26.613	-7.685	-17.80	-87.373
t value	0.45	4.37*	-9.19*	-2.95*	
4]Z_{4t-1}	44.380	186.799	-43.944	-135.006	-619.58
t value	0.28	4.63*	-7.92*	-3.37*	
5]Z_{5t-1}	-0.00047	0.348	-0.212	-0.267	-5.563
t value	-0.59	2.29*	-10.19*	-1.77	
6]Z_{6t-1}	-0.2706	-0.439	0.129	0.101	-4.576
t value	-1.12	-4.52*	9.69*	1.05	

*Source: Calculated by Author; *=significant at 5% level*

In the Figure 4, the co-integrating relationships have been depicted neatly where part 3 of the figure has reached to the equilibrium and the part 2 and 5 have been marching towards equilibrium and others are diverging. Therefore, the equilibrating co-integrating equation implies that there are long run causalities running from GDP per capita, electricity consumption, foreign direct investment inflows and trade openness to the per capita CO_2 emission in India during 1970-2016, respectively. In the long run all the variables are associated which are very clear in the figures.

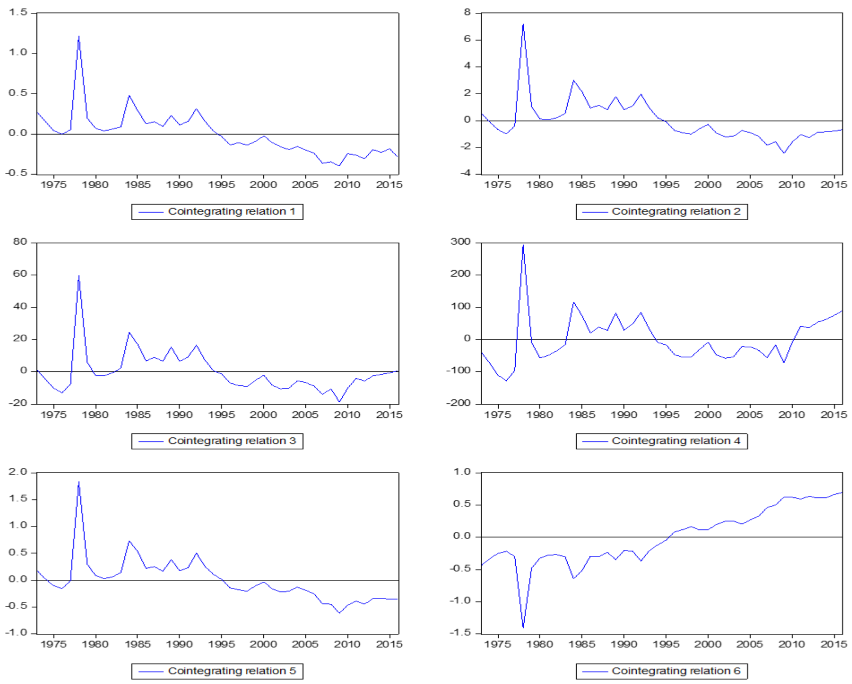

Figure 4. Co-integrating relation.

Source: Plotted by author

Cholesky response of one standard deviation innovations of cube of GDP per capita to per capita CO_2 emission, foreign direct investment inflows and from FDI to energy use and trade openness have been approaching towards equilibrium which are clearly reflected by the Impulse Response Functions. Even the response from GDP per capita to FDI also moves to equilibrium. Thus, IRF of the VECM are of good fit indeed.

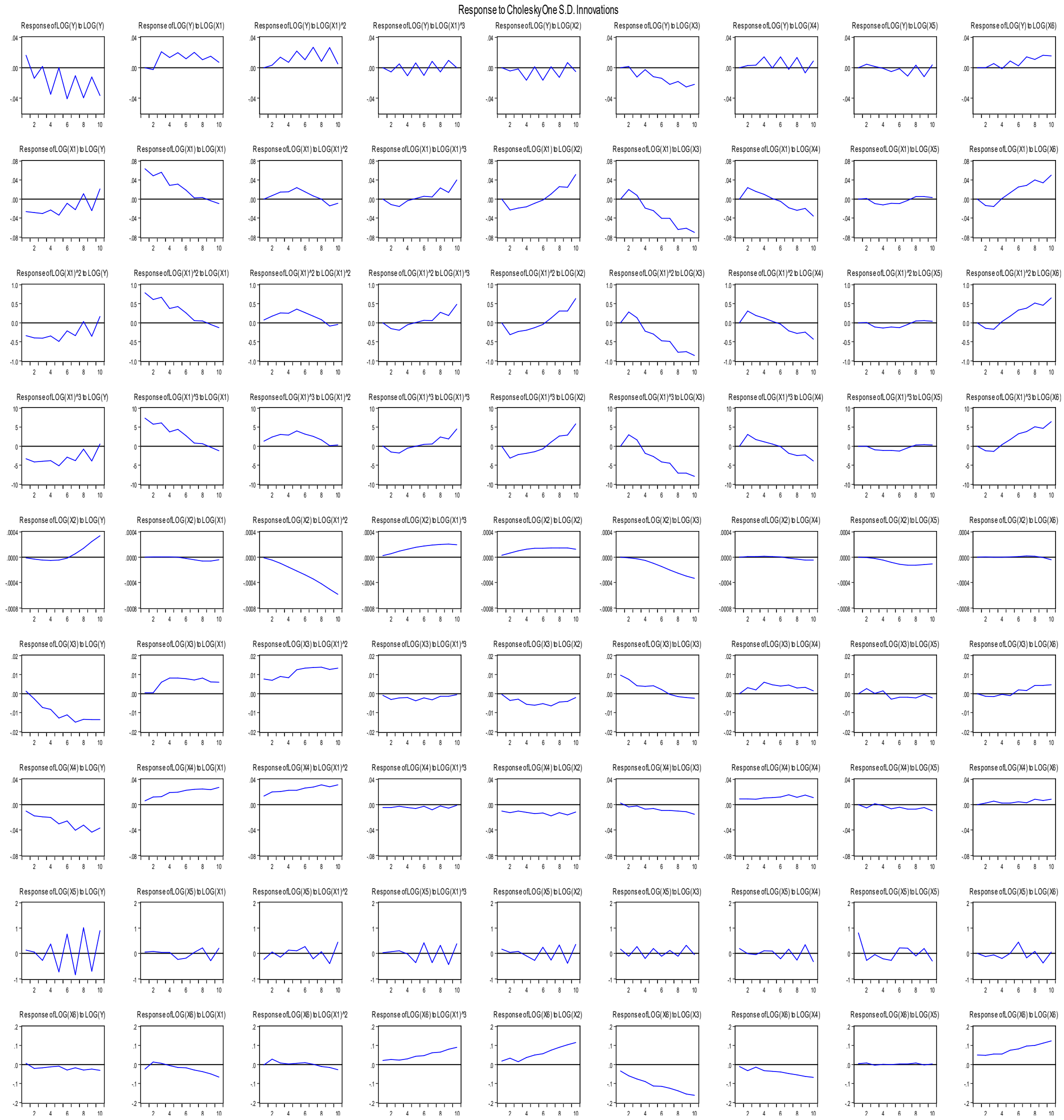

Figure 5. Impulse response functions.

Source: Plotted by author

But there are autocorrelation problems among the variables which have been observed in the multiple regression models in the VECM estimated equations which have been proved by the correlogram of the VECM where vertical lines in both the axes are the signs of autocorrelations and partial auto-correlations, respectively (Figure 6).

Figure 6. Auto-correlation problem.

Source: Plotted by author

VEC residual normality test of Hansen-Doornik (1994)model assuming H0=residuals are multivariate normal during 1970-2016 confirmed that the Chi-square values of skewness in component 4 and in component 3 of Kurtosis and Jarque-Bera are rejected and even joint component in Kurtosis is also rejected. Therefore, the residuals are not normally distributed which are tabulated in the Table 5.

Table 5. Normality test.

Components	Skewness	Chi-square	Degree of freedom	Probability
1	-0.520900	2.335422	1	0.1265
2	-0.328413	0.972274	1	0.3241
3	0.265055	0.640526	1	0.4235
4	0.728899	4.283459	1	0.0385
5	0.101067	0.094885	1	0.7581
6	-0.158269	0.231596	1	0.6303
7	0.191398	0.337476	1	0.5613
8	-0.240129	0.527751	1	0.4676

9	0.124699	0.144201	1	0.7041
Joint		9.567591	9	0.3866
Component	**Kurtosis**	**Chi-square**	**Degree of freedom**	**Probability**
1	3.905272	1.822452	1	0.1770
2	3.535378	1.735472	1	0.1877
3	4.197974	5.763229	1	0.0164
4	4.305439	1.264417	1	0.2608
5	2.732453	0.065961	1	0.7973
6	3.779459	3.845736	1	0.0499
7	2.725702	0.019367	1	0.8893
8	3.628008	2.655636	1	0.1032
9	2.804926	0.142515	1	0.7058
Joint		17.31478	9	0.0440
Component	**Jarque-Bera**	**Degree of freedom**	**Probability**	
1	4.157873	2	0.1251	
2	2.707745	2	0.2582	
3	6.403756	2	0.0407	
4	5.547876	2	0.0624	
5	0.160846	2	0.9227	
6	4.077332	2	0.1302	
7	0.356843	2	0.8366	
8	3.183387	2	0.2036	
9	0.286716	2	0.8664	
Joint	26.88237	18	0.0812	

Source: Calculated by author

The two roots of the characteristic polynomial of the variables are greater than one, three roots are unit, three roots are negative, two roots are positive but less than one and 18 roots are imaginary. That's why VECM is unstable and non-stationary (Table 6).

Table 6. Value of roots.

Roots	Modulus
-1.060696	1.060696
1.026425	1.026425
0.983833 - 0.191045i	1.002210
0.983833 + 0.191045i	1.002210
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
-0.869392 + 0.366233i	0.943382
-0.869392 - 0.366233i	0.943382
0.764599 + 0.502976i	0.915203
0.764599 - 0.502976i	0.915203
0.897955	0.897955
0.487846 - 0.654408i	0.816237
0.487846 + 0.654408i	0.816237
-0.133869 - 0.793670i	0.804880
-0.133869 + 0.793670i	0.804880
0.337368 - 0.719646i	0.794800
0.337368 + 0.719646i	0.794800
0.097712 - 0.778804i	0.784909
0.097712 + 0.778804i	0.784909
-0.313103 - 0.707178i	0.773392
-0.313103 + 0.707178i	0.773392
-0.771873	0.771873
-0.520351 - 0.523278i	0.737960
-0.520351 + 0.523278i	0.737960
0.488386	0.488386
-0.133908	0.133908

Source: Calculated by author

All the roots have been plotted in the unit circle where two roots lie outside the unit circle and all other roots are inside or on the circle which indicate that the model is unstable. It is seen in the Figure 7.

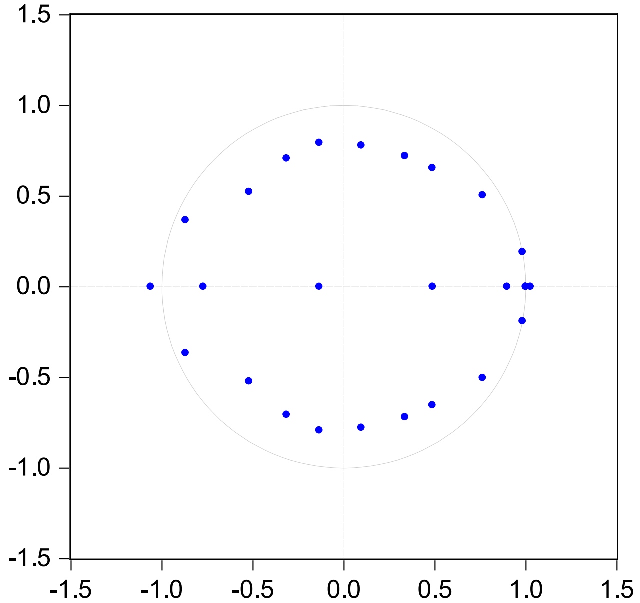

Figure 7. Inverse roots of AR characteristic polynomial.

Source: Plotted by author

POLICY RECOMMENDATION

India's high emission rate enhances warming in which policy of renewable energy production is urgent where India's National Action Plan for climate policy showed eight objectives and India's sustainable development goals relating to goal 13 of UNO SDG have been emphasized for quick implementation. Moreover, Task Force of NITI Aayog has been adopted all policy issues relating to SDG and climate change. Other important policies relating to carbon tax, green investment for renewable energy, protection for environmental goods, negotiations for WTO laws, long term policy for energy use and trades and preservation and protection of forests and forests products are necessary. Waste management, disaster management, rehabilitation of climate refugees, early warning system of weather are the simultaneous important policy decisions that a good government can take. Assessment and monitoring are the significant aspects of the plans which can make long run goals success. A separate climate fund for India to cope up with adverse impact of climate change should be set up.

CONCLUDING REMARKS

The paper concludes that per capita CO_2 emission of India during 1970-2016 has been catapulting at the rate of 3.49% per year significantly. It has significant four upward structural breaks in 1983, 1990, 1998 and 2008.India's CO_2 emission per capita has been decoupled absolutely and relatively with GDP per capita showing N shaped EKC along with high degree of openness. Same conclusion can be drawn when population density, energy use, electricity consumption, FDI inflows and trade openness are being considered as other determinants of CO_2 emission where pollution hale hypothesis with FDI was observed. Trade openness showed significant positive relation but population density indicated insignificant negative effect. Johansen test confirmed at least six co-integrating equations showing long run associations among the variables. Long run causalities were found from GDP per capita, electricity consumption, FDI inflows and trade openness to the CO_2 emission per capita. There are short run causalities running from population density, energy use, electricity consumption to the CO_2 emission per capita. There is bidirectional short run causality between FDI and population density. But short run causality was found from energy use to trade openness. The vector error correction model is unstable, non-stationary and non-normal.

Irrespective of that, there are shortcomings too. The model suffers from autocorrelation problems and that's why insignificant relation with FDI and trade openness has been found. Even there are volatilities of trade openness, GDP per capita and FDI so that perfect N shaped EKC is not visible. If other data of GHG emissions are included in the model then it might obtain more clear shape of EKC so that the flawless policy prescriptions can be formulated.

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