Causal Analysis of India's Energy-led Growth and CO2 Emission (1960-2010)

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ABSTRACT

For any developing nation, GDP growth and CO_2 emission goes hand-in-hand. GDP growth affects the CO_2 emission level and vice versa. EKC hypothesis ensures the interaction between income level and environmental degradation. Based on this foundation, bi-directional causal relationship between these two factors for India has been obtained in this paper. For empirical analysis, data for GDP growth of and CO_2 emission over the period 1960-2010 has been considered. Vector Error Correction model using lag-augmented VAR model has been employed for the analysis. The result obtained is new in the considering the existing body of literature.

JEL classification: Q50; Q53; Q56

Keywords: CO_2 emission; Economic growth; Environmental Kuznets curve, India; Vector error correction

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INTRODUCTION

Indian growth history has been fairly a grown up subject matter of interest for researchers across the world. Since 1960, India is experiencing an elevated decadal average growth rate. Beginning with a decadal average of 4.03% in 1961-70 and 3.08% in 1971-80, the gross domestic product (GDP) has ascended to 5.57% in 1980-2000 and 7.47% in 2001-10. Enabler of this significant growth is the energy consumption, which was evident in the form of electrical power consumption [Ghosh 2002]. During 1960-2010, energy consumption of India has gone up to more than five times. It can be said that this intensification in electrical power consumption has heightened the economic growth. Indian economic growth and energy consumption follow a causal relationship, which says that energy consumption is the reason behind economic growth of India [Cheng 1999]. This established causal relation can be considered as the foundation of our discussion.

However, certainly there is shadow beneath the lamp. Elevated electrical power consumption has also heightened the level of emission in the environment. Majority of the power utilized in economic development is power generated from fossil fuels. During 1960-2010, amount of fossil fuel consumption as a fraction of total power consumption has almost doubled. This has resulted in huge level of Carbon Dioxide (CO_2) emission in the atmosphere. During 1960-2010, CO_2 emission has gone up from 120,581.96 kilo tons in 1960 to 1,979,424.60 kilo tons in 2010, i.e. nearly an increase of 16.41 times. Consequently, the amplified utilization of fossil fuel, which is facilitating the economic growth of India, is as well worsening the atmosphere. Nevertheless, this phenomenon is quite understandable for the case of India, as for a developing nation, attracting more investment and employment of the same is endowed with more importance than the environmental protection [Acharyya 2009]. This underestimation of environmental damage can in turn bring harm to the economic growth.

This argument can be put forward in terms of Environment Kuznets Curve (EKC) hypothesis. In accordance with this hypothesis, inverted U-curve association subsists between environmental degradation and economic growth for developing nations [Panayotou 1993]. Interaction between economic growth and environmental degradation leads to reduction of the latter one after certain level of the former one. Divergence among researchers exists on the subject of the turnaround point of the EKC [Dinda 2004]. In spite of this, EKC hypothesis confirms one thing that a causal association exists between economic growth and environmental degradation. This causal relation can be unidirectional or bidirectional in nature. Based on this foundation, it can be stated that, in order to scrutinize the sustainability of economic growth of any nation, it is needed to discover the direction of this causality.

Hence, while assessing the growth trajectory of India, it is needed to establish a directional causal relationship between CO_2 emission growth and GDP growth. In the existing body of knowledge, there are only a handful number of studies, which focus on the Granger causal association between income expansion and environmental degradation. Studies have been taken up in the United States [Soytas, Sari, and Ewing 2007] and China [Zhang and Cheng 2009]. However, these studies are mainly focused on the unidirectional relationships. In both of the aforementioned studies, Granger's causality test using the augmented VAR approach has been employed. In this paper, we intend to investigate about the direction of causal relationship between CO_2 emission growth and GDP growth.

DATA AND ECONOMETRIC ANALYSIS

For this paper, we have considered Indian GDP (G), CO_2 emission (C), gross capital formation (K), and urban population percentage (U) data for 1960-2010. We have considered the total dataset here, as dividing the actual figures with amount of population will nothing but scale down the variable value [Soytas, Sari, and Ewing 2007]. All the data has been used taking their natural logarithm and the trends of original data have been shown in Figure 1. Data has been obtained from the World Bank database. In most of the existing studies, either labor force or entire population has been used as an indicator of growth [Song, Zheng, and Tong 2008]. However, in this paper, we have considered percentage of urban population as an indicator. As starting from the second five-year plan Indian economy has started a rapid shift from agricultural base to industrial base, the availability of jobs in the industrial sector is on a rise. Therefore, urban infrastructure of India is facing a problem regarding accommodation of the migrated rural population [Misra 1978]. As primary sector is taking a backseat in economic growth and the void is being filled up rapidly by secondary and tertiary sectors, consideration of the urban population percentage as a parametric depiction of institutional and developmental paradigm shifts in India is justifiable. Moreover, this is that fraction of the entire populace, which adds the most to GDP, and gets affected the most by rapid environmental degradation issues, like air pollution.

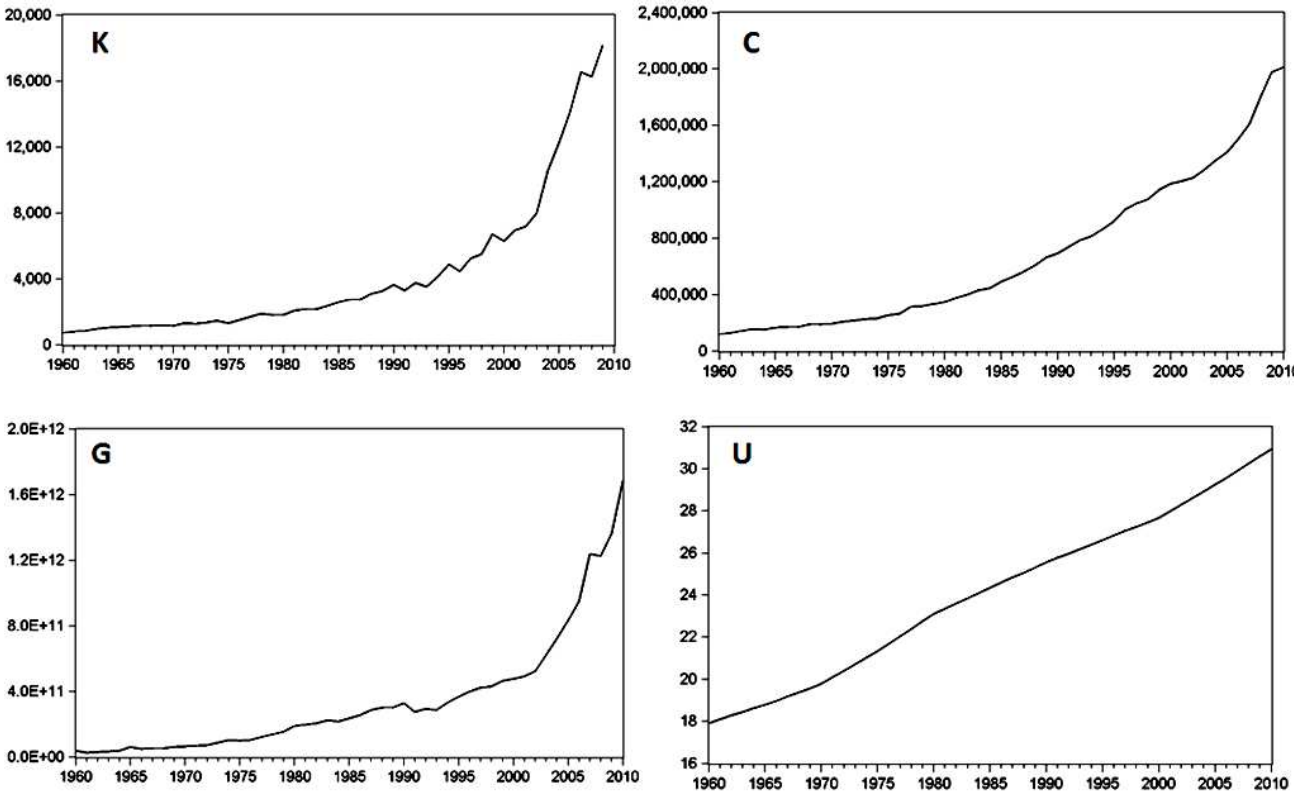

Figure 1: Trend of the parameters (1960-2010)

For formulation of the Vector autoregressive (VAR) equations, following steps are to be followed:

1. Determination of maximal order of integration (m),
2. Determination of optimal lag length (l),
3. Estimation of the following lag-augmented VAR(l + m) model:

$$\Delta X_t = \alpha_0 + \sum_{g=1}^{p} a_{1g} \Delta X_{t-1} + \sum_{g=1}^{p} a_{2g} \Delta X_{t-2} + \ldots + \sum_{g=1}^{p} a_{(l+m)g} \Delta X_{t-l-m} + ECT_{t-1} + \varepsilon_t$$

Where, α_0 is vector of constant terms, a_{tg} are coefficient matrices, X_t are the matrices of parameters, *ECT* is the error correction term, and ε_t is white noise residual.

4. Checking the robustness of the VAR model by conducting diagnostic tests

In order to go ahead with the lag-augmented VAR, maximal order of integration (m) of the two variables is required. For this purpose, we have carried out Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. The results of unit root tests are shown in Table 1. The GDP series, CO_2 emission series and Gross capital formation series are showing I(1) and urban population percentage series is showing I(2) at 1% significance level. Stationary natures of these variables were achieved at their respective differentiation levels. This ensures the linear combination of the variables out of the reduced form of inverted U-shaped EKC model [De Bruyn, van den Bergh, and Opschoor 1998]. The maximum order of integration has been found out to be *m=2*.

Table 1: Unit Root Test Results

		ADF	*PP*	*KPSS*
Levels				
Intercept	G	0.552447	0.816045	0.946524
	C	-0.023383	0.001080	0.961396
	K	2.219109	2.832474	0.928168
	U	-0.992634	-1.000431	0.951654
Intercept and Trend	G	-2.249676	-2.388506	0.122770
	C	-2.036926	-2.076394	0.104834
	K	0.015694	-0.297698	0.210019
	U	-2.510906	-1.110603	0.205080
First Difference				
Intercept	G	-8.551713[a]	-8.759905[a]	0.165826
	C	-7.810065[a]	-7.794741[a]	0.080138
	K	-8.720170[a]	-8.623014[a]	0.338505
	U	-1.719114	-1.745534	0.214559
Intercept and Trend	G	-8.444515[a]	-8.631400[a]	0.105034
	C	-7.742916[a]	-7.732306[a]	0.079091
	K	-9.377852[a]	-9.816594[a]	0.120373
	U	-1.851124	-1.877558	0.109443
Second Difference				
Intercept	U	-6.905665[a]	-6.905659[a]	0.108115
Intercept and Trend	U	-6.841476[a]	-6.841476[a]	0.102225

[a] Value at 1% significance level

Optimum lag length of the VAR model has been decided by LR test statistic (LR), Final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SIC), and Hannan-Quinn information criterion (HQ). The results obtained are recorded in Table 2. All the five tests confirm the optimal lag length of 1 for the VAR model. No structural breaks have been found in both the series. This gives us *l=1*. Now we can see some inconsistency in Table 1 in terms the order of integration of the variables. Now, the lag-augmented VAR model becomes VAR(3) (1 + m = 3). In order to go ahead with the VECM approach, robustness of the VAR model needs to be checked. For this reason, a series of residual diagnostic checks have been performed. Those tests are Breusch-Godfrey Serial Correlation LM Test, White test, Jarque-Bera test, and Ramsey Reset test.

Table 2: Lag Length Selection Criteria

Lag	*LogL*	*LR*	*FPE*	*AIC*	*SIC*	*HQ*
0	385.5578	NA	2.31e-13	-17.74687	-17.58304	-17.68646
1	424.7788	69.32079[a]	7.86e-14[a]	-18.82692[a]	-18.00776[a]	-18.52484[a]
2	432.5072	12.22169	1.18e-13	-18.44220	-16.96770	-17.89845
3	437.6799	7.217770	2.06e-13	-17.93860	-15.80878	-17.15319
4	453.4682	19.09281	2.31e-13	-17.92875	-15.14360	-16.90168
5	467.6695	14.53157	3.01e-13	-17.84509	-14.40461	-16.57635
6	489.8468	18.56701	3.05e-13	-18.13241	-14.03659	-16.62200

[a] Value at 1% significance level
Maximum lag length is taken as 8

The results of diagnostic tests are recorded in Table 3. The reported values of R^2 and adjusted R^2 signify that the explanatory powers of all the equations are very high. B-G test results show that no serial correlation is present for the entire set of equations. White test results show that no heteroscedasticity is present for the entire set of equations. However, for gross capital formation equation J-B test shows the absence of normality, it can be surpassed by the results concerning the stability of the parameters reported by Ramsey Reset test. The tests confirm that VAR(3) model is even with every one of unit roots contained by the unit circle. The diagnostic test results are satisfactory enough for conducting the causality test.

Table 3: Diagnostic Test Result

Equation	R^2	*Adjusted* R^2	*B-G test*	*J-B test*	*White test*	*Ramsey Reset test*
G	0.990746	0.990143	0.534357(1)	95.53258	0.602204	0.074485
C	0.995153	0.994837	0.289217(1)	13.65512	1.095800	0.965410
K	0.975350	0.973742	1.863012(1)	0.789274[a]	1.273934	0.638193
U	0.996827	0.996620	0.160367(2)	318.8309	0.347279	0.449075

[a] Value at 1% significance level
Lag lengths are inside the parentheses

Before conducting the causality test, we have to choose between the standard Granger's causality test [1969] and Engle-Granger Vector Error correction model [1987]. The linear combination of these non-stationary variables is found out to be stationary. This confirms the applicability of VECM test. The results of the causality test are recorded in Table 4. Directions of the causality associations are significant enough. Causality association between CO_2 emission growth and GDP growth is bi-directional in nature. At the same time, unidirectional causality exists from growth in gross capital formation to growth in CO_2 emission.

Table 4: Results of Causality Test

	Independent Variable				*Error Correction Term*
Dependent Variable	G	C	K	U	*t-statistics*
G	-	9.695956[a]	4.269863	5.907375	-0.18279[a]
C	7.628166[a]	-	7.875574[a]	4.242392	3.71899[a]
K	0.584942	1.526221	-	0.754456	2.30047[a]
U	0.332688	1.188693	1.901497	-	-0.24844[a]

[a] Value at 5% significance level

The directions of causality associations bring forth interesting results considering policy decisions. It is evident that for India, GDP growth and growth in CO_2 emission affects each other significantly. A possible explanation of this association might be found from the EKC hypothesis. Along the EKC, CO_2 emission growth is enhanced by increasing growth in income, i.e. GDP. However, this enhancement in turn brings harm to the environment. This is reflected by the very direction of long run causality from CO_2 emission growth to GDP growth. This part of the finding may be proven out to be of interest for the policy makers. Existence of this causality will restrict India to reach the turnaround point of the EKC. While one direction of causality is in line with the EKC hypothesis, the other direction describes the obstacle on the way of achieving the turnaround point of EKC. Generalized impulse responses (Figure 2) show that the response of CO_2 with GDP is in accordance with EKC hypothesis. However, the response of GDP to CO_2 is significant, as growth in CO_2 is causing a gradual reduction in GDP, which is all but similar for the case of the response of Capital to CO_2.

At the same time, if we consider the existing literature on EKC hypothesis, it confirms the growth of environmental degradation with rise in economic growth, though the first one comes down subsequent to arrival of the latter one at the threshold level. However, many-a-times this hypothesis has been empirically criticized for not encompassing the feedback effect of environmental degradation on economic growth [Arrow et al. 1995]. This argument can be considered as true as income was considered as an exogenous variable in the hypothesis [Stern

2004]. Existence of causality from growth in CO_2 emission from GDP growth, which we have found through econometric analysis, reinstates this argument.

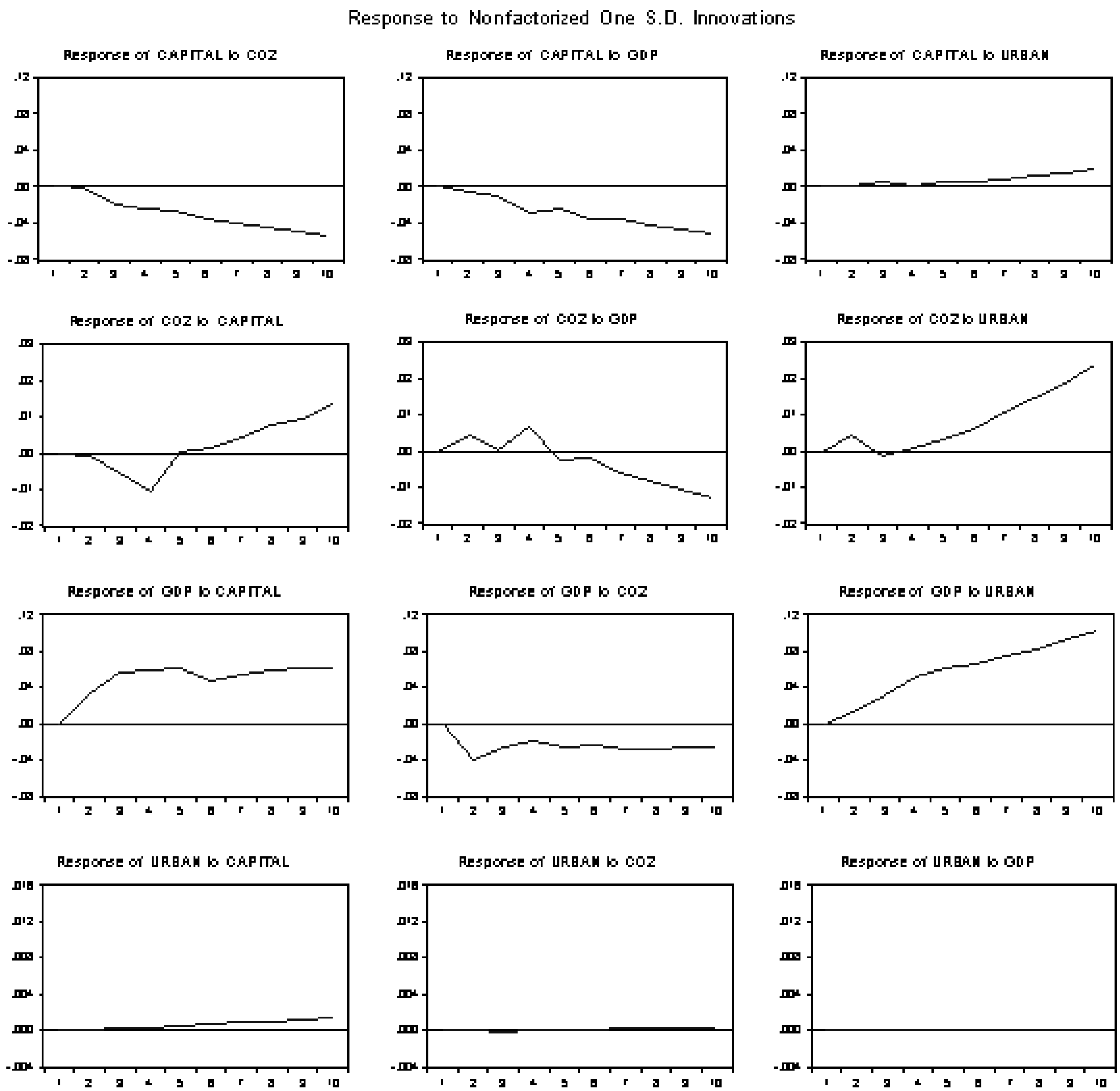

Figure 2: Generalized impulse responses

CONCLUSION AND POLICY IIMPLICATIONS

So far, it has been established that a bi-directional causal association exists between GDP growth and CO_2 emission growth. Any of these two directions of this causal relationship has already been established in several literatures, but the bi-directional causal association is a new finding. The established associations are all long run in nature, as we are not dealing with short run phenomena in this study. Direction of causality from CO_2 emission growth to GDP growth finds its significance within disproving the EKC hypothesis. Policymakers have to be careful about this direction of association, as this emerges because of the other direction. Kind of energy usage in India has to undergo a paradigm shift in order to combat this existential association, so that EKC turnaround point can be achieved and environmental degradation can be reduced over a period.

For a developing nation, GDP growth is enabled by growth in electricity consumption, and vice versa. This association is already well established in economic literature. Hence, keeping the growth perspective in mind, government of India was pursuing conservative energy policy, overlooking the aspects of environmental degradation. However, subsequent to Bhopal gas disaster in 1984, regulatory frameworks concerning environmental protection experienced an unprecedented shock. That was the time, when India started to take the environmental protection policies more seriously than ever.

Indian electricity production sector is majorly dependent on coal consumption. During 1971-2010, coal consumption in electricity sector has gone up from 13.21 million metric tonnes to 411.06 million metric tonnes. Our results show that the GDP growth enabled by this enhanced electricity consumption is causing growth in CO_2 emission. This enhanced growth in CO_2 emission is in turn deteriorating the environment, in which the economy is operating. Hence, our results confirm that the conservative energy policy has to be replaced by renewable energy policy. Presently renewable energy resources constitute in excess of 30% of India's major energy contribution. During 2002-2010, renewable energy production capacity (as a fraction of total energy production capacity) has increased almost 5.27 times. This conforms to our result that due to the causal association from growth of CO_2 emission to growth of GDP, focus on environmental protection is gaining significance.

Another causal association from growth in gross capital formation to growth of CO_2 emission shows that the GDP growth enabled by capital formation is also deteriorating the environment by increasing pollution. For a developing nation, this fact is true, as environment is provided with less importance with a view to exerting a pull on fresh investments. Thus, the resultant environmental damage being caused by income growth is in the similar lines with the EKC hypothesis. Therefore, it is the duty of the government to take care of the environment, in which the economic operation is taking place. This causal association can bring forth optimistic insights concerning the choice of technology being used for production, as traditional production technologies have the tendency of consuming more of natural capital compared to the green technologies. However, acquiring green technologies can have a direct impact on GDP, as importing of green technologies can affect the trade balance adversely. Moreover, loss of human capital due to CO_2-caused pollution restricts firms from replicating the low cost or cost effective local technological expertise across the nation.

In terms of contribution to economic literature, this paper empirically scrutinizes GDP-CO_2 causal association in the case of India. The findings are crucial considering environmental policy implications. Due to unavailability of data, the study is limited to the period of 1960-2010. Therefore, the interpretation might change with the increase in sample size.

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