Carbon Emissions and Mortality Rates: A Causal Analysis for India (1971-2010)

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Abstract. For any developing nation, industrialization and CO_2 emission goes hand-in-hand. Industrialization affects the CO_2 emission level and consequently the pregnancy outcomes and hygienic states of children. Environmental Kuznets Curve hypothesis ensures the interaction between income level and environmental degradation. Based on this foundation, causal relationships between industrialization, CO_2 emission and mortality rates for India has been obtained in this paper. For empirical analysis, data for the parameters under consideration over the period 1971-2010 has been considered. Vector Error Correction model using lag-augmented VAR model has been employed for the analysis. Bidirectional causal associations have been found between changes in infant mortality rate and growth in CO_2 emission, and between growth in gross capital formation and changes in child mortality rate, respectively. In both the cases, it has been found that growth in industrialization is causing rise in CO_2 emission. The result obtained is new in the considering the existing body of literature.

Key words: Child mortality rate, Environmental Kuznets Curve, Gross capital formation, Infant mortality rate, India
JEL classification: I15, Q53, Q58

1 Introduction

If we look at the growth pattern of India, then we can experience that the level of economic growth achieved by India during the period of 1971-2010, is primarily because of the consumption of commercial energy, which is generated out of the continuous combustion of fossil fuels (Masih and Masih, 1996; Cheng, 1999; Asafu-Adjaye, 2000; Ghosh, 2002; Fatai *et al*, 2004; Lee and Chang, 2008). During 1971-2010, amount of fossil fuel consumption as a fraction of total power consumption has almost doubled, and this has resulted in huge level of Carbon Dioxide (CO_2) emission in the atmosphere. During 1971-2010, CO_2 emission has gone up from 205,869.05 kilo tons in 1971 to 2,009,551.18 kilo tons in 2010, i.e. nearly an increase of 9.76 times. Therefore, the major driver of economic growth is causing harm to growth itself by causing predicaments like environmental degradation (Paul and Bhattacharya, 2004; Mukhopadhyay and Forssell, 2005; Garg and Shukla, 2009). Effects of this environmental degradation can be seen in various facets of growth like, on agriculture, hygienic state of labour force, urbanization, loss of bio-diversity etc. However, in light of this discussion, negative impacts of environmental degradation can be largely seen in terms of the pregnancy outcomes, i.e. the mortality rates and life expectance at birth, which are some of the major building blocks of social sustainability aspects of a nation.

Going by the description of *Environmental Kuznets Curve*, provided by Grossman and Krueger (1995), the interaction between economic growth and environmental degradation was built without considering the social sustainability aspects. However, devoid of considering the social sustainability aspects, the study of environmental degradation in any context can never be complete. Researchers have considered aspects of social sustainability in diverse contexts, namely for finding out the interaction between life expectancy at birth and environmental quality (Mariani *et al*, 2010), morbidity, mortality and particulate emission (Pope *et al*, 1995; Pope, 2000), and hygienic state of newborns in industrial areas (Šrám *et al*, 2005). In all of these cases, it has been found that for developed nations, ambient air pollution and environmental quality as a whole have significant impacts on the mortality rates. However, considering the state of developing nations and their growth patterns, this study may find its significance in finding out the causal association between mortality rates and carbon emission, as driven by the negative consequences on social sustainability aspects, respective governments in developing nations are striving to look for alternate, clean, and eco-friendly sources of energy. Therefore, possible existence of any bidirectional causal association may be found out between environmental degradation and mortality rates.

In this study, we want to find out the direction of causality between carbon emission and mortality rates for India during 1971-2010. In the existing body of knowledge, we haven't encountered any study, which focus on the causal association between the mentioned parameters. 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 carbon dioxide (CO_2) emission growth and mortality rates.

2 Data and Econometric analysis

For this paper, we have considered GDP (EG), CO_2 emission (CE), gross capital formation (K), infant mortality rate (IMR), and child mortality rate (CMR) data for India during 1971-2010. We have considered the total dataset rather than per capita figures, as dividing the actual figures with amount of population will nothing but scale down the variable value. Data has been obtained from the World Bank database and the Reserve Bank of India. For formulation of Vector autoregressive (VAR) equations, following steps are to be followed:

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

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

  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.
- 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, results of which are recorded in table 1. The GDP series, CO_2 emission series and Gross capital formation series are showing I(1) and infant mortality rate and child mortality rate series are showing I(2) at 1% significance level. Stationary natures of these variables were achieved at their respective differentiation levels. The maximum order of integration has been found out to be $m=2$.

Table 1. Unit root test results

	ADF	*PP*	*KPSS*
Level data			
EG	0.552	0.816	0.947
CE	-0.023	0.001	0.961
K	2.062	5.173	0.762
IMR	1.819	7.524	0.777
CMR	4.472	7.701	0.776
First Difference			
EG	-8.551[a]	-8.760[a]	0.166
CE	-7.810[a]	-7.795[a]	0.080
K	-7.936[a]	-7.936[a]	0.470
IMR	-1.156	-1.224	0.701
CMR	-0.250	-1.389	0.690
Second Difference			
IMR	-4.918[a]	-4.918[a]	0.104
CMR	-2.840[a]	-4.806[a]	0.115

[a] Value at 1% significance level

Optimum lag length of the VAR model has been decided by Akaike information criterion (AIC), Schwarz information criterion (SIC), and Hannan-Quinn information criterion (HQ), which are recorded in table 2. For both the VAR models to be considered for further analysis, the optimum lag lengths have been selected as 2. No structural breaks have been found in both the series. This gives us $l=1$. Now we can see some disparity in Table 1 in terms the order of integration of the variables. Now, the lag-augmented VAR model becomes VAR(4) ($l+m=4$). 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, and Ramsey Reset test. The results of the diagnostic tests are recorded in table 3.

Table 2. Lag length criteria

Lag	*LogL*	*AIC*	*SIC*	*HQ*
VAR model for CMR				
0	92.711	-4.9284	-4.752	-4.867
1	349.226	-18.290	-17.411	-17.983
2	387.991	-19.555*	-17.972*	-19.002*
3	397.058	-19.167	-16.883	-18.372
4	410.266	-19.015	-16.024	-17.971
VAR model for IMR				
0	95.953	-5.109	-4.933	-5.047
1	356.219	-18.679	-17.799	-18.372
2	385.845	-19.436*	-17.852*	-18.883*
3	400.662	-19.370	-17.083	-18.572
4	409.482	-18.971	-15.980	-17.927

* Lag length selected by the criteria
Maximum lag length is taken as 4

The reported values of the diagnostic tests 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. Ramsey Reset test results show that for both of the associations, stability of the parameters under consideration are very high. The tests confirm that both the VAR(4) models are 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 results

Equation	*B-G test*	*White test*	*Ramsey Reset test*
VAR model for CMR			
EG	2.209	0.871	1.213
CE	0.422	0.773	1.505
K	0.365	1.237	1.358
CMR	0.833	1.612	1.122
VAR model for IMR			
EG	2.486	0.883	1.374
CE	1.340	0.919	1.888
K	0.899	1.283	1.950
IMR	0.977	1.742	2.665

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 Vector error correction modelling (VECM) test. Results of causality analysis for both the models are recorded in table 4. In the first model, bidirectional causality exists between GDP growth and growth in CMR, and growth in capital formation and growth in CMR. In the second model, bidirectional causality exists between growth in CO_2 emission and growth in IMR. Apart from this, unidirectional causality associations exist from economic growth to growth in IMR and growth in capital formation to growth in IMR.

Table 4. Causality test results

	Independent Variable				ε_t
Dependent Variable	EG	CE	K	CMR	*t-statistics*
EG	-	0.935	0.293	7.657[a]	-0.620
CE	1.469	-	0.656	1.677	-0.706
K	0.845	8.782[a]	-	8.146[a]	-3.386
CMR	7.036[a]	2.086	6.369[a]	-	-2.226
	Independent Variable				ε_t
Dependent Variable	EG	CE	K	IMR	*t-statistics*
EG	-	0.418	0.162	0.142	-0.309
CE	0.910	-	0.428	7.691[a]	0.635
K	2.050	8.511[a]	-	1.247	-4.025
IMR	19.221[a]	15.390[a]	14.58[a]	-	-0.966

[a] Value at 5% significance level

Now, directions found out in causality analysis for both the models, call for significant policy analysis regarding the pattern of economic growth and industrialization in India. Economic growth pattern and rise in CO_2 emission sway each other, following the missing feedback link in EKC hypothesis (Sinha and Mehta, 2014). However, there are several ways, in which the swaying can actually occur, and perhaps the pregnancy outcomes is one of the major ways, in which this problem may prove out to be grievous, as it directly affects the future labour force of India, as well as its social sustainability aspects. Let us consider the first model for analyzing CMR. In this case, we have seen that a bidirectional causal association exists between the change in CMR and the growth in gross capital formation. Now, as the economy starts to grow, industrialization sets in, and the growth in industrialization also catalyzes the economic growth endogenously. The growth in industrial output is reflected by the gross capital formation and this is acting as proxy of industrialization for this model. Now, it is beyond doubt that continuous combustion of fossil fuel generates energy, which sets the pace of industrial growth. However, due this growth in industrialization, emissions rise in the atmosphere, specifically the particulate matters and greenhouse gases, which affect hygienic states of the children (Bobak and Leon, 1992; Bailis *et al*, 2005). Being faced by this predicament, government is striving to look for alternate sources of energy, which are clean and eco-friendly, as well as providing proper sanitation facilities and fresh drinking water to the people, living in slum areas. As the emissions directly affect newborns in the industrial areas and effects on children are indirect, therefore, measures for preventing the incidents of child mortality are more rigorous, as during the age of 5-10 years industrialization can affect them in many ways. Strict environmental protection measures being taken up by government, so that the amount of industrial waste being produced by industries can be reduced, and consequently the incidents of child mortality, as this hazard is not only economic in nature, but also social. This argument supports the established bidirectional causal association between changes in CMR and growth in industrialization.

Let us now look at the second model for analyzing IMR. In this case, we have seen that a bidirectional causal association exists between change in IMR and the growth in CO_2 emission. Due to the effects of industrial emissions, maternal health is being affected the most, across various countries (Ataniyazova *et al*, 2001). Exposure to greenhouse gases, like CO_2 can always have the possibility to result in defects in the newborns, and many-a-times death (Stephenson *et al*, 2010). For developing nations, this is a major predicament, while going for rapid industrialization, as while moving along the growth trajectory, environmental protection generally takes the backseat, and these kinds of negative issues arise (Acharyya, 2009). The emissions are also associated with the growth of transportations, which have been seen in various countries (Pereira *et al*, 2011). Like the previous case of CMR, statutory measures being taken up by government are just the similar in this case as well. Removal of harmful subsidies, afforestation programs, quest for alternate energy resources are some of the initiatives being taken up by government in order to reduce the CO_2 emission level in the atmosphere. This argument supports the established bidirectional causal association between changes in IMR and growth in CO_2 emission.

Now, if we look at both the models closely, new insights may come up, which can be prove out to be significant from policy perspectives. It is noteworthy to visualize that in both the models, growth in industrialization has been Granger caused by CO_2 emission. This clearly indicates towards the missing feedback link of EKC hypothesis, which has been pointed out by various researchers (Arrow *et al*, 1995). Considering industrialization as an indicator of economic growth, this established causal association indicates the missing feedback link of EKC hypothesis, which is directed from environmental degradation to economic growth. If we look at the social viewpoint of EKC hypothesis, which is also one of its missing aspects, the bidirectional causal associations depict that the omitted variable bias present in EKC hypothesis can be solved by incorporation of social aspects, and these aspects possibly have the explanatory power to explain the feature of turning around of EKC (Roberts and Grimes, 1997; Islam *et al*, 2003). Considering the literature of EKC hypothesis, these results are possibly two significant contributions.

In order to set off the study, we have shown the generalized impulse responses for both of the models. These responses show that the response of mortality rates with gross capital formation and CO_2 emission follow the trajectory defined by EKC hypothesis. Looking at figure 1 and figure 2, we can see the response of CMR with respect to Cholesky innovation of one standard deviation to gross capital formation, and vice versa. These responses act in accordance with the EKC hypothesis.

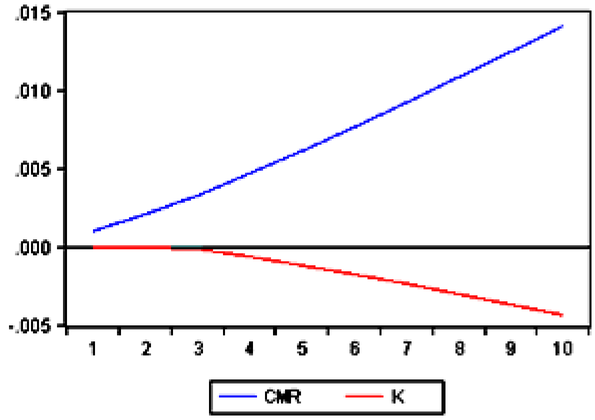

Figure 1. Accumulated response of CMR to Cholesky One S.D. Innovations

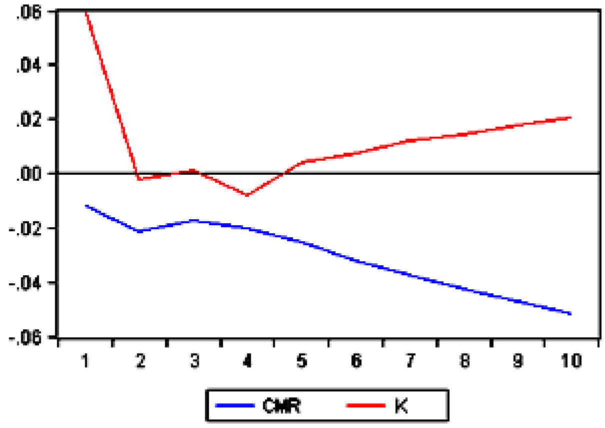

Figure 2. Accumulated response of K to Cholesky One S.D. Innovations

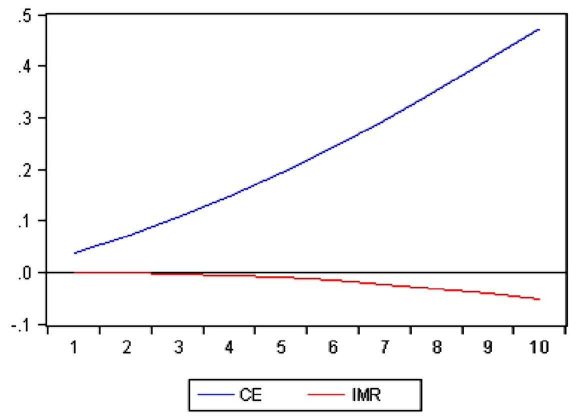

Figure 3. Accumulated response of CE to Cholesky One S.D. Innovations

Similarly, looking at figure 3 and figure 4, we can see the response of IMR with respect to Cholesky innovation of one standard deviation to CO_2 emission, and vice versa. These responses act in accordance with the EKC hypothesis, as well.

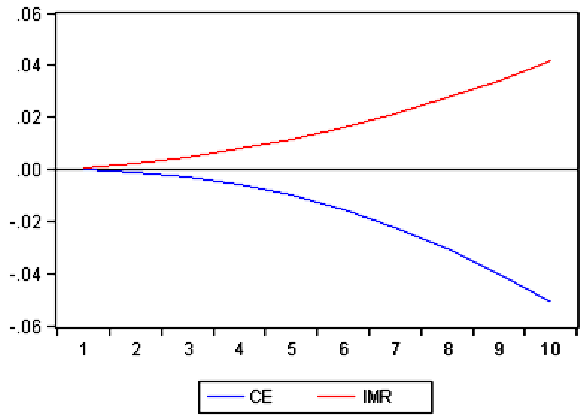

Figure 4. Accumulated response of IMR to Cholesky One S.D. Innovations

3 Conclusions and Policy recommendations

So far, it has been established that bidirectional causal associations exist between the negative environmental consequences of economic growth and mortality rates. Quantitatively established associations between mortality rates and the negative environmental consequences of economic growth have by and large depicted unidirectional causal associations, going by the generally accepted notions of EKC hypothesis. However, the incidents of mortality rates can also have consequences of economic growth pattern, and this is the area, which was largely missing in the existing literature of ecological economics. There lies the novelty of the results being established in this paper. Directions of causal associations from mortality rates to environmental degradation not only points towards the missing feedback link and omitted variable bias of EKC hypothesis, but also sends a signal for the policymakers, regarding the possible negative consequences of the policies being designed by them. 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, and consequently the incidents of mortality rates.

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 with reference to 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 gross capital formation, focus on environmental protection is gaining significance.

For a developing nation like India, incidents of mortality are equivalent to loss of prospective future human capital, which can contribute significantly in the economic growth and development. Presently, in a scenario, where the local technological expertise is not getting replicated across the nation, expensive technological procurements from developed nations are causing serious balance of payment deficits, India should focus more on nurturing and providing the future human capital of nation with the best environment possible. Established bidirectional causal associations intend to send this signal to the policymakers of India.

In terms of contribution to economic literature, this paper empirically scrutinizes mortality rate-industrialization 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 1971-2010. Therefore, the interpretation might change with the increase in sample size.

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