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Revisiting the growth-emission feedback mechanism: a note on contradicting results

Avik Sinha
Department of General Management and Economics, Goa Institute of Management, India

Abstract

There is a plethora of studies on the causal association between economic growth, energy consumption, and carbon emissions, and Granger causality approach has been largely employed in those studies. Majority of these studies have employed annual data, which is low in terms of frequency. Therefore, there are unobserved shortcomings in those studies in terms of methodological selection for handling low frequency data, and this issue has never been addressed in the literature of energy and environmental economics. In this study, we are presenting an innovative approach for estimating the instantaneous feedback between the variables by employing Geweke causality approach. By highlighting the shortcomings of Granger causality approach, we have chosen the studies on growth-emission nexus carried out in Indian context, and we have applied Geweke causality analysis on the datasets used in those selected studies. Barring a few, our results have contradicted the findings of those studies in terms of the evidence of feedback hypothesis. We have also shown how the causality results should comply with the study context by comparing Granger and Geweke causality results.

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Contact: Avik Sinha - f11aviks@iimidr.ac.in.
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1. Introduction

While investigating about the impact of North American Free Trade Agreement (NAFTA) on environmental quality, Grossman and Krueger (1991) found the association between income and environmental degradation to be inverted U-shaped. Shape of this curve was in the similar lines with the finding of Simon Kuznets (1955), who described the inverted U-curve association between income inequality and economic development. That is the reason behind the name of Environmental Kuznets Curve (EKC) hypothesis. According to this hypothesis, when an economy starts to grow, the pattern of growth results in rise in environmental degradation. When the economic growth reaches a certain point, the environmental degradation starts coming down, and this phenomenon takes place owing to the rise in social and ecological awareness among citizens.

Now, if the formulation of EKC hypothesis is scrutinized, then it can be seen that the nature of association between environmental degradation and economic growth is unidirectional, which can be questioned based on the discussion so far (Shahbaz and Sinha, 2019). Reflecting on this possible feedback link from environmental degradation to economic growth, it is required to analyze, whether the effect is directed towards economic growth itself, or towards the drivers of economic growth. For any developing nation, a major driver of economic growth is consumption of energy, which is generated primarily from fossil fuel. If the growing literature on energy economics across diverse contexts is analyzed, then it can be seen that researchers have divided the associations between energy consumption and economic growth into four categories, which are listed as per the following:

- Neutrality hypothesis: In this case, there is no causal association between energy consumption and economic growth.
- Conservation hypothesis: In this case, causal association runs from economic growth to energy consumption.
- Growth hypothesis: In this case, causal association runs from energy consumption to economic growth.
- Feedback hypothesis: In this case, bidirectional causal association exists between energy consumption and economic growth.

Out of these four hypotheses, feedback hypothesis is the point of interest for the present study, as this hypothesis demonstrates the opposite direction of growth-emission association, as it is stated by EKC hypothesis. Over the years, a huge volume of research has been carried out for finding out the feedback link of EKC hypothesis, and most these studies have been used Granger causality analysis technique (Granger, 1969). Most of these studies have tried to find out the possible causal linkages economic growth and the environmental degradation for a wide array of contexts using bivariate and multivariate models, and the results are inconclusive in nature.

Although Granger causality analysis has been widely used so far in the literature of energy and ecological economics, several researchers have pointed out that this methodology loses its explanatory power in case of low-frequency data (Geweke and Porter-Hudak, 1983; Diebold and Rudebusch, 1989; Gonzalo and Granger, 1995; Serletis and Krause, 1996; Breitung and Candelon, 2006). If the country-level growth-emission studies are analyzed, then we can see that those studies have mostly used yearly data, which is low in terms of frequency. Therefore, it can be possible that the directions of causality obtained in those studies may not depict the true scenario.

Bi-directionality is an inherent feature of any developmental policy, and it is true for the energy and environmental policies, as well (Bot *et al.*, 2015; Sinha *et al*., 2018). While carrying out Granger causality test, this aspect of bidirectionality is not considered, and it is due to the traditional vector autoregression (VAR) approach, where individual matrix elements are considered while deriving the Wald statistics. This is where the Granger causality approach turn towards unidirectional measure, and if two unidirectional causal association among two variables are found, then the causal association is considered as bidirectional. Therefore, Granger causality test doesn't cover the bidirectional causality, which is the primary feature of instantaneous causality (Geweke and Porter-Hudak, 1983).

In the present study, the causal linkage between economic growth, energy consumption, and carbon emissions in India is analyzed, using the Geweke causality analysis approach (Geweke, 1982). This study is intended to depict a comparative scenario, and to achieve this, studies analyzing the feedback hypothesis in Indian context are chosen. Application of this methodology can capture the contemporaneous causal impact, which is not possible using the traditional Granger causality approach. While estimating causality using standard VAR methodology, researchers try to derive the impact of one variable on another by controlling their lag lengths, and in this process, the instantaneous causal effect is automatically left out. By using the variance-covariance matrix of residuals obtained from the VAR, Geweke causality analysis approach computes the instantaneous causality between a pair of variables. For this study, the datasets used in the chosen studies are analyzed, and Geweke causality analysis approach has been applied on the same datasets.

2. The approach

Geweke (1982) proposed the subsequent methods of determining causal association between the two variables (e.g., *A* and *B* in this case):

$$A_{i,t} = a + \sum_t \sum_i b_{i,t} A_{i,t-1} + \epsilon_{1_{i,t}} \quad , Var\left(\epsilon_{1_{i,t}}\right) = \sigma_{1\,i,t}^2 \tag{1}$$

$$A_{i,t} = a + \sum_t \sum_i b_{i,t} A_{i,t-1} + \sum_i \sum_{t=1}^{T} c_{i,t} B_{i,t-1} + \epsilon_{2_{i,t}} \quad , Var\left(\epsilon_{2_{i,t}}\right) = \sigma_{2\,i,t}^2 \tag{2}$$

$$A_{i,t} = a + \sum_t \sum_i b_{i,t} A_{i,t-1} + \sum_i \sum_{t=0}^{T} c_{i,t} B_{i,t-1} + \epsilon_{3_{i,t}} \quad , Var\left(\epsilon_{3_{i,t}}\right) = \sigma_{3\,i,t}^2 \tag{3}$$

$$A_{i,t} = a + \sum_t \sum_i b_{i,t} A_{i,t-1} + \sum_i \sum_{t=-h}^{T} c_{i,t} B_{i,t-1} + \epsilon_{4_{i,t}} \quad , Var\left(\epsilon_{4_{i,t}}\right) = \sigma_{4\,i,t}^2 \tag{4}$$

where, the mathematical associations comply with asymptotic Chi-square distribution. Undertaking the degree of freedom as *f*, the maximum likelihood procedures of determining the causality are as per the following:

$$\text{Instantaneous causality: } \ln\left(\sigma_{2\,i,t}^2 / \sigma_{3\,i,t}^2\right) * n \sim \chi^2(1) \tag{5}$$

$$\text{Total causality: } \ln\left(\sigma_{1\,i,t}^2 / \sigma_{4\,i,t}^2\right) * n \sim \chi^2(2d+1) \tag{6}$$

Equations (5) and (6) show that Geweke causality test considers the instantaneous and total causality. While considering any dataset of low frequency, instantaneous correlation between variables can be missed, and this issue is present in Granger (1969) causality test. Using the residuals of Granger (1969) causality tests, Geweke causality test can capture the

instantaneous feedback. This causality approach takes care of the non-linear association between variables, as well. Owing to these reasons, Geweke causality test complements the problems of Granger (1969) causality test.

Table 1: Comparison of the Granger and Geweke causality results

Author(s)	*Study period*	*Granger causality result**	*Geweke causality result***
Ghosh (2010)	1971-2006	Y ↔ C	Y --- C
		E → C	E ↔ C
		Y → E	Y --- E
Alam *et al*. (2011)	1971-2006	Y --- C	Y ↔ C
		E ↔ C	E --- C
		Y --- E	Y ↔ E
Tiwari (2011a)	1971-2005	Y ← C	Y ↔ C
		E ↔ C	E --- C
		Y --- E	Y --- E
Tiwari (2011b)	1971-2007	Y ← C	Y --- C
		E ← C	E ↔ C
		Y → E	Y --- E
Ozturk and Salah Uddin (2012)	1971-2007	Y --- C	Y ↔ C
		E → C	E ↔ C
		Y ↔ E	Y --- E
Vidyarthi (2013)	1971-2009	Y ← C	Y ↔ C
		E → C	E --- C
		Y → E	Y --- E
Bhattacharya *et al*. (2014)	1980-2010	Y → C	Y --- C
		E --- C	E ↔ C
		Y ↔ E	Y ↔ E
Yang and Zhao (2014)	1970-2008	Y ↔ C	Y ↔ C
		E --- C	E --- C
		Y ← E	Y --- E
Ohlan (2015)	1970-2013	Y ← C	Y ↔ C
		E --- C	E ↔ C
		Y --- E	Y --- E
Sinha (2015)	1971-2010	Y --- C	Y --- C
		E ↔ C	E ↔ C
		Y ↔ E	Y --- E
Srinivasan and Ravindra (2015)	1970-2014	Y ← C	Y ↔ C
		E --- C	E ↔ C
		Y ↔ E	Y --- E
Srinivasan *et al*. (2015)	1970-2012	Y ← C	Y ↔ C
		E ← C	E --- C
		Y → E	Y ↔ E

Note: Y, E, and C denote GDP, energy consumption, and CO_2 emission respectively

* Granger causality results are obtained directly from the studies cited

** author's calculations; only significant results are shown

To start with, first, the studies analyzing the growth-emission nexus in India using Granger causality approach are chosen. These studies are multivariate in nature, and out of all the variables, energy consumption (E), economic growth (Y), and carbon emission (C) are chosen, while controlling for other explanatory variables. For example, Tiwari (2011b) has considered energy consumption, economic growth, and carbon emission in his model, whereas

Ozturk and Salah Uddin (2012) have considered energy consumption, economic growth, carbon emission, and trade openness in their model. Although both studies have analyzed the same data, for the second case, trade openness is controlled. After controlling the other explanatory variables, pair-wise variables are taken, i.e. Y-C, E-C, and Y-E, and Geweke causality analysis approach has been applied on these three pairs.

3. Results and Discussion

The results of the Geweke causality analysis are shown in Table 1. It is quite evident from the results that for almost all the cases, the feedback mechanism among the variables have undergone a change. Now the pairs of variables will be considered, and each of them will be discussed, respectively.

First, the feedback mechanism between economic growth and carbon emissions is considered. Out of the cited studies, only Ghosh (2010) and Yang and Zhao (2014) have given the evidence of feedback mechanism between these two variables using Granger causality approach. However, after applying Geweke causality technique, evidence of instantaneous feedback for a total of eight cases are found, and only the results obtained by Yang and Zhao (2014) match with these results. The evidence of neutrality hypothesis matches with the results obtained by Sinha (2015). The obtained results have contradicted 10 out of 12 studies carried out in Indian context.

Second, the feedback mechanism between energy consumption and carbon emissions is considered. Out of the cited studies, Alam *et al*. (2011), Tiwari (2011a), and Sinha (2015) have given the evidence of feedback mechanism between these two variables using Granger causality approach. However, after applying Geweke causality technique, we have found that a total of seven cases are showing the evidence of instantaneous feedback, and only the results obtained by Sinha (2015) match with the results of the resent study. The evidence of neutrality hypothesis matches with the results obtained by Yang and Zhao (2014). In this case also, the obtained results have contradicted 10 out of 12 studies carried out in Indian context.

Lastly, the feedback mechanism between energy consumption and economic growth is considered. Out of the cited studies, Ozturk and Salah Uddin (2012), Bhattacharya *et al*. (2014), Sinha (2015), and Srinivasan and Ravindra (2015) have given the evidence of feedback mechanism between these two variables using Granger causality approach. However, after applying Geweke causality technique, the evidence of instantaneous feedback can be found in three cases, and the results obtained by Bhattacharya *et al*. (2014) match with this set of results. The evidence of neutrality hypothesis matches with the results obtained by Tiwari (2011a) and Ohlan (2015). In this case, the set of obtained results have contradicted 9 out of 12 studies carried out in Indian context.

Now, if we sum up these results, several aspects come to pass. The model variables i.e. control and moderating variables, for any test depict the large economic context, in which the study is conducted. Therefore, presence of those variables should have an impact on the causal associations among the control variables. Choice of study period and choice of variables demonstrate the research context, and therefore, having unidirectional causal associations might not depict the true picture of the context. This is because the causality results should comply with the contextual structure. For example, the studies by Ghosh (2010) and Alam *et al*. (2011) were conducted for same period. However, for Ghosh (2010) the moderating variables were real investment and employment, whereas for Alam *et al*. (2011) the moderating variables were labor

force and gross capital formation. Clearly, for Ghosh (2010), the context was inclined towards infrastructural investment and employment creation, whereas for Alam *et al*. (2011), the context was inclined towards creation of economic output. Therefore, the causal associations found by Ghosh (2010) were not complying with the context setting, as the energy consumption was going up due to investment, and not economic growth, and therefore, the carbon emissions were rising. On the flipside, rise in carbon emissions is expected to impact the driver of growth, and not the growth itself. Therefore, the causal association found by Ghosh (2010) can be nullified by our finding of the bidirectional causal association between energy consumption and carbon emissions. Now, for Alam *et al*. (2011), the creation of capital was adding to the economic growth, and it called for more consumption of energy. But the carbon emissions generated during the capital creation process can harm the process itself, by deteriorating the hygienic state of the labor force, and thereby, hurting the economic growth itself. So, the bidirectional causality found by Alam *et al*. (2011) can be nullified by our finding of the bidirectional causal association between economic growth and energy consumption, and economic growth and carbon emissions, respectively. In a nutshell, we would say that the results of causality tests cannot be justified without the compliance with the context setting, and through Geweke (1982) causality analysis, we have pointed on that aspect.

Results of this study clearly depict the unobserved limitations of the studies, which have tried to investigate the feedback mechanism between economic growth and carbon emissions. All the studies used the annual data for all the variables, and due to the limitations of Granger causality analysis regarding low frequency, the instantaneous feedback among the variables were not captured. The unobserved feedback mechanisms lying with the lagged variables were thus brought out by Geweke causality mechanism.

4. Conclusion

By far, the present study analyzed the growth-emission studies in Indian context, and analyzed the datasets used in those studies by means of Geweke causality analysis. This study first described the shortcomings of Granger causality analysis, and after that proposed a mechanism to achieve the instantaneous feedback between pairs of variables. In this paper, only three variables were considered, and those are energy consumption, economic growth, and carbon emissions, as these three variables are largely used in the growth-emission studies.

As the volume of literature on estimating the feedback mechanism between economic growth and environmental degradation is rising, and annual data will be used in most of those studies, so this study may find its own relevance in terms of estimating the feedback mechanism in the most effective way. It is true that this technique has not been used much in the field of economics and it is mostly used in the field of medicine, there is a huge scope for researchers to implement this mechanism in their studies, where low frequency data will be used.

As the growth-emission studies are huge in terms of volume, therefore it is a huge scope for the researchers to explore more on this technique and revisit those studies, so that the unobserved limitations of those studies can be addressed effectively.

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