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Casuality Between Energy Consumption and Output Growth in Indian Cement Industry: An Application of Panel Vector Error Correction Model

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CAUSALITY BETWEEN ENERGY CONSUMPTION AND OUTPUT GROWTH IN INDIAN CEMENT INDUSTRY: AN APPLICATION OF PANEL VECTOR ERROR CORRECTION MODEL

Sabuj Kumar Mandal[1], S Madheswaran[2]

Abstract

The aim of this paper is to examine the existence and direction of the causal relationship between energy consumption and output growth for Indian cement industry for the period 1979-80 to 2004-05. The most recently developed panel unit root, heterogeneous panel cointegration and panel-based error correction models have been applied in a multivariate framework including capital stock, labor, and material other than energy and output. The empirical results confirm a positive long-run cointegrated relationship between output and energy consumption when heterogeneous state effect is taken into account. It is also found that there exists a long run bi-directional relationship between energy consumption and output growth in Indian cement industry for the study period, implying that an increase in energy consumption directly affects growth of this sector and that growth also stimulates further energy consumption. These empirical findings imply that energy consumption and output are jointly determined and affect each other. Also, energy conservation policies should be associated with consistent encouragement and support from the government for adoption of energy efficient technologies in order to avoid negative impacts of theses policies on the growth of this industry.

Introduction

Energy is an essential input for almost all productive sectors in general, and industry in particular. However, in the context of growing energy prices and a concern for the potential detrimental impacts of energy use on the environment, energy conservation policies have drawn much attention from the policy makers across the world. Conservation of energy could ensure not only energy security but also lower emissions of green house gases.

However, implementation of energy conservation policies needs a careful investigation of the direction of causation between energy consumption and output growth because the direction of causation has significant implications for policy formulation. If, for example, there exist a unidirectional causality running from output growth to energy consumption, energy conservation policies may be implemented with little adverse or no effects on output growth (Paul et al. 2004). On the other hand, a unidirectional causality running from energy consumption to output growth implies that energy is a prerequisite for output growth and in that case reducing energy consumption could lead to a decline in output growth. In contrast, a bi-directional causality implies energy and output are jointly determined and affect each other. And lastly, the absence of no causality in either direction implies energy is neutral to economic growth and energy conservation policies do not affect economic growth (Asafu-Adjaye,

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2000). Thus, this paper makes an attempt to examine the existence and direction of the causal relationship between energy consumption and output growth in Indian cement industry.

The context of Indian cement industry

Indian cement industry witnessed an unprecedented growth as a sequel to government's liberalization policy initiated in the form of partial decontrol in 1982, and subsequently culminated in total decontrol in 1989. And the industry has, in fact, become the second largest in the world in terms of cement production. However, this huge growth in cement production has been associated with a price to pay in terms of higher utilization of energy. Among the energy intensive industries in India, cement industry has the highest energy intensity along with second highest share in fuel consumption (15.60%), after Iron and Steel (18.10%), mostly in the form of coal utilization. Its expansion could not have been achieved without a very large increase in energy input, especially in the form of coal combustion.

This has resulted in severe environmental problems not only in the coal mining regions but also around the cement producing plants. In addition, India's annual emission of green house gases from the cement industry increased from 7.32 mt in 1993 to 16.73 mt in 2003 and its share in total CO_2 emission by India increased from 3.3% to 4.8% for this period (ICRA, 2006). The Indian Government, recognizing the potential dangers of these environmental problems, has since effected many policy changes over the past 25 years or so to increase the energy efficiency of the firms and thereby reduce CO_2 emissions, with particular emphasis on energy-intensive heavy industries such as the cement industry.[1] A recent addition to these policies includes the Energy Conservation Act, 2001 which has earmarked Indian cement industry, along with some others, as 'designated consumers' of energy. The Energy Conservation Act, 2001 has empowered the central and state governments to direct these 'designated consumers' to comply with certain norms and standards regarding energy use. Now, the impact of these energy conservation policies on the growth of this industry depends on existence and direction of the causal relationship between energy consumption and output growth of this sector. Therefore, it is worth investigating the causality issue in the context of Indian cement industry. In this paper we make an attempt in that direction.

Rest of the paper unfolds as follows. The next Section presents a review of literature related to energy-growth causality. Followed by definitions of the variables used and discussion of data sources. Econometric methodology and empirical results are presented in the next section. The last section concludes the paper with policy implications.

Review of literature

Considering its important implications for policy formulation, several scholarly attempts have been made to study the existence and direction of causality between energy consumption and economic growth across the world. However, in the Indian context, very less attention has been paid to investigate the causal relationship between energy consumption and economic growth. Notable studies in this regard include Masih and Masih (1996) where in cointegration and vector error correction model was used to examine the direction of causal relationship between energy consumption and economic growth in India along with other Asian countries. Empirical results of their study established a unidirectional causality running from energy consumption to economic growth in India for the study period 1955 to 1990. In contrast, Cheng (1999), using cointegration and granger causality test, established a unidirectional causal relationship running from economic growth to energy consumption. Ghosh (2002) also established a unidirectional Granger causality running from economic growth to electricity consumption. Again, the findings of Asafu-Adjaye (2000) support the findings of Masih and Masih (1996) but contrast the findings of Cheng (1999). In a recent study, Paul and Bhattacharya (2004) found bi-directional causality between energy consumption and economic growth in India for the period 1950 to 1996.

Therefore, in the Indian context, the empirical findings on the causal relationship between energy consumption and economic growth are found mixed or conflicting in nature. These kind of conflicting results are common not only in Indian context but also in the context of several other countries. Depending on the country and the time period covered, methodology used, number of variables included in the model, structure of energy used- aggregate or specific, the direction of causality between energy consumption and economic growth varies from one study to another.

However, one common limitation of the existing studies concerning the causality issue is that almost all the studies have been conducted at the aggregate economy level. However, an economy consists of different sectors, such as agriculture, industry and service. Dependency on energy varies from one sector to another, and overtime, the importance of a specific sector may also change (Mishra et al. 2009). Therefore, the relationship between energy consumption and real GDP may not be uniform across sectors, though studies conducted at the aggregate level implicitly assume such a uniform relationship between energy consumption and GDP. A recent study by Payne and Bowden (2009) found the relationship between energy consumption and real GDP not uniform across sectors of the U.S economy for the period 1949 to 2006. Their study found no causality existing between energy consumption and GDP in transport sector; bi-directional Granger-causality between commercial and residential primary energy consumption and real GDP, respectively and finally unidirectional causality running from energy consumption to real GDP in industrial sector. Our present study goes one step further in terms of disaggregation by considering a particular industry from the entire industrial sector because of the existence of heterogeneity in energy use intensity in a particular sector also. For example, in the industrial sector, while there are high energy intensive industries, others are less energy intensive. We are interested in studying the issue of energy-growth causality in the context of Indian cement industry which is the highest energy intensive industry among all other industries in India. To the best of our knowledge, this is the first study of its kind dealing with the issue of energy-growth causality in a specific industrial sector applying most recently developed panel vector error correction model.

Definition of variables and data sources

Our data set consists of a balanced panel of 18 major Indian cement producing states for the time period 1979-80 to 2004-2005. There is a lot of heterogeneity across the states in terms of their industrial structure, level of cement production and availability of coal which is the major fuel used in this industry. We attempt to investigate the energy-income/output relationship from a production side model which conceptualizes output as a function of energy, capital stock, labor and material. Data regarding output and inputs has been collected from Annual Survey of Industries (1970 NIC code 324 for the years 1979-80 to 1997-98 and 1998 NIC code 269 afterwards). All the nominal variables are converted into real terms with 1993-94 as the base. Output is measured by the value of ex-factory products and by- products, deflated by the whole sale price index for cement. The capital input is measured as a stock by taking the value of fixed capital, deflated by the wholesale price index for machinery and machine tools. Labor is measured by total number of persons employed. Energy is measured in terms of expenditure on fuels deflated by the wholesale price index for fuel, power, light and lubricants. Similarly, the material input is measured by the expenditure on materials, deflated by wholesale price index for non-metallic mineral products. All inputs and outputs are divided by the total number of factories in a particular state so as to obtain information on the variables of a 'typical firm' within each state.[2]

Econometric methodology and results

Following the literature, four steps have been carried out for the cointegration and causality analysis. First, we test for a panel unit root to examine whether or not the variables in our model are stationary. Second, we test for cointegration among the variables employing the heterogeneous panel cointegration test developed by Pedroni (1999). Third, once cointegration relationship is established, we investigate the causal relationship between energy consumption and output growth applying panel vector error correction model. Finally, we estimate long-run elasticities using fully modified OLS technique (Pedroni, 2000).

Panel unit root[3]

In the literature, a number of panel unit root tests have been advanced among which Maddala and Wu (1999), Breitung (2002), Im et al. (2003) are important. But recently Hlouskova and Wagner (2006), by a large scale Monte Carlo simulation, found that the Breitung (2000) panel unit root test has the highest power and smallest size distortions among all other panel unit root tests. Narayan et al. (2009) also used only Breitung (2000) unit root test for their study.

The Breitung (2000) panel unit root test is presented in the following form:

$$y_{it} = a_{it} + \sum_{k=1}^{p+1} b_{ik} X_{i,t-k} + e_t \qquad (1)$$

In Equation (1), the Breitung (2000) test statistic tests the following null hypothesis that the process is difference stationary: $H_0 : \sum_{k=1}^{p+1} b_{ik} - 1 = 0$. The alternative hypothesis assumes that the panel series is stationary, i.e., $\sum_{k=1}^{p+1} b_{ik} - 1 < 0$ for all i. Breitung (2000) uses the following transformed vectors to construct the test statistic:

$$Y_i^* = AY_i = \left[y_{i1}^*, y_{i2}^*, ..., y_{iT}^*\right]^/$$

$$X_i^* = AX_i = \left[x_{i1}^*, x_{i2}^*, ..., x_{iT}^*\right]^/$$

These transformed vectors are then used to construct the following test statistic:

$$l_B = \frac{\sum_{i=1}^{N} s_i^{-2} y_i^{*/} x_i^{*/}}{\sqrt{\sum_{i=1}^{N} s_i^{-2} X_i^{*/} A^/ A X_i^*}} \tag{2}$$

The statistic follows a standard normal distribution.

The results of the Breitung (2000) panel unit root test are reported in Table 1. The test statistics for the log-levels of output, energy, capital, labor and material are insignificant, implying that each of these five variables are panel non-stationary. However, when we apply the panel unit root test to the first difference of the log-levels variables we could reject the null hypothesis of unit root for each of the variables at the 1% level of significance. These results suggest that the five variables contain a panel unit root.

Table 1: Panel unit root test

Variables	Breitung t-test	Probability value
Levels		
Output	1.9849 (4)	0.9764
Energy	-0.0570 (1)	0.4772
Capital	-1.2034 (3)	0.3810
Material	1.8587 (4)	0.9685
Labor	-1.2529 (4)	0.2710
First difference		
Output	-8.7929 (3) *	0.0000
Energy	-12.2928 (1) *	0.0000
Capital	-9.9779 (1) *	0.0000
Material	-6.9659 (4) *	0.0000
Labor	-10.3750 (3) *	0.0000

Notes: Breitung unit root test was carried out with individual trends and intercept for each series. All variables are in natural logarithm. Number in the parenthesis denotes optimal lag length selected automatically using the Schwarz information criteria. The null hypothesis is unit root. * denotes statistical significance at 1% level.

Panel cointegration

Once it is found from the unit root test that the variables are non-stationary, i.e., they are integrated of order one, then the next step is to apply cointegration analysis to examine whether a long run cointegration relationship exists among those variables. In this study, we apply Pedroni's method of cointegration as it allows for heterogeneity across individual members of the panel. In its most general form, he considered the following type of regression:

$$y_{it} = a_i + d_i t + b_i X_{it} + e_{it} \qquad (3)$$

where X_{it} is an m - dimensional column vector for each member i and b_i is an m - dimensional row vector for each member i of the panel. The variables y_{it} and X_{it} are assumed to integrated of order one, denoted by I(1), for each member of i of the panel, and under the null of no cointegration the residual e_{it} will also I(1). The parameters a_i and d_i allow for the possibility of member specific effect and deterministic trend respectively. The slope coefficients b_i s are also permitted to vary across individuals, so that, in general, the cointegrating vectors may be heterogeneous across members of the panel. Therefore, four statistics are developed to test the unit roots of the estimated residuals that are based on the "within-dimension" approach, which pools the autoregressive coefficients across members of the panel. These four statistics are: (a) the panel variance –statistic, (b) the panel rho-statistic, (c) the panel PP-statistic, and (d) the panel ADF-statistic. In addition, Pedroni (1999) has also developed a test based on the "between dimensions" approach, which simply averages the individually estimated coefficients for each member using three statistics: (e) the group rho-statistic, (f) the group PP-statistic, and (g) the group ADF-statistic (see Pedroni 1999, 2004 for details about these statistics). The distributions of these seven statistics are all asymptotically standard normal. Each of these tests is able to accommodate individual specific short-run dynamics, individual specific fixed effects and deterministic trends as well as individual specific slope coefficients (Pedroni, 2004).

Table 2: Pedroni panel cointegration tests

Test statistics	Fixed time effects	No time effects
Panel v	0.5037	-0.5710
Panel rho	-0.1390	-1.5797
Panel PP	-7.6145 *	-4.9733 *
Panel ADF	-7.9684 *	-4.8763 *
Group rho	1.9308	0.9255
Group PP	-7.8434 *	-2.9020 *
Group ADF	-6.7372 *	-2.8462 *

Notes: Statistics are asymptotically distributed as normal. The panel v-test is right-sided, while the others are left sided. * implies rejection of the null of no cointegration at the 1% level.

The results of the panel cointegration test are reported in Table 2. Note that the dependent variable is log of output. Except for the Panel variance, the Panel rho and the Group rho statistics, all other statistics significantly reject the null of no cointegration.[4] Thus it can be inferred from the cointegration result that there exists a co-movement among output, capital, labor, material and energy in the long-run.

Panel causality test

Once the variables are cointegrated, the next step we perform is the causality test. We, therefore, use a panel-based vector error correction model (VECM) to identify the existence and direction of long-run equilibrium relationship, using the two-step procedure of Engle and Granger (1987). In the first step, we estimate the long run model like equation (4):

$$\ln Y_{it} = a_{it} + d_{it} t + g_{1i} \ln E_{it} + g_{2i} \ln K_{it} + g_{3i} \ln L_{it} + g_{4i} \ln M_{it} + e_{it}, \qquad (4)$$

where Y, E, K, L and M stand for output, energy, capital, labor and material respectively.[5] Estimating equation (4) we have obtained the estimated residual e (the error correction term; ECT hereafter). In the second step, we estimate the panel granger causality model with dynamic error correction as follows:

$$\Delta Y_{it} = q_{1j} + l_{1i} ECT_{it-1} + \sum_k q_{11ik} \Delta Y_{it-k} + \sum_k q_{12ik} \Delta E_{it-k} + \sum_k q_{13ik} \Delta K_{it-k} + \sum_k q_{14ik} \Delta L_{it-k}$$
$$+ \sum_k q_{15ik} \Delta M_{it-k} + u_{1it} \qquad (5)$$

$$\Delta E_{it} = q_{2j} + l_{2i} ECT_{it-1} + \sum_k q_{21ik} \Delta E_{it-k} + \sum_k q_{22ik} \Delta Y_{it-k} + \sum_k q_{23ik} \Delta K_{it-k} + \sum_k q_{24ik} \Delta L_{it-k}$$
$$+ \sum_k q_{25ik} \Delta M_{it-k} + u_{2it} \qquad (6)$$

where Δ denotes first difference and k is the lag length. We use an instrumental variable estimator to eliminate the correlation between the error term and the lagged dependent variables in the dynamic panel data model. Optimum lag length is chosen at k=3 because when k=3, the error term satisfies all the essential classical assumptions. We use four and five periods as instrument for the lagged dependent variable following Lee et al. (2008). The labor force, capital stock and material equations are omitted here because our aim is to examine causality between energy and output only.

The sources of causation can be identified by testing the significance of the coefficients of the dependent variables in Eq. (5) and Eq. (6). For short-run causality, we test the null hypothesis $H_0 : q_{12ik} = 0$ for all i and k in Eq.(5) or $H_0 : q_{22ik} = 0$ for all i and k in Eq.(6). Masih and Masih (1996) and Asafu-Adjaye (2000) interpreted the 'short run' causality as weak Granger causality.

Another possible source of causation is the ECT in Eqs. (5) and (6). The coefficients of the ECTs, l, is called speed of adjustment which represents how fast deviations from the long- run equilibrium are eliminated following changes in each variable (Mehrara, 2007). For long- run causality, we test $H_0 : l_{1i} = 0$ for all i in Eq. (5) or $H_0 : l_{2i} = 0$ for all i in Eq. (6). For example, if, $l_{1i} = 0$, then output (Y) does not respond to a deviation from the long- run equilibrium in the previous period. Indeed $l_{1i} = 0$ or $l_{2i} = 0$ for all i is equivalent to both Granger non-causality in the long run and weak exogeneity (Hatanaka, 1996 in Mehrara, 2007).

Finally, we test whether the two sources of causation are jointly significant. This is done by testing the joint hypothesis $H_0 : l_{1i} = 0$ and $q_{12ik} = 0$ for all i and k in Eq.(5) or $H_0 : l_{2i} = 0$ and $q_{22ik} = 0$ for all i in Eq. (6). We use standard F-test to test the hypothesis of joint significance. Results of panel causality test are reported in Table 3.

Table 3: Panel causality tests results

Dependent Variable	Sources of causation (independent variable)										
	Short-run					Long-run					
	ΔY	ΔE	ΔK	ΔL	ΔM	ECT	(ECT, Y)	(ECT, E)	(ECT, K)	(ECT, L)	(ECT, M)
ΔY	-	23.59*	37.28*	11.84*	31.25*	6.59*	-	24.04*	38.24*	11.95**	31.43*
ΔE	57.49*	-	43.36*	6.17	26.37*	6.70*	58.37*	-	44.85*	7.15	28.38*

Note: All values inside the table are F-statistics
* and ** denote statistical significance at 1% and 5% level respectively.
For long run causality, we have tested the joint significance of error correction term ECT with lag terms of the variables. Due to space problem, we have omitted the Δ sign before the variables.

As it is clear from Table 3, the coefficients of E and ECT are significant at 1% level in output equation. Again, coefficients of Y and ECT are also significant at 1% level in energy equation. This implies that there is both short run and long run bi-directional causality between energy consumption and output growth in Indian cement industry. Moreover, the ECT, combined with the joint tests of E, K, L and M in output equation are statistically significant at 1% level, implying all these variables play important roles in determining output and correspond with theoretical expectations. Similarly, in the energy equation, the joint tests of ECT with other variables are significant except labor, implying capital and material determine energy demand both in the short run and in the long-run.

Our finding of bi-directional causality between energy consumption and output growth in Indian context is consistent with the findings of Paul et al. (2004), though their study used aggregated Indian data covering the period 1950 to 1996, while ours is a disaggregated study considering only cement industry for the period 1979-80 to 2004-05.

Panel long-run elasticities

Once the direction of long-run causality is established, the final step is to estimate the long-run elasticities. Following Pedroni (2000), the fully modified OLS (FMOLS)[6] estimates for heterogeneous cointegrated panel are estimated. Table 4 displays FMOLS estimates.

Table 4: Fully modified OLS estimates

Dependent variables	Independent variables				
	Y	E	K	L	M
Y	-	0.34(23.74)*	0.15 (6.03)*	0.05(6.48)*	0.58 (37.64)*
E	0.62(24.39)*	-	-0.13(5.68)*	0.11(1.09)	0.77(13.97)*

Note: All variables are in natural logarithmic form. *t*-values are given in the parenthesis. * indicates significant at 1% level.

Since our causality test confirms bi-directional causality between output and energy consumption, we estimate FMOLS considering both output and energy as dependent variables and estimate two separate equations to obtain elasticity of output with respect to energy and vice versa.

When output is considered as a dependent variable, all the independent variables are significant at 1% level. Since all the variables are converted into logarithmic form, coefficients of the independent variables can be considered as long-run elasticities. Elasticity of output with respect to energy is 0.34, implying a 1% increase in energy consumption increases output by 0.34%. While elasticity of energy with respect to output is 0.62, implying a 1%increase in output increases energy consumption by 0.62%. The coefficient of capital in the energy equation is negative, implying that firms with more capital consume less energy to produce a given level of output. This result indicates that energy saving is a capital intensive process.

Concluding remarks and policy implications

The purpose of this paper is to examine the existence and direction of causal relationship between energy consumption and output growth in the context of Indian cement industry. Using data for 18 major cement producing states, and by applying panel vector error correction model, the study establishes a bi-directional causality between energy consumption and output growth for the study period 1979-80 to 2004-05. This bi-directional causality implies that energy consumption and output growth are jointly determined and affect each other at the same time. Energy might Granger cause output because it is an important input in the production process. Output might Granger cause energy because expansion of output requires additional energy consumption, particularly when degree of substitution between energy and non-energy inputs is very low, which is true for this energy intensive industry. However, elasticity of output with respect to energy is lower than elasticity of energy with respect to output. A 1 per cent increase in energy consumption increases output by 0.34 per cent, while a 1 per cent increase in output increases energy consumption by 0.62%.

In the presence of bi-directional causality, energy conservation measures may negatively affect economic growth (Yoo, 2006). So, in the context of Indian cement industry, the energy conservation policies may prevent the growth of this sector. Therefore, the industry faces dual challenges. On the one hand, due to governments' emphasis on infrastructure building where cement is used as a core input, the industry is likely to experience a rapid growth which could be achieved only by massive consumption of energy. This calls for energy conservation policies to be implemented for reducing energy consumption by this industry. On the other hand, stringent energy conservation policies may negatively affect the growth of this industry due to the very nature of energy-output causality found in this sector.

Technology has an important role to play in tiding over these dual challenges. If the energy conservation policies could induce the industry for technological innovation and adoption of energy efficient technologies, it would serve the dual objectives of reducing energy consumption and its adverse effect on environment, while avoiding the negative effect of lowering energy consumption on output growth (Mishra et al. 2009). In Indian cement industry, successful efforts have been made to develop and adopt energy efficient technologies. As a result, there has been a major shift from the energy intensive 'wet process' to less energy intensive 'dry process'. Today, around 93% of the Indian cement plants are based on 'dry processes' and the industry mostly follows the world's best practice technologies.

Therefore, we conclude by suggesting that energy conservation policies could be implemented in this industry, but such policies must be carefully framed with a continuous encouragement and support from the governments for adoption of energy efficient technologies.

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End Notes

[1] For details of the energy efficiency policies initiated by the Indian Government, see Yang, 2006.

[2] This approximation of firm level data of the industry is not absolutely perfect because, here, we assume that all firms in a particular state produce equally using equal amount of inputs. In the absence of firm level data within the states, we have used this kind of approximation. Mukherjee (2008), in the context of Indian manufacturing, also used the same approximation.

[3] The discussion of Breitung panel unit root test draws heavily on Narayan and Smyth (2009).

[4] Pedroni (1999) shows that the panel-ADF and group-ADF tests have better small-sample properties than the other tests, and hence, they are more reliable (Lee et al.2008).

[5] Following Lee et al. (2008), we have used Cobb-Douglas functional form to estimate the long-run equilibrium relationship among the variables.

[6] FMOLS takes care the simultaneity between output and energy.

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