ENERGY-GDP CAUSAL RELATIONSHIP FOR PAKISTAN: A GRAPH THEORETIC APPROACH

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Abstract

The question of causal relationship between energy consumption and economic growth has significant importance in energy economics. This study aims at investigating "does energy consumption cause economic growth or economic growth leads to more energy consumption?" For this purpose, departing from the standard Granger approach of causality we employ "Graph Theoretic Approach for Causal Inference" in a multivariate framework for Pakistan using the annual data over the period of 1971-2005. Graph theoretic models provide an effective mathematical tool for researchers to determine causal direction and manipulate them in relation to the associated probability distributions. Particularly, these graphical patterns require a definite relationship of conditional independence and dependence among the variables. The empirical findings of the study show that one–way causality is running from energy consumption to economic growth. It implies that while designing energy policy, policy makers should take into account the impact of any energy conservation policy on economic growth.

Keywords: Graph Theoretic Models, Causation, Causal Search Algorithms, Energy-GDP Causal Relationship

1. Introduction

Energy works as lifeblood to meet the needs of an escalating activity of the economy. It is a prime source of value in the production and manufacturing of all goods. The increasing significance of the value of the energy in growth and development of the nation attracted the attention of the researcher in finding the relationship between energy consumption and economic growth. Therefore, one finds substantial amount of literature on the subject.

The aim of the present study is to determine the causal relationship between energy consumption and economic growth. We make a contribution to this debate in the following manner. Firstly, by departing from the traditional approaches to search cause and effect relationship we have adopted "graph-theoretic approach" of causal search algorithm to find the causal relationship between energy consumption and economic growth for Pakistan in a multivariate framework. Secondly, it is probably the first study on the subject where graph theoretic approach has been used. Against the backdrop of recent energy crisis in Pakistan it has become really important for the policy makers to determine how energy conservation policies can be adopted without having a compromise on economic growth.

The pioneering study on the issue was conducted by Kraft and Kraft (1978).They utilized Sims (1972) approach to find the causal relationship between gross energy inputs

and Gross National Product (GNP) for USA using the annual data over the period of 1947–1974. They find an evidence of unidirectional causality running from GNP to energy consumption which implies that economic activity may influence energy consumption but energy consumption has no causal influence on economic growth. Akarca and Long (1980) use the same data over the period of 1947-1972 and fail to support Kraft (1978) results. Yu and Jin (1992) use monthly data over the period 1974:1–1990:4 for the USA and examine the causal relationship between energy consumption, GNP and employment. They do not find any causality between energy consumption and economic growth, and support Akarca and Long (1980) results.

Previous work for discussing the causal relationship between energy consumption along with its various components and economic growth in Pakistan has prompted with Masih and Masih (1996) investigate the mutual causality for Pakistan while Aqeel and Butt (2001) report that economic growth causes total energy consumption. Asghar (2008) shows that causality runs from GDP to total energy consumption for Pakistan. Hence the canvasses of literature on the causal relationship between energy consumption and economic growth are replete with mixed results. These results have central importance for the researchers and policy makers in decision making regarding energy conservation. Some of these can be classified as under:

The unidirectional causality has been investigated between energy consumption and economic growth running from energy consumption to economic growth by Masih and Masih (1996) for India, Asafu-Adjaye (2000) for India and Indonesia for the period 1973-1995, Stern (2000) for USA, Soytas and Sari (2003) for Turkey, France, Germany and Japan, Wolde-Rufael (2004) for Shanghai. This signifies an energy dependent economy context. In other words, energy is a stimulus for economic growth and shortage of it may negatively affect economic growth. While Masih and Masih (1996) for Indonesia, Cheng and Lai (1997) for Taiwan for the period 1955-1993, Soytas and Sari (2003) for Itlay and Korea, Fatai et al. (2004) for Newzeland and Australia, Yang (2000) for Taiwan, Paul and Bhattacharya (2004) for India, Oh and Lee (2004) for Korea, Ghali and Saka (2004) for Canada, Zamani (2007) for Iran and Erdal and Esengun (2008) for Turkey report bidirectional causality between energy consumption and economic growth, which indicates that both high level of economic activity and energy consumption mutually influence each other.

While no causality (Altinay and Karagol (2004) for Turkey and Asghar (2008) for India) between energy consumption and economic growth referred to as "neutrality hypothesis" implies that energy conservation policies may be pursued without adversely affecting the economy.

The new scientific approach of causal search named as "graph theoretic" has several advantages over the more commonly used causality tests. First, causality tests (mainly based on Granger causality) constitute statistical tests for temporal ordering and do not allow for analyzing the causal relationship between contemporaneous variables while the graph-theoretic approach can be applied to contemporaneous variables in a straightforward manner. Second, Granger causality tests are generally run on a small set of pre-specified, reduced form equations that are only consistent with a limited set of true structural relationships. However, as shown by Spirtes et al. (2000, pp.191-194), an incorrect choice of independent variables may result in improper causal inferences. In contrast, the graph-theoretic approach is used to determine the correct set of independent variables (Perez and Seigler (2006).

We employ one of the graph theoretic causal search algorithm known as PC algorithm that can easily be implemented in TETRAD IV software. A brief description of PC algorithm is given in the section on methodology. Following Asafu-Adjaye (2000) we have used energy consumption, economic growth and energy prices. However, we have also used gross capital formation as a proxy for investment variable. An increase in investment may imply an increase both in energy consumption and economic growth. It has also been suggested in energy economics literature that capital stock, export, employment etc should be included explicitly in the model while exploring causal direction between energy consumption and economic growth. Therefore, we have used these four variables namely gross capital formation as a proxy for investment, economic growth, energy consumption and energy price.

In section two, we have described methodology for working on Graph theoretic approach and in section three empirical analyses have been discussed while in the last section of the paper we conclude.

2.   Methodology and Data

The following procedures are employed here sequentially in order to test the causality between energy consumption and economic growth.

- Unit root test
- Vector autoregressive (VAR)
- Direction of causation determined through Graph Theoretic Approach **(PC Algorithm)**

The simple structural VAR model can take the form as follows:

$$\Gamma Y_t = B(L)Y_{t-1} + \varepsilon_t \qquad (2.1)$$

Where Y_t is a n x 1 vector of contemporaneous variables, Γ is n x n matrix and B (L) is polynomial in lag operator. ε_t is a n x 1 vector of serially uncorrelated disturbances and shocks which can be assigned to a particular equation because the covariance matrix $\sum = E(\varepsilon\varepsilon^{/})$ is diagonal.

Reduced form of model 2.1 can be derived by premultiplying Γ^{-1} on both sides of the equation (2.1)

$$Y_t = \Gamma^{-1}B(L)Y_{t-1} + \Gamma^{-1}\varepsilon_t$$
$$Y_t = B^{*}(L)Y_{t-1} + U_t \qquad (2.2)$$

Where B*= $\Gamma^{-1}B$ and $\Gamma^{-1}\varepsilon_t = U_t$ for all t= 1,2,. . . .,T.

If we know Γ then equation (2.1) can be easily recovered from the estimates of equation (2.2) but the covariance matrix $\Lambda = (UU^{/})$ of the disturbance term U_t is no more a diagonal matrix. Therefore, it is not possible to evaluate the effect of individual shocks to the particular variables of the system.

For known Γ, identification problem reduces but for unknown Γ there is need to impose restrictions on Γ matrix. For the true identification scheme first we need to fulfill the property of orthogonal innovation and use transformations to make the covariance

matrix diagonal. Let P be the set of orthogonal transformation i-e $P = \{P_i\}$. However, there are a large number of P_i matrices of order n x n that may be used by premultiplying equation (2.2) to make the covariance matrix $\Omega = E(P_i^{-1}U(P_i^{-1}U)^{/})$ diagonal. Main issue in identification is to select one member of P_i ($P_i = \Gamma$) that corresponds to the true data generating process when Γ is unknown.

To resolve the problem of identification we have to impose restrictions on P_i. For the identification of P_i we have to impose $n(n-1)/2$ restrictions on P_i. These restrictions can be imposed in several ways. Most of the researchers confine themselves to just identify the lower triangular matrices. The selection of P_i matrix through 'just identified scheme' is called Choleski decomposition and there are generally n! Choleski orderings, and each corresponds to Wold or recursive casual order of the variables in Y.One of these Choleski orderings can be used for the identification of Pi. Choleski transformation is observationally equivalent in the sense that different structural models give rise to the same reduced form.

In case we restrict ourselves to just identified SVAR, issue of interest is choose one Choleski ordering out of n! Choleski orderings. Sometimes economic theory is considered to get 'just identification' but mostly researchers decide arbitrarily to get 'just identified' SVAR.

Rather than restricting ourselves to 'just identified' SVAR, if we have over identified SVAR then we have another option of choosing P_i. Hoover, Demirlap, and Perez (2008) state that "If, however, the true SVAR is over identified, then we have another option. Graph theoretic causal search provides a method of choosing **P***i*, very much in the spirit of Hendry's general to specific model selection."

According to the Cowles Commission approach, an econometric model consists of two unrelated parts: Probability distribution of the variables and causal structure. Pearl (2000) and Sprites et al. (2000) give a justified way to maintain this track of causal relationship. They show that there is isomorphism between graph and probability distribution of the variables. Graph theory provides an effective mathematical tool to determine causal direction and to manipulate them in relation to the associated probability distributions. Particularly these graphical patterns require definite relationship of conditional independence and dependence among the variables. Working backward from statistical measures of conditional independence and dependence, it is possible to infer the class of graphs compatible with the data. Sometimes that class has only a single member, and then A_0 can be identified statistically".

The details of some terms used in graph theoretic approach are given as:
Causal relations between pair of variables represented by straight lines are known as links or edges. An edge may represent as follows:
- ❖ No edge (A   B)
- ❖ Undirected edge: (A—B)
- ❖ Unidirectional edge: (A→B) or(A←B)
- ❖ Bidirectional edge: (A←→B)

The map showing the causal links between set of variables with their direction is known as causal graph. In a causal graph, the arrowhead shows the direction of causation. Merely representation of variables by graph ignoring the direction of arrowhead is the skeleton of the graph. A path is a sequence of causal link between two variables. It may be directed or undirected for example if X is a common cause between Y and Z, and Y

causes Z then XYZ is a direct path between X and Z. Suppose Y←X→Z ,here YXZ is a path but not a direct path from Y to Z. If there is a direct path between X and Y then X is an ancestor of Y and Y is descendent of X. A graph is said to be acyclic if there are no direct paths from a descendent to its own ancestor. If every cause of all variable in a graph is also a variable in that graph, then the graph is causally sufficient. If we have three variables X, Y, Z and Y←X→Z then Y and Z would be dependent but conditional on X they would be independent, and then X is called the common cause of Y and Z. If the causal connection between X, Y, Z is shown as X→Z←Y and there is no direct path between X and Y then Z is an unshielded collider between X and Y and if there is a direct link between X and Y then Z is said to be a shielded collider.

> *"A graph and probability distribution is said to be faithful if and only if there is one to one correspondence between conditional independence relationship implied by causal Markov condition and the probability distribution. Any probability distribution that can be faithfully represented in a causally sufficient, acyclical graph can be equally well represented by any other acyclical graph that has the same skeleton and the same unshielded colliders"* (cf. Spirtes et al., 2000, ch. 4).

As a result, there may be observationally equivalent causal structures in which some causal links are reversed but all unshielded colliders preserved. In such cases, the algorithm leaves the reversible links undirected. This partial causal ordering defines an equivalence class whose members correspond to the permutations of the orientations of the undirected links. A just-identified model has no unshielded colliders. It follows immediately that all just identified models are observationally equivalent" (Demirlap and Hoover 2003).Graph theoretic approach have many causal search algorithm. The PC algorithm is one of the most commonly used causal search algorithm. It assumes that graphs are acyclical. Demirlap and Hoover (2003) shows that PC algorithm is a very efficient tool to recover the skeleton of data generating process and intermediately effective to detect the direction of each causal link even though signal to noise ratios are high. The detail of PC algorithm is as follows:

It assumes that graphs are acyclical or strictly recursive – that is, loops in which $A \rightarrow B \rightarrow C \rightarrow A$ are ruled out. Hoover (2005) illustrates following steps of this algorithm.

(1)   It starts with the complete set of variables in the VAR in which all variables are connected by undirected edges, i.e. a line without arrow head.

(2)   It then tests for unconditional correlation among all pairs of variables, and removes any edge for which unconditional correlation is zero.

(3)   Test for correlation among pair of variables conditioning on one other variable, again removes any edge for which conditional correlation vanishes .It then tests for conditioning on two, three variables until all variables are exhausted. This results in a skeleton. Orientation of edges has been carried out in the next three steps.

(4)   The algorithm starts orienting edges by seeking triples of linked $(A—B—C)$ variables. For each conditionally uncorrelated pair of variables (i.e ones without a direct link)that are connected through third variables (A—B—C) to test whether they become correlated conditional on that third variable(B) or not. This is the pattern of an unshielded collider, where (B) is

unshielded collider. Then orient the edges pointing toward unshielded collider $(A \rightarrow B \leftarrow C)$.

(5)   If two variables (A and B) are not directly connected, but are connected through a third variable (C), so that one link points to the third variable (say, $A \rightarrow C$) and the other link is undirected ($C\!\!-\!\!B$),then the undirected link is pointed away from third variable($C \rightarrow B$) This follows because, orienting the arrow toward C will make again unshielded collider which is already completed in previous step.

(6)   Some edges may be oriented logically (rather than statistically), based on maintaining the assumption of acyclicality and avoiding implying the existence of unshielded colliders not identified statistically.

Further in applications, Fisher's z statistics is used to test whether the conditional correlations are significantly different from zero.

3   Data and Empirical Results

We use annual data for Pakistan (1971-2005), for energy consumption (energy), economic growth (real GDP), energy prices (prices) and gross capital formation (CF). We have used gross capital formation as a proxy for investment variable. An increase in investment may imply an increase both in energy consumption and economic growth. Therefore, we have included this variable in order to see direct or indirect impact of investment both on energy consumption and economic output. We have used the consumer price index (base year 2000) to proxy energy prices following Fatai et al (2004). Energy consumption is measured in kg of oil equivalent per capita. We use data set available through international financial statistics (IFS CD-ROM), except energy consumption for which we have used World Development Indicator *(source website: econo.worldbank.org*.). All variables are also transformed into natural logarithm.

In order to test the stationarity of the series we employ Augumented Dicky Fuller test of unit root. The results of the ADF test shows that all the series are first difference stationary at 5% level of significance.

Table 1. Results of ADF Test for Unit Root

Variables	Test statistic		5% critical value	
	Levels	**First difference**	**Levels**	**First difference**
Energy	-0.433312(0)	-5.036706(0)	-2.9499	-2.9527
Prices	-2.448686(1)	-3.887008(1)	-2.9527	-2.9558
GDP	-1.035809(0)	-4.806057(0)	-2.9499	-2.9527
CF	-1.932799(1)	-4.326631(1)	-2.9527	-2.9558

     * Lag length is given in parenthesis

After testing the existence of the unit root and finding that all variables are first difference stationary we estimate the VAR models on first differenced variables by using the software EVIEWS. By using the innovations obtained from these SVAR models we run the PC algorithm and record the results. TETRAD IV software is used to analyze the causal relationship between energy consumption, economic growth, energy prices and

capital formation. In PC algorithm it is assumed that graphs are acyclical. Demirlap and Hoover (2003) shows that PC algorithm is very efficient tool to recover the skeleton of data generating process and intermediately effective to detect the direction of each causal link even though signal to noise ratios are high enough.

As Spirtes et al (2000) algorithms do not work directly for time-dependent data, so we use residuals obtained from VAR to prefilter the data to remove time dependence as suggested by Swanson and Granger (1997). The results of PC causal search algorithm for prefiltered data are shown in figure B. Figure A shows all possible edges among the variables included in the model.
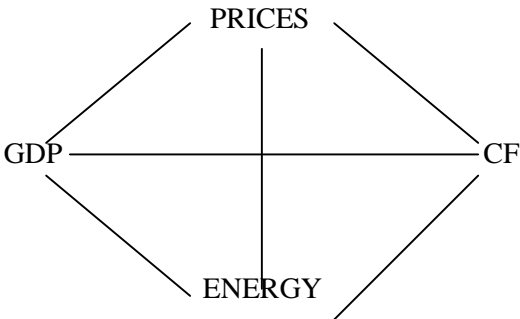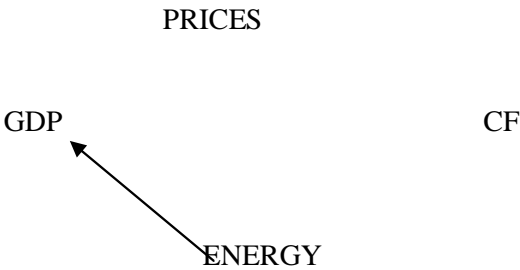

Figure A

Figure B

We started our graph with all possible edges among the variables (Figure A) and then using PC algorithm all edges are eliminated but an arrow indicating unidirectional causality running from energy consumption to economic growth (figure B) still exists. Absence of lines among other variables in figure B indicates that they are independent of each other. The results verify the hypothesis that energy consumption stimulates economic growth.

4. Conclusions

Pakistan has been facing serious energy crisis for the last four years and its economic performance has also declined over this period from an economic growth of over 8% in 2005 to around 2% in 2008-09. Moreover, the performance of the manufacturing sector, which is one of the most energy dependent sectors, has declined from 18% in 2005 to almost 1% in 2008-09. With the present analysis it can be suggested

that being an energy dependent economy, the energy conservation polices may significantly retard the economic growth of the country. This may not be affordable in the prevalent scenario of poor economic performance, and deteriorating law and order situation in the country as well.

The present and future growth prospects of economy would considerably be hampered due to shortage of energy. So, bridging of energy demand-supply gap should be one of the top most priorities of the present government. The results indicate that any policy to conserve energy may adversely affect economic performance. Where as for a developing country like Pakistan the challenge is to expand and improve the provision of energy services to industrial and commercial sector in order to arrest her declining economic growth.

This challenge can be met through: demand-or supply side management of energy resources, and more investment in R&D in the energy sector. In demand side management, conservation of energy by switching to more efficient energy using devices, shifts in transport mode, fuel switching, good house keeping practices, energy metering, use of energy saving material in construction etc could be done. In supply side management, there is no easy way to explore new and alternative resources without having sufficient R&D in the energy sector and/or foreign investment.

The empirical results presented here are quite substantive. At the same time they are also, and perhaps more importantly, an explicit illustration of the method of PC algorithm. However, it also implies that causal linkage among energy and several other variables needs to be further investigated. For future research there is a gratifying way by proceeding further into exploring whether energy conservation policies affect economic growth or not by including some other relevant variables like employment, export and components of energy consumption as well as total energy consumption uses index without considering the domestic and/or foreign supply constraint.

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Appendix-A.

Table 2. Results of VAR(2) for Pakistan

Standard errors & t-statistics in parentheses				
	EN	GDP	PRICE	CF
EN(-1)	-0.424695	-0.007695	0.212537	1.240533
	(0.23644)	(0.28915)	(0.45267)	(1.33999)
	(-1.79623)	(-0.02661)	(0.46952)	(0.92578)
EN(-2)	-0.199376	-0.348531	-0.109881	-0.994604
	(0.20914)	(0.25577)	(0.40041)	(1.18529)
	(-0.95331)	(-1.36268)	(-0.27442)	(-0.83912)
GDP(-1)	0.485774	0.338263	0.209136	0.383884
	(0.18035)	(0.22056)	(0.34530)	(1.02215)
	(2.69344)	(1.53363)	(0.60567)	(0.37557)
GDP(-2)	0.332752	0.334235	-0.092297	0.021753
	(0.20021)	(0.24485)	(0.38331)	(1.13467)
	(1.66202)	(1.36509)	(-0.24079)	(0.01917)
PRICE(-1)	-0.036112	0.083589	0.796638	0.968735
	(0.07764)	(0.09495)	(0.14865)	(0.44003)
	(-0.46511)	(0.88033)	(5.35919)	(2.20152)
PRICE(-2)	0.045885	-0.135671	-0.183148	0.247244
	(0.09340)	(0.11422)	(0.17882)	(0.52934)
	(0.49127)	(-1.18777)	(-1.02421)	(0.46708)
CF(-1)	-0.068839	-0.039509	-0.008499	0.181424
	(0.03769)	(0.04610)	(0.07217)	(0.21363)
	(-1.82621)	(-0.85704)	(-0.11777)	(0.84923)
CF(-2)	-0.050506	0.015849	-0.024256	-0.225591
	(0.03402)	(0.04160)	(0.06513)	(0.19278)
	(-1.48477)	(0.38100)	(-0.37245)	(-1.17017)
C	0.004387	0.031300	0.026187	0.028827
	(0.01136)	(0.01389)	(0.02174)	(0.06437)
	(0.38623)	(2.25356)	(1.20436)	(0.44786)