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Hierarchical structure of the countries based on electricity consumption and economic growth

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HIGHLIGHTS

- We examined the hierarchical structures of EC of countries.
- The relationships between EC and GDP in countries are studied.
- We constructed networks by using hierarchical structure methods.
- We carried out bootstrap technique to determine the reliability of the links.
- A strong relation between energy consumption and economic growth is found.

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ABSTRACT

We investigate the hierarchical structures of countries based on electricity consumption and economic growth by using the real amounts of their consumption over a certain time period. We use electricity consumption data to detect the topological properties of 64 countries from 1971 to 2008. These countries are divided into three clusters: low income group, middle income group and high income group countries. Firstly, a relationship between electricity consumption and economic growth is investigated by using the concept of hierarchical structure methods (minimal spanning tree (MST) and hierarchical tree (HT)). Secondly, we perform bootstrap techniques to investigate a value of the statistical reliability to the links of the MST. Finally, we use a clustering linkage procedure in order to observe the cluster structure more clearly. The results of the structural topologies of these trees are as follows: (i) we identified different clusters of countries according to their geographical location and economic growth, (ii) we found a strong relation between energy consumption and economic growth for all the income groups considered in this study and (iii) the results are in good agreement with the causal relationship between electricity consumption and economic growth.

1. Introduction

Electricity consumption has become a topic of immense importance. The growing interest in developed and developing countries has largely been triggered by the growing demand for energy across the world fueled mainly by increasing

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economic activities, particularly in emerging countries. Estimating electricity consumption in advance is crucial in the planning, analysis and operation of power systems in order to ensure an uninterrupted, reliable, secure and economic supply of electricity. Moreover, modeling and predicting electricity consumption play a vital role in developed and developing countries for policy makers and related organizations. The causal relationship between electricity consumption and economic growth has been investigated and the empirical literature has focused on four hypotheses when dealing with the causal relationship between electricity consumption and economic growth: conservation, growth, feedback, and neutrality. The first is the conservation hypothesis which is supported if an increase in economic growth causes an increase in electricity consumption. Under this scenario, an increase in economic growth would have a negative impact on electricity consumption. The second is the growth hypothesis which supposes that electricity consumption can directly impact on economic growth and indirectly as a complement to labor and capital in the production process. The growth hypothesis verified if there is a unidirectional causality from electricity consumption to economic growth. If this is the case, an increase in electricity consumption has a positive impact on economic growth; energy conservation oriented strategies that decrease electricity consumption may have a harmful impact of economic growth. Thirdly is a feedback hypothesis which highlights the interdependent relationship between electricity consumption and economic growth. The existence of bidirectional causality between electricity consumption and economic growth provides support for the feedback hypothesis. Fourth, the neutrality hypothesis suggests that energy consumption provides a relatively trivial position in the determination of economic growth.

Payne [1] compares the various hypotheses associated with the causal relationship between electricity consumption and economic growth using a survey of the empirical literature. The results illustrate that 31.15% supported the neutrality hypothesis; 27.87% of studies the conservation hypothesis; 22.95% the growth hypothesis; and 18.03% the feedback hypothesis.

There are several studies in the empirical literature on the causal relationship between electricity consumption and economic growth. Summary of recent literature review for energy consumption and economic growth is given in Refs. [2–4]. Recently, a few papers have focused on the network topology of electricity consumption [5,6]. Kantar et al. [5] investigated by using the minimum spanning tree (MST) approach the relationship between energy consumption and economic growth in a sample of 30 Asian countries covering the period 1971–2008. Akkaya Deviren [6,7] studied the topological relationships among the CO_2 emissions, per capita of Gross Domestic Product (GDP) and electricity consumptions by using the concept of hierarchical structure methods for over the period of 1970–2010.

The topic of the causal relationship between energy consumption and economic growth has been well studied in the energy economics literature. Different studies have focused on different countries, time periods, proxy variables and different econometric methodologies have been used to determine the energy consumption and growth relationship. Moreover, a literature survey on the relationship between energy consumption and economic growth is given in detail by Ozturk [8].

Complex networks provide a very general framework, based on the concepts of statistical physics, for studying systems with large number of interacting assets. These networks have been able to successfully describe the topological properties and characteristics of many real-life systems such as multilocus sequence typing for analyses of clonality [9], scientific collaboration in the European framework programs [10], taxonomy of correlations of wind velocity [11], Brazilian term structure interest rates [12], the international hotel industry in Spain [13], foreign trade [14], energy consumption [5] and countries debts [15]. Moreover, the most recent literature has studied networks generated by correlations of stock prices [16–28]. In this paper, we focus on the electricity consumption and the main objective is to characterize the topology and taxonomy of the network of the countries. To the best of the authors knowledge, this is the first study on electricity consumption and economic growth by using the hierarchical structure methods.

The aim of the present paper is to examine relationships among countries, based on low income group, middle income group and high income group countries, by using the concept of the minimal spanning tree (MST) and hierarchical tree (HT) over the period between 1971 and 2008. From these trees, both geometrical (through the MST) and taxonomic (through the HT) information about the correlation between the elements of the set can be obtained. Note that the MST and then the HT are constructed using the Pearson correlation coefficient as a measure of the distance between the time series. In this paper, we use the Pearson correlation coefficient which is a measure of the strength and direction of the linear relationship between two countries' electricity consumption data that is defined as the covariance of the country' electricity consumption data divided by the product of their standard deviations. Moreover, we use the bootstrap technique to associate a value of reliability to the links of the MST. We also use average linkage cluster analysis to obtain the HT. These methods give a useful guide to determining the underlying economic or regional causal connections for individual countries.

The remainder of the paper is structured as follows. Section 2 briefly introduces the set of empirical data we work with. Section 3 is targeted at presenting the method. Section 4 presents the empirical results. Finally, Section 4 provides some final considerations.

1.1. Minimal spanning tree (MST) and hierarchical tree (HT)

In order to construct the MST following the method suggested by Mantegna [16], the correlation coefficient between a pair of countries based on electricity consumption should be calculated in the first step. The correlation coefficient between