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The relationship between carbon dioxide emission and economic growth: Hierarchical structure methods

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HIGHLIGHTS

- The relationship between CO_2 emission and economic growth is investigated.
- Networks of 33 countries are constructed by using hierarchical structure methods.
- The high income & OECD countries are closely connected to each other.
- G7 countries are located at the center of the MST for CO_2 emission.
- We used average linkage cluster analysis to observe cluster structures more clearly.

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ABSTRACT

Carbon dioxide (CO_2) emission has an essential role in the current debate on sustainable development and environmental protection. CO_2 emission is also directly linked with use of energy which plays a focal role both for production and consumption in the world economy. Therefore the relationship between the CO_2 emission and economic growth has a significant implication for the environmental and economical policies. In this study, within the scope of sociophysics, the topology, taxonomy and relationships among the 33 countries, which have almost the high CO_2 emission and economic growth values, are investigated by using the hierarchical structure methods, such as the minimal spanning tree (MST) and hierarchical tree (HT), over the period of 1970–2010. The average linkage cluster analysis (ALCA) is also used to examine the cluster structure more clearly in HTs. According to their proximity, economic ties and economic growth, different clusters of countries are identified from the structural topologies of these trees. We have found that the high income & OECD countries are closely connected to each other and are isolated from the upper middle and lower middle income countries from the MSTs, which are obtained both for the CO_2 emission and economic growth. Moreover, the high income & OECD clusters are homogeneous with respect to the economic activities and economic ties of the countries. It is also mentioned that the Group of Seven (G7) countries (CAN, ENG, FRA, GER, ITA, JPN, USA) are connected to each other and these countries are located at the center of the MST for the results of CO_2 emission. The same analysis may also successfully apply to the other environmental sources and different countries.

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1. Introduction

The increase of greenhouse gas emissions, especially CO_2 emission, the reason behind the global warming and climate change, is one of the most important issue in the environmental and economical area. The CO_2 emission is directly linked to the economic growth, which is an important factor in the economy of the world both for production and consumption. Also most of the CO_2 emissions come from gaseous/liquid/solid fuel consumption, which is an essential source of the automobile and industry that are closely related to the economic development and economic growth. Therefore the inseparable relationship between the CO_2 emissions and economic growth acts as an important bridge between the economical and environmental policy.

On the other hand, there are a number of studies considering the inseparable relationship between the CO_2 emission and economic growth in recent years. In these studies, different countries, time periods, proxy variables and different methodologies have been used. The relationship between CO_2 emissions and economic growth has been studied by using Auto Regressive Distributed Lag (ARDL) bounds for the selected nineteen countries from the European continent over the period of 1960–2005 [1], for Turkey over the period of 1965–2008 [2], for India with Granger approach [3], for South Korea from 1991 to 2011 with Markov switching model [4], for Japan using time series data for the period of 1960–2009 [5], for Iran with the relatively new time series technique during the period of 1967–2007 [6]. These studies may be useful to formulate policy recommendation from the point of view of energy conservation, emission reduction and economic performance. Moreover, Alkhathlan et al. studied the long run and short run relationships between the CO_2 emissions, economic growth and energy consumption in Saudi Arabia by applying ARDL and Vector Error Correction Model (VECM) techniques [7]. Xingjun et al. investigated the relationship between the economic development and environmental pressures for Chine by using Daly's dematerialization theory from 1968 to 2008 [8]. Also Liao et al. examined the historical relationship of economic development and CO_2 emission as well as robustness from three aspects: data sources, model specifications and estimation methods by employing the CO_2 emission and economic development panel data set of 132 countries in the time period of 1971–2009 and a flexible econometric model [9]. Shafiei et al. examined the relationship between the disaggregated energy consumption and CO_2 emission using the stochastic impacts by regression on population, affluence and technology (STIRPAT) model and data from 1980 to 2011 for OECD countries [10]. The causal link between electricity consumption, economic growth and CO_2 emissions was examined in the BRICS countries (i.e., Brazil, Russia, India, China, and South Africa) for the period 1990–2010, using panel causality analysis, accounting for dependency and heterogeneity across countries [11]. C. Magazzino analyzed the relationship among economic growth, energy use and carbon dioxide (CO_2) emissions in Israel over the period 1971–2006 [12]. The relationship between the CO_2 emission and economic development has been previously studied by using different methods as mentioned in above studies. In guide of the sociophysics, to the best of our knowledge, there is only one study which has been examined the relationship between electricity consumption and economic growth of the Asian countries by using the minimal spanning tree (MST) and hierarchical tree (HT) [13]. Therefore, the main objective of this paper is to characterize the topology, taxonomy and relationships among the 33 countries, which have almost the high CO_2 emission and economic growth values, by using the hierarchical structure methods, such as the MST and HT, over the period of 1970–2010. Both geometrical and taxonomic information about the correlation between the elements of the set can be obtained from these trees. Moreover the average linkage cluster analysis (ALCA) is used to observe the cluster structure more explicitly in HTs. In guide of these methods, the economic and/or regional causal connections can be determined for individual countries. To the best of the authors knowledge, this paper is the first study on the CO_2 emission and economic growth by using the hierarchical structure methods.

The MST and HT introduced by Mantegna [14], and Mantegna and Stanley [15], are methodologically simple approaches using only simple correlations as a starting point with no prior assumptions. These methods have been applied several times on various types of assets and systems, such as foreign exchange rates [16], import/export networks [17], interest rates and network theory [18], commodities [19], general complex system [20], economy analysis [21], portfolio analysis [22], volatility [23], the national debt in European countries [24], stock market analysis [25,26] and international real estate securities markets [27]. The clustering behavior of individual stocks within a single country is studied by using these trees [28–32]. The evolution of interdependence in world equity markets [33], taxonomy of stock market indices [34], European equity markets [35] and commodity markets [36] are also examined by using the MST and HT. It is also mentioned that the dynamic MST was applied to investigate for the market correlations, financial markets, stock returns and price return and volatility in Refs. [22,37,38]. Finally, correlation based clustering has been used to infer the hierarchical structure of a portfolio of stocks from its correlation coefficient matrix [14,39]. Some important examples of correlation based networks apart from the MST are the planar maximally filtered graph [20] and the average linkage MST [17,40–44].

The rest of the paper is organized as follows. In Section 2, we briefly describe the data and the methodology. Section 3 presents numerical results and discussions. Finally, we give a brief summary and conclusion in Section 4.

2. Data and methodology

2.1. Data set

The annual time series data of CO_2 emission are retrieved from Carbon Dioxide Information Analysis Center (CDIAC), which is available online (http://cdiac.esd.ornl.gov/) and covers 33 countries which have almost the high CO_2 emission