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

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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 60 countries from 1971 to 2008. These countries are divided into three subgroups: 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.

Keywords: Hierarchical Structure Methods; Bootstrap Technique; Electricity Consumption and Economic Growth

I. 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 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. The feedback hypothesis 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.

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| Author(s) | Period/Countries | Methodology |
|-----------|------------------|-------------|
| **Unidirectional causality** | | |
| Ghosh [1] | 1950-1997/India | Johansen-Juselius; Granger causality-VAR |
| Narayan et al. [2] | 1966-1999/Australia | ARDL bounds testing; Granger causality |
| Yoo and Kim [3] | 1971-2002/Indonesia | Engle-Granger; Johansen-Juselius; Hsiao’s causality |
| Ho and Sui [4] | 1966-2002/Hong Kong | Johansen-Juselius; Granger causality |
| Mozunder and Marathe [5] | 1971-1999/Bangladesh | Johansen-Juselius; Granger causality |
| Jamil and Ahmad [6] | 1960-2008/Pakistan | Johansen-Juselius; Granger causality |
| Shahbaz and Feridun [7] | 1971-2008/Pakistan | Toda Yamamoto Wald-test causality tests |
| **From electricity consumption to economic growth** | | |
| Aqeel and Butt [8] | 1955-1996/Pakistan | Engle-Granger; Hsiao’s causality |
| Shiu and Lam [9] | 1971-2000/China | Johansen-Juselius; Granger causality |
| Altinay and Karagol [10] | 1950-2000/Turkey | Dolado-Lutkepohl test for causality |
| Lee and Chang [11] | 1954-2003/Taiwan | Johansen-Juselius; Weak exogeneity test |
| Yoo [12] | 1970-2002/Korea | Johansen-Juselius; Granger causality |
| Narayan and Singh [13] | 1971-2002/Fiji Islands | ARDL bounds testing; Granger causality |
| Yuan et al. [14] | 1978-2004/China | Johansen-Juselius; Granger causality |
| Odhiambo [15] | 1971-2006/Tanzania | ARDL bounds testing; Granger causality-VECM |
| Abosedra et al. [16] | 1995-2005/Lebanon | Granger causality |
| Chandran et al. [17] | 1971-2003/Malaysia | ARDL bounds testing; Engle-Granger; Johansen-Juselius; Granger causality |
| Narayan and Narayan [18] | 1980-2006/93 Countries | Granger causality |
| Ahamed and Nazrul [19] | 1997-2008/Bangladesh | Granger causality |
| Bildirici and Kayikci [20] | 1990-2009/11 Commonwealth Independent States | Fully Modified Ordinary Least Squares and Panel ARDL |
| **Bidirectional causality** | | |
| Yang [21] | 1954-1997/Taiwan | Engle-Granger; Granger causality-VAR |
| Jumbe [22] | 1970-1999 Malawi | Engle-Granger; Johansen-Juselius-VECM |
| Zachariadis and Pashourtidou [23] | 1960-2004/Cyprus | Johansen-Juselius; Granger causality-VECM |
| Tang [24] | 1972-2003/Malaysia | Granger causality |
| Tang [25] | 1970-2005/Malaysia | ARDL bounds testing; Granger causality |
| Odhiambo [26] | 1971-2006/South Africa | Johansen-Juselius; Granger |
| Lean and Smyth [27] | 1971-2006/Malaysia | A RDL bounds testing; Johansen-Juselius |
| Ouedraogo [28] | 1968-2003/Burkina Faso | ARDL bounds testing; Granger |
| Shahbaz et al. [29] | 1971-2009/Portugal | Granger causality |
| Kouakou [30] | 1971-2008/Cote d’Ivoire | Granger causality |
| Gurgul and Lach [31] | Q1 2000-Q4 2009/Poland | Toda-Yamamoto |
| Shahbaz and Lean [32] | 1972-2009/Pakistan | Granger causality |
| **Neutrality** | | |
| Wolde [33] | 1971-2001/17 African countries | ARDL Bounds testing; Toda-Yamamoto’s causality |
| Chen et al. [34] | 1971-2001/10 Asian countries | Johansen-Juselius; Granger causality |
| Narayan and Prasad [35] | 1960-2002/30 OECD countries | Toda-Yamamoto’s causality test |
| Payne [36] | 1949-2006 US | Granger causality |
| Ozturk and Acaravci [37] | 1980-2006/4 European countries | ARDL Bounds test and Granger causality |
| Ozturk and Acaravci [38] | 1971-2006 MENA countries | ARDL Bounds test-VECM |

**TABLE I: Summary of literature on electricity consumption - economic growth nexus.**

Payne [39] 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. The results in the literature, however, are ambiguous and are presented in Table 1.
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 detailed by Ozturk [40].

Complex networks provide a very general framework, based on the concepts of statistical physics, for studying systems with large numbers 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 [41], scientific collaboration in the European framework programs [42], taxonomy of correlations of wind velocity [43], Brazilian term structure interest rates [44], the international hotel industry in Spain [45], and foreign trade [46]. Moreover, the most recent literature has studied networks generated by correlations of stock prices [47–60]. 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 author’s 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 1971-2008. 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. 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. The next section briefly introduces the set of empirical data we work with. Sec. III is targeted at presenting the method. Sec. IV presents the empirical results. Finally, Sec. IV provides some final considerations.

II. THE DATA

We chose data on the electricity consumption of 60 low income group, middle income group and high income group countries. We used the data period from 1971 to 2008 and listed the countries and their corresponding symbols in Table 2. The annual amounts were downloaded from the World Bank database (http://data.worldbank.org/).

III. THE METHOD

In this section, we describe the methodology used for the analysis of the data. Recent empirical and theoretical analysis have shown that useful economic information can be detected in a correlation matrix using a variety of methods [47, 48, 50–52, 56, 57, 61–80]. In this paper, we use three different approaches, based on hierarchical methods (MST and HT), the bootstrap technique, and the ALCA technique. We will briefly describe the basic aspects of these three different methods in the subsections.

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

In order to construct the MST following the method suggested by Mantegna [47], the correlation coefficient between a pair of countries based on electricity consumption should be calculated in the first step. The correlation coefficient between a pair of countries based on electricity consumption defines a degree of similarity between the synchronous time evolution of a pair of assets between the countries.

\[
C_{ij} = \frac{\langle R_i R_j \rangle - \langle R_i \rangle \langle R_j \rangle}{\sqrt{\langle R_i^2 \rangle - \langle R_i \rangle^2} \sqrt{\langle R_j^2 \rangle - \langle R_j \rangle^2}},
\]

where \( R_i \) is the vector of the time series of log-returns, \( R_i(t) = \ln P_i(t + \tau) - \ln P_i(t) \) is the log return, and \( P_i(t) \) is the electricity consumption amount of a country \( i (i=1,\ldots, N) \) at time \( t \). We take \( \tau \) as one annual in the following analysis throughout this paper.
We create a country network with a significant relationship between countries using the MST. The MST, a theoretical concept in graph theory [81], is the spanning tree of the shortest length using the Kruskal algorithm [82–84]. Hence, it is a graph without a cycle connecting all nodes with links. This method is also known as the single linkage method of cluster analysis in multivariate statistics [85]. The MST is generated from the graph by selecting the most important correlations between foreign trade prices. The MST reduces the information space from \( N(N - 1)/2 \) separate correlation coefficients to \((N - 1)\) linkages, known as tree “edges”, while retaining the salient features of the system [74]. Therefore, the MST is a tree which has \( N - 1 \) edges that minimize the sum of the edge distances in a connected weighted graph of the \( N \) rates.

Mantegna [47], and Mantegna and Stanley [48] showed that the correlation coefficients can be transformed into distance measures, which can in turn be used to describe hierarchical organization of the group of analyzed assets. Distance measure

\[
    d_{ij} = \sqrt{2(1 - C_{ij})},
\]

where \( d_{ij} \) is a distance for a pair of the rate \( i \) and the rate \( j \), and it fulfills the three axioms of Euclidean distance [47].

Now, one can construct an MST for a pair of countries using the \( N \times N \) matrix of \( d_{ij} \). Hence, a country network with a significant relationship between countries using the MST is obtained. The MST, a theoretical concept in graph theory [81], is the spanning tree of the shortest length using the Kruskal algorithm [82–84]. Hence, it is a graph without a cycle connecting all nodes with links. This method is also known as the single linkage method of cluster analysis in multivariate statistics [85].

We also introduce the ultrametric distance or the maximal \( d_{ij}^{\wedge} \) between two successive countries encountered in order to construct an HT, when moving from the first country \( i \) to the last country \( j \) over the shortest part of the MST connecting the two countries. (For a fuller technical discussion see [47–49, 51, 54, 56, 57, 59].) The hierarchical tree ranks the linkages between countries via the subdominant ultrametric distance, beginning with the pair exhibiting the shortest distance measure. Successive countries are added to the center of this tree in order of increasing distances. Thus, the last country added to the hierarchical tree are those with the most distant linkages to the center country or countries.

**B. The stability of links with the bootstrap technique**

The major weakness of the described methodology lies in the fact that the calculated MST and HT might be unstable. Moreover, without further statistical analysis, we cannot be sure whether the links present in the MST are actually the important links in the network or are rather a statistical anomaly, i.e. whether the results are sensitive to the sampling. We use a bootstrap technique proposed by Tumminello et al. [54, 86, 87] specifically for MST and HT analysis to deal with the problem. The bootstrap technique, which was invented by Efron [88], and has been widely used in phylogenetic analysis since the paper by Felsenstein [89] as a phylogenetic hierarchical tree evaluation method [90]. This technique was used to quantify the statistical reliability of the hierarchical structures of Turkey’s foreign trade [46] and major international and Turkish companies [59].

In the technique, by using the original MST and HT, we construct a bootstrapped time series from the original while keeping the the length of the time series fixed (i.e. the observations may repeat in the bootstrapped sample). MST and HT are then constructed for the bootstrapped time series and links are recorded. It is then checked whether the connections in the original MST are also present in the new MST based on bootstrapped time series. We repeat such procedure 1000 times so that we can distinguish whether the connections in the original MST and HT are the strong ones or statistical anomalies [57]. The bootstrap value gives information about the reliability of each link of a graph.

**C. Cluster analysis**

The correlation matrix of the time series of a multivariate complex system can be used to extract information about aspects of the hierarchical organization of such a system. Correlation based clustering has been used to infer the hierarchical structure of a portfolio of stocks from its correlation coefficient matrix [47, 49, 91]. The correlation based clustering procedure also allows a correlation based network to associate with the correlation matrix. For example, it is natural to select the MST as the correlation based network associated with single linkage cluster analysis. A different correlation based on networks can be associated with the same hierarchical tree putting emphasis on different aspects of the sample correlation matrix. Useful examples of correlation based networks apart from the minimum spanning tree are the planar maximally filtered graph [92] and the average linkage minimum spanning tree [46, 54, 59].
We use average linkage cluster analysis (ALCA) in order to observe more clearly the different clusters of countries according to their geographical location and economic growth. Since the ALCA, which is a hierarchical clustering method, and an account of the method was presented in detailed by Tunminello et al. 

In this section, we present the MST, including the bootstrap values, and HT of 60 countries based on electricity consumption from 1971 to 2008. These countries are divided into three subgroups: low income group, middle income group and high income group countries. We also investigate cluster structures by using a clustering linkage procedure. We construct the MST by using Kruskal’s algorithm for the electricity consumption based on a distance-metric matrix. The amounts of the links that persist from one node (country) to the other correspond to the strength of the link is very high. Otherwise, the statistical reliability or the strength of the link is lower. We carried out the bootstrap technique to associate a value of the statistical reliability to the links of the MST. If the values are close to one, the statistical reliability or the strength of the link is very high. Otherwise, the statistical reliability or the strength of the link is lower.

We also obtained the cluster structure of the hierarchical trees much better by using average linkage cluster analysis. We can establish this fact from the bootstrap values of the links between these countries, which are equal to 1.00, 0.91, 0.91 in a scale from zero to one, respectively; hence these countries are very closely connected with each other. The second cluster is composed of some European and South American countries, namely, HUN, POL, ROM, BGR, CZE, BRA, ARG, URY, MEX, OMN and NZL. In this cluster, there are strong relationships among HUN - MEX, BRA - OMN and POL - ROM. We can establish this from the bootstrap values of the links among the countries, which are equal to 1.00, 0.87 and 0.78 in a scale from zero to one, respectively. The third cluster was formed mainly by some European and South American countries; and mainly African countries formed the third cluster with a GDP of under $5,000. It can also be clearly seen that in the MST, the European Union countries form the central structure. It is observed that DEU is at the center of the European Union countries and it is the predominant country for this period. The first cluster consists of DEU, AUT, FRA, ITA, DNK, NLD, ESP, LUX, BEL, IRL, FIN, GBR, SWE, NOR, GRC, USA, JPN, CAN and CHE, which are an European Union countries except USA, JPN, CAN and CHE; hence it is a heterogenous cluster. In this cluster, there are strong relationships among BEL - NLD, SWE - NOR, AUT - CHL and USA - JPN. We can establish this fact from the bootstrap values of the distances between these countries, which are equal to 1.00, 0.91, 0.91 in a scale from zero to one, respectively; hence these countries are very closely connected with each other. The second cluster is composed of some European and South American countries, namely, HUN, POL, BGR, CZE, BRA, ARG, URY, MEX, OMN and NZL. In this cluster, there are strong relationships among HUN - MEX, BRA - OMN and POL - ROM. We can establish this from the bootstrap values of the links among the countries, which are equal to 1.00, 0.87 and 0.78 in a scale from zero to one, respectively. The third cluster was formed mainly by mainly African countries, and was separated four sub-groups. The first sub-group contains SEN, KEN and ETI, and there is a strong relationships between SEN and KEN. We can establish this from the bootstrap value of the link between the SEN and KEN, which is equal to 1.00 in a scale from zero to one. The second sub-group consists of SEN, BEN, BGD and PAK, and the bootstrap values of the links between BEN - BGD and BGD - PAK are equal to 0.83 and 0.74, respectively in this sub-group; hence these countries are very closely connected with each other. The third sub-group consists of BEN, BGD and PAK, and the bootstrap values of the links between BEN - BGD and BGD - PAK are equal to 0.83 and 0.74, respectively in this sub-group; hence these countries are very closely connected with each other. (MAR, ZMB and CMR) and (YEM and NPL) formed the third and fourth sub-groups, respectively. On the other hand, the bootstrap values of the links between GHA - ZWE, LUX - CHL, TUR - IND, TUR - VNM and KEN - ETH are very low, as seen in Fig. 1. This means that these links could only demonstrate a statistical fluctuation. It is worth mentioning that in comparison with other regions, such as Latin America, the Middle East, Europe, and North America, Africa has one of the lowest per capita consumption rates. Modern energy consumption in Africa is very low and heavily reliant on traditional biomass.

The HT of the subdominant ultrametric space associated with the MST is shown in Fig. 2. Two countries (lines) link when a horizontal line is drawn between two vertical lines. The height of the horizontal line indicates the ultrametric distance at which the two countries are joined. To begin with, in Fig. 2, we can observe three clusters. The first cluster is composed of countries with a GDP per capita of over $30,000 and consists of three sub-groups, namely European Union countries (DEU, AUT, FRA, ITA, BEL, NLD and FIN), USA and JPN, and SWE and NOR. The distance between ITA and BEL is the smallest of the sample, indicating the strongest relationship between these two countries. The second cluster is mainly made up of countries from Europe and South America. In this cluster, the distance between ROU and CZE is the smallest of the sample, indicating the strongest relationship between these two countries. The third cluster is composed of mainly African countries; it also includes of the two sub-groups, namely YEM and NPL, and BGD and PAK.

In the HT, we used average linkage cluster analysis (ALCA) in order to observe the cluster structure more clearly. The HT seen in Figs. 3 is obtained from data based on electricity consumption for the period 1971-2008. When comparing the HT and ALCA, similar cluster structures were observed; however, the number of countries in the ALCA cluster was found to be more than in the HT. For example, seven countries in the cluster with a GDP per...
capita of over $30,000 were seen in the HT, but seventeen countries were seen in ALCA, as can be verified by comparing Fig. 2 with Fig. 3. In addition the groups of African countries are more clearly. Thus, we see that the cluster structures are obtained more efficiently by using ALCA.

Overall results of the study show that even there is a strong relationship between energy consumption and economic growth for some individual countries, and also three different clusters are detected: mainly European Union countries formed the first cluster of countries with a GDP of over $30,000; the second cluster was formed mainly by some European and South American countries; and mainly African countries formed the third cluster with a GDP of under $5,000. In other words, there is an evidence indicating that energy consumption leads economic growth in some of the three income groups considered in this study. Therefore, a stronger energy conservation policy should be pursued in all countries. In addition, policymakers should take into consideration the degree of economic growth in each country when energy consumption policy is formulated.

V. SUMMARY AND CONCLUSION

There is a growing literature that examines the relationship between energy consumption and economic growth. The bulk of this literature focuses on developing, developed and emerging countries. It is important for policymakers to understand the relationship between energy consumption and economic growth in order to design effective energy and environmental policies. A general conclusion from these studies is that there is no consensus either on the existence of the relationship or the direction of causality between energy consumption and economic growth in the literature.

In this paper attempts were made to re-examine the strong relationship between energy consumption and economic growth and vice versa in 60 countries by using the concept of the MST, including the bootstrap values, and the HT for the 1971-2008 period. We also divided these countries into three subgroups: low income group, middle income group and high income group countries. We obtained the clustered structures of the trees and identified different clusters of countries according to their geographical proximity and economic growth. From the topological structure of these trees, we found that the European Union countries are at the center of the network and the bootstrap values show that they are closely connected to each other. We also found that these countries play an important role in world electricity consumption. Moreover, African countries have low energy consumption compared to other regions such as Latin America, the Middle East, Europe, and North America. We performed the bootstrap technique to associate a value of statistical reliability to the links of MST to obtain information about the statistical reliability of each link of the trees. From the results of the bootstrap technique, we can see that, in general, the bootstrap values in the MST are highly consistent with each other. We also used average linkage cluster analysis to obtain the cluster structure of the hierarchical trees more clearly. The results are in good agreement with the causal relationship between the electricity consumption and economic growth along a survey of the empirical literature. The findings of this study have important policy implications and it shows that this issue still deserves further attention in future research. Finally, it is important for policymakers to understand the relationship between energy consumption and economic growth in order to design effective energy and environmental policies.
REFERENCES

[1] Ghosh S. Electricity consumption and economic growth in Taiwan. Energy Policy 2002;30:125–129.
[2] Narayan PK, Smyth R. Electricity consumption, employment and real income in Australia evidence from multivariate Granger causality tests. Energ Policy. 2005;33:1109-16.
[3] Yoo SH, Kim Y. Electricity generation and economic growth in Indonesia. Energy 2006;31:2890-2899.
[4] Ho CY, Siu KW. A dynamic equilibrium of electricity consumption and GDP in Hong Kong: An empirical investigation. Energ Policy. 2007;35:2507-13.
[5] Mozumder P, Marathe A. Causality relationship between electricity consumption and GDP in Bangladesh. Energ Policy. 2007;35:395-402.
[6] Jamil F, Ahmad E. The relationship between electricity consumption, electricity prices and GDP in Pakistan. Energ Policy. 2010;38:6016-25.
[7] Shahbaz M, Feridun M. Electricity consumption and economic growth empirical evidence from Pakistan. Qual Quant. 2012;46:1583-99.
[8] Aqeel A, Butt MS. The relationship between energy consumption and economic growth in Pakistan. Asia-Pacific Development Journal 2001;8:101-109.
[9] Shiu A, Lam PL. Electricity consumption and economic growth in China. Energ Policy. 2004;32:47-54.
[10] Altinay G, Karagol E. Electricity consumption and economic growth: Evidence from Turkey. Energ Econ. 2005;27:849-56.
[11] Lee CC, Chang CP. Structural breaks, energy consumption, and economic growth revisited: Evidence from Taiwan. Energ Econ. 2005;27:857-72.
[12] Yoo SH. Electricity consumption and economic growth: evidence from Korea. Energy Policy 2005;33:1627-1632.
[13] Narayan PK, Singh B. The electricity consumption and GDP nexus for the Fiji Islands. Energ Econ. 2007;29:1141-50.
[14] Yuan JH, Zhao CH, Yu SK, Hu ZG. Electricity consumption and economic growth in China: Cointegration and co-feature analysis. Energ Econ. 2007;29:1179-91.
[15] Odhiambo NM. Energy consumption and economic growth nexus in Tanzania: An ARDL bounds testing approach. Energ Policy. 2009;37:617-22.
[16] Abosedra S, Dah A, Ghosh S. Electricity consumption and economic growth, the case of Lebanon. Applied Energy 200;86:29-432.
[17] Chandran VGR, Sharma S, Madhavan K. Electricity consumption-growth nexus: The case of Malaysia. Energ Policy. 2010;38:606-12.
[18] Narayan PK, Narayan S, Popp S. A note on the long-run elasticities from the energy consumption GDP relationship. Applied Energy 2010;87:1054-1057.
[19] Ahamad MG, Islam AKMN. Electricity consumption and economic growth nexus in Bangladesh: Revisited evidences. Energ Policy. 2011;39:6145-50.
[20] Bildirici ME, Kayikci F. Economic growth and electricity consumption in former Soviet Republics. Energ Econ. 2012;34:747-53.
[21] Yang HY. A note of the causal relationship between energy and GDP in Taiwan. Energy Economics 2000;22:309-317.
[22] Jumbe CBL. Cointegration and causality between electricity consumption and GDP: empirical evidence from Malawi. Energ Econ. 2004;26:61-8.
[23] Zachariadis T, Pusouwaitidou N. An empirical analysis of electricity consumption in Cyprus. Energ Econ. 2007;29:183-98.
[24] Tang CF. A re-examination of the relationship between electricity consumption and economic growth in Malaysia. Energ Policy. 2008;36:3077-85.
[25] Tang CF. Electricity consumption, income, foreign direct investment, and population in Malaysia: new evidence from multivariate framework analysis. Journal of Economic Studies 2009;4:371-382.
[26] Odhiambo NM. Electricity consumption and economic growth in South Africa: A trivariate causality test. Energ Econ. 2009;31:635-40.
[27] Lean HH, Smyth R. On the dynamics of aggregate output, electricity consumption and exports in Malaysia: Evidence from multivariate Granger causality tests. Appl Energ. 2010;87:1963-71.
[28] Ouedraogo IM. Electricity consumption and economic growth in Burkina Faso: A cointegration analysis. Energ Econ. 2010;32:524-31.
[29] Shahbaz M, Tang CF, Shabbir MS. Electricity consumption and economic growth nexus in Portugal using cointegration and causality approaches. Energ Policy. 2011;39:3529-36.
[30] Kouakou AK. Economic growth and electricity consumption in Cote d’Ivoire: Evidence from time series analysis. Energ Policy. 2011;39:3638-44.
[31] Gurgul H, Lach L. The electricity consumption versus economic growth of the Polish economy. Energ Econ. 2012;34:500-10.
[32] Shahbaz M, Lean HH. The dynamics of electricity consumption and economic growth: A revisit study of their causality in Pakistan. Energy. 2012;39:146-53.
[33] Wolde-Rufael Y. Electricity consumption and economic growth: a time series experience for 17 African countries. Energ Policy. 2006;34:1106-14.
[45] Bonanno G, Vandewalle N, Mantegna RN. Taxonomy of stock market indices. Phys Rev E. 2000;62:R7615-R8.

[51] Onnela JP, Chakraborti A, Kaski K, Kertesz J. Dynamics of market correlations: Taxonomy and portfolio analysis. Phys Rev E. 2003:68.

[56] Feng XB, Wang XF. Evolutionary Topology of a Currency Network in Asia. Int J Mod Phys C. 2010;21:471-80.

[57] Keskin M, Deviren B, Kocakaplan Y. Topology of the correlation networks among major currencies using hierarchical structure methods. Physica A. 2011;390:719-30.

[58] Keskin, M, Deviren, B, Kantar, E. Advanced in Complex System, submitted.

[59] Kantar E, Deviren B, Keskin M. Investigation of major international and Turkish companies via hierarchical methods and bootstrap approach. Eur Phys J B. 2011;84:339-50.

[60] Kantar E, Keskin M, Deviren B. Analysis of the effects of the global financial crisis on the Turkish economy, using hierarchical methods. Physica A. 2012:391:2342-52.

[61] Mizuno T, Takayasu H, Takayasu M. Correlation networks among currencies. Physica A. 2006:364:336-42.

[62] Ortega GJ, Mateosan D. Cross-country hierarchical structure and currency crises. Int J Mod Phys C. 2006:17:333-41.

[63] Brida JG, Gomez DM, Risso WA. Symbolic hierarchical analysis in currency markets: An application to contagion in currency crises. Expert Syst Appl. 2009;36:7721-8.

[64] Naylor MJ, Rose LC, Moyle BJ. Topology of foreign exchange markets using hierarchical structure methods. Physica A. 2007:382:199-208.

[65] Bonanno G, Caldarelli G, Lillo F, Micciche S, Vandewalle N, Mantegna RN. Networks of equities in financial markets. Eur Phys J B. 2004;38:363-71.

[66] Vandewalle N, Brisbois F, Tordoix X. Non-random topology of stock markets. Quantitative Finance 2001;1:372-374.

[67] Brida JG, Risso WA. Dynamics and Structure of the 30 Largest North American Companies. Comput Econ. 2010;35:85-99.

[68] Eom C, Oh G, Kim S. Topological properties of a minima spanning tree in the Korean and the American stock markets. J Korean Phys Soc. 2007;51:1432-6.

[69] Brida JG, Risso WA. Dynamics and structure of the main Italian companies. Int J Mod Phys C. 2007;18:1783-93.

[70] Brida JG, Risso WA. Dynamic and Structure of the Italian Stock Market based on returns and volume trading. Economic Bulletin 2009;29:2420-2426.

[71] Garas A, Argyrakis P. Correlation study of the Athens Stock Exchange. Physica A. 2007;380:399-410.

[72] Brida JG, Risso WA. Hierarchical structure of the German stock market. Expert Syst Appl. 2010;37:3846-52.

[73] Coelho R, Gilmore CG, Lucey B, Richmond P, Hutzler S. The evolution of interdependence in world equity markets - Evidence from minimum spanning trees. Physica A. 2007:376:455-66.
Gilmore CG, Lucey BM, Boscia M. An ever-closer union? Examining the evolution of linkages of European equity markets via minimum spanning trees. Physica A. 2008;387:6319-29.

Siezka P, Holyst JA. Correlations in commodity markets. Physica A. 2009;388:1621-30.

Tabak BM, Serra TR, Cajueiro DO. Topological properties of commodities networks. Eur Phys J B. 2010;74:243-9.

Onnela JP, Chakraborti A, Kaski K, Kertesz J. Dynamic asset trees and portfolio analysis. Eur Phys J B. 2002;30:285-8.

Onnela JP, Chakraborti A, Kaski K, Kertesz J, Kanto A. Asset trees and asset graphs in financial markets. Phys Scripta. 2003;T106:48-54.

Micciche S, Bonanno G, Lillo F, Mantegna RN. Degree stability of a minimum spanning tree of price return and volatility. Physica A. 2003;324:66-73.

Coelho R, Hutzler S, Repetowicz P, Richmond P. Sector analysis for a FTSE portfolio of stocks. Physica A. 2007;373:615-26.

West, D. B. 1996. Introduction to Graph Theory, Prentice-Hall, Englewood Cliffs, NJ.

Kruskal, J. B. 1956. On the shortest spanning subtree of a graph and the traveling salesman problem. Proceedings of the American Mathematical Society 7, 48-50.

Cormen TH, Leiserson CE, Rivest RL, 1990. Introduction to Algorithms. MIT Press, Cambridge, MA.

Prim RC, Shortest Connection Networks And Some Generalizations. Bell System Technical Journal 1957;36:1389-1401.

Everitt BS, 1974. Cluster Analysis, Heinemann Educational Books, London.

Tumminello M, Lillo F, Mantegna RN. Hierarchically nested factor model from multivariate data. Epl-Europhys Lett. 2007;78.

Tumminello M, Lillo F, Mantegna RN, Correlation, hierarchies, and networks in financial markets. Journal of Economic Behavior and Organization. 2010;75:40-58.

Efron B, Bootstrap Methods: Another Look at the Jackknife. Ann. Stat. 1979;7:1-26.

Felsenstein J, Confidence limits on phylogenies: An approach using the bootstrap. Evolution 1985;39:783-791.

Efron B, Halloran E, Holmes S, Bootstrap confidence levels for phylogenetic trees. Proceedings of the National Academy of Sciences of the United States of America 1996;93:7085-7090.

Bonanno G, Lillo F, Mantegna RN, Quantitative Finance 2001;1:96.

Tumminello M, Aste T, Di Matteo T, Mantegna RN, Proceedings of the National Academy of Sciences of the United States of America 2005;102:10421.
Fig. 1

Middle income

Low income

High income
