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Hierarchical structure of the European countries based on debts as a percentage of GDP during the 2000–2011 period

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HIGHLIGHTS

- The relationships between countries based on the debts of countries are studied.
- We constructed networks by using hierarchical structure methods.
- We carried out bootstrap technique to determine the reliability of the links.
- We used average linkage cluster analysis to observe cluster structures more clearly.
- The less and most affected countries by the debt crisis are formed as a cluster.

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ABSTRACT

We investigate hierarchical structures of the European countries by using debt as a percentage of Gross Domestic Product (GDP) of the countries as they change over a certain period of time. We obtain the topological properties among the countries based on debt as a percentage of GDP of European countries over the period 2000–2011 by using the concept of hierarchical structure methods (minimal spanning tree, (MST) and hierarchical tree, (HT)). This period is also divided into two sub-periods related to 2004 enlargement of the European Union, namely 2000–2004 and 2005–2011, in order to test various time-window and observe the temporal evolution. The bootstrap techniques is applied to see a value of statistical reliability of the links of the MSTs and HTs. The clustering linkage procedure is also used to observe the cluster structure more clearly. From the structural topologies of these trees, we identify different clusters of countries according to their level of debts. Our results show that by the debt crisis, the less and most affected Eurozone's economies are formed as a cluster with each other in the MSTs and hierarchical trees.

1. Introduction

Financial integration has increased dramatically over the past decade, especially among advanced economies. There has also been an increasing presence of foreign intermediaries in several banking systems (including many emerging markets). The interconnection in the global financial system means that if one nation defaults on its sovereign debt or enters into recession thus putting some external private debt at risk, the banking systems of creditor nations face losses. For example, in October 2011 Italian borrowers owed French banks $366 billion (net) [1,2]. Should Italy be unable to finance itself, the

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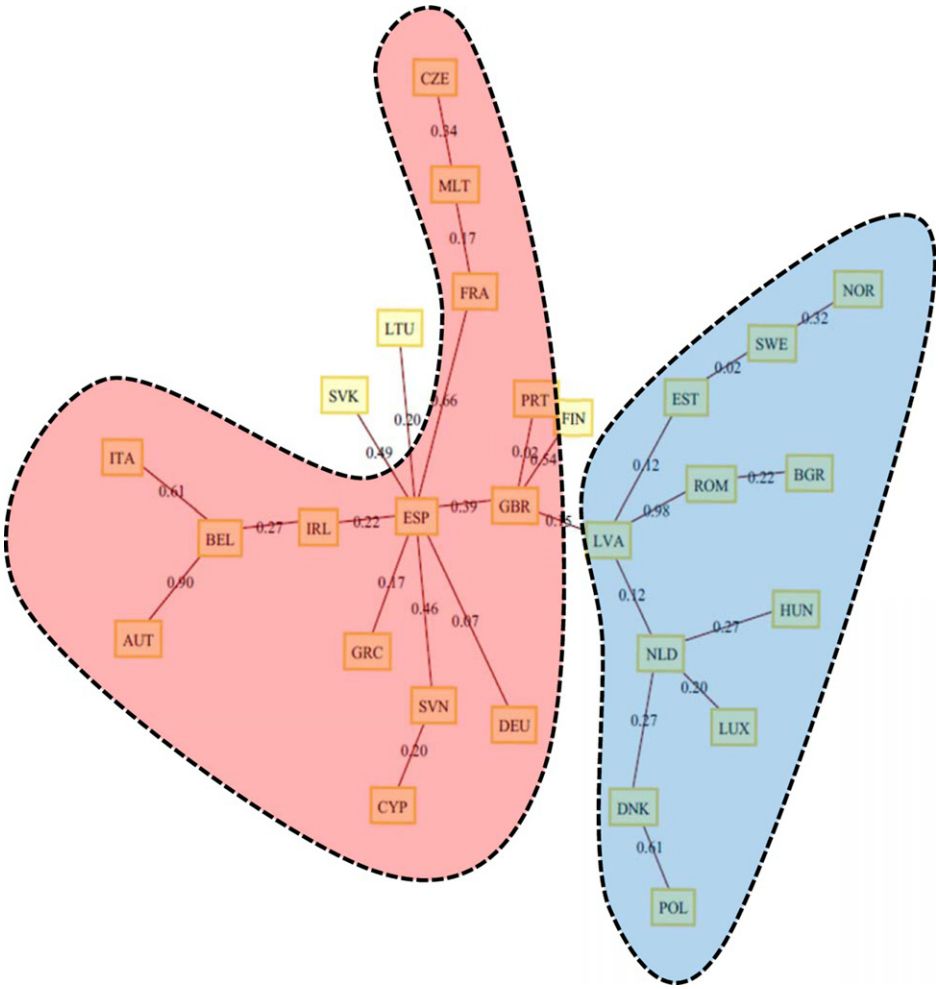

Fig. 1a. (Color online) Minimal spanning tree associated to quarterly data of the 28 countries in Europe during the 2000–2011 period.

French banking system and economy could come under significant pressure, which in turn would affect France's creditors and so on. This is referred to as financial contagion [1,2]. As a result, international risk sharing and efficiency among the economies of countries have increased. From late 2009, fears of a sovereign debt crisis developed among fiscally conservative investors concerning some European states, with the situation becoming particularly tense in early 2010 [3,4]. This included Eurozone members Greece, Ireland and Portugal and also some European Union (EU) countries outside the area. Iceland, the country which experienced the largest crisis in 2008 when its entire international banking system collapsed, has emerged less affected by the sovereign debt crisis as the government was unable to bail the banks out. In the EU, especially in countries where sovereign debt has increased sharply due to bank bailouts, a crisis of confidence has emerged with the widening of bond yield spreads and risk insurance on credit default swaps between these countries and other EU members.

On one hand, complex networks have been able to successfully describe the topological properties and characteristics of many real-life systems [5–8]. Moreover, there are studies which focus on understanding the complex structure of stock markets and financially growing systems; these topology [9], viscoelastic behavior [10] anomalous diffusion [11], phase plots [12], phase transition [13], wavelet techniques [14], the Le Chatelier principle [15], non-equilibrium dynamics [16], networks [17], graph theory [18], quantum field theory and path integrals [19,20], uncertainty [21], and spin models [22]. The properties of economic crisis have been previously studied by using correlation networks [23–27]. However, to the best of our knowledge, use of the countries, network to analyze an economic crisis has only been examined in a few studies, such as [28,29]. Dias [28] analyzed the topology of correlation networks among countries based on daily yield rates on 10-year government bonds for nineteen EU using the concept of an MST and HT for the 2007–2010 period and three sub-periods, namely 2007–2008, 2008–2009 and full year of 2010. He performed a technique to associate the value of statistical reliability to the links of the MSTs and HTs by using bootstrap technique. Moreover, Lee et al. [29] investigated the crisis spreading dynamics by using the GDP and the international trade data of the countries in the 2002–2006 period.

On the other hand, hierarchical structure of the European countries based on debts as a percentage of GDP during the 2000–2011 period is not investigated. Therefore, the purpose of this work is to investigate hierarchical structures of the