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Spanning trees and the Eurozone crisis

João Dias *

ISEG (School of Economics and Management) of the Technical University of Lisbon and UECE (Research Unit on Complexity and Economics), Rua do Quelhas, 6, 1200-781 Lisboa, Portugal

HIGHLIGHTS

- This work analyzes the sovereign debt crisis in the euro area.
- Maximum Spanning Trees are used as a first tool to analyze our data.
- Two measures of euro area segmentation are proposed.
- Asynchronization of government bond rates are well described by XST.
- Increasing separation of vulnerable and resilient countries is clearly detected.

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ABSTRACT

The sovereign debt crisis in the euro area has not yet been solved and recent developments in Spain and Italy have further deteriorated the situation. In this paper we develop a new approach to analyze the ongoing Eurozone crisis. Firstly, we use Maximum Spanning Trees to analyze the topological properties of government bond rates' dynamics. Secondly, we combine the information given by both Maximum and Minimum Spanning Trees to obtain a measure of market dissimilarity or disintegration. Thirdly, we extend this measure to include a convenient distance not limited to the interval [0, 2]. Our empirical results show that Maximum Spanning Tree gives an adequate description of the separation of the euro area into two distinct groups: those countries strongly affected by the crisis and those that have remained resilient during this period. The measures of market dissimilarity also reveal a persistent separation of these two groups and, according to our second measure, this separation strongly increased during the period July 2009–March 2012.

1. Introduction

The euro area has been under great strain during the last four years due to the sovereign debt crisis that emerged in some member countries and has been contaminating the economic, social and political climate in Europe. The difficulties began in Greece but quickly spread out to other countries and, more recently, the crisis has further deteriorated with its extension to Spain and Italy. However, while Greece has so far remained at the center of turbulence, Germany has appeared as the main hub of resistance to the crisis.

From a political point of view, it has now already been admitted that there is the possibility of a country leaving the euro and reintroducing its own national currency. In economic terms, those countries most deeply touched by the crisis went into severe recession as they implemented strict austerity measures. As a result, unemployment has risen to unacceptable levels. In Greece, the unemployment rate jumped from 7% in 2008 to around 25% in 2012 with very high increases also observed in Portugal, Ireland and Spain. However, even after adopting these austerity measures, the budgetary and debt problems are

* Tel.: +351 213925852; fax: +351 213971196.
E-mail address: jdias@iseg.utl.pt.

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Table 1
Country codes and data characterization: 10-year government bond yield rates, 07/01/2009–03/08/2012.

Country	Code	Group	Mean	Std dev	Minimum	Maximum
Austria	AT	2	3.35	0.37	2.51	4.15
Belgium	BE	1	3.84	0.43	2.82	5.87
Finland	FI	2	3.06	0.46	2.11	3.89
France	FR	2	3.27	0.33	2.47	3.82
Germany	DE	2	2.76	0.53	1.69	3.50
Greece	GR	1	13.74	9.13	4.42	39.85
Ireland	IE	1	7.21	2.35	4.37	14.55
Italy	IT	1	4.68	0.88	3.66	7.31
Netherlands	NL	2	3.05	0.49	2.03	3.84
Portugal	PT	1	7.53	3.41	3.71	17.36
Spain	ES	1	4.71	0.74	3.72	6.75
Average	G1		6.95	2.58	4.02	12.55
	G2		3.10	0.42	2.22	3.81

not yet strictly under control. Government debt attained 171% of GDP in Greece in 2011. Portugal, Ireland, Italy and Belgium also recorded values of more than 100%. In fact, from the list of the eleven Eurozone countries considered here, only Finland did not exceed, in 2012, the government debt limit of 60% as required by the Maastricht Treaty.

Economists have been active in a broad research agenda on the crisis and its effects. This agenda has included, among other relevant areas, the issue of fiscal deficits and crisis in Europe [1], the impact of discretionary fiscal policies in a time of crisis [2], the link between the current crisis and European integration [3], association between stock and bond markets in Europe [4], and fragility of government bond markets in the euro zone [5]. However, in spite of the existence of a large body of research on financial markets, there are still not many contributions from econophysics about government bonds, and in particular concerning the Eurozone debt crisis. Comovements in government bond markets were analyzed in Ref. [6], including comovements among several Eurozone countries. A recent paper [7] studied the issue of government bond market efficiency. Ref. [8] is directly related to the sovereign debt crisis in the EU. In this paper, 19 EU countries were included covering the period from April 2007 to October 2010.

Standard analysis of financial issues in econophysics has been largely based on the Minimum Spanning Tree (*MinST*), (as in Refs. [6,8]), although occasionally Maximum Spanning Trees (*MaxST*) have been used as well. For example, Ref. [9] used *MaxST* to analyzed world stock market indices. In a more theoretical context, Ref. [10] investigated some properties of *MinST* and *MaxST*.

This paper analyzes the topological properties of the sovereign debt crisis in the euro area using Maximum Spanning Trees. Combined with additional information obtained from *MinST*, we also derive two measures to analyze the evolution of government bond dissimilarity within the Eurozone.

Besides this introduction, the paper is structured as follows. Section 2 briefly describes the data used and country selection. Section 3 presents the methodology developed to pursue the analysis. Section 4 shows the main results and Section 5 concludes.

2. Data and country selection

The euro area includes now 17 countries. However, we exclude here six countries due to lack of data. In any case, the excluded countries are recent members of the Eurozone (except Luxembourg) and they represent only 1.6% of the euro area GDP. The retained eleven countries adopted the euro since its creation in 1999, apart from Greece (2001). In order to analyze these eleven countries, we applied 10-year government bond yield rates as defined by the Thomson Reuters Government Bond Indices and obtained from Datastream. Daily values are used, covering the period 07/01/2009 up to 03/08/2012, when the yield rates for Greece attained its maximum in 2009–2012.

We separate our list into two groups of countries. The first group (G1) consists of Greece, Ireland, Portugal, Spain, Italy and Belgium as they all revealed serious vulnerabilities in this period. While the inclusion of Belgium is eventually less obvious, this follows on from the results obtained in the empirical section. The second group (G2) includes the remaining five countries (Austria, Finland, France, Germany and the Netherlands), which are those so far more resilient to the crises. Table 1 lists the countries, their abbreviation and grouping and data characterization.

Greek rates exhibit an extremely high average and display abrupt fluctuations while those of Germany record extreme lows. The dramatic evolution of Greek rates is shown in Fig. 1, rising from an average of 4.9 in July 2009 to peak at 39.9 in March 2012. There was an abrupt drop following the second bailout of Greece, which included an agreement on debt restructuring, but the uptrend resumed shortly later. By contrast, Germany's rates have remained low and even decreased from an initial level around 3.4 in July 2009 to an average of 2.8 throughout this period. A similar contrast, although slightly less pronounced, is also observed when comparing the data for G1 and G2 (Fig. 2). The maximum value attained on average by G1 was over three times that of G2, with an upward trend in the first case and a slightly downward trend in the second. This behavior of G1 closely follows major events in the Eurozone, namely the downgrade of Greece's notation by major rating agencies and the bailouts for Greece, Ireland and Portugal. For G2, we have only a clear period of rising yield rates (from 2.4