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Comovements in government bond markets: A minimum spanning tree analysis

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ABSTRACT

The concept of a minimum spanning tree (MST) is used to study patterns of comovements for a set of twenty government bond market indices for developed North American, European, and Asian countries. We show how the MST and its related hierarchical tree evolve over time and describe the dynamic development of market linkages. Over the sample period, 1993–2008, linkages between markets have decreased somewhat. However, a subset of European Union (EU) bond markets does show increasing levels of comovements. The evolution of distinct groups within the Eurozone is also examined. The implications of our findings for portfolio diversification benefits are outlined.
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1. Introduction

There is a large body of literature examining evolving linkages between international equity markets, employing a variety of methodologies [1,2]. The issue is of great importance not only to policymakers but also to investors, because of the implications for international asset allocation decisions and diversification benefits. Findings generally show that the benefits of international portfolio diversification have likely decreased for equity markets over time as comovements have tended to increase. There is a relatively smaller amount of research examining the evolution of relationships between international bond markets and the impact on diversification benefits. Comovements between bond markets may be influenced over time by a number of factors, including increased monetary policy coordination in regions like the European Union (EU) and European Monetary Union (EMU) and closer alignment of economic fundamentals resulting from increased globalization of product markets [3].

An early study [4] found low correlations between world bond markets, indicating that international diversification of bond market portfolios may be beneficial. Several later studies [5,6] indicated increasing correlations across the G7 countries, except for Japan, but determined that benefits from international diversification were still possible. Research on government bond markets in Canada, Germany, Japan, the UK, and the US for the period 1986–1996 [7] concluded that they were only partially integrated, with little change in the extent of integration over the period. Several other recent studies found substantial differences in patterns of correlation across bond markets [3,8].

Some research has also focused on the impact of the introduction of a single currency, the euro, on the convergence of EMU government bond markets. Euro-area government bond markets exhibit a fairly high degree of integration; however,

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liquidity differences, decentralized management of public debt markets, and remaining differences in credit risk between countries, produce continued fragmentation in this market [9]. A dramatic convergence of EMU government bond yield spreads occurred in the run-up to the introduction of the euro in 1999 [10,11], with a leveling off thereafter.

The present research analyzes the dynamic evolution of linkages between global government bond markets, as well as the impact of the euro on EMU markets, using a methodology drawn from the econophysics literature. Originally suggested by Mantegna [12] minimum spanning tree (MST) analysis involves transforming the correlation matrix of asset returns into distances to produce a connected graph. The procedure provides a parsimonious representation of the correlations between markets and is particularly suitable for extracting the most important information concerning linkages when a large number of markets is under consideration. It also provides an additional tool to measure financial integration, in terms of the "distances" between markets (a decrease in distance indicating an increase in financial integration).[1] A dynamic application reveals the evolution of patterns of important connections between global bond markets and helps answer a number of questions concerning their interrelationships. Is there a consistent group of "core" markets which maintain the closest linkages over time? Have bond market comovements increased substantially due to effects of globalization? Is there a substantial difference in linkages between EMU markets and other bond markets as a consequence of the harmonization of policies associated with the introduction of the euro? Our results indicate that the full sample of twenty countries shows a tendency toward decreasing levels of comovements in recent years. In contrast, the EMU subgroup has increased its already high level of integration, while two non-EMU members of the EU, Sweden and the UK, have moved to the fringes of the EMU markets. No single market forms the "center" of the linkages over time, but France, rather than Germany, is the market most closely linked to others over a higher percentage of the time. The implication of our findings is a likely reduction of country diversification benefits for investors across EMU equity markets but somewhat improved benefits from a broader, global portfolio.

The paper is organized as follows. Section 2 describes the methodology and Section 3 the data. Section 4 contains the results, while Section 5 presents the conclusions.

2. Methodology

As proposed by Mantegna [12], linkages between financial markets can be examined via a simple transformation of the elements of the correlation matrix of returns into distances. A connected graph is constructed in which each "node" corresponds to a specific asset (e.g., a bond index) and the "distances", or "edges", between them are obtained from the appropriate transformation of the correlation coefficients. An MST is generated by selecting the most important correlations between the index returns. The MST reduces the information space from $N(N-1)/2$ separate correlation coefficients to $(N-1)$ tree edges, while retaining the salient features of the system.

Specifically, the correlation coefficient is calculated from the index returns data at a selected time horizon (here monthly). Each correlation coefficient $\rho_{i,j}$ in the correlation matrix of the N markets is then converted to a metric distance between pairs of indices:

$$d_{i,j} = \sqrt{2(1-\rho_{i,j})} \tag{1}$$

to form an $N \times N$ distance matrix D. The distance $d_{i,j}$ varies from 0 to 2, corresponding to correlation values, which run from -1 to $+1$, high correlations corresponding to small values of $d_{i,j}$. This distance matrix is then used to construct the MST.

The MST is built up by linking all the elements of the set together in a graph characterized by a minimal distance between indices. One starts with the pair of elements with the shortest distance (highest correlation). Next the second-smallest distance is identified and added to the MST. Successive equity markets are added, with the condition that no closed loops are created. The MST is thus a simply connected graph that connects all N nodes of the graph with $N-1$ edges such that the sum of all edge weights is a minimum.

The MST provides the subdominant ultrametric hierarchical organization of the nodes (index returns) into what is called a hierarchical tree. The subdominant ultrametric distance between i and j nodes is the maximum value of the metric distance detected by moving in single steps from i to j through the path connecting i and j in the MST. For example, if the metric distance between markets A and B is 1.00 and the distance between markets B and C is 1.20, then the ultrametric distance between markets A and C is 1.20. The hierarchical tree is then constructed as follows. Vertical lines representing A and B markets are linked at a distance of 1.0, and market C is next linked to this pair at a distance of 1.2, and so forth. This procedure establishes a unique hierarchy of linkages between markets. The hierarchical tree presentation is particularly useful for the issues we explore, so it will be the focus of presentation of our results.

3. Data

The sample consists of monthly yields on twenty developed-country government bond markets. These include thirteen EU markets: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden,

[1] A variety of definitions of financial integration exists in the literature, with the definitions generally corresponding to the methodology employed. See Ref. [9], also Ref. [8], where a general definition of integration is expressed as a strengthening of comovements between financial asset returns.

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