

# The evolution of interdependence in world equity markets—Evidence from minimum spanning trees

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## Abstract

The concept of a minimum spanning tree is used to study the process of market integration for a large group of national stock market indices. We show how the asset tree evolves over time and describe the dynamics of its normalized length, mean occupation layer, and single- and multiple-step linkage survival rates. Over the period studied, 1997–2006, the tree shows a tendency to become more compact. This implies that global equity markets are increasingly interrelated. The consequence for global investors is a potential reduction of the benefits of international portfolio diversification.

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## 1. Introduction

This paper examines the extent and evolution of interdependence between world equity markets over a 10-year period using the minimum spanning tree (MST) approach of Mantegna [1]. The approach derives ultimately from graph theory and has been used as a simple way to study the correlations of stocks in a stock market. One advantage that MST analysis has over traditional finance perspectives on international equity market integration is that it provides a parsimonious representation of the network of all possible interconnectedness. With  $N$  equity indices the number of possible nodal connections is large,  $N(N - 1)/2$ . The MST can greatly reduce this complexity by showing only the  $N - 1$  most important non-redundant connections in a graphical manner. The MST approach also provides useful information in terms of the centrality or otherwise of individual equity markets (nodes) in the overall system.

A large body of research exists in the finance literature on the integration of international equity markets. There are three basic approaches to defining the extent to which international financial markets are integrated. These fall into two broad categories, direct measures and indirect measures. The first approach, a direct

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measure, is couched in terms of the extent to which the rates of return on financial assets with similar risk characteristics and maturity are equalized across political jurisdictions. We call this a direct measure as it invokes the so-called law of one price. The second approach involves the concept of international capital market completeness and in essence examines the extent to which asset prices and returns are a function of domestic or international factors. The third approach is based on the extent to which domestic investment is financed from world savings rather than from domestic savings. Both of these latter measures can be called indirect.

In general, where possible, finance researchers consider the direct approach to be preferable [2]. The direct approach to integration has been studied by a number of researchers who have evaluated the evolution of equity market correlations, the extent to which common stochastic trends in returns emerge, and the specification of dynamic paths toward greater integration between the returns on equities. Surveys of this literature can be found in Refs. [2–4]. We contribute to the research on the dynamic process of integration through the use of MST analysis, which is particularly suitable for extracting the most important information when a large number of markets are under examination.

MST analysis has been applied previously to analyze the clustering behavior of individual stocks within a single country, usually the US [5–8]. These studies typically find a strong correspondence between business sector and cluster structure, illustrating the ability of the MST methodology to convey meaningful economic information. While these are static analyses, a variety of dynamic analyses of the time-varying behavior of stocks has also been developed in Refs. [9–14]. MST analysis has also been applied to the foreign exchange markets as a means to trace the dynamics of relationships between currencies [15].

To our knowledge only one study has been published to date applying the MST approach to groups of national equity markets [16]. There is one other earlier study [17], which however used clustering analysis. A simple dynamic analysis based on partially overlapping windows of indices for 20 countries for the years 1988–1996 finds that markets group according to a geographical principle, as is also the case for a static examination of 51 world indices for the years 1996–1999 in the same study [16]. The temporal evolution showed the stability of the North-America cluster and the increase in the size of the European and Asian-Pacific clusters, in time. Our research significantly extends this work by applying dynamic MST methods to examine the time-varying behavior of global equity market co-movements for a group of 53 developed, emerging and developing countries over the years 1997–2006. This period includes major market events such as the Asian and Russian economic crises, the introduction of the euro, and the enlargement of the European Union (EU). In addition to confirming the earlier evidence of a geographical organizing principle we document a tendency of the MST toward higher density over time, indicating an increasing degree of integration of international equity markets. Such a finding is of interest to portfolio managers and investors, as the implication is of decreased potential for diversification benefits and thus perhaps decreased returns for international investors.

## 2. Data

We analyze the returns on 53 countries' equity markets. The data consist of Morgan Stanley Capital International (MSCI) daily closing price indices for 44 countries, for the period 8 January 1997, through 1 February 2006. An additional nine countries are also included in the sample, for a total of 53. These countries and indices are: Croatia (Nomura), the Czech Republic (PX 50), Hungary (BUX), Iceland (ICEX 15 Cap), Lithuania (Nomura), Malta (HSBC Bank), Romania (Nomura), Slovakia (SAX) and Slovenia (HSBC Bank). All series are expressed in US dollar terms as the reference currency, thus reflecting the perspective of an international investor. All data are sourced from DataStream, Thomson Financial. One issue that needs to be addressed is the non-synchronous nature of the data, that is the fact that equity markets open at different times. Recent research suggests that the use of daily data may lead to significant underestimation of equity market integration [18]. As a consequence, to minimize the problem of non-synchronous trading the daily index level data were converted to weekly (Wednesday) returns:  $R_{i,t} = \ln(P_{i,t}/P_{i,t-1})$ , where  $P_{i,t}$  is the closing price of index  $i$  at time  $t$ . The resulting number of weekly observations is 475. The 53 countries in our study and the respective symbols are represented in Table 1.

The reliance for the most part on MSCI indices allows for significant confidence in the findings, as these indices are designed explicitly to allow for cross-market consideration of returns by investors. By contrast,

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