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Networks of volatility spillovers among stock markets

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HIGHLIGHTS

- We analyze volatility spillovers and its determinants among 40 stock markets.
- Networks of volatility spillovers are highly persistent.
- The significance of a temporal proximity effect is confirmed.
- Spatial dependence among markets is high.
- The most relevant determinants are market size, liquidity and economic openness.

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ABSTRACT

In our network analysis of 40 developed, emerging and frontier stock markets during the 2006–2014 period, we describe and model volatility spillovers during both the global financial crisis and tranquil periods. The resulting market interconnectedness is depicted by fitting a spatial model incorporating several exogenous characteristics. We document the presence of significant temporal proximity effects between markets and somewhat weaker temporal effects with regard to the US equity market — volatility spillovers decrease when markets are characterized by greater temporal proximity. Volatility spillovers also present a high degree of interconnectedness, which is measured by high spatial autocorrelation. This finding is confirmed by spatial regression models showing that indirect effects are much stronger than direct effects; i.e., market-related changes in 'neighboring' markets (within a network) affect volatility spillovers more than changes in the given market alone, suggesting that spatial effects simply cannot be ignored when modeling stock market relationships. Our results also link spillovers of escalating magnitude with increasing market size, market liquidity and economic openness.

1. Introduction: Motivation, related literature and contribution

Recent econophysics literature has analyzed the most important phenomena of the last decade: the global financial crisis (GFC) of 2008 and spillover effects on financial markets. Number of empirical analyses document severe effects of the GFC on world financial markets that materialized via far reaching contagions [1–4]. It was also documented that excessive

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co-movements between stocks and stock market indices were associated with contagion [5,6]. The stock and commodity markets were in particular peril as they exhibit a long-range dependence [7]. However, the impact of the GFC was not limited only to stock markets of large economies as the Eurozone [8], the U.S. [3], or China [3,9] but it also spread to relatively smaller, yet important, economies in Asia [10–15], Africa [16] and Latin America [17].

Spillover effects, often associated with the GFC, have been recently analyzed in the econophysics literature predominantly from the type-of-the-market or type-of-the-asset perspective. Attention has been paid by the researchers to the equity and stock markets [17–21] as well as to commodity markets [22,23]. Additional evidence has been put forward for spillovers between spot and futures markets [24,25] or spot and derivative markets [26]. Among the assets, a special attention was received by crude oil [21,27] due to its general economic importance. Finally, it was shown that stock market linkages and their structure vary with crisis periods [6,28–30].

The two strands of the econophysics literature briefly reviewed above motivate our research. We aim to bring additional insights into the underlying phenomena behind the elusive dynamics of volatility spillovers on stock markets, namely crashes, distress and contagion that were all part of the GFC [7,31,32]. Crashes in financial markets are (by definition) unexpected and they represent a major concern for policy makers, investors, and the general public as market downturns or crashes are connected with crucial periods of high volatility [33]. The above motivation is firmly grounded in the fact that volatility has long ago become a standard measure of risk in finance. Hence, the issue of how the volatility spillovers propagate across stock markets over space and time has become central to investors (i) in managing their portfolio diversification strategies [34,35], (ii) in determining the cost of capital along with evaluating various asset allocation decisions [36] and (iii) to policy makers in fostering financial stability [37].

In our approach we differentiate from the spillover literature in that we focus on *volatility spillovers*. Our analysis is based on the network approach that has gained currency in the econophysics literature (see for example [1,6,12,14,16,19,30]). Specifically, we build on the approach of the bi-directional Granger causality networks between daily returns of developed stock markets around a world [19] where return spillovers were observed to be more probable when markets trade (in terms of trading hours) more closely to each other. Similarly, stronger return spillovers were identified also between markets which, in a given time zone, trade at similar trading hours [38]. Despite the above evidence of a temporal proximity effect between equity market *returns*, the temporal proximity links between *volatilities* on specific markets have not yet been sufficiently explored.

Volatility propagates across markets via spillovers that exert greater impact when markets are more connected [39,40]. Hence, we employ a network approach and analyze volatility spillovers across 40 stock markets over the 2006–2014 period. In our analysis we contribute to the econophysics literature in that we show how topology of stock market linkages change with respect to market distress associated with market volatility – we describe and model volatility spillovers during both the GFC and tranquil periods. We document the presence of significant temporal proximity effects between markets and somewhat weaker temporal effects with regard to the US equity market volatility spillovers decrease when markets are characterized by greater temporal proximity. Our results also link spillovers of escalating magnitude with increasing market size, market liquidity and economic openness.

The remainder of this paper is organized as follows. In Sections 2 and 3, we describe our data and methodology. In Section 4, we present and discuss our results. Section 5 briefly concludes and offers some implications.

2. Data description and return alignment procedure

Our sample covers the daily data on the key stock market indices from 40 markets across five continents from January 2, 2006, until December 31, 2014. According to the Dow Jones Classification System, 21 markets may be regarded as developed, 14 as emerging, and 5 as frontier. The list of countries is available in Table 1. Further we employ the following data: market capitalization of listed companies (% of GDP and in current US$), net trade in goods and services (% of GDP), turnover ratio (%), foreign direct investment — net inflows and net outflows (% of GDP); the data were obtained from the World Development Indicators database of the World Bank and definitions of variables correspond to the that of the source. Data on equity prices and exchange rates are collected from the Thomson Reuters Datastream. Detailed description of the data can be found in a working paper version of this manuscript, in Appendix A–C [41]. We chose our sample of markets based on the availability of the following data: (i) closing values, (ii) closing hours, and (iii) changes in closing hours. Our analysis of equity volatility spillovers is based on local currency, as we did not want to obscure the extent of market co-movements with forex market fluctuations [42].

Because we cover markets in different time zones, we carefully address the issue of non-synchronous trading to avoid distorted results. Especially with respect to performing the Granger causality test, caution must be exercised because information sets must be precisely aligned with respect to time. Our return alignment procedure follows [19], which we briefly summarize below:

(1) Closing prices for two stock markets are pairwise synchronized; i.e., when there is a missing observation (non-trading day) on one market, observations corresponding to this day on the other market are deleted.
(2) Consecutive returns are computed, which means that returns over non-trading days during the week are excluded.
(3) Returns are aligned to address the different closing hours on the respective national stock exchanges. By this step, we also take into account historical changes in trading hours (collected directly from the national stock exchanges), daylight saving time, and the type of closing auctions.