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International stock market comovement in time and scale outlined with a thick pen

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ABSTRACT

We quantify time-varying, bivariate and multivariate comovement between international stock market returns, across various time scales, based on a novel approach of Fryzlewicz and Oh (2011) called thick pen transform. With help of this nonparametric and simple tool, we study 11 countries and examine their comovement with respect to (non-dyadic) time scales/frequencies, development and region. We also consider all possible 2036 different combinations of two or more of these countries. In the two-country case, we make comparisons with cross-correlations, either rolling-window or based on the multi-period returns. We find that in the bivariate set-up with the USA, the BRIC countries, except for Brazil (especially over small time scales), offer diversification benefits, while in the multivariate one, clustering with respect to America or Europe (but not Asia) leads to homogeneous groups. Hence development and region cannot always be considered as ultimate clustering factors. Leave-one-out cross-validation shows a nuanced interplay of time scales, development and region as grouping factors for Brazil, Japan, Hong Kong and Russia. Additionally, we provide an example of a time-scale-dependent portfolio strategy.

1. Introduction

Stock market comovement is an important topic in finance, primarily due to its relevance for asset allocation, portfolio diversification, risk management and functioning of financial systems. Here we use ‘comovement’ to label a broadly-understood phenomenon in which two or several entities/time series ‘move together’.

We deliberately avoid any reference to a particular quantitative measure, e.g., cross-correlation, regression coefficient, quantiles, tail-dependence coefficient, copula, TailCoR (Ricci and Veredas, 2015) or to a time series model, be it bivariate, multivariate, linear or nonlinear, e.g., uni- and multivariate GARCH, VAR, copula (Rodriguez, 2007), regime switching (Gallo and Otranto, 2008), latent component (Berger and Pozzi, 2013). We also refrain from specifying timing, e.g., pre-, post- or crisis dates, time scales, e.g., short- or long-term, constancy of the quantitative measure over time or its lack, e.g., CCC-GARCH or DCC-GARCH (Engle, 2002), data type, e.g., returns, volatilities, prices, or data frequency. Other broad terms employed in a similar way are linkage and interdependence, albeit the latter is used with large rather than small time scales, similarly to integration, which often appears in the context of emerging markets. Nevertheless it seems that there is some degree of consensus over the characterization of contagion, which is an important subclass of comovement. This is done by combining comovement with timing and time scales: contagion is a comovement in a period of crisis, which is short-lived and often considered as atypical (other words used are deviation, change, increase, break, excess); ‘transmission of shocks’ is a common phrase used then. On the other hand, spillover, often associated with volatility, is considered as ‘typical’ and sometimes used with large time scales. Large time scales are also linked with the more technical concept

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of cointegration. The literature on comovement, notably contagion, including definitions and econometric techniques employed, is vast. Here we give an indicative but not exhaustive list of references: Forbes and Rigobon (2002), Kaminsky et al. (2003), Bae et al. (2003), Baur (2004) and Dungey et al. (2005).

When examining comovements in international stock markets, factors such as level of development (developed or emerging markets) or geographical location (America, Europe, Asia) are taken into consideration. The USA is often considered as a reference market, typically in a bivariate set-up. More recently a third factor, time scale, has been included in the analysis by several authors. Because of the duality between a time scale and a frequency, small (time) scales are associated with high frequencies while large (time) scales with low frequencies. A natural framework for studying time series with respect to time and scale simultaneously is wavelet analysis (e.g., Percival and Walden, 2000), as it allows a time series to be split into several components, each corresponding to a particular dyadic (i.e., 2 raised to an integer power) frequency band (equivalently, dyadic time scale interval). A collection of wavelet-based applications in finance can be found, for example, in In and Kim (2012). Those dealing with market comovement include the study by Rua and Nunes (2009) who use wavelet squared coherency to measure the extent to which two time series move together over time and across frequencies (see also Madaleno and Pinho, 2012). Gallegatti (2012) employs wavelet (contemporaneous) cross-correlations over three smallest time scales ($[2^1, 2^2]$, $[2^2, 2^3]$, $[2^3, 2^4]$ days) to test for market contagion (after filtering out the remaining, long-term component). Lehkonen and Heimonen (2014) assess market comovement by fitting a bivariate DCC GARCH(1,1) model (subject to AR-filtering) to wavelet-decomposed returns of USA and other ten international stock markets. These 11 countries are considered here as well.

In this paper we take a totally new approach in studying comovement from a time-and-scale perspective and apply the so-called thick pen transform (TPT) of Fryzlewicz and Oh (2011), which has a number of very useful properties. In contrast to wavelet analysis, this technique is not restricted to dyadic time scales. It is nonparametric (neither model nor stationarity are imposed), easy to implement and allows for missing values to be present. Based on TPT, Fryzlewicz and Oh (2011) introduce a measure to quantify comovement between two or more time series, thick pen measure of association (TPMA), which is time-varying and visually interpretable. Measure introduced by Baur (2004) shares some of the aspects of the TPT.

Our objective is to use this novel tool to gain new insights into the comovement between 11 international stock markets with respect to level of development, geographical location and (time) scales, and at the same time, demonstrate the usefulness of the TPT in financial applications. Our main result from the bivariate set-up, in which the US market is paired with the remaining 10 countries, is that one of the BRIC (Brazil, Russia, India and China) countries, Brazil, shows higher degree of comovement with the USA compared to the other three and seems to be more similar to Australia and Hong Kong at most time scales (except for the shortest, where it actually is more similar to Canada, UK and Germany). At the largest time scales considered, it is Japan that joins Russia, India and China.

Our main findings from the multivariate analysis in which we examine the role of development and region on market comovement, are that American and European markets show highest degree of comovement and that increasing time trends (peaking around 2010) can be observed. Furthermore, when considering all possible combinations of countries, it turns out that grouping with respect to emerging markets (4 countries) or Asian markets (5 countries) leads to lower degree of comovement compared to other groups of 4 and 5 countries. When five principal groups (developed, emerging, American, European, Asian) are considered in a cross-validation experiment (with group-size adjustment), some expected and unexpected tendencies are uncovered, the latter involve Brazil, Russia, Japan and Hong Kong.

Some of the results based on cross-correlations are similar to those based on the TPMA, but differences exist.

In practical terms, for an US-based investor, short- as well as long-term, Canada, Germany and UK never offer diversification benefits, while China always does. A short-term investor is unlikely to gain benefits by considering Brazil, but a long-term one should consider India, Russia and Japan. Japan, Australia, Hong Kong could, to some extent, be considered useful for the short-term investments, but less so, for the long-term ones. For the international investors (not only US-based), who are interested in time scales of 4–10 days, China might offer some diversification possibilities. Another practical way of using our results is to implement an TPMA-based portfolio strategy and we give an example of such at the end.

The paper is organized as follows. In Section 2, we present the definition of the thick pen transform of Fryzlewicz and Oh (2011) and the thick pen measure of association. In Section 3, we describe the dataset, perform bivariate and multivariate comparisons, then all possible comparisons and leave-one-out cross-validation. In the last experiment as well as in the two-market analyses, we provide results based on cross-correlation. To conclude, in Section 3 we provide an example of a portfolio strategy that takes into account short-, intermediate- and long-term holding periods. We summarize our findings and provide a critique of data and methods in Section 4.

2. Methodology

2.1. Thick pen transform

The principal idea behind the TPT can be explained as follows. Imagine plotting a time series $X_1, X_2, \ldots, X_T$ on a piece of paper or using software. This boils down to making a scatterplot of the points (t, X_t) and connecting the points, sequentially, with a line drawn by a pen. Now, imagine repeating the same exercise, but with a thicker pen. And so on. By varying the thickness of the pen, we are able to visualize different features of the data, from high-frequency ones, outlined with small-thickness pens, to low-frequency ones, marked by large-thickness pens. As a result we obtain a time-and-thickness (or time-and-scale) representation of the data, which is not confined to the dyadic scales. Formally, let $X = \{X_t\}_{t=1}^{T}$ be a univariate time series (not necessary stationary) and consider a