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International comovement of stock market returns: A wavelet analysis

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ABSTRACT

The assessment of the comovement among international stock markets is of key interest, for example, for the international portfolio diversification literature. In this paper, we re-examine such comovement by resorting to a novel approach, wavelet analysis. Wavelet analysis allows one to measure the comovement in the time–frequency space. In this way, one can characterize how international stock returns relate in the time and frequency domains simultaneously, which allows one to provide a richer analysis of the comovement. We focus on Germany, Japan, UK and US and the analysis is done at both the aggregate and sectoral levels.

1. Introduction

The analysis of the comovement of stock market returns is a key issue in finance as it has important practical implications in asset allocation and risk management. Since the seminal work of Grubel (1968) on the benefits of international portfolio diversification (see also, Levy and Sarnat (1970) and Agmon (1972)) this topic has received a lot of attention in international finance. In fact, a growing body of literature has emerged more recently on studying the comovement of international stock prices (see, for example, King et al. (1994), Lin et al. (1994), Longin and Solnik (1995, 2001), Karolyi and Stulz (1996), Forbes and Rigobon (2002), Brooks and Del Negro (2005, 2006)). In particular, most of those studies have found that the comovement of stock returns is not constant over time. For instance, Brooks and Del Negro (2004) and Kizys and Pierdzioch (2009) found evidence of increasing international comovement of stock returns since the mid-90s among the major developed countries. It has been current practice to evaluate the comovement of stock returns through the correlation coefficient while the evolving properties have been investigated either through a rolling window correlation coefficient (see, for example, Brooks and Del Negro (2004)) or by considering non-overlapping sample periods (see, for example, King and Wadhwani (1990) and Lin et al. (1994)).

However, the comovement analysis should also take into account the distinction between the short and long-term investor (see, for example, Candelon et al. (2008)). From a portfolio diversification view, the first kind of investor is naturally more interested in the comovement of stock returns at higher frequencies, that is, short-term fluctuations, whereas the latter focuses on the relationship at lower frequencies, that is, long-term fluctuations. Hence, one has to resort to the frequency domain analysis to obtain insights about the comovement at the frequency level (see, for example, A'Hearn and Woitek (2001) and Pakko (2004)). One should note that, despite its recognized interest, analysis in the frequency domain is much less found in the financial empirical literature (see, for example, Smith (2001)).

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In this paper, we re-examine the stock return comovement among the major developed economies through a novel approach, wavelet analysis. Wavelet analysis constitutes a very promising tool as it represents a refinement in terms of analysis in the sense that both time and frequency domains are taken into account. Although wavelets have been more popular in fields such as signal and image processing, meteorology, physics, among others, such analysis can also provide fruitful insights about several economic phenomena (see, for example, Ramsey and Zhang (1996, 1997)). The pioneer work of Ramsey and Lampart (1998a,b) draws on wavelets to study the relationship between several macroeconomic variables (see, for example, Crowley (2007) for a survey). In particular, wavelet analysis provides a unified framework to measure comovement in the time–frequency space.

The study of the comovement of stock market returns is crucial for risk assessment of portfolios. A higher comovement among the assets of a given portfolio implies lower gains, in terms of risk management, stemming from portfolio diversification. Hence, the evaluation of the comovement is of striking importance to the investor so that he can best assess the risk of a portfolio. On one hand, it has been acknowledged that the comovement of stock returns varies over time. Hence, one has to be able to capture this time-varying feature as it implies an evolving risk exposure. On the other hand, the distinction between short and long-term investors should not be ignored as the first is more interested on short-run movements whereas the latter on long-run fluctuations. That is, if the degree of the comovement of stock returns varies across frequencies the risk for each type of investor will also be different. In contrast with time or frequency domain approaches which allow one to focus only on one of these issues, wavelet analysis encompasses both. In particular, through wavelets one can assess simultaneously the strength of the comovement at different frequencies and how such strength has evolved over time. In this way it is possible to identify regions in the time–frequency space where the comovement is higher and the benefits of portfolio diversification in terms of risk management are lower.

In addition, we also extend such analysis to the sectoral level. That is, besides considering the aggregate stock returns, we also distinguish ten sectors for each country. For the international diversification of equity portfolios, the assessment of the comovement at the sectoral level also plays a role (see, for example, Roll (1992), Heston and Rouwenhorst (1994) and Griffin and Karolyi (1998)). For instance, it is important to assess if the evidence of greater interdependence of international stock markets is confined or not to a small set of sectors (see, for example, Berben and Jansen (2005)). Again, wavelet analysis can provide interesting insights on how such international comovement has evolved over time across frequencies for the different sectors.

Hence, this paper provides a fresh new look into the characterisation of the comovement among international stock returns. We focus on the major developed economies, namely Germany, Japan, United Kingdom and United States over the last four decades. Moreover, by considering the decomposition of the aggregate index in ten sectors, we also provide insights at the sectoral level.

This paper is organised as follows. In Section 2, the comovement measure in the wavelet domain is presented. In Section 3, a data overview is provided and in Section 4 the empirical results for the major developed economies are discussed. Finally, Section 5 concludes.

2. Wavelet analysis

The wavelet transform decomposes a time series in terms of some elementary functions, the daughter wavelets or simply wavelets $\psi_{\tau,s}(t)$. Wavelets are ‘small waves’ that grow and decay in a limited time period. These wavelets result from a mother wavelet $\psi(t)$, that can be expressed as function of the time position τ (translation parameter) and the scale s (dilation parameter), which is related with the frequency. While the Fourier transform decomposes the time series into infinite length sines and cosines, discarding all time-localization information, the basis functions of the wavelet transform are shifted and scaled versions of the time-localized mother wavelet. More explicitly, wavelets are defined as

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right) \tag{1}$$

where $\frac{1}{\sqrt{s}}$ is a normalization factor to ensure that wavelet transforms are comparable across scales and time series. To be a mother wavelet, $\psi(t)$, must fulfil several conditions (see, for example, Gencay et al. (2002), Percival and Walden (2000) and Bruce and Gao (1996)): it must have zero mean, $\int_{-\infty}^{+\infty}\psi(t)dt = 0$; its square integrates to unity, $\int_{-\infty}^{+\infty}\psi^2(t)dt = 1$, which means that $\psi(t)$ is limited to an interval of time; and it should also satisfy the so-called admissibility condition, $0<C_\psi = \int_0^{+\infty}\frac{|\hat{\psi}(\omega)|^2}{\omega}d\omega < +\infty$ where $\hat{\psi}(\omega)$ is the Fourier transform of $\psi(t)$, that is, $\hat{\psi}(\omega) = \int_{-\infty}^{+\infty}\psi(t)e^{-i\omega\tau}dt$. The latter condition allows the reconstruction of a time series $x(t)$ from its continuous wavelet transform, $W_x(\tau,s)$. Thus, it is possible to recover $x(t)$ from its wavelet transform through the following formula

$$x(t) = \frac{1}{C_\psi}\int_{-\infty}^{+\infty}\left[\int_{-\infty}^{+\infty}\frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right)W_x(\tau,s)d\tau\right]\frac{ds}{s^2}. \tag{2}$$

The continuous wavelet transform of a time series $x(t)$ with respect to $\psi(t)$ is given by the following convolution

$$W_x(\tau,s) = \int_{-\infty}^{+\infty}x(t)\psi^*_{\tau,s}(t)dt = \frac{1}{\sqrt{s}}\int_{-\infty}^{+\infty}x(t)\psi^*\left(\frac{t-\tau}{s}\right)dt \tag{3}$$

where * denotes the complex conjugate. For a discrete time series, $x(t)$, $t=1,\ldots,N$ we have

$$W_x(\tau,s) = \frac{1}{\sqrt{s}}\sum_{t=1}^{N}x(t)\psi^*\left(\frac{t-\tau}{s}\right) \tag{4}$$