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Wavelet-based multi-resolution GARCH model for financial spillover effects☆

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Abstract

This study proposes a wavelet-based multi-resolution BEKK-GARCH model to investigate spillover effects across financial markets. Compared with traditional multivariate GARCH analysis, the proposed model can identify or decompose cross-market spillovers on multiple resolutions. Taking two highly correlated indices, the NASDAQ (U.S.) and TWSI (Taiwan composite stock index) for analysis, the empirical results show that the NASDAQ returns strongly predict the movements of TWSI on the raw data level, but via wavelet-based multi-resolution analysis we find that the prediction power unevenly spreads over each time scale, and the spillover patterns are totally different as that revealed on the raw data level. The direction and magnitude of return and volatility spillovers significantly vary with their time scales. Considering the fact that heterogeneous groups of investors trade on different time horizons, the results of this study help investors to uncover the complex pattern of return and volatility spillovers on their own horizon, and make a good hedge on their risk.

Keywords: Wavelet analysis; Spillover effects; BEKK-GARCH model; Multi-resolution decomposition; Financial risk

1. Introduction

With the continued liberalization of cross-border cash flows, international financial markets have become increasingly interdependent. Investors are highly exposed to the exchange risk and equity price fluctuations over the world. In order to manage such risks, return and volatility spillovers across financial markets are the most important mechanism to analyze. However, international investors are heterogeneous in their trading strategies. Each group of investors operate on their only time horizon. As a result, the transmission and causal relationship between stock markets are different on each time scale. Prior research adopted multivariate generalized autoregressive conditional heteroscedasticity (GARCH) models (McAleer [24]; McAleer et al. [25]) for the analysis. Multivariate GARCH models capture market information on aggregate level. To address these issues, this study proposes a new strategy based on wavelet analysis to improve multivariate GARCH models on the investigation of complex transmission or spillover mechanism across financial markets.

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Recently, it has been widely accepted that most high technology investments over the world concentrate on U.S. and Eastern Asia, especially in U.S. Silicon Valley and Taiwan. In addition, owing to the popularization of computer technology and world-wide network, the quick processing of news has shorten the reaction time for domestic stock markets to new information from international markets. As a consequence, an increasing attention has been given in recent literature to the topic of international transmission of stock market returns and volatility (Eun and Shim [9]; Maasoumi and McAleer [23]; Huang et al. [16]; Hakim and McAleer [15]). This study takes two highly correlated indices, the NASDAQ and TWSI (Taiwan composite stock index), as an illustration to investigate the financial spillover effects. First, the returns series of the NASDAQ and TWSI are decomposed into four time scales by a wavelet basis, and then the return and volatility spillovers under each time scale are analyzed by a multivariate BEKK-GARCH model (Engle and Kroner [8]; Gallagher and Twomey [10]; Dunne [7]). Compared to traditional multivariate GARCH analysis, the new method can identify or decompose the market transmissions on multi-resolutions, and hence help traders to reduce risk on their investing time horizons.

Reviewing the applications of wavelet analysis in economics and finance, Ramsey and Zhang [28] investigated foreign exchange data using waveform dictionaries; Davidson et al. [6] analyzed the commodity price behavior by wavelet analysis; Ramsey and Lampart [29,30] have used wavelet analysis to decompose economic relationships of expenditure and income; Pan and Wang [26] have examined the stock market inefficiency by wavelet analysis; Gençay et al. [11,13,14] have used wavelet analysis to investigate scaling properties of foreign exchange volatility and systematic risk (the beta of an asset) in a capital asset pricing model; Recently, In and Kim [17] and Kim and In [19] used wavelet analysis to study the multiscale hedge ratio and relationship between financial variables and real economic activity; Lee [21] employed wavelet analysis to study the transmission of stock market movements; Yamada [31] used a wavelet-based beta estimation to investigate Japanese industrial stock prices.

As indicated by Kim and In [19], due to the lack of analytical tools to decompose data into more than two time scales, financial and economic analysts often have been restricted to at most two time scales (the short-run and the long-run). The main contribution of this study lies in combining wavelet analysis and the multivariate BEKK-GARCH model to decompose the return and volatility spillovers over each time scale. Our analysis breaks down the traditional barrier, and reveals the micro transmission mechanism over each time scale. The results of this study help investors to implement good hedge strategies, and reduce their risk in the international investments.

Our wavelet-based multi-resolution BEKK-GARCH model shows that the spillovers between the two indices vary with the time scale. Conventional multivariate GARCH estimate is only an "average" of the multi-scale BEKK-GARCH estimates. In the aggregate market spillover will be the outcome of various time-horizon micro-spillovers. In almost all decomposed series, the GARCH coefficients are significant which indicate volatilities of the decomposed series are still heteroscedastic. A interesting result is the prediction power of NASDAQ returns is unevenly spread over four time scales. The return spillovers from U.S. to Taiwan are significant and strong at scales 1, 3, 4, while the spillovers from Taiwan to U.S. are only weak significant at scales 2, 3, 4 and with much smaller magnitudes. The volatility spillovers show a similar pattern that the spillovers from U.S. to Taiwan in almost all components are more significant and strong than the opposite direction from Taiwan to U.S. The volatility spillovers are also unevenly spread in four time scales. The empirical results show that this study successfully decomposes the total spillover into five sub-spillovers.

The remainder of the paper is organized as follows. Section 2 describes the wavelet analysis and multi-resolution decomposition. Section 3 introduces the BEKK-GARCH models and its statistical properties. Section 4 describes the data used in the study and discusses the empirical findings. Finally, conclusions are given in Section 5.

2. Wavelet analysis

Wavelet theory is a comparatively new and powerful mathematical tool for time series analysis. This section reviews two basic tools of wavelet analysis: the discrete wavelet transform (DWT) and the multiresolution decomposition (MRD). For a thorough review of wavelet analysis please refer to Chui [3], Daubechies [5], and Percival and Walden [27]. Practical applications of wavelet analysis is given in Lee [20] and Gençay et al. [12]. Technical details of wavelet analysis are discussed in Bruce and Gao [2].