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Quantitative measurement of the contagion effect between US and Chinese stock market during the financial crisis

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HIGHLIGHTS

- A quantitative measurement method of contagion effect is proposed.
- The tail dependence is analyzed by an improved dynamic Clayton copula.
- The Markov regime switching model is used to determine the crisis sample.

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ABSTRACT

In this paper, we study the quantitative measurement of contagion effect between US and Chinese stock market during the financial crisis by combining multifractal volatility (MFV) with the copula method. At first, we employ MFV to filter volatility of the two markets due to the existence of heteroskedasticity. Then we use an improved time-varying Clayton copula to estimate the dynamic lower tail dependence (lower Kendall's τ). After determining crisis and non-crisis periods by Markov regime switching model, we find that the statistical characteristics of lower Kendall's τ during crisis and non-crisis periods are obviously different. Time-varying lower Kendall's τ of the crisis period is about 1.87 times that of in non-crisis period on average, indicating that the contagion effect increased about 87% during the crisis period. It is very drastic that the fluctuations of lower tail dependence during crisis period, so the static measurement of contagion effect may not provide effective suggestions for investors. Thus, we propose a dynamic method to measure the strength of contagion effect.

1. Introduction

The 2007 United States (US) financial crisis, which started from the subprime market, had developed into the most severe worldwide economic crisis since the 1927 Great Depression. The study of the international equity market contagion has rapidly become one of the important research topics of financial economics. In order to deal with financial crisis and the propagation of shocks across international equity markets, extensive literature has investigated the nature of return co-movements and the impact of financial crisis on the financial system from one region to the other regions. These studies employ the correlation test as a standard methodology for testing contagion, with a focus on the sharp increase in return co-movements which occur after an extremely negative return shock to one country. A variety of papers [1–4] found that correlations among different financial markets had changed over time, and tended to increase during the unstable periods.

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Furthermore, King and Wadhwani [5], Bertero and Mayer [6] provided the evidence that correlations among international markets tended to increase in periods of market crises. However, Refs. [7–9] show that the conventional correlation coefficient analysis is considerably biased and inaccurate due to the heteroskedasticity existing in most financial return series. So the correlation coefficient is biased in high volatility regimes [9] and may be misleading if volatility is an important factor of contagion [7,10].

Therefore, we have to filter the volatility before investigating the contagion effect because of heteroskedasticity. The commonly used method is GARCH-type model. For example, Longin and Solnik [11] used a bivariate GARCH model and found that the correlations between the major stock markets rised in periods of high volatility. Ramchand and Susmel [12] employed a switching ARCH model and concluded that the correlations between the US and other world markets were on average 2–3.5 times higher when the US market was in a high variance state compared to a low variance regime. Recently, many other studies [13–17] have also applied GARCH-type models to examine the contagion phenomenon. However, we use a more accurate method to filter the heteroskedasticity of financial time series in this paper, i.e., the multifractal volatility (MFV) proposed by Wei and Wang [18].

Since the original studies of Mandelbrot [19,20], a series of studies in a line of literature known as econophysics had found that many financial market time series displayed the fractal and multifractal characteristics [21–25]. Multifractal tools are also used to take into account some important stylized facts that cannot be described by the traditional methods such as GARCH-type models [26–30] and other financial researches such as volatility forecasting [29–32], market efficiency [33–35] and portfolio allocation [36–38]. Multifractal characteristics of financial markets have not only been limited to developed financial markets, but also been found in the emerging stock market like China [39–41]. Thus, we use the multifractal volatility (MFV) proposed by Wei and Wang [18] to filter the heteroskedasticity of financial time series in this paper. Wei and Wang [18] proved that the MFV model is more powerful than GARCH and stochastic volatility models when dealing with measuring and forecasting volatilities of financial markets.

Recently, copulas have been widely used in contagion researches [42–46] among other methods. A substantial advantage of copula functions is that the marginal distributions could come from different families. This construction allows researchers to consider marginal distributions and dependence as two separate but related issues [47]. Thus, we can use the MFV method to filter the volatility of financial series to obtain the marginal distributions at the first step.[1] Another advantage of copulas is that it can capture nonlinear dependence. In particular, copulas contain information about the joint behavior of the random variables in the tails of the distribution, which should be of primary interest in the study of contagion effect during financial crisis [42]. Thus, we argue that if both lower and upper tails have been taken into account, the estimated dependence coefficient is an unreliable measurement of contagion effect since only lower tail dependence could represent the contagion effect. Therefore we advocate only focusing on the lower tail dependence structure to measure contagion effect. Then an improved time-varying Clayton copula is used to model the dynamic lower tail dependence in this paper.

The diversification cannot be effective if dependence structure does significantly and rather abruptly change in certain time periods, so the investigation of changes in dependence structure is crucial for portfolio and risk management. Consequently, it is not only important to assess the existence of contagion (which has been proved in Ref. [48]), but also the strength of contagion [10]. So, we try to propose a quantitative measurement of contagion effect in this paper. The conclusion may be helpful for risk management and portfolio selection.

In brief, the aim of this paper is to propose a quantitative measurement of contagion effect between US and Chinese stock market during financial crisis. First, we employ the MFV model to obtain the conditional volatility of S&P 500 and SSEC indices returns and then get the standardized returns. Then the marginal distributions of the joint distribution of S&P 500 and SSEC are achieved by the probability integral transform (PIT) for the standardized returns. Third, an improved time-varying Clayton copula is used to study lower tail dependence of these two markets. Lastly but most importantly, to avoid the subjective determination of the crisis and non-crisis periods, we use a Markov regime switching model to investigate the variation of time-varying tail dependence parameters (lower Kendall's τ) at different states (volatility regimes). We find that the statistical characteristics of lower Kendall's τ during crisis and non-crisis periods are obviously different. Generally speaking, time-varying lower Kendall's τ of crisis period is 1.87 times that of non-crisis period on average, indicating that the contagion effect increased about 87.39% during financial crisis period.

The rest of this paper is organized as follows. We introduce the sample data and discuss how daily returns are constructed in Section 2. A model for analyzing the multifractal spectrum of high-frequency intraday data and the multifractal volatility measurement is introduced in Section 3. Section 4 presents an improved time-varying Clayton copula and shows the dynamic dependence structure between US and Chinese stock markets. Section 5 employs Markov regime switching model for crisis and non-crisis periods selection and shows the measurement of the strength of contagion effect. Section 6 comes up with our conclusions.

2. Data

The data set in our empirical study consists of high-frequency (every 5 min) price quotes for the Standard & Poor's 500 (S&P 500) index and Shanghai Stock Exchange Composite (SSEC) index during the periods from January 3, 2002, to December

[1] Since the number of parameters can be large even in moderate dimensions, two step methods are usually employed.