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Financial market volatility and contagion effect: A copula–multifractal volatility approach

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HIGHLIGHTS

- A new approach based on the multifractal volatility method (MFV) is proposed to study the financial contagion effect.
- The tail dependence structure between the U.S. and Chinese stock market is analyzed by copulas.
- The multifractal volatility method is used to construct the marginal distributions for different kinds of copulas.

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ABSTRACT

In this paper, we propose a new approach based on the multifractal volatility method (MFV) to study the contagion effect between the U.S. and Chinese stock markets. From recent studies, which reveal that multifractal characteristics exist in both developed and emerging financial markets, according to the econophysics literature we could draw conclusions as follows: Firstly, we estimate volatility using the multifractal volatility method, and find out that the MFV method performs best among other volatility models, such as GARCH-type and realized volatility models. Secondly, we analyze the tail dependence structure between the U.S. and Chinese stock market. The estimated static copula results for the entire period show that the SJC copula performs best, indicating asymmetric characteristics of the tail dependence structure. The estimated dynamic copula results show that the time-varying t copula achieves the best performance, which means the symmetry dynamic t copula is also a good choice, for it is easy to estimate and is able to depict both the upper and lower tail dependence structure. Finally, with the results of the previous two steps, we analyze the contagion effect between the U.S. and Chinese stock markets during the subprime mortgage crisis. The empirical results show that the subprime mortgage crisis started in the U.S. and that its stock market has had an obvious contagion effect on the Chinese stock market. Our empirical results should/might be useful for investors allocating their portfolios.
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1. Introduction

The successful experience of financial liberalization that started in the early 1980s in some of the emerging economies in Europe, Asia and Latin America provided a positive incentive to other emerging economies around the globe to follow the same policy initiatives. Although the benefits of economic and financial liberalization are well-documented in the literature, a surge of quick profiteering through liberalization forced the countries to implement fast but poorly managed reforms without sound frameworks of financial sector supervision and management. Many economists have now realized that contagion played a role in propagating the subprime mortgage crisis to the emerging market economies after 2008.

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The term "contagion" refers to a significant increase in cross-market linkage after a shock to one country or a group of countries [1,2]. With regard to the financial market contagion phenomenon, there are several most common methods used to investigate it. In earlier studies, a variety of papers [3–6] found that the correlations have changed over time, tending to increase during unstable periods. Furthermore, King and Wadhwani [7] and Bertero and Mayer [8] found that international correlation tends to increase during periods of market crises. However, the correlation coefficient is biased on high volatility regimes [9] and may be misleading if volatility is an important factor for contagion [2].

To avoid this bias, a common method is to use a GARCH-type model to estimate dynamic conditional correlation, and then test whether significant increases occur or not after the shock. For example, Longin and Solnik [10] use a bivariate GARCH model and found that correlations between the major stock markets rise in periods of high volatility. Ramchand and Susmel [11] used a switching ARCH model and found that the correlations between the U.S. and other world markets are on average 2 to 3.5 times higher when the U.S. market is in a high variance state as compared to a low variance state. Many other studies (such as Refs. [12–16]) have also used GARCH-type models to research the contagion phenomenon.

However, correlation is only a linear measure of dependence.[1] How can one measure nonlinear dependence? There is another way: copula approach. Recently, copulas have been widely used in contagion research (e.g. Refs. [17–21]). Copulas contain all the information about the dependence structure of a vector of random variables. They can capture nonlinear dependence, while correlation is only a linear measure of 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 a study of contagion during financial crises [17].

It is well-known that, when using the copula approach, we can employ a two-step procedure for the estimation of model parameters: (1) transform the raw data to independent and identically distributed (i.i.d) random variables and estimate the marginal distributions; (2) fit the copula function parameters. But there exists heteroskedasticity in financial time series, so how to filter heteroskedasticity and make the data transform to an i.i.d. series is a key issue when the copula method is applied. The most popular method to filter heteroskedasticity is using a GARCH-type model for each series, followed by a second step that is known as the copula-GARCH model. A series of papers [22–26] have found that volatility measurements based on multifractal methods obtain better forecasting accuracy than GARCH-type or RV models. So, in this paper, we use a more accurate method to filter the heteroskedasticity of financial time series, i.e., multifractal volatility (MFV), as proposed by Wei and Wang [22]. Just as the name copula-GARCH model suggests, in combination with the second step we call it the copula-MFV model.

Since the original studies of Mandelbrot [27,28], a series of studies in a line of literature known as econophysics have revealed that many financial market time series display fractal and multifractal characteristics [29–33]. Multifractal tools are also used to take into account some important stylized facts that cannot be described by traditional methods, such as the GARCH-type model [34–38], and other financial research, such as volatility forecasting [37–40], market efficiency [41–43], and portfolio allocation [44,45]. The multifractal characteristics of financial markets have not been limited to developed financial markets, but also have been noted in recent studies of the emerging stock market in China [46–48].

In this paper, we study the dependence structure between the U.S. and Chinese stock markets, and analyze the dependence variation from 2006 to 2012 by using the time varying parameters copula approach so as to detect the contagion effect after the subprime mortgage crisis. To begin with, we employ a multifractal volatility model to estimate the volatility for each market, and transform i.i.d. standardized returns to a uniform distribution on (0, 1) by the probability integral transform. Second, in order to capture the nonlinear dependence, especially the tail dependence between the U.S. and Chinese stock markets, we show several copula dependence structures. Finally, in order to test the contagion effect, we use the time varying parameters copula to analyze the variation of the tail dependence between the U.S. and Chinese stock markets. The main contribution of this paper is the combination of multifractal methods and copulas to study the contagion effect between the U.S. and Chinese stock markets after the subprime mortgage crisis. The multifractal method can filter the heteroskedasticity more accurately, and the copulas contain all the information about the dependence structure of a vector of random variables.

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 measure is introduced in Section 3. Section 4 presents various static copulas and shows the dependence structure between the U.S. and Chinese stock market. Time varying parameters copulas and the contagion effect test are introduced in Section 5. In Section 6 we give 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 the Shanghai Stock Exchange Composite (SSEC) index during the period from January 2, 2004, to June 29, 2012. The S&P 500 is one of the most commonly followed indices and many consider it the best representation of the market and a bellwether for the U.S. economy. The National Bureau of Economic Research has classified common stocks as

[1] In fact, another method, linear regression, is also used to test contagion; for example, the vector autoregressive method is such a method using only a linear measure of dependence.

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