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Study on spillover effect of copper futures between LME and SHFE using wavelet multiresolution analysis

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Abstract: Research on information spillover effects between financial markets remains active in the economic community. A Granger-type model has recently been used to investigate the spillover between London Metal Exchange (LME) and Shanghai Futures Exchange (SHFE), however, possible correlation between the future price and return on different time scales have been ignored. In this paper, wavelet multiresolution decomposition is used to investigate the spillover effects of copper future returns between the two markets. The daily return time series are decomposed on 2^n (n=1, …, 6) frequency bands through wavelet multiresolution analysis. The correlation between the two markets is studied with decomposed data. It is shown that high frequency detail components represent much more energy than low-frequency smooth components. The relation between copper future daily returns in LME and that in SHFE are different on different time scales. The fluctuations of the copper future daily returns in LME have large effect on that in SHFE in 32-day scale, but small effect in high frequency scales. It also has evidence that strong effects exist between LME and SHFE for monthly responses of the copper futures but not for daily responses.

Key words: Spillover effect, Copper future, Future market, Wavelet multiresolution analysis
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INTRODUCTION

As international capital market has been increasing interdependently, spillover effects have been widely discussed in the global market. Study on information spillover effects between international financial markets is extremely active in the economic researchers community. For example, the spillover effect between international stock markets was investigated by some researchers using Granger-type model (Eun and Shim, 1989; Kim and Rogers, 1995). It was found that the global financial market with biggest exchanges strongly lead other markets. The volatility spillover between US and Australia stock and bond markets was investigated using a matricular decomposition of the bivariate GARCH model (Fang *et al*., 2005). The common volatility spillover from multiple financial markets to one financial market was studied with Principal Components Analysis (PCA) and GARCH model (Zhang *et al*., 2006).

While new evidence on international spillover effects has widely been discussed around the globe, Chinese financial markets have received little attention. Along with the continued development of the Chinese industry economy, the demands from the producing enterprises for various raw metal materials are increasing unceasingly, and Chinese financial markets are becoming more and more interdependent on international markets. Shanghai Futures Exchange (SHFE) is an only metal exchange in China. Trade quantity of the copper future contracts in SHFE is increasing by year, and has exceeded that in the Commodity Exchange of New York (COMEX) in recent years. SHFE has become a global second largest metal exchange that is next only to London Metal Exchange (LME). Some Chinese researchers utilized Granger model to study the price transmission of copper futures between SHFE and LME (Wu *et al.*, 2006; Li, 2006). In view of the recent development, news can disseminate instantaneously around the world through Internet and telephone network, thus a shock in one future market can be transmitted to another market within a very short period of time. It is thus essential to use high frequency data such as daily closing quotation to examine the spillover effect between Chinese and oversea future markets. However, the previous works ignores the possible correlation between the future price and return on different scaled time.

This paper investigates the price transmission of copper future between SHFE and LME on different frequencies which are separated by wavelet multiresolution method. Wavelet analysis has been used to analyze the financial time series in recent years. The fluctuation of S&P 500 index (Ramsey *et al.*, 1995) and market dynamics of both high-frequency Nasdaq E-mini Futures and daily Dow Jones data (Bartolozzi *et al.*, 2006) were investigated using the wavelet method, and it was also applied to analyze and forecast the time sequence of Chinese stock index (Wang and Pan, 2004; Deng and Song, 2006) and to examine the stock index volatility (Xu and Zhang, 2005). Wavelet and fractal theory were applied to stock price index time sequences for understanding China's stock market (Chen and Wang, 2003). Other researchers used the discrete wavelet transform to study the reaction of emerging and mature stock markets to crashes and events (Sharkasi *et al.*, 2006).

The remainder of this paper is organized as follows. Section 2 briefly describes the methodology. Section 3 presents statistical results of wavelet analysis in decomposing time series. The final section provides conclusion and future works.

METHODOLOGY

Wavelet transform (WT) is a mathematical tool that can be used for many applications such as signal processing, data compression, and medical imaging. In particular, the discrete wavelet transform (DWT) can be used in dividing the data series into components of different frequencies, so that each component can be studied separately to investigate data series in depth. There are two types of wavelets defined on different normalization rules, i.e., father wavelets $\varphi(t)$ and mother wavelets $\psi(t)$, where

$$\int \varphi(t)\mathrm{d}t = 1 \quad \text{and} \quad \int \psi(t)\mathrm{d}t = 0.$$

The smooth and low frequency parts of a signal are described by using the father wavelets, while the detailed and high frequency components are described by the mother wavelets. Thus, they are used in pairs within a family of wavelet functions, with the father wavelets used for the trend components and the mother wavelets for all the deviations from the trend. The orthogonal wavelet families have four different types which are typically used in practical analysis, namely, the haar, daublets, symmlets and coiflets. The haar wavelet has compact support and is symmetric; but, unlike the other wavelets, it is not continuous. The daublets are continuous orthogonal wavelets with compact support. The symmlets are constructed to be as nearly symmetric as possible. The coiflets are built to be nearly symmetric.

Wavelets are derived using a two-scale dilation equation. For father wavelets $\varphi(t)$ and mother wavelets $\psi(t)$, the equation is defined respectively by

$$\varphi(t) = \sqrt{2}\sum_k l_k \varphi(2t-k), \tag{1}$$

$$\psi(t) = \sqrt{2}\sum_k h_k \psi(2t-k), \tag{2}$$

where the coefficients l_k and h_k are the low-pass and high-pass coefficients given by

$$l_k = \frac{1}{\sqrt{2}}\int \varphi(t)\varphi(2t-k)\mathrm{d}t, \tag{3}$$

$$h_k = \frac{1}{\sqrt{2}}\int \psi(t)\psi(2t-k)\mathrm{d}t. \tag{4}$$

The orthogonal wavelet series approximation to a signal $f(t)$ is defined by

$$f(t) = \sum_k s_{J,k}\varphi_{J,k}(t) + \sum_k d_{J,k}\psi_{J,k}(t) + \ldots + \sum_k d_{1,k}\psi_{J,k}(t), \tag{5}$$

where J is the number of multiresolution levels and k ranges from 1 to the number of coefficients in the specified component. The coefficient $s_{J,k}$, $d_{J,k}$, …, $d_{1,k}$ are the wavelet transform coefficients given by

$$s_{J,k} = \int \varphi_{J,k}(t) f(t)\mathrm{d}t, \tag{6}$$

$$d_{j,k} = \int \psi_{j,k}(t) f(t)\mathrm{d}t,\ \ j=1, 2, \ldots, J. \tag{7}$$

The magnitudes give a measure of the contribution of the corresponding wavelet function to the signal. The basic function $\varphi_{J,k}(t)$ and $\psi_{j,k}(t)$ (j=1,2,…,J) are the approximating wavelet functions, generated from φ and ψ through scaling and translation as follows:

$$\varphi_{J,k}(t)=2^{-J/2}\varphi(2^{-J}t-k)=2^{-J/2}\varphi[(t-2^{J}k)/2^{J}], \quad (8)$$

$$\psi_{J,k}(t)=2^{-J/2}\psi(2^{-J}t-k)=2^{-J/2}\psi[(t-2^{J}k)/2^{J}]. \quad (9)$$

The DWT is used to compute the coefficient of the wavelet series approximation in Eq.(5) for a discrete signal f_1, …, f_n of finite extent. The DWT maps the vector $\boldsymbol{f}=[f_1, …, f_n]^{\mathrm{T}}$ to a vector of n wavelet coefficients $\boldsymbol{w}=[w_1, …, w_n]^{\mathrm{T}}$ which contain both the smoothing coefficient $s_{J,k}$ and the detail coefficients $d_{j,k}$ (j=1,…,J). $s_{J,k}$ describes the underlying smooth behaviour of the signal at coarse scale 2^J while $d_{J,k}$ describes the coarse scale deviations from the smooth behaviour and $d_{J-1,k}$, …, $d_{1,k}$ provide progressively finer scale deviations.

In the case when n is divisible by 2^J, there are $n/2$ coefficients $d_{1,k}$ at the finest scale 2^1=2 and $n/4$ observation in $d_{2,k}$ at the second scale 2^2=4. Likewise, there are $n/2^J$ observations in each of $d_{J,k}$ and $s_{J,k}$ where

$$n=n/2+n/4+\ldots+n/2^{J-1}+n/2^{J}+n/2^{J}. \quad (10)$$

The multiresolution decomposition of a signal can now be defined by

$$S_J(t)=\sum_k s_{J,k}\varphi_{J,k}(t), \quad (11)$$

$$D_j(t)=\sum_k d_{j,k}\psi_{j,k}(t),\quad j=1, \ldots, J. \quad (12)$$

These two functions are called the smooth signal and the detail signal, respectively, which constitute a decomposition of a signal into orthogonal components at different scales. A signal $f(t)$ can now be written in terms of these signals as follows:

$$f(t)=S_J(t)+D_J(t)+\cdots+D_1(t). \quad (13)$$

As each term in Eq.(13) represents a component of $f(t)$ at a different resolution, it is called a multiresolution decomposition.

EMPIRICAL ANALYSIS

In this section, the daily return series data of the copper futures of SHFE and LME are split into different frequency components to get a clear picture of the movements in the two markets with the wavelet multiresolution decomposition method discussed in the previous section. On the other hand, the choice of an appropriate wavelet for a given application is an important question. In this study, the Haar wavelet is used to deal with copper future daily return data because it is known to provide a better localization in both spatial and frequency domains.

Three month copper future contract is the main exchange contract which represents the price trend of all futures contract in SHFE. Therefore, the data used in the analysis to follow consist of three month copper future daily closing price in LME and SHFE from June 16, 1998 to Feb. 16, 2007, as shown in Fig.1. As SHFE uses RMB to quote price of the futures and LME uses US dollar, the closing prices in SHFE are changed into US dollar according to the 8.23 fixed exchange rates only for easy comparing. It is shown in Fig.1 that the closing prices of SHFE_Cu3 are always higher than those of LME_Cu3 by a certain value which may be caused by the expenses of insurance, ship transportation and customs duty. It also can be found that the variation tendency of the copper future price in the two markets is basically identical. Since SHFE uses RMB for presenting the copper future price and LME uses US dollar, the closing prices are dealt with as daily returns with the equation R_d=100×ln(P_d/P_{d-1}), where R is the daily return and P_d is the closing price at day d and P_{d-1} is the closing price at day d−1, to avoid the influence of exchange rate

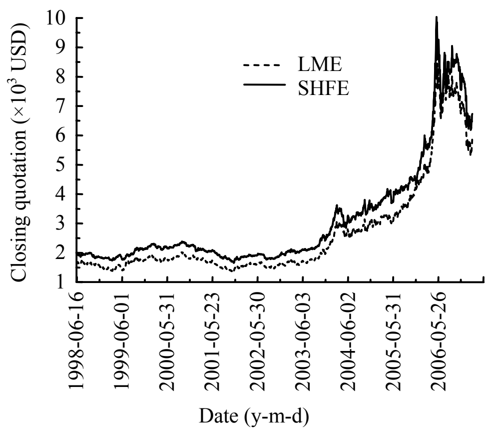

Fig.1 Closing quotations of LME and SHFE

and actual copper trade expenses. The effects of the differences of time, holiday and abnormal trade stop between London and Shanghai are also treated for original experimental data. Total 2075 individual numbers for each market are used as the experimental sample for later wavelet decomposition.

Time series of the copper futures price daily return in LME and SHFE are decomposed in six layers with Haar wavelet multiresolution, it can be written as $S=d_1+d_2+d_3+d_4+d_5+d_6+a_6$, as shown in Figs.2 and 3. Layer d_1 represents short-term variations due to shocks occurring within a day or two, and layer d_2 represents variations at a time scale of 2^2=4 d, and so on, layer a_6 illustrates the remaining portion.

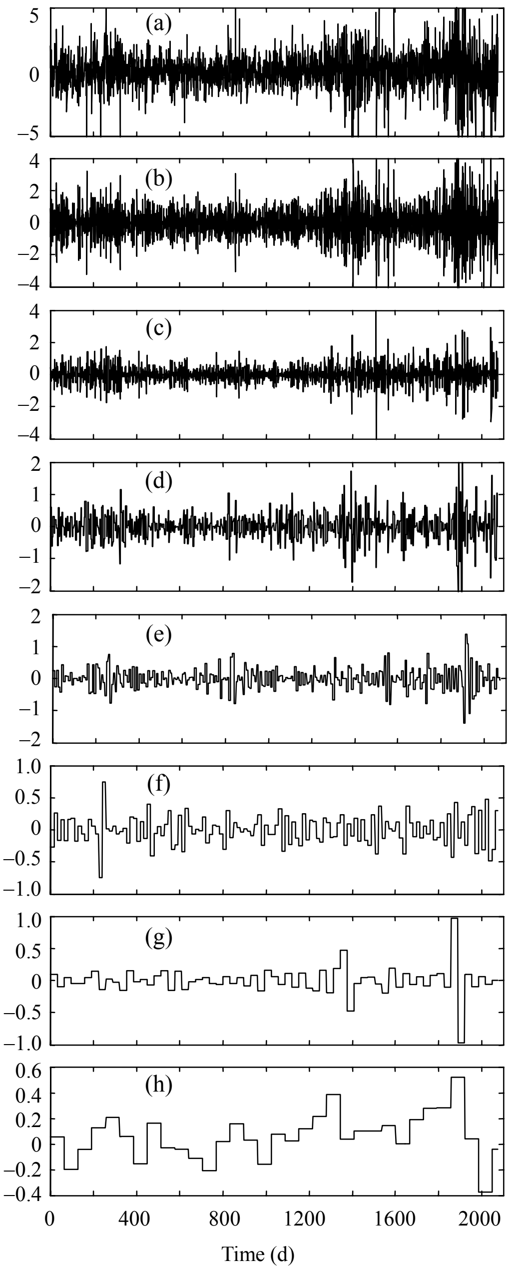

Fig.2 Copper future daily returns wavelet decomposition of LME. (a) Daily return variation of LME decomposed in six time scales of (b) 2^1 d, (c) 2^2 d, (d) 2^3 d, (e) 2^4 d, (f) 2^5 d and (g) 2^6 d with (h) the remaining portion

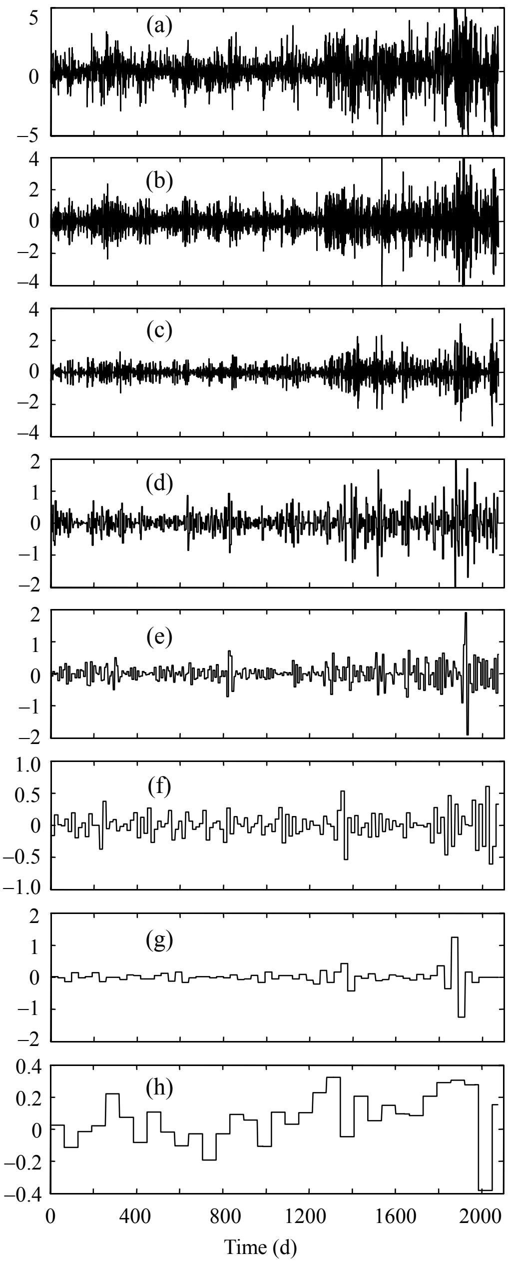

Fig.3 Copper future daily returns wavelet decomposition of SHFE. (a) Daily return variation of SHFE decomposed in six time scales of (b) 2^1 d, (c) 2^2 d, (d) 2^3 d, (e) 2^4 d, (f) 2^5 d and (g) 2^6 d with (h) the remaining portion

Energy percentages which denote the proportion of energy in the original signal accounted for by each layer are listed in Table 1. From the energy statistics for the wavelet layers of the future returns, we can find that high-frequency detail components represent much more energy than low-frequency components. Nearly 75% energy is included in d_1+d_2. It is shown that the fluctuations of the copper future daily return are mostly caused by short-term effects. On the other hand, it is mostly impossible to predict the price fluctuations in a future market by technique analysis.

Table 1 Energy percentage of different frequency bands

Frequency bands	Energy percentage (%)	
	LME	SHFE
d_1	54.99	47.43
d_2	22.47	25.48
d_3	11.50	12.01
d_4	5.25	6.87
d_5	2.22	2.40
d_6	2.01	4.14
a_6	0.00	0.00

The correlation between two exchanges is studied for the returns on different frequency bands. The linear regression results of the returns between the two markets on different frequency bands are listed in Table 2. It indicates that the future prices in SHFE almost cannot be predicted from that in LME with technical data analysis. The relativities of copper future daily returns in LME and SHFE are different on the time scales. It is shown that high volatility spillover effects exist in 32-day scale between LME and SHFE, and caused by monthly trade of the copper futures in SHFE.

Table 2 Relativity of copper future daily returns of LME and SHFE

Frequency bands	Linear regression coefficient	Correlation coefficient
S	0.018	0.136
d_1	0.033	−0.181
d_2	0.075	0.274
d_3	0.253	0.503
d_4	0.559	0.748
d_5	0.677	0.823
d_6	0.412	0.638

CONCLUSION AND FUTURE WORKS

In this paper, we study the spillover effect of copper future daily returns between SHFE and LME. The closing quotation daily return time series are decomposed on 2^n (n=1, …, 6) wavelet frequency components for correlation analysis. Using the DWT to study the behavior of copper future markets provides a clear view on the influence between LME and SHFE. It is shown that high frequency detail components represent much more energy than low-frequency smooth components. And it is also shown that large effects exist between LME and SHFE for monthly price responses of the copper futures but not for daily price responses. Future researches include empirical investigation into a variety of futures and more international future markets.

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