Comparison on turnovers of agricultural products futures based on wavelet packet transform method

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Received 1 March 2014, www.cmnt.lv

Abstract

In order to distinguish the different patterns and evolving trends on turnovers of agricultural products futures between Zhengzhou Commodity Exchange and Dalian Commodity Exchange. A time-frequency analysis approach, i.e. wavelet packet energy spectrum, is investigated in this paper. Firstly, wavelet packet energy spectrum is briefly introduced. Secondly, two different non-stationary signals of turnover of agricultural products futures from 2009 to 2013 coming from Zhengzhou Commodity Exchange and Dalian Commodity Exchange are described in wavelet packet energy spectrum. First, reconstructed coefficients of main analysis wavelets packet of signals of turnover of agricultural products futures of Zhengzhou commodity exchange and Dalian Commodity Exchange are calculated. The obtained frequency band power ratios are used to show the different characteristics and evolving trends on turnovers of agricultural products futures between Zhengzhou Commodity Exchange and Dalian Commodity Exchange. With these results, the two signals are distinctly different from each other. It is proved that the technique of wavelet packet energy spectrum is effective for the purpose of distinction of turnover of agricultural products futures in commodity exchanges.

Keywords: turnover amounts, time-frequency analysis, non-stationary signals, wavelet packet energy spectrum, frequency band power ratios

1 Introduction

Turnover of agricultural products futures of Zhengzhou Commodity Exchange (Z-CE) and Dalian Commodity Exchange (D-CE) includes so much information that it can be used to diagnose, treat or predict economic trends. The data turnover of agricultural products futures has one or more of the following problems, (a) the total data span is too short, (b) the data is non-stationary and (c) the data represents nonlinear process [1-3].

In this paper, we choose turnover of agricultural products futures between Zhengzhou commodity exchange and Dalian commodity exchange to analysis. From their time domain waveforms and their power spectrum densities, they are not easily to be distinguished.

Wavelet packet energy spectrum analysis features multi-definition in time-frequency domain as follows: signal is decomposed into two parts in a wavelet transform, low frequency part and high frequency part. Then the low frequency part is decomposed as mentioned above again while the high frequency part remained. Repeatedly, multi-level frequency decomposition can be achieved. Wavelet packet energy spectrum is based on this, and it conducts an equal-band and orthogonal decomposition in the whole frequency domain. After that, energies of the reconstructed signal in the related frequency band are calculated, and frequency-band energy ratio (FBER) is obtained [4].

In this paper, wavelet packet energy spectrum is adopted to decompose the turnover of agricultural products futures between Zhengzhou commodity exchange and Dalian commodity exchange in the whole domain, and using proper frequency bands signals are reconstructed according to the turnover of agricultural products. Energies of the corresponding reconstructed signals are estimated by calculating the frequency-band energy ratio, which is used as a qualitative index for estimating different sleeping states. Plenty of experimental data [5] are used to validate the method, and the FBER is confirmed to be effective.

2 Basic algorithm procedure of wavelet packet energy spectrum

Wavelet transform is used to describe the signal, which is a 1-dimension signal in time domain originally, as a 2-dimension signal in time-frequency domain. Wavelet transform of function is defined as follows:

$$Wf(a,b) = (1/\sqrt{a})\Phi(\frac{t-b}{a})f(t)\mathrm{d}t\,, \tag{1}$$

where $\Phi(t)$ is called the mother wavelet, a and b are scale parameter and position shift parameter, respectively.

Wavelet packet features orthogonal, independent and multi-definite decomposition, the general form is

$$W_j = \bigoplus_{m=0}^{2^k-1} U_{j-k}^{2^k+m} \qquad \left(j,k,m \in Z\right), \tag{2}$$

where $j = 1,2,\cdots$; $k = 1,2,\cdots,j$; and $m = 0,1,2,\cdots,$ $2^k - 1$.

According to multi-definition theory, wavelet packet transform treated Hilbert space as orthogonal summation of all the sub spaces, namely $L^2\left(R\right) = \oplus W_j$, $j \in Z$. Therefore, wavelet packet transform can decompose the signal into independent frequency bands orthogonally, and with

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no redundancy or leakage. In a wavelet packet transform with a definition *j*, $x^{k,m}(i)$ represents the discrete signal in subspace $U_{j-k}^{2^k+m}$ corresponding to x_{2^k+m}.

The number of levels in the wavelet packet energy spectrum is determined according to the signal itself and the characteristic parameter. The frequency range of the bands obtained after decomposition is

$$f(j,i)=\left[\frac{f_s(j-1)}{2^{(i+1)}},\ \frac{f_s j}{2^{(i+1)}}\right], \tag{3}$$

where, $f(j,i)$ represents the range of band *j* in level $i(j=1,2,\cdots,2^i)$, f_s is sample frequency.

Schematic plan of wavelet packet decomposition is shown in Figure 1

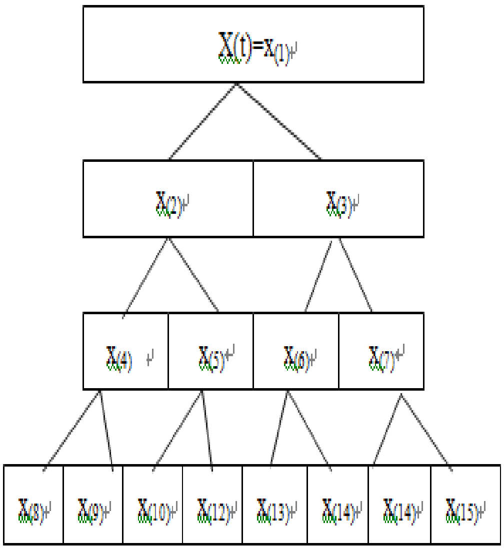


FIGURE 1 Schematic plan of wavelet packet decomposition

Assume that the data length of discrete signal $x^{k,m}(i)$ is *N*, the energy can be represented as

$$E_n\left(x^{k,m}(i)\right)=\frac{1}{N-1}\sum_{i=1}^{N}\left(x^{k,m}(i)\right)^2, \tag{4}$$

where, k is the times of decomposition, *m* is the sequence number of the frequency bands after decomposition.

According to conversation of energy theory, we have

$$E_n\left(x(t)\right)=\sum_{m=0}^{2^k-1}E_n\left(U_{j-k}^{2^k+m}\right)= \sum_{m=0}^{2^k-1}E_n\left(x_{2^k+m}\right)=\sum_{m=0}^{2^k-1}E_n\left(x^{k,m}(i)\right). \tag{5}$$

The ratio of energy of frequency band m to that of the signal, namely, frequency-band energy ratio in unitary wavelet packet transform is:

$$E_n(m)=\frac{E_n\left(x^{k,m}(i)\right)}{E_n\left(x(t)\right)}. \tag{6}$$

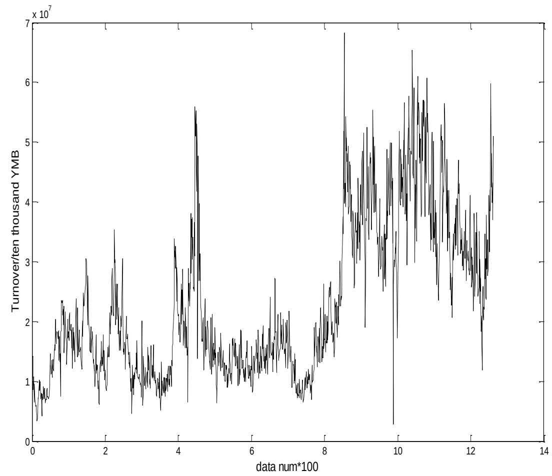
The summation of all the frequency-band energy ratios is 1, namely

$$\sum_{m=0}^{2^k-1}E_n(m)=1. \tag{7}$$

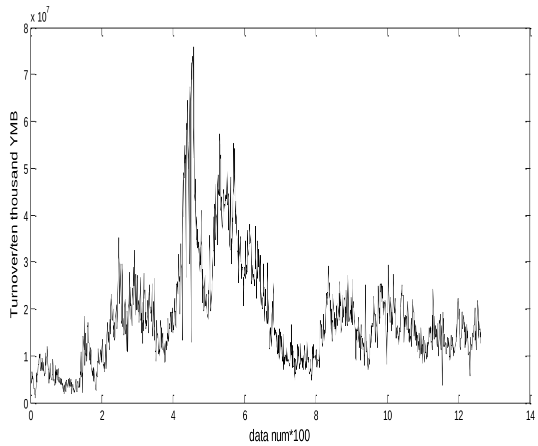
3 Results

We choose two time series of turnover of agricultural products futures between Zhengzhou commodity exchange and Dalian commodity exchange to be analyzed. These two time series are recorder as turnover of every day agricultural products futures of Zhengzhou commodity exchange and Dalian commodity exchange from the beginning of 2009 to the end of 2013.

There are two different non-stationary signals are shown in Figure 2. From Figure 2, the difference is obviously, but it is not easy to identify one from each other.



a) Turnover of agricultural products futures of Z-CE



b) Turnover of agricultural products futures of D-CE

FIGURE 2 Original signals of turnover of agricultural products futures of Zhengzhou commodity exchange and Dalian commodity exchange

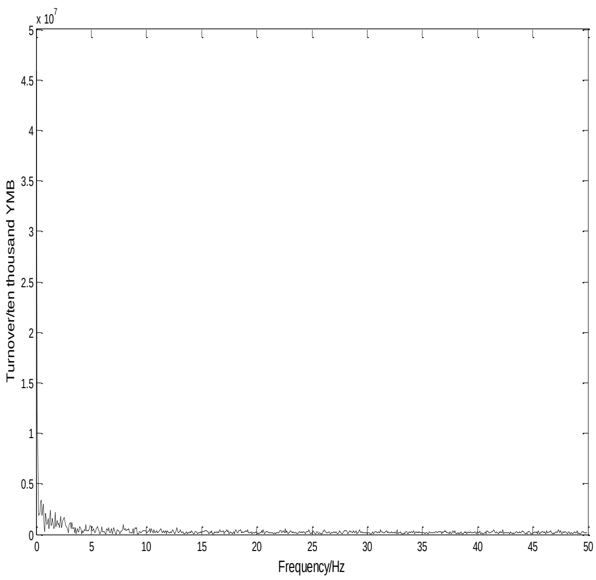
The method above is verified in signals of turnover of agricultural products futures of Zhengzhou commodity exchange and turnover of agricultural products futures of Dalian commodity exchange. The original signal is sampled in 500 Hz priory to make sure that the frequency range of wavelet packet analysis is consistent with the frequency bands of the turnover of agricultural products futures of Zhengzhou commodity exchange and turnover of agricultural products futures of Dalian commodity exchange. Frequency range of 4th level of turnover of agricultural products with wavelet packet decomposition is shown in Table 1. There are 16 wavelet packets in the high scale; each frequency width is 31.25 Hz.

TABLE 1 Frequency range of 4th level of turnover of agricultural products with wavelet packet decomposition

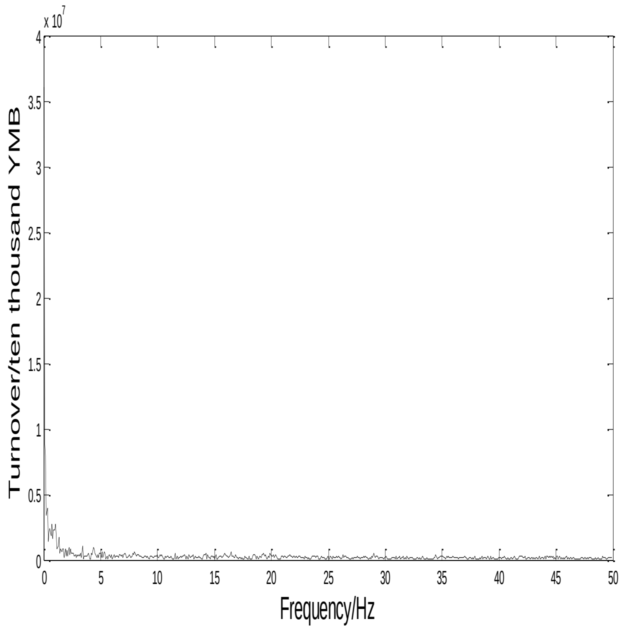
No.	**4 layer number**	**Frequency sphere (Hz)**	**No.**	**4 layer number**	**Frequency sphere (Hz)**
1	[4,0]	0~31.25	9	[4,12]	250~281.25
2	[4,1]	31.25~62.5	10	[4,13]	281.25~312.5
3	[4,3]	62.5~93.75	11	[4,15]	312.5~343.75
4	[4,2]	93.75~125	12	[4,14]	343.75~375
5	[4,6]	125~156.25	13	[4,10]	375~406.25
6	[4,7]	156.25~187.5	14	[4,11]	406.25~437.5
7	[4,5]	187.5~218.75	15	[4,9]	437.5~468.75
8	[4,4]	218.75~250	16	[4,8]	468.75~500

Frequency spectrum analysis of turnover of agricultural products futures of Zhengzhou commodity exchange and turnover of agricultural products futures of Dalian commodity exchange is shown in Figure 3. According to the main frequency, four wavelet packets of the signals are analyzed. The frequency bands are 31.25-62.5 Hz, 125-156.25 Hz, 187.5-218.75 Hz, 281.25-312.5 Hz.

Figures 4 and 5 are the main analysis wavelet packets reconstruct figures according to the signal components.

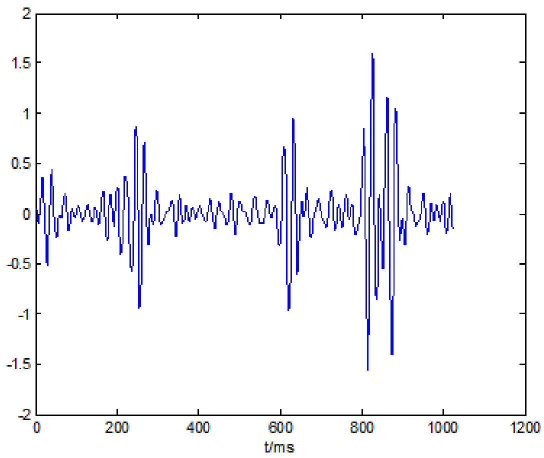


a) Turnover of agricultural products futures of Zhengzhou commodity exchange

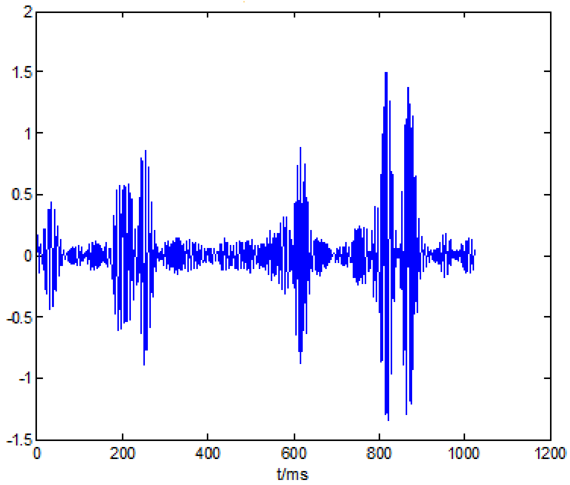


b) Turnover of agricultural products futures of Dalian commodity exchange

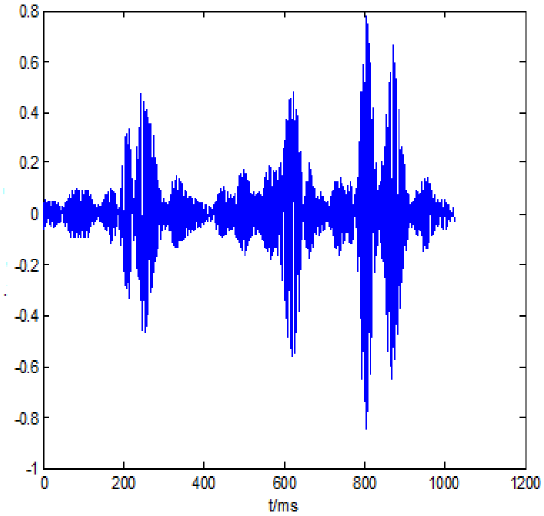
FIGURE 3 Frequency spectra of original signals of turnover of agricultural products futures of Zhengzhou commodity exchange and Dalian commodity exchange



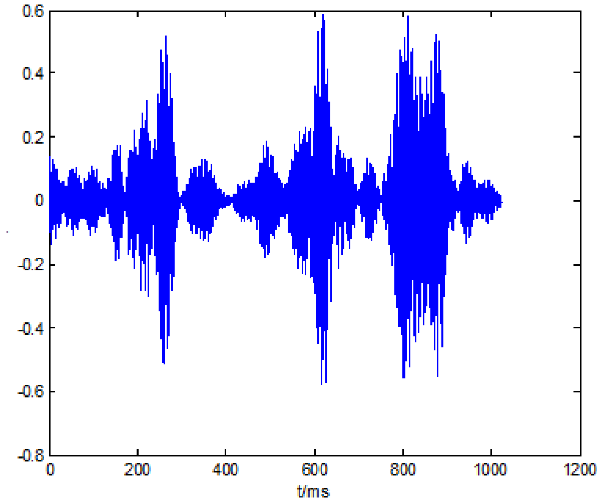
a) Reconstruct packet (4,1) 31.25-62.5 Hz



b) Reconstruct packet (4,6) 125-156.25 Hz

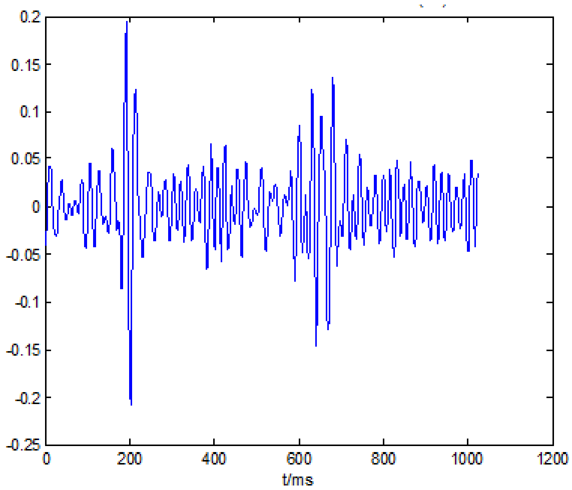


c) Reconstruct packet (4,5) 187.5-218.75 Hz

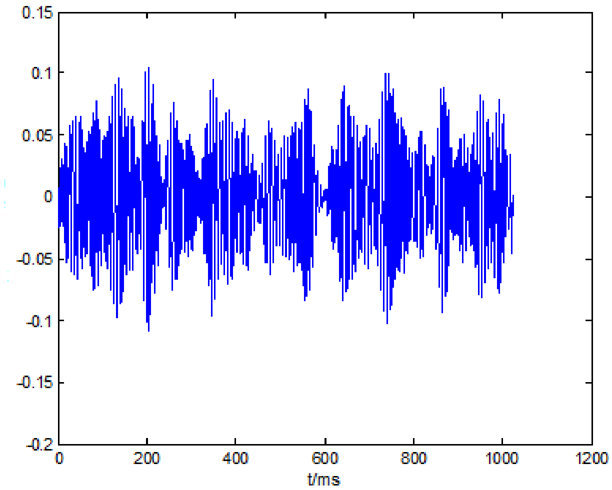


d) Reconstruct packet (4,13) 281.25-312. 5Hz

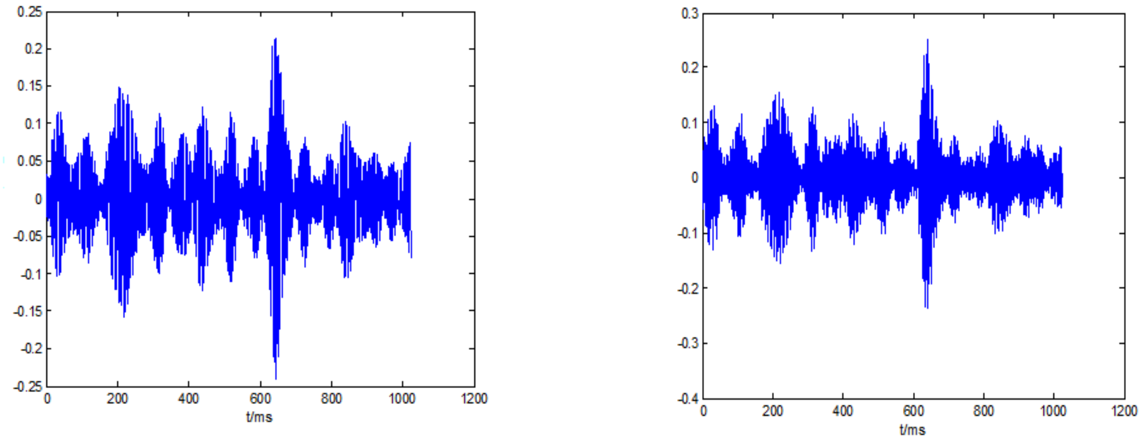
FIGURE 4 Reconstructed coefficients of main analysis wavelets packet of signals of turnover of agricultural products futures of Zhengzhou commodity exchange



a) Reconstruct packet (4,1) 31.25-62.5 H



b) Reconstruct packet (4,6) 125-156.25 Hz



c) Reconstruct packet (4,5) 187.5-218.75 Hz d) Reconstruct packet (4,13) 281.25-312.5 Hz

FIGURE 5 Reconstructed coefficients of main analysis wavelets packet of signals of turnover of agricultural products futures of Dalian commodity exchange

The FBERs of the 2 groups of signals obtained are shown in Figures 6 and 7.

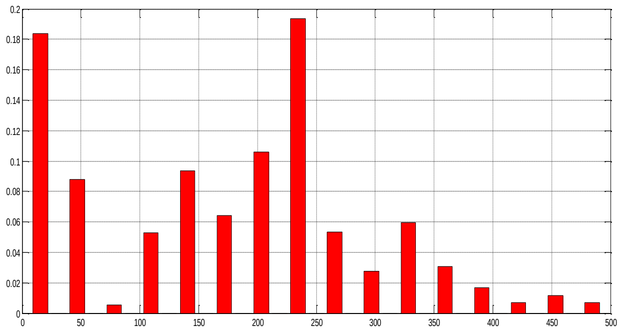


FIGURE 6 Power ratio bars for different frequency bands of turnover of agricultural products futures of Zhengzhou commodity exchange with wavelet packet decomposition

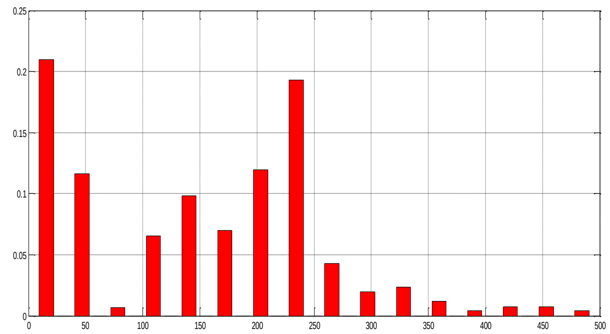


FIGURE 7 Power ratio bars for different frequency bands of turnover of agricultural products futures of Dalian commodity exchange with wavelet packet decomposition

The FBERs of the signals of turnover of agricultural products futures of Zhengzhou commodity exchange and turnover of agricultural products futures of Dalian commodity exchange are shown in Table 2 and Table 3. We can find the values and their tendency of the total amplitude contributions of turnover of agricultural products futures are remarkable different of Zhengzhou commodity exchange and Dalian exchange.

TABLE 2 Calculated results of scaled energy in frequency bands of turnover of agricultural products futures of Zhengzhou commodity exchange with wavelet package

No.	4 layer number	FBER	No.	4 layer number	FBER
1	[4,0]	0.1836	9	[4,12]	0.0532
2	[4,1]	0.0878	10	[4,13]	0.0275
3	[4,3]	0.0054	11	[4,15]	0.0597
4	[4,2]	0.0528	12	[4,14]	0.0305
5	[4,6]	0.0938	13	[4,10]	0.0166
6	[4,7]	0.0641	14	[4,11]	0.0067
7	[4,5]	0.1058	15	[4,9]	0.0118
8	[4,4]	0.1938	16	[4,8]	0.0068

TABLE 3 Calculated results of scaled energy in frequency bands of turnover of agricultural products futures of Dalian commodity exchange with wavelet package

No.	4 layer number	FBER	No.	4 layer umber	FBER
1	[4,0]	0.2096	9	[4,12]	0.0427
2	[4,1]	0.1160	10	[4,13]	0.0194
3	[4,3]	0.0071	11	[4,15]	0.0234
4	[4,2]	0.0657	12	[4,14]	0.0177
5	[4,6]	0.0986	13	[4,10]	0.0041
6	[4,7]	0.0699	14	[4,11]	0.0077
7	[4,5]	0.1193	15	[4,9]	0.0077
8	[4,4]	0.1927	16	[4,8]	0.0044

4 Conclusions

Turnover of agricultural products futures of Zhengzhou commodity exchange and Dalian commodity exchange as two different non-stationary signals are used as examples to be described and distinguished in the time-frequency analyses of wavelet package decomposition in the paper. The technique of wavelet package decomposition is proved to be effective on processing and distinguishing the differences of the non-stationary signals.

For the original non-stationary signals of turnover of agricultural products futures of Zhengzhou commodity exchange and Dalian commodity exchange given here, the obtained wavelet package decomposition are easily distinguished from each other. The frequency spectra are also different between them. These results demonstrate that the wavelet package decomposition can offer a more effective way for identifying the different features of turnover of agricultural products futures of Zhengzhou commodity exchange and Dalian commodity exchange.

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