CHINESE GEOGRAPHICAL SCIENCE
Volume 14, Number 3, pp. 193-201, 2004
Science Press, Beijing, China

R/S AND WAVELET ANALYSIS ON EVOLUTIONARY PROCESS OF REGIONAL ECONOMIC DISPARITY IN CHINA DURING PAST 50 YEARS

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ABSTRACT: This paper shows the dynamic process of regional disparity of economic development in China in the past 50 years from a new insight by using the rescaled range statistic (R/S) analysis and wavelet analysis of the Theil index sequence with different time scales. The main conclusions are: 1) The regional disparity of economic development in China, including the inter-provincial disparity, inter-regional disparity and intra-regional disparity, has existed for many years. Theil index by the comparative price has revealed the true trend for comparative disparity of regional economic development from 1952 to 2000. 2) Decomposition of Theil index indicates that the dynamic trend of comparative inter-provincial disparity in the coastal region is in line with dynamic trend of inter-provincial disparity in the whole China. 3) The R/S analysis results tell us that during 1966-1978, the Hurst exponent H=0.504≈0.5, which indicates that in that period the evolution of comparative inter-provincial disparity of economic development showed a random characteristic, and in the other periods, i.e. 1952-1965, 1979-1990 and 1991-2000, the Hurst exponent H>0.5, which indicates that in those periods the evolution of the comparative inter-provincial disparity of economic development in China had a long-enduring characteristic. 4) By using wavelet analysis at different time scale, we arrived at a conclusion that the evolutionary process of the disparity of economic development of China is not a simple inverted U shape but a compound of several U shapes. The result tells us that the evolutionary plot of inter-provincial disparity in China follows the inverted U on the whole at the higher scale, 2^4 (16 years). That is to say, the disparity tends to rise in the first stage of economic development, and fall slowly over the peak in the second stage of economic development. However, if we shorten the time scale to 2^3 (8 years), then a link of several U shapes will appear.

KEY WORDS: China; regional economic disparity; Theil index; R/S analysis; wavelet analysis

CLC number: TP79; F124 Document code: A Article ID: 1002-0063(2004)03-0193-09

1 INTRODUCTION

There have been many literatures about the regional disparity of economic development in China since the late 1970s. Some scholars argue that disparity of regional development in China has been expanded since 1978, but others find it has reduced since 1978. The findings of some scholars show that the evolutionary process of the disparity of regional economic development in China follows the inverted U shape, but some others do not think so. What is the true tendency, and is it really inverted U shape? How did the disparity of regional economic development in China evolve during the past 50 years from 1952-2000? This paper attempts to answer the questions in a new insight of rescaled range statistic (R/S) and wavelet analysis of Theil index sequence analysis. Firstly, Theil index is calculated and decomposed from 1952-2000 by the comparative price in 1978, which reveals the change of inter-provincial disparity in whole China, coastal, middle and western region, and the disparity between the latter three regions. Secondly, R/S and wavelet analysis is used to produce Theil index sequence by different time scales, which shows the dynamic process of regional disparity of economic development in China during the past five decades.

Received date: 2003-10-08
Foundation item: Under the auspices of National Philosophy and Social Sciences Foundation of China (No. 00BJL051, 03BJL027)
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2 METHODOLOGY AND DATA

2.1 Division of Spatial Unit

There is usually a spatial criterion for studies on regional disparity. What spatial criterion should we choose for researches? It depends on study purposes and specific objectives. The purpose of this paper is to reveal provincial disparity, regional disparity in economic development from 1952-2000 and their evolution. Provincial administrative unit is a political and economic region with an integrated function, and each with a complete system of statistical data, which is readily available. Thus, we choose the provincial region (provinces, municipalities and autonomous regions) as basic spatial unit for this analysis, and also choose the three supra-provincial regions: coastal, middle and western region as more overall spatial units. The coastal provinces are Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi and Hainan. The middle provinces are Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan. The western provinces are Yunnan, Guizhou, Sichuan, Chongqing, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang.

2.2 Selection of Statistical Indicators and Sample Data

As for study of dynamic evolution of regional disparity in China, per capita GDP of each province may be appropriate. Per capita GDP is widely used because it is the best approximation and can well reflect the overall development level and people's well being. Moreover, the time series data in per capita GDP in each province are complete and can be used for spatial and temporal comparison. Therefore, we choose 31 provinces (municipalities, autonomous regions) in China as spatial samples, the period 1952-2000 as temporal samples.

The primary data are mainly from National Bureau of Statistics of China (NBSC, 1997, 1999, 2001, 2002). In a general way, the data are creditable and authoritative theoretically. However, several years' data such as those during the "Great Leap Forward" period are distorted because of none-economic factors, which is proved by Gini and Theil index in section 3.1 in this paper. Consequently, these data are not so credible and the result calculated by using them is not so precise. However, as we study regional economic disparity in China in a long period, the primary data can only be from National Bureau of Statistics of China.

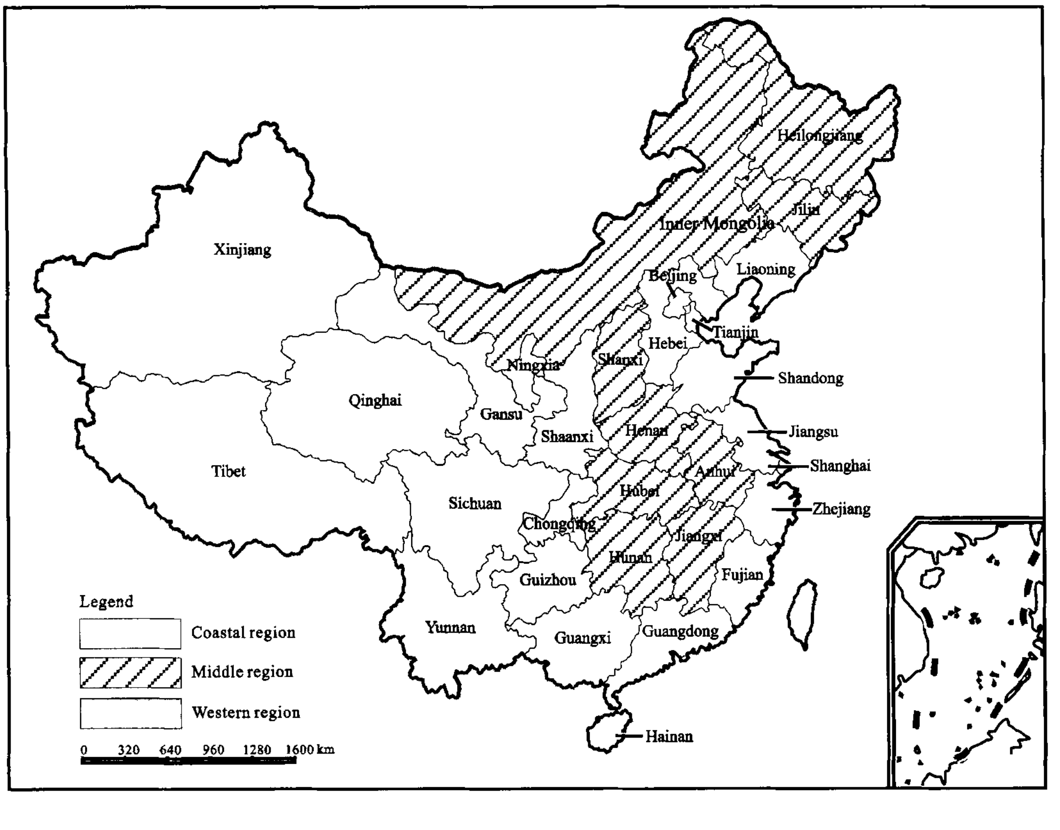

Fig. 1 Division of the spatial unit of China

2.3 Data Processing Method for Eliminating Influence of Prices

If the price of products and services does not change at all, we can ignore the influence from price change. China is, however, a large country with a big spatial difference. During its past 50 years of economic development, China has undergone several different stages when the comprehensive price index and inflation rate was constantly changing in different periods and at different places. Therefore, if we discuss regional development disparity using present price, we may have a false conclusion. In order to accurately reflect the disparity and its evolution, we must consider the influence of the price factor. So we convert all GDP data of each region into present value by using price index (1) as follows (HU and ZOU, 2000).

$$X_i(t)=X_i(t_0)\times \beta_i(t) \quad (1)$$

where $X_i(t)$ is the real GDP data of the region i at the tth year, $X_i(t_0)$ is the real GDP data of the region i at the first period (the t_0th year), $\beta_i(t)$ is the GDP growth exponent of the region i from the base year (the t_0th year) to the tth year.

In this article, the year 1978 is the base year, and the GDP data of each year were the real data converted in term of comparable price.

2.4 Quantitative Analysis Methods

2.4.1 Quantitative indicators

There are so many quantitative exponents used to describe regional disparity (BORTS and STEIN, 1964; DUNFORD, 1993; DOWRICK and NGUYEN, 1989), such as extreme deviation, standard deviation, coefficient of variation, Engel coefficient, Gini coefficient, location entropy and so on. Because it not only is preferable to describe the relative disparity among regions, but also can be decomposed into sub-regions, Theil index was chosen as main quantitative indicator for analysis and Gini coefficient as circumstantial evidence.

Theil index is also called Theil entropy, which was proposed by THEIL(1967). Theil index (T) is defined in the following way:

$$T=\sum_{i=1}^{N} Y_i \log\frac{Y_i}{P_i} \quad (2)$$

where N is the number of areas, Y_i is the GDP share of region i in total one in the whole country, P_i is the population share of region i in total one in the whole country.

If T is bigger, disparity in economic development among various regions will be bigger. Otherwise, disparity will become smaller.

Another characteristic of Theil index is that it may be decomposed into two parts: inter-group disparity and intra-group disparity, which make us more clear about the evolution of both inter-group and intra-group disparities and their respective importance in overall disparity. In China, for instance, Theil index can be decomposed into inter-regional disparity and intra-regional disparity (ZHOU, 1999) as follows:

$$T=T_{\text{inter}}+T_{\text{intra}}=\sum_{i=1}^{3} Y_i \log\frac{Y_i}{P_i}+\sum_{i=1}^{3} Y_i \left[\sum_j Y_{ij} \log\frac{Y_{ij}}{P_{ij}}\right] \quad (3)$$

where i (i=1, 2, 3) is one of three supra-provincial regions (coastal, middle or western region), and when i=1, j=1, 2, ..., 12, which respectively correspond to 12 provinces in coastal region; when i=2, j=1, 2, ..., 9, which respectively correspond to 9 provinces in middle region; when i=3, j=1, 2, ..., 10, which respectively correspond to 10 provinces in western region. Y_i is the GDP share of supra-provincial region i in national one; P_i is the population share of supra-provincial region i in national one; Y_{ij} is the GDP share of province j in overall one of supra-provincial region i; P_{ij} is the population share of province j in total one of supra-provincial region i.

2.4.2 R/S analysis

All statistical methods assume that all data of time series be independent (i.e. fit for Gauss distribution), hence the series is stochastic. When HURST(1951, 1955), a British physicist, analyzed water level of the Nile River, he found that such time series like river water level was not fit for Gauss distribution, showing a characteristic of discontinuity and durability. Based on the empirical findings of H E HURST, B B MANDELBROT made a breakthrough on fundamental theories of traditional statistical methods. He divided time series into two categories: discontinue and durable, of which the former is called Noah Effects and the latter is called Joseph Effects, both originating from Genesis 6 of Old Testament as "...were all the fountain of the great deep broken up, and the window of heaven were opened. And the rain was upon the earth for forty days and forty nights." The torrential rain lasting for 40 days and nights presents a characteristic of unevenness in rainfall and discontinuity in time. The story of Joseph in Genesis 41 reads like "...there came seven years of great plenty throughout the land of Egypt. And there shall arise after them seven years of famine" showing the periodical occurrence of humidity and aridity with a characteristic of durability. The idea was proposed in his speech named "New forms of chance in the sciences" and recorded in references of MANDELBROT and WALLIS (1968) and MANDELBROT (1973). Under the effect of Noah Effects and Joseph Effects, time series no longer presents a random Brownian movement unrelated to the past, but shows a characteristic of long-term correlation (COMTE and RENAULT, 1996), which was called fBM (fractional Brownian Movement) by B B MANDELBROT and could be studied by rescaled range statistic (R/S) analysis. The R/S analysis, as a non-linear method for forecast, has been widely used in many researches (CHEN *et al.*, 1992).

The principle of R/S analysis is as follows: Considering the time series $\{\xi(t)\}(t=1, 2, \cdots)$ of Theil index variation, for any positive integer $\tau \geqslant 1$, the mean value series is defined as

$$\langle\xi\rangle_\tau=\frac{1}{\tau}\sum_{t=1}^{\tau}\xi(t) \qquad \tau=1, 2, \cdots$$

The accumulative deviation is

$$X(t, \tau)=\sum_{u=1}^{t}(\xi(u)-\langle\xi\rangle_\tau) \qquad 1\leqslant t\leqslant \tau$$

The extreme deviation is

$$R(\tau)=\max_{1\leqslant t\leqslant \tau} X(t, \tau)-\min_{1\leqslant t\leqslant \tau} X(t, \tau) \qquad \tau=1, 2, \cdots$$

The standard deviation is

$$S(\tau)=\left[\frac{1}{\tau}\sum_{t=1}^{\tau}(\xi(t)-\langle\xi\rangle_\tau)^2\right]^{\frac{1}{2}} \qquad \tau=1, 2, \cdots$$

When analyzing the statistic rule of $R(\tau)/S(\tau)\triangleq R/S$, HURST discovered a relational expression

$$R/S\propto(\frac{\tau}{2})^H \qquad (4)$$

It shows there is Hurst phenomenon in time series, and H is called the Hurst exponent. According to $(\tau, R/S)$, H can be obtained by least square method (LSM) in log-log grid. HURST *et al.*(1965) once proved that if $\{\xi(t)\}$ is independently random series with limited variance, the expression H=0.5, H $(0<H<1)$ is dependent of an incidence function $C(t)$:

$$C(t)=2^{2H-1}-1 \qquad (5)$$

When $H>0.5$, $C(t)>0$, it means that the future trend of time series will be consistent with the past. In other words, if the past disparity of regional economic development has been enlarged, the disparity in the future will also be enlarged. The process of regional economic development will assume a divergent trend. When $H<0.5$, $C(t)<0$, it means the future trend of time series will be opposite from the past. In other words, if the past disparity of regional economic development has an expansive trend, the disparity of the future will assume the contractive trend. The process of the regional economic development will assume a convergent trend. When $H=0.5$, $C(t)=0$, it means time series is completely independent. There is no correlation or only short-range correlation in time series and we cannot conclude whether the disparity of regional economic development will expand or contract. The process of regional economic development will neither converge nor diverge (XU and AI, 2003).

2.4.3 Wavelet analysis

The literature on wavelet is growing rapidly, but very few in the field of economics. In the papers written by RAMSEY *et al.*(1997, 1998a, 1998b, 1999), efforts have been made to use wavelet to decompose the economic and financial data by time scale. Wavelet may well be able to provide new insights into the analyses of economic and financial data. The most important property of wavelet for economic analysis is decomposed by time scale.

Consider the time series of Theil index $T(t)$, which can be built up, as a sequence of projections onto Father and Mother wavelets indexed by both $\{k\}$, $k=\{0, 1, 2, ...\}$ and $\{s\}$, $s=2^j$, $\{j=1, 2, 3, ...\}$.

The coefficients in the expansion are given by the projections

$$S_{J,K}=\int T(t)\,\Phi_{J,K}(t)\mathrm{d}t \qquad (6)$$

$$d_{j,k}=\int T(t)\,\Psi_{j,k}(t)\mathrm{d}t, j=1, 2, ..., J$$

where J is the maximum scale sustainable by the number of data points, $\Phi_{j,k}=2^{-j/2}\Phi(\frac{t-2^jk}{2^j})$ is Father wavelet, and $\Psi_{j,k}=2^{-j/2}\Psi(\frac{t-2^jk}{2^j})$ is Mother wavelet. Father wavelet is used for the lowest-frequency smooth components, which requires wavelet with the widest support; Mother wavelet is used for the highest-frequency detail components. Father wavelet is used for the trend components and Mother wavelet is used for all deviations from trend.

The representation of the signal $T(t)$ now can be given by

$$T(t)=\sum_k S_{J,k}\Phi_{J,k}(t)+\sum_k d_{J,k}\Psi_{J,k}(t)+\sum_k d_{J-1,k}\Psi_{J-1,k}(t)+...+\sum_k d_{1,k}\Psi_{1,k}(t)$$

We can represent the approximation in a more revealing manner for our purposes:

$$T(t)=S_J+D_J+D_{J-1}+ ... D_j+...+D_1 \qquad (7)$$

where $S_J=\sum_k S_{J,k}\Phi_{J,k}(t)$ and $D_j=\sum_k d_{j,k}\Psi_{j,k}(t), j=1, 2, ..., J$.

In general, we have

$$S_{j-1}=S_j+D_j \qquad (8)$$

$\{S_J, S_{J-1}, ..., S_1\}$ is a sequence of multi-resolution approximations of the function $T(t)$ at ever-increasing levels of refinement. The corresponding multi-resolution decomposition of $T(t)$ is given by $\{S_J, D_J, D_{J-1}, ...D_j, ..., D_1\}$.

The main interest of this research is in the approximations of time series by time scale. The objective is to examine the extent to an allowance for different effects by scale, and to have an insight into the total variation of the signal over time. We choose the Symmlet as the basic wavelet, designated "S 8". We experimented with alternative choices of scaling functions and of wavelet, but the qualitative results were very robust to such changes and the initial choice of wavelet seemed to be the best on balance. In all cases, the levels analyzed are restricted to S4, S3, and S2 to represent the trend elements.

3 RESULTS AND DISCUSSION

3.1 Theil Index and Its Decomposition

With reference to Fig. 2, we can see that Theil index and Gini coefficient revealed the same trend of the evolutionary process of inter-provincial disparity. From 1952 to 1978, except for several unusual data in the "Great Leap Forward" period, the disparity assumed the upward trend on the whole; from 1979 to 1990 the disparity assumed the slowly downward trend. But from 1991 to 2000 the disparity assumed the slowly upward trend again. In other words, while the strategy to balance regional development before the reform and opening up has not succeeded in reducing comparative disparity in China's regional economic development, the lopsided development strategy after 1978 also has not enlarged disparity.

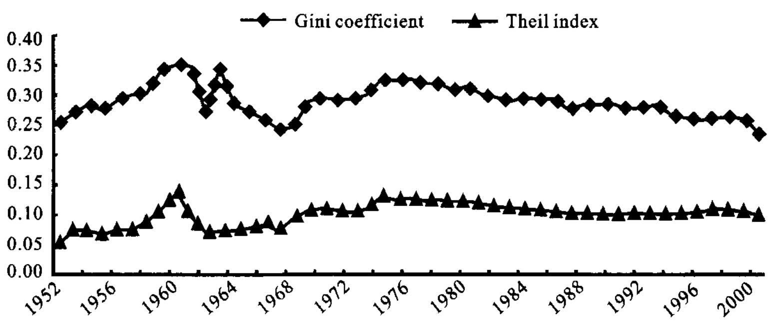

Fig. 2 Same trend of Theil index and Gini coefficient

Decomposition of Theil index can further reveal regional reasons of disparity evolution from a regional perspective and evolution of intra-regional disparity. Fig. 3 reveals the evolution of regional disparity and intra-regional disparity. The dynamic trend of inter-provincial disparity in the coastal region is consistent with the dynamic trend of the overall national disparity. The disparity between the provinces in the middle region and that in western remains small, and the evolution is rather slow. Development disparity between the three supra-provincial regions has been continuously on the increase and was even greater since the 1990s.

It is evident from Fig. 4 that the intra-regional disparity between the three supra-provincial regions contributes more and more to China's overall disparity. Over half of the disparity results from inter-provincial disparity in the coastal region. The contribution of coastal region reduced from 63.42% (1952) to 51.15% (2000) and the ones of middle and western regions respectively reduced from 16.32%, 2.83% (1952) to 5.95%, 2.74% (2000). The contribution of the disparity between three supra-provincial regions however increased from 14.31% (1952) to 27.25% (1990), and to 43.27% (2000).

3.2 R/S Analysis Results of Theil Index Sequence

While scholars both in China and abroad study disparity in regional economic development of China, they have been concerned about a common issue, i. e., whether economic development in different regions of China will converge, or whether the income level in each region will have a convergence? Based on the Solow Growth Model, CHEN and FLEISHER (1996) studied China's regional disparity by using per capita GDP, and discovered that regional economic disparity from 1978 to 1993 in China showed a conditional convergence, i. e., it depended on the share of physical capital, employment growth, investment in human capital, foreign direct investment and location. On the contrary, YAO and ZHANG (2001) analyzed convergence of China's regional economy from 1952 to 1997 with per capita GDP. The result indicates regional disparity of economic development in China would expand. What is the true tendency of the evolutionary process on the regional economic disparity in China during the past 50

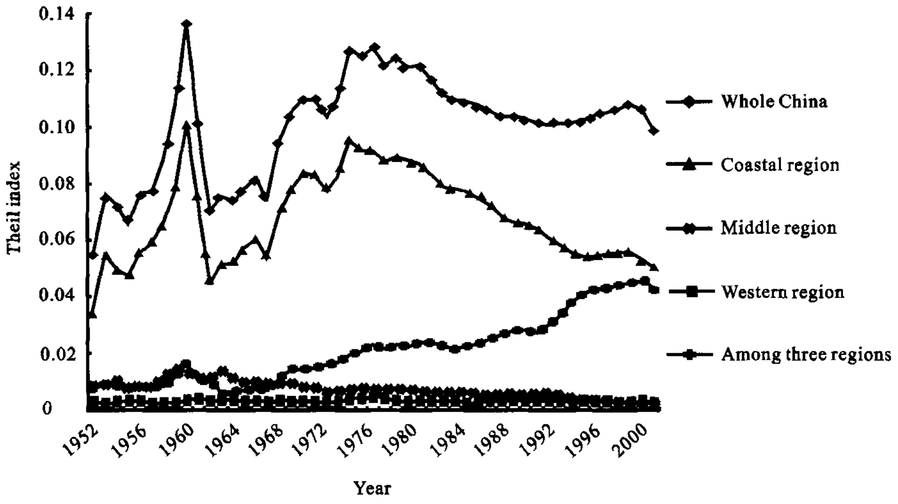

Fig. 3 Theil index and its decomposition from 1952 to 2000

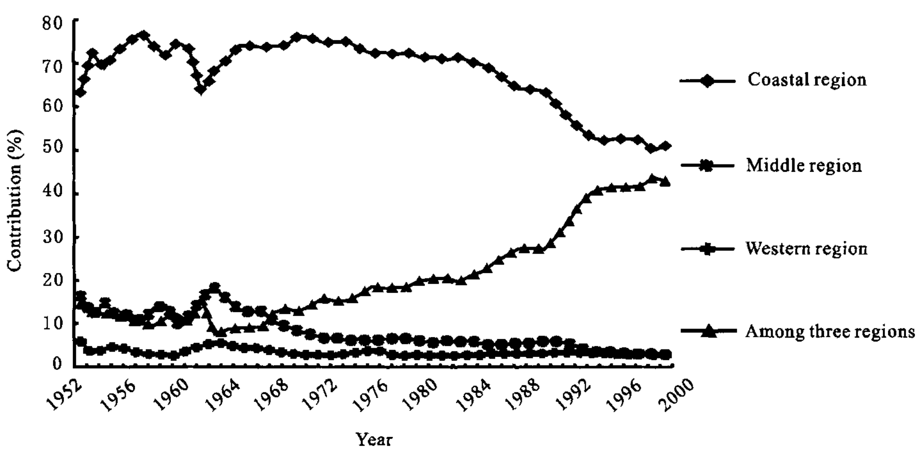

Fig. 4 Contributions of inter-regional and intra-regional disparities to the disparity in whole China

years? The following is our R/S analysis on this issue.

Taking Theil indices from 1952 to 2000 obtained in former paragraphs as time series $\xi(t)$, we have calculated the Hurst exponent H according to temporal characteristics of economic development in China. The result is in Table1.

With reference to Table 1, we may reach the following conclusions:

(1) In the period 1952–1965, the Hurst exponent H=0.670>0.5, which indicates that in this period evolution of comparative inter-provincial disparity of economic development showed a long-enduring characteristic. In the period 1966–1978, the Theil index assumed an increasing trend, which has confirmed this conclusion.

Table 1 Hurst exponent of Theil exponent series of per capita GDP in China from 1952 to 2000

Period	1952-1966	1967-1978	1979-1990	1991-2000	1952-2000
Hurst exponent	0.670	0.504	0.722	0.730	0.545

(2) In the period 1966–1978, the Hurst exponent H=0.504≈0.5, which indicates that in this period the evolution of comparative inter-provincial disparity of economic development showed a random characteristic. It is in the period of the "Great Cultural Revolution", so conclusion was verified.

(3) In the period 1979–1990, the Hurst exponent H=0.772>0.5, which indicates that in this period the evolution of the comparative inter-provincial disparity of economic development between provinces in China has a long-enduring characteristic, in the period 1991–

2000 Hurst exponent H=0.730>0.5, which has also verified the conclusion.

3.3 Multi-resolution Approximation of Time Series of Theil Index

Fig. 5 and 6 are time-series plots of the approximation for Theil index in whole China and the coastal region at level S4 & S3 respectively. Fig. 5 shows that the disparity in whole China follows the inverted U on the whole at level S4, namely at the time scale of 16 years. That is to say that the disparity tends to rise in the first stage of economic development, and fall slowly over the peak in the second stage of economic development. However, if we rescale the time scale to 2^3 (8 years), then a link of several U shapes will be seen at level S3. There are two local maximum points in 1958 and 1959 at level S3, i.e., the regional disparity in China increased in the "Great Leap Forward" period (1958-1960). China's economy recovered from 1961 to 1966, which led to a decrease in the regional disparity. Theil index reached a local minimum point in 1965 at level S3. The disparity between regions increased continually during 1966-1976, which led to the Theil index reached its peak in 1976. This suggests that the strategy of regional balanced development before the reform and opening up did not bring us a reduction in comparative disparity of regional economic development but increased the disparity. With the changes of economic policies, the disparity between regions reduced after the reform and opening up, which is in accordance with conclusions drawn by YANG (1994). In addition, Fig. 5 also shows that the disparity between provinces reduces from 1978 to 1990, but widens after 1990 at level S3. The same conclusions were also drawn by YING (1999). Therefore, the conclusions drawn by YANG (1994), YING (1999) are the special case at level S3, the lower time scale. Fig. 6 also shows that the same conclusion as Fig. 5, i.e., there is only one inverted U shape at level S4 and a link of several U shapes at level S3. The approximations for Theil index at level S4 and S3 indicate that the dynamic trend of the disparity in the coastal region is in line with dynamic trend of the disparity in whole China.

Fig. 7 and Fig. 8 are tie series plots of the approximation for Theil index in the middle region at level S4, S3, and S2 respectively. The disparity in the middle region follows the inverted U on the whole at level S4. The economic disparity in middle region has widened since 1952 and reached its vertex during the "Great Leap Forward". Afterwards, the disparity began

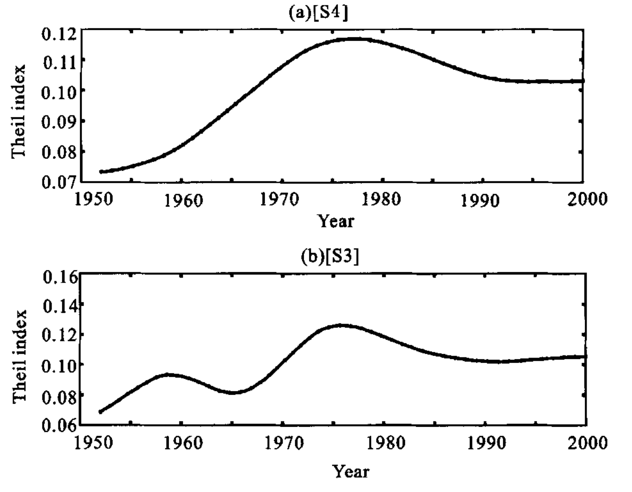

Fig. 5 Time series plots of the approximation for Theil index in the whole China

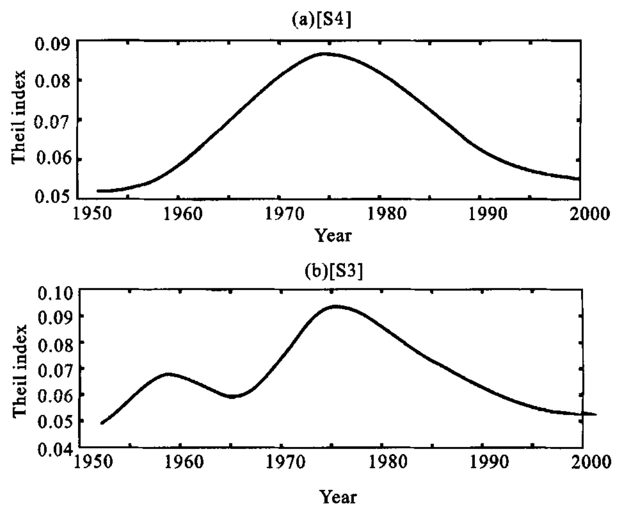

Fig. 6 Time series plots of the approximation for Theil index in the coastal region

to reduce. If we rescale the time scale to 8 years, then a link of several U shapes will be seen in Fig. 7. Two local maximum points appeared in 1978 and 1990. When we rescale the time scale to 4 (2^2) years for further details, Theil index reached its vertex during the "Great Leap Forward" period, and began decreasing till 1975, and then increased before 1978 at level S2. After the reform and opening up policy, the economic policy favors the eastern region, and the middle region lays stress on development of energy, raw material and supplied the coastal with primary product, which led to an increase of disparity during the 7th Five Year Plan (1986-1990). However, the disparity reduced after 1991 due to the adjustment of the policy during the 8th Five Year Plan.

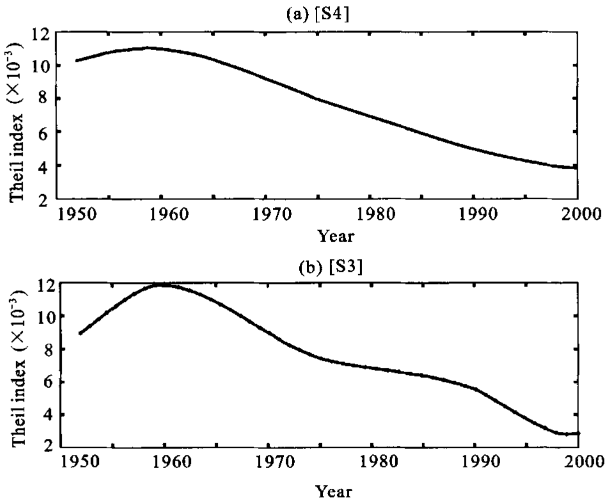

Fig. 7 Time-series plots of the approximation for Theil index in the middle region

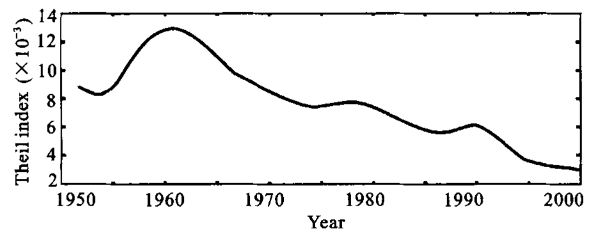

Fig. 8 Time-series plots of the approximation for Theil index in the middle region at level S2

Fig. 9 shows that regional disparity in the western region at level S4 and S3 respectively. The disparity in the western region almost follows the inverted U on the whole at level S4 with a maximum point in 1974. There is a local maximum point in 1990 and a link of several U shapes at level S3. It is clear that the year reaching maximum is quite distinct in the coastal, the middle, the western regions as well as the whole country. Time series plotting for the Theil index of among the three supra-provincial regions at level S4 and S3 are omitted, and the disparity among the three supra-provincial regions is expanding. In conclusion, using wavelet by different times scale in coastal, middle, western regions as well as three supra-provincial regions, findings show that regional development which is based on the decomposition and approximation of Theil index is different. Therefore, we draw a conclusion that the evolutionary process of the disparity of economic development in China is not a simple inverted U shape but a compound of several U shapes.

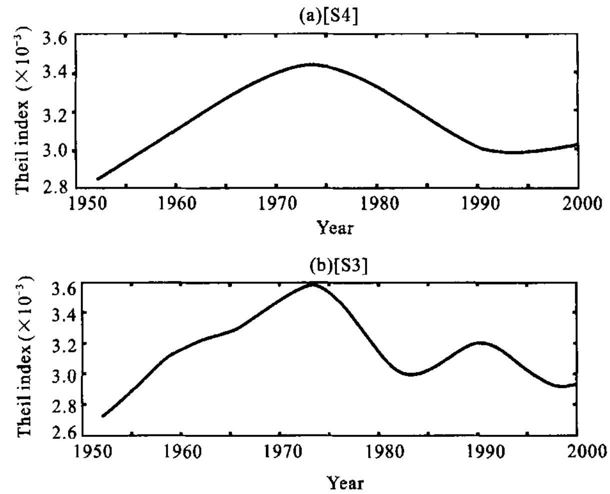

Fig. 9 Time-series plots of the approximation for Theil index in the western region

4 CONCLUSIONS

From above research results, we elicit the following conclusions.

(1) Regional disparity in economic development in China, including the inter-provincial disparity, inter-regional disparity and intra-regional disparity, has existed for many years. Theil index have revealed a dynamic trend for comparative disparity in economic development between provinces in China. From 1952 to 1978, except for "Great Leap Forward" period, comparative disparity basically assumed an upward trend and it assumed a slowly downward trend from 1979 to 1990. Afterwards from 1991 to 2000 the disparity assumed a slowly upward trend again. In other words, the comparative disparity of regional economy had been neither decreased by the strategy of regional balanced development before the reform and opening up, nor widened by the lopsided development strategy in China since then.

(2) Decomposition of Theil index indicates that the dynamic trend of comparative inter-provincial disparity in coastal region is in line with dynamic trend of inter-provincial disparity in the whole China. In other words, inter-provincial disparity gradually expanded from 1952 to 1978 and then began to reduce until 1990. The inter-provincial disparity in middle and western regions has reduced all the time, but at a slow pace, and during the whole period 1952–2000, disparity in economic development among the three supra-provincial regions was continuously on the increase, especially in the 1990s disparity among the three supra-provincial regions rapidly expanded.

(3) The R/S analysis results tell us that during 1966–1978, the Hurst exponent $H=0.504\approx0.5$, which indicates that in this period the evolution of comparative inter-provincial disparity of economic development showed a random characteristic, and in the other periods, i.e., 1952–1965, 1979–1990 and 1991–2000, the Hurst exponent $H>0.5$, which indicates that in those periods the evolution of the comparative inter-provincial disparity of economic development in China had a long-enduring characteristic.

(4) Based on the decomposition and approximation of Theil index, using wavelet by different time scale, we arrived at a conclusion that the evolutionary process of the disparity of economic development of China is not a simple inverted U shape but a compound of several U shapes. The result tells us the evolutionary plot of inter-provincial disparity in China follows the inverted U on the whole at the higher scale, 2^4 (16 years). That is to say, the disparity tends to rise in the first stage of economic development, and fall slowly over the peak in the second stage of economic development. However, if we shorten the time scale to 2^3(8 years), then a link of several U shapes will appear.

REFERENCES

BORTS G H, STEIN J L, 1964. *Economic Growth in a Free Market* [M]. New York: Columbia University Press.

CHEN J, FLEISHER B M, 1996. Regional income inequality and economic growth in China [J]. *Journal of Comparative Economics*, 22(2): 141–164.

CHEN Rong, WANG Fang, LI Hou-qiang *et al.*, 1992. The R/S analysis of China's population development [J]. *Population Science of China*, (4): 27–32. (in Chinese)

COMTE F, RENAULT E, 1996. Long memory continuous time models [J]. *Journal of Econometrics*, 73(1):101–149.

DOWRICK S, NGUYEN D, 1989. OECD comparative economic growth 1950–1985: catch-up and convergence [J]. *American Economic Review*, 79(5):1010–1030.

DUNFORD M, 1993. Regional disparities in the European community: evidence from the REGIO databank [J]. *Regional Studies*, 27(8): 727–743.

HU An-gang, ZOU Ping, 2000. *Society and Development: A Study of China's Regional Social Development Disparity* [M]. Hangzhou: Zhejiang People's Publishing House. (in Chinese)

HURST H E, 1951. Long-term storage capacity of reservoirs [J]. *Transactions of American Society of Civil Engineers*, 116: 770–808.

HURST H E, 1955. Methods of using long-term storage in reservoirs [R]. In: *Proc. of the Institution of Civil Engineers*[A]. Part I, 519–577.

HURST H E, BLACK R P, SIMAIKE Y M, 1965. *Long-term Storage: An Experimental Study* [M]. London: Constable, 1–155.

MANDELBROT B B, 1973. Formes nouvelles du hasard dans les sciences [J]. *Èconomie Appliquè*, 26(2): 307–319. (in French)

MANDELBROT B B, WALLIS J R, 1968. Noah, Joseph and operational hydrology [J]. *Water Resources Research*, 4(5): 909–918.

NBSC (National Bureau of Statistics of China), 1997. Historical data of China gross domestic product estimates 1952–1995 [R]. Beijing: China Statistics Press. (in Chinese)

NBSC, 1999. Comprehensive statistical data and materials on 50 years of new China [R]. Beijing: China Statistics Press. (in Chinese)

NBSC, 2001. China Statistical Yearbook 2000[R]. Beijing: China Statistics Press. (in Chinese)

NBSC, 2002. China Statistical Yearbook 2001[R]. Beijing: China Statistics Press. (in Chinese)

RAMSEY J B, 1999. Regression over time scale decompositions: a sampling analysis of distributional properties [J]. *Economic Systems Research*, 11(2): 163–183.

RAMSEY J B, LAMPART C, 1997. The decomposition of economic relationships by time scale using wavelet [R]. *Working Paper 97-08, C.V. Starr Center for Applied Economics*. New York: New York University.

RAMSEY J B, LAMPART C, 1998a. The decomposition of economic relationships by time scale using wavelet: money and income [J]. *Macroeconomic Dynamics*, 2(1): 49–71.

RAMSEY J B, LAMPART C, 1998b. The decomposition of economic relationships by time scale using wavelet: expenditure and income [J]. *Studies in Nonlinear Dynamics and Econometrics*, 3(1): 23–42.

THEIL H, 1967. *Economics and Information Theory* [M]. Amsterdam: North Holland.

XU Jian-hua, AI Nan-shan, 2003. Quantitative analysis on the disparity of regional economic development in China and its evolution from 1952 to 2000 [J]. *Regional Development Studies*, 9:115–129.

YANG Kai-zhong, 1994. The evolution of the regional economic disparities in China [J]. *Economic Research Journal*, (12): 28–33. (in Chinese)

YAO S, ZHANG Z, 2001. On regional disparity and diverging clubs: a case study of contemporary China [J]. *Journal of Comparative Economics*, 29(3): 466–484.

YING L G, 1999. China's changing regional disparity during the reform period [J]. *Economic Geography*, 75(1): 59–70.

ZHOU Guo-fu, 1999. *A Comprehensive Study on the Regional Discrepancies in China's Economic Development* [M]. Dalian: Northeast University of Finance & Economics Press. (in Chinese)