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Development Measurement of China's Commodity Retail Market Based on RPI Data

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Abstract: Retail price index (RPI) is a comprehensive index containing a large amount of commodity retail market information. In order to effectively measure the operation of China's commodity retail market and analyze the dynamic evolution characteristics of China's regional commodity retail, this paper quantitatively describes the relationship between the changes of China's inter provincial and regional RPI index by using the eigenvalues and eigenvectors of random matrix. Based on China's inter-provincial RPI data, this paper defines the system risk entropy, synchronicity ratio, and degree of stability, which carry out the quantitative characterization of market evolution characteristics, analyzes the regional difference and synchronicity of RPI and assesses the market development in China's commodity retail field.

Keywords: RPI; System Risk Entropy; Synchronicity Ratio; Degree of Stability.

1 Introduction

Retail price index (RPI) refers to the price index of retail goods paid in cash or credit card, which reflects the relative number of of the trend and degree of changes in the retail prices of commodities in a certain period of time. The commodity retail price index is divided into 14 categories: food, beverage, tobacco and alcohol, clothing, shoes and hats, textiles, Chinese and Western medicines, cosmetics, books, newspapers and magazines, cultural and sporting goods, daily necessities, household appliances, jewelry, fuel, building decoration materials, electromechanical products, etc. The adjustment and change of retail prices directly affects the living expenses of urban and rural residents and the national fiscal revenue, affects the purchasing power of residents and the balance of market supply and demand, and affects the proportion of consumption and accumulation. The basic situation of China's interest rate can be reflected by the monetary policy of RPI index, that is, RPI has a good explanatory power to China's monetary policy in most ranges. Therefore, the calculation of retail price index can observe and analyze the above economic activities from one side. This paper describes the random matrix theory, defines the indicators such as system risk entropy, synchronization ratio and stability, makes an empirical analysis of China's commodity retail market by using the RPI data of 31 provinces in China, and measures the risk, consistency and stability of the market.

2 Materials and Methods

2.1 Random matrix theory

RPI of different zones are denoted as $p_i(t)$, $i = 1, 2, \cdots, N$, $t = 1, 2, \cdots, M$. Where N shows the amount of different zones required in researching the commodity retail market , M shows the amount of time span selected in researching RPI.The length of sliding window $L > N$,then we can get the time window of $H = M - L + 1$. In each sliding window $[t - L + 1, t]$,when $t \geq L$,the correlation matrix $C(t)$,is calculated calculated according to the following

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formula (1):

$$C_{ij}(t)=\frac{1}{\sigma_i\sigma_j}\sum_{k=t-L+1}^{t}\left[p_i(k)-\mu_i\right]\left[p_j(k)-\mu_j\right] \tag{1}$$

where μ_i shows sample mean and σ_i shows sample standard deviation. For each correlation matrix $C(t)$, its corresponding eigenvalue $\{\lambda_l : l=1,2,\cdots,H\}$ and eigenvectors $u_l(t)=[u_{l,1}(t),u_{l,2}(t),\cdots,u_{l,N}(t)]^T$.

For random matrix:

$$R=\frac{1}{L}AA^T \tag{2}$$

Where A refers to a $N\times L$ random matrix, consisting of N independent sequences with the length of L,and each subsequence is subject to $N(0,1)$. When $N\to\infty$, $L\to\infty$,and $Q=L/N(>1)$ is determined, the distribution function $P(\lambda)$ of λ, which is the eigenvalues of R has the following analytical form:

$$P(\lambda)=\frac{Q}{2\pi\sigma^2}\frac{\sqrt{(\lambda_{\max}-\lambda)(\lambda-\lambda_{\min})}}{\lambda} \tag{3}$$

Where $\lambda_{\min}\le\lambda\le\lambda_{\max}$ and $\lambda_{\min,\max}=\sigma^2\left(1+1/Q\pm2\sqrt{1/Q}\right)$, $\sigma^2=1$.Whether empirical correlation matrix has vast noise information is judged through comparing whether the eigenvalue λ_l of empirical correlation matrix is within $[\lambda_{\min},\lambda_{\max}]$ .If the eigenvalue of empirical correlation matrix $\lambda_l>\lambda_{\max}$, λ_l and its corresponding eigenvector u_l contain valuable market information. Much information in the real market is reflected by virtue of the contrast difference with completely random matrix.

2.2 Index selection of market measurement in commodity retail

The market development situation of China's commodity retail field is evaluated through analyzing regional difference and synchronicity of China's retail price index. Indexes of system risk entropy, synchrony ratio, and degree of stability are introduced, and the definition is as follows:

2.2.1 System risk entropy

To measure the system risk of research system, the system risk entropy SRE is defined through the eigenvalue λ_i , $i=1,2,\cdots,H$ of empirical correlation matrix that contains information of the real market,and the calculation formula is as follows[1,2]:

$$SRE=(-1/\log(N))\sum_{i=1}^{H}(\lambda_i/N)\log(\lambda_i/N) \tag{4}$$

Where$H$ is the amount of correlation matrix eigenvalue that contains information of the real market, N is the dimensionality of correlation matrix, λ_i is the eigenvalue that contains market information, $i=1,2,\cdots,H$,$H\le N$. The system risk entropy has the following natures:

(1)$0\le SRE\le1$, because we can get the following formula through simplifying formula (4)

$$SRE=\sum_{i=1}^{H}\frac{\lambda_i}{N}\left(1-\frac{\log(\lambda_i)}{\log(N)}\right) \tag{5}$$

So it can be obtained that $0\le SRE\le1$.

(2)When and only when there is one in λ_i is equal to N and the other eigenvalues are 0,$SRE=0$.

(3)When and only when $H=N$,$\lambda_1=\lambda_2=\cdots=\lambda_H$,$SRE=1$.

When system risk entropy is closer to 0, it shows the risk information represented by empirical matrix eigenvalue is larger and the system risk is higher; on the contrary, when is closer to 1, it shows the risk information embodied by empirical matrix eigenvalue is smaller and the system risk is lower.

2.2.2 Dynamic synchronicity ratio

Market identity means basing on dynamic synchrony ratio to describe the measurement of synchronous change of market and its submarket.In correlation coefficient matrix $C(t)$, within each sliding window $[t-L+1,t]$, N market segment is clustered into three kinds through clustering algorithm according to group-average method. In each sliding window, the number of each kind of member is calculated.The kind with most members is called synchronization market, recorded as $\Omega_{syn}(t)$. If $[\{r_i(t)\}\not\subset\Omega_{syn}(t)$ and $[\overline{C[r_i(t-\delta),\overline{r_1(t)}]}>\overline{C[r_i(t),\overline{r_1(t)}]}]$, where $\overline{r_1(t)}$ shows the mean value of synchronous market data,$\overline{C[x]}$ shows the mean value of correlation coefficient, so the market formed by $\{r_i(t)\}$

is called leading market,recorded as $\Omega_{pre}(t)$. If $\{r_i(t)\} \not\subset \Omega_{syn}(t)$ and $\{r_i(t)\} \not\subset \Omega_{pre}(t)$,the market formed by $\{r_i(t)\}$ is called lagging market, recorded as $\Omega_{lag}(t)$.

Dynamic synchrony ratio is defined as follows [3]:

$$SYN(t) = \frac{N[\Omega_{syn}(t)]}{N} \tag{6}$$

Where $N[\Omega_{syn}(t)] = \max\{N_1(t), N_2(t), N_3(t)\}$, $N_i(t)$ shows the amount of market marked by i in time t,$N$is the amount of submarket.

The dynamic leading ratio is defined as follows[3]:

$$PRE(t) = \frac{N[\Omega_{pre}(t)]}{N} \tag{7}$$

Where $N[\Omega_{pre}(t)]$ shows the amount of leading market.

The dynamic hyteresis ratio is defined as follows[3]:

$$LAG(t) = \frac{N[\Omega_{lag}(t)]}{N} \tag{8}$$

Where $N[\Omega_{lag}(t)]$ shows the amount of lagging market.

For Chinese commodity retail market, the Chinese market is divided into 31 provincial and municipal segments according to geographical location and administration. Due to different geographical environments, consumers often have different needs and preferences for the same kind of consumer goods, the development of provincial and municipal segments of retail commodities is not balanced.In the empirical analysis part, we will use the dynamic synchronization ratio to quantitatively describe the consistency level between China's commodity retail market and the market segments of various provinces and cities.

2.2.3 Degree of stability

Market stability measures the degree that the economic development of market segment changes over time. According to the definition of above dynamic synchrony ratio, first calculate the dynamic synchrony ratios of time windows, recorded as$\varphi_i^{syn}(t)$,$i = 1, 2, \cdots$ respectively

$$\varphi_i^{syn}(t) = \frac{n_i(t)}{N_i} \tag{9}$$

Where $n_i(t)$ shows the amount of submarket that is synchronous with the whole market at time t in the market , shows the amount of submarket contained in the ith market segment. The concept of state stability of market segment is proposed according to the dynamic synchrony ratio in different market segments. The calculation formula is as follows[3]:

$$STA = 1 - \frac{\sum_{t=1}^{n-1} \operatorname{sgn}\left|\varphi_i^{syn}(t+1) - \varphi_i^{syn}(t)\right|}{n} \tag{10}$$

Where sgn shows sign function,$n = M - L + 1$ is the amount of sliding window. For Chinese commodity retail market, state stability is to describe the change of position of some province and city or economic area in the whole country during economic development. If the stability of some province and city or economic area is less than the given threshold value over time, then the development state of this province and city or area is stable relative to the overall national level.

3 Empirical Research

The RPI data in this paper come from the RPI(year-on-year price=100)of China's commodity retail market provided by State Statistics Bureau.Thirty one provinces and municipalities are selected: Beijing(BJ), Tianjin(TJ), Hebei(HE), Shanxi(SX), Neimenggu(NM), Liaoning(LN),Jilin(JL),Heilongjiang(HL), Shanghai(SH),Jiangsu(JS), Zhejiang(ZJ),Anhui(AH), Fujian(FJ),Jiangxi(JX),Shandong(SD), Henan(HA), Hubei(HB), Hunan(HN),Guangdong(GD), Guangxi(GX),Hainan(HI), Chongqing(CQ),Sichuan(SC),Guizhou(GZ),Yunnan(YN),Xizang(XZ),Shaanxi(SN),Gansu(GS), Qinghai(QH),Ningxia(NX), Xinjiang(XJ). The data selection period is: from Jan. 1995 to Dec. 2016, 264 data in each province, a total of 8184 data.

Based on the selected data and the built sliding windows,RPI of various provinces is recorded as $r_i(t)$,$i = 1, 2, \cdots 31$ when the time (t) is 1, 2, ...264 respectively.At this moment, ,then, the random matrix theory will be adopted and the sliding length $L > N$,$L = 60$,is selected to obtain the RPI. 205 time windows will be obtained.

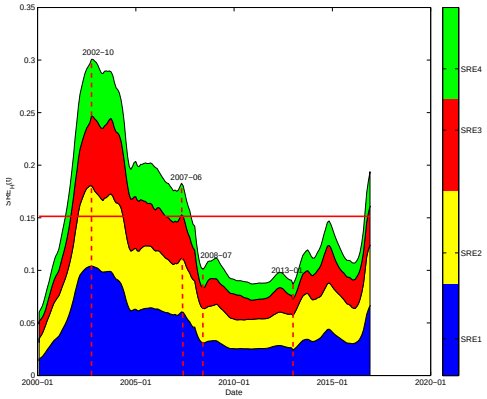

Figure 1: RPI system risk entropy evolution map

3.1 Risk measurement of Chinese commodity retail market

Based on the system risk entropy as specified in formula (4), H=4.According to the RPI matrix, the first four eigenvalues of RPI($\lambda_1(t), \lambda_2(t), \lambda_3(t), \lambda_4(t)$)will be calculated in every sliding window until the system risk entropy,$SRE(t)$ which evolves as time goes by is obtained.As shown in Figure 1, the blue, yellow, red and green signify the system risk entropy which correspond with the first, second, third and fourth big eigenvalue. According to the definition, the larger system risk entropy, the smaller system risk. According to Figure 1, the average system risk entropy of Chinese commodity retail market over the years is 0.1514 (indicated by the red solid line in the figure).Before 2000, affected by the Asian financial crisis in 1997, the system risk entropy of Chinese commodity retail market was very small, which meant that the systematic risk of the market was very large.After 2000, the loose monetary policy implemented by the government gradually became effective. At the same time, driven by the essence of a series of major reforms such as state-owned enterprise reform, financial reform and housing reform, the system risk entropy began to rise and the corresponding system risk began to decline. In October 2002, the system risk entropy also reached the highest value of 0.3008 in previous years and the market system risk reached the lowest, It has successfully walked out of the impact of the Asian financial crisis.In 2004, although China's economic growth was still about 9%, the inflation rate was also as high as about 5%, the system risk entropy began to decline, and the corresponding market system risk began to rise.In August 2007, the U.S. subprime crisis began to sweep the world's major financial markets such as the United States, the European Union and Japan. Affected by this, the systematic risk entropy of China's commodity retail market began to decline sharply, rapidly fell below the average level over the years, and the market risk began to rise sharply. By July 2008, the financial crisis broke out in an all-round way.The risk entropy of Chinese commodity retail system has dropped to the lowest point of 0.1011 since 2003, and the corresponding system risk has also reached the maximum.Then entered the recovery period after the impact of the financial crisis, the market system risk entropy remained at a low level, and the market risk was still very high. After 2013, the international economic situation began to improve, and the system risk entropy of the Chinese commodity retail market also showed an upward trend. System risk began to decline. From 2015 to 2016, the system risk entropy was in the shape of an inverted "U", which first decreased and then increased, and market system risk first increased and then decreased.

3.2 Consistency of Chinese commodity retail market

The regional market development in China's modern market system is inconsistent, thus forming the different regional markets. The mutual integration and role of regional markets constitute China's market system. To analyze the evolution relationship between all regional commodity retail markets and national commodity retail market, the dynamic clustering analysis of all provinces shall be made in each sliding window. China's commodity retail market is divided into three regions: Region of synchronous change, leading change and lagging change, respectively, thus obtaining the clustering relationship among China's 31 provinces and cities from 2000 to 2016. With the economic development and adjustment of inter-provincial industrial structure, the clustering relationship among commodity retail markets of various provinces also is evolving.

The dynamic synchronism ratio(formula 6), leading ratio (formula 7) and lagging ratio (formula 8) are used to measure the consistency level of China's commodity retail market, and the national RPI synchronous change ratio and asyn-

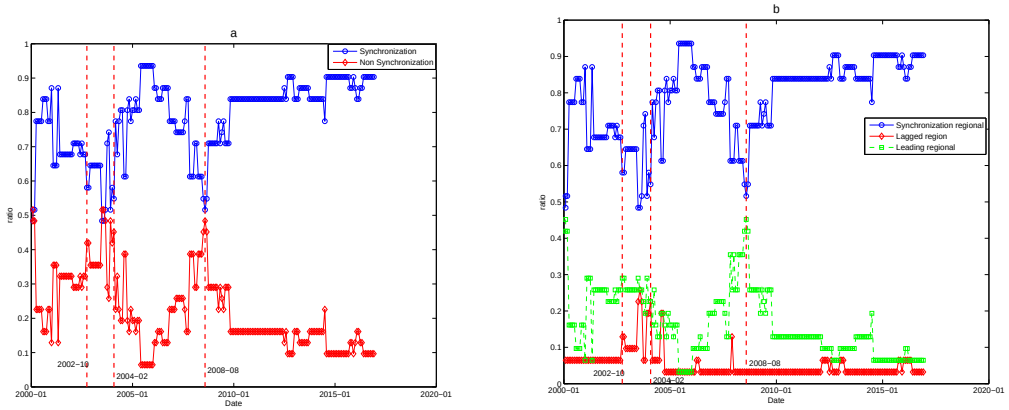

Figure 2: (a)Synchronism and asynchronism ratio evolution of RPI , (b) Synchronism ratio, leading ratio and lagging ratio evolution of RPI

chronous change ratio evolution map is obtained through calculation, as shown in Figure 2(a)-(b). The blue line indicates the synchronism ratio, while the red line shows the asynchronism ratio.The fluctuation range of synchronism ratio of RPI is from 0.4839 to 0.9355, with the average value of 0.7824.The synchronism area of China's commodity retail market occupies the leading position. According to the evolution process of RPI, as depicted in Figure 2(a), it has four stages divided by the red dotted line in the figure. The average value of synchronism ratio from the first stage to the fourth stage is 70.21%, 60.34%, $78.14\%$and 84.06% respectively. Thus, due to the international and domestic financial crisis and economic market impact, the synchronism from Oct. 2002 to Feb. 2004 (second stage)is the poorest, and the proportion of asynchronism area is close to or beyond that of synchronism one.In the asynchronous regions, as shown in Figure 2 (b) , the proportion of leading regions (indicated by the green □ in the figure) is more than that of lagging regions (indicated by the red ◊ in the figure), indicating that with the economic development, the overall integration level of China's commodity retail market is rising, and the regions with rapid economic growth are also rising.However, it can be seen from Figure 2 that the synchronization difference between regions in individual years is expanded, which means that there are still factors leading to market segmentation among China's regions.

From the perspective of RPI of various provinces and cities, the correlation coefficient of RPI fluctuation between various provinces and cities and whole country are calculated in each sliding window, the correlation coefficient matrix is used to make the dynamic clustering, and the clustering effect evolution of whole country and various provinces and cities is obtained.From Jan. 2000 to Dec. 2016, China's RPI fluctuation experienced 46 state changes, with an average of 4.4 months.In the process of state evolution, there were five stable states for more than one year:Dec.2001 -Jul.2003, Nov.2004- Nove.2006, Dec.2009- Apr.2012, Feb.2013-Mar.2014 and Sep.2014- Oct.2015.The trend of commodity retail price index leading or lagging behind the whole country in China's three major economic regions is completely different.Before the outbreak of the financial crisis, the changes of commodity retail price indexes in eastern and central provinces and cities lagged behind the whole country, and the western provinces and cities took the lead, synchronized and lagged behind the whole country.After the outbreak of the financial crisis, the RPI change in the east region has gradually changed from lagging behind the whole country to leading the whole country, the RPI change in the middle region has gradually changed from lagging behind the whole country to synchronizing with the whole country, while the western region has a variety of changes from leading to lagging, synchronous to lagging, leading and lagging to synchronization.

3.3 Stability of Chinese commodity retail market

Investigate the consistency between the commodity retail market in China's eight economic regions and the national market, as shown in Figure 3 (a). I in the figure indicates the northeast economic zone;II indicates the northern coastal economic zone;III indicates the eastern coastal economic zone;IV indicates the southern coastal economic zone;V indicates the middle Yellow River economic zone;VI indicates the middle Yangtze River economic zone; VII indicates the southwest economic zone;VIII indicates the northwest economic zone.Based on the consistency level of the commodity retail market of China's eight economic zones and national market, the stability of the commodity retail market state of China's eight economic zones is calculated with formula (10).The top two commodity retail markets in China's eight economic zones are the middle reaches of the Yellow River economic zone and the northeast economic zone, with synchronization

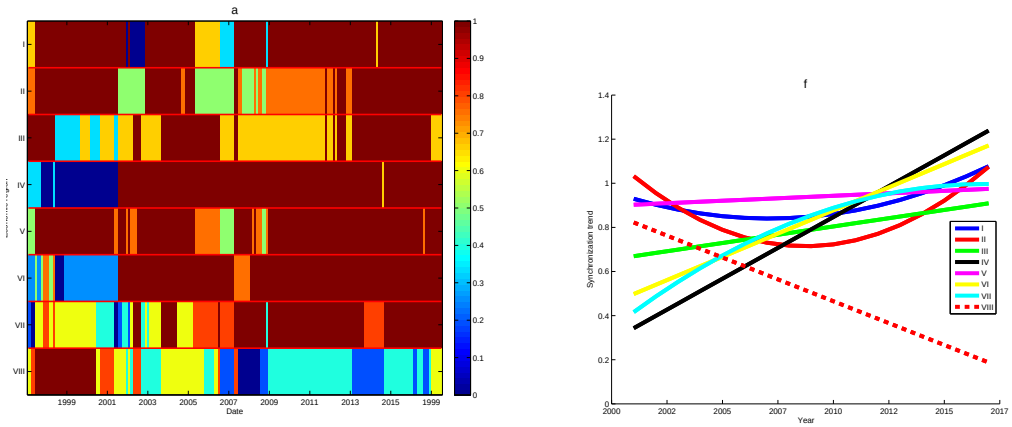

Figure 3: (a)Synchronism ratio evolution of RPI of China's eight economic zones , (b) Synchronism trend line of RPI of China's eight economic zones

rates of 0.939 and 0.9073 respectively. The greater northwest economic zone is less synchronized, with synchronization rate of 0.5054.From the perspective of stability, the commodity retail stability of China's eight economic zones is higher, and the stability fluctuation range is 0.8788-0.9394. The most stable one is the southern coastal economic zone, while the most unstable ones is southwest economic zone.

The least square regression is used to obtain the development trend of the consistency between the commodity retail market in China's eight economic regions and the national market, as shown in Figure 3 (b). There are four development trends: rising trend, declining trend, U-shaped trend and inverted U-shaped trend. The eastern coastal economic zone, southern coastal economic zone, middle Yellow River economic zone and middle Yangtze River economic zone present an upward trend; The northeast economic zone and northern coastal economic zone present the U-shaped trend; The southwest economic zone presents an inverted "U" trend; The great northwest economic zone presents a declining trend.It can be seen that although the degree of integration of China's commodity retail market is gradually improving, the regional characteristics are still obvious. The consistency level of commodity retail market in different economic regions and the national market, and the stability of economic structure between provinces and cities in different economic regions show different characteristics.

4 Conclusions

The degree of integration of China's commodity retail market is gradually improving, and the synchronization difference between regions in individual years is expanding, which means that there are still factors leading to market segmentation among regions in China.At the same time, due to the differentiation of the proportion of leading regions and lagging regions, the gap between developed regions and economically weak regions is further widened. We should prevent all kinds of development funds from gathering in developed regions due to excessive economic growth in developed regions, so as to induce overall problems.Therefore, the regulation of China's commodity retail market must take different governance measures for different regions. First, we must appropriately control areas with excessive economic growth; Second, support for economically weak areas should be strengthened, especially some unconventional policies can be introduced.

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