

# A Comparative Study of the Efficiency of Chinese and American Housing Markets—Based on the Hurst index from Fractal Market Theory

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**Abstract.** Based on the fractal structure theory of stock market, this paper applied Hurst index as a measure and then explored the rationality of housing prices and the effectiveness of real estate markets in China and the United States. by using data from several large and medium-sized cities in China and each state in America. Statistical analysis shows that the real estate markets of China and the United States didn't reach weak effective, that is, the information response of real estate markets in both countries is inadequate. Therefore, it's urgent for government to solve the problem that how to strengthen the information transparency of the real estate industry so as to improve the efficiency of this market.

## 1. Introduction

The real estate industry has dual attributes of consumption and investment. As a consumer, the equilibrium price depends on the supply and demand, and as an investment product, its price has significant financial characteristics, which is related to the possibility of investment appreciation. The property attribute of real estate itself is the main source of house price fluctuation. Since 2003, in order to curb the trend of excessive housing price growth and stabilize housing prices, the government has implemented a series of regulatory policies intensively to restrain the overheating of the economy and maintain the stable and orderly development of the real estate industry. From the continuous intervention of the government, we can see the significance of real estate to the development of national economy. As an important part of the real estate industry, the price of housing industry is also one of the most important factors affecting the quality of life of residents and has become a focus of attention. Referring to the theory of market effectiveness of financial market, this paper intends to use efficiency as a measure to evaluate the development of housing industry in China and the United States. Moreover, we can provide reference for the government to implement housing price control policy and housing system reform.

## 2. Fractal Market Theory

Modern finance theory cannot explain many anomalies in financial markets, such as herding effect and stock market irrational prosperity. Therefore, the effective market hypothesis has been suspected. Since then, new theories and tools have been brought to study financial market behavior. Among them, the Fractal Markets Hypothesis (FMH) is the most successful, which is based on the non-linear dynamic system. FMH theory originated from Mandelbrot. When Mandelbrot observed the time series of cotton price in 1968, he found that the return rate of cotton didn't follow Gauss distribution, instead possessed the characteristics of peak and thick tail. At the same time, he found there was a certain long-term memory in price rather than the memory-free as the efficient market theory said, that is, the price may rise or fall sustainably in certain degree. Later, it was found that so did the stock market. On this basis, Peter put forward the fractal market hypothesis theory in 1994. The theory holds that the stock returns follow a random walk with a certain degree of

skewness and a non-linear characteristic. Actually, the stock market has fractal characteristics (Peter, 1994).

Hurst index is an important statistic in fractal structure analysis. It is proposed by Hurst, a British hydrologist, to measure the degree of biased random walk to determine whether time series are time-dependent. When he studied the flow of rivers, he found that it was not independent and identically distributed Gauss distribution, nor did it have the characteristics of traditional Markov chain, but appeared a certain degree of sustainability. Intuitively, river flooding often followed one by one. According to fractal theory, he proposed the rescaled range (R/S) analysis method to calculate a new index to characterize the clustering phenomenon of time series and then judge whether it is random walk or not. This index was named Hurst index. Hurst found that there was relationship between the rescaled range and the sequence length as following formula (1):

$$(R / S)_n = C * n^H \tag{1}$$

Where C is a constant and H represents Hurst index. The longer the time series length- n is, the higher the precision of the fitting index is. Therefore, the calculation of the index requires a large number of sample. The value of index is between 0 and 1.

However, due to the limitation of actual sample size, n is usually very small, which leads to the inaccuracy of the estimated index H. For example, it's meaningless but frequent that H>1 appears. In order to remedy this defect, many scholars put forward supplementary methods, among which Weron (2002) put forward a modified R/S analysis method. The original R/S method was modified as formula (2):

$$\ln H_n = \ln[(R / S)_n] - \ln E(R / S)_n + \ln(n) / 2 \tag{2}$$

Where we have

$$E(R / S)_n = \begin{cases} \frac{n - 0.5}{n} \frac{\Gamma(\frac{n-1}{2})}{\sqrt{\pi}\Gamma(\frac{n}{2})} \sum_{i=1}^{n-1} \sqrt{\frac{n-i}{n}}, & n \leq 340 \\ \frac{n - 0.5}{n} \frac{1}{\sqrt{n\pi / 2}} \sum_{i=1}^{n-1} \sqrt{\frac{n-i}{n}}, & n > 340 \end{cases} \tag{3}$$

And  $\Gamma(\bullet)$  is a Gamma function. Then we can acquire H by making following formula (4) regression:

$$\ln H_n = H \ln n + \ln C \tag{4}$$

The value of Hurst index is between 0 and 1, with 0.5 as the demarcation point. If the value of H is in different intervals, it shows that time series have different characteristics:

(1)  $0 < H < 0.5$ : Anti-persistent fractional Brownian motion

In this situation, the time series has anti-persistence, which means the time series tends to reverse to the historical starting point and its divergence is slower than the standard Brownian motion. Theoretically, an anti-persistent sequence would return to its historical starting point many times.

(2)  $H = 0.5$ : Standard Brownian Motion

When  $H = 0.5$ , the time series presents random walk characteristics and Markov chain characteristics.

(3)  $0.5 < H < 1$ : Long-term persistence

During this interval, the time series has the characteristics of long-term persistence, and the characteristics of long-term growth will last for a long time, forming a large cycle. However, these

cycles do not have a fixed cycle and cannot predict the future accurately. In particular, it is not known when this long-term persistence will end, perhaps abruptly, or unpredictably in advance.

(4)  $H = 1$ : Complete prediction

When  $H = 1$ , the time series is a straight line, its future direction can be accurately predicted.

### 3. Empirical Test

#### 3.1. Modeling

In an effective market, housing prices are generally considered to be proportional to resident income. After adding the intercept item, we construct an econometric model in formula (5):

$$p = \alpha + \beta I + \varepsilon \quad (5)$$

Where  $\alpha, \beta$  are constants,  $p$  represents the housing price,  $\varepsilon$  is a random disturbance.

If the housing market is effective, then the part of housing price that is not reasonably explained by income should be effective, that is, it has the features of random walk. In this way we just need to consider whether  $\varepsilon$  is a random walk or not. Moreover, we can quickly judge the efficiency of the housing market by calculating whether  $H$  is 0.5 or not.

#### 3.2. Data Selection

In order to compare the efficiency of the housing markets between China and the United States, our paper chose Chinese market data from 68 units subject and American market data from 52 units subject. Chinese market data mainly came from Wind financial terminal and China's economic and social big data research platform. Only HPI in the U.S. data came from the U.S. Economic Research Center, while the rest came from the U.S. National Bureau of Economic Analysis or the Federal Reserve's St. Louis Branch.

For the purpose of reflecting the relative changes of housing prices among the research units better, this paper selected the housing price index and per capita income index as measure. We collected data from 67 large and medium cities in China (excluding Anqing, Dali and Yangzhou in 70 large and medium cities) and the overall housing market which was regarded as the 68st subject from July 2005 to December 2017 totaling 150 months. In order to collect as much data as possible, the frequent of US market data is quarter. This paper selects 52 units of the US housing market from the first quarter of 1975 to the first quarter of 2014 totaling 157 quarters in 50 states, Washington, D.C. and the whole America which is the 52st unit. A little missing data was supplemented by linear interpolation. In order to eliminate the influence of seasonal factors, seasonal adjustments have been made to the data.

For convenience, the research units were ranked according to the first letter of the cities and the states, and the overall housing market performance of China and the United States were both ranked last, that is, they were numbered 68 and 52 respectively.

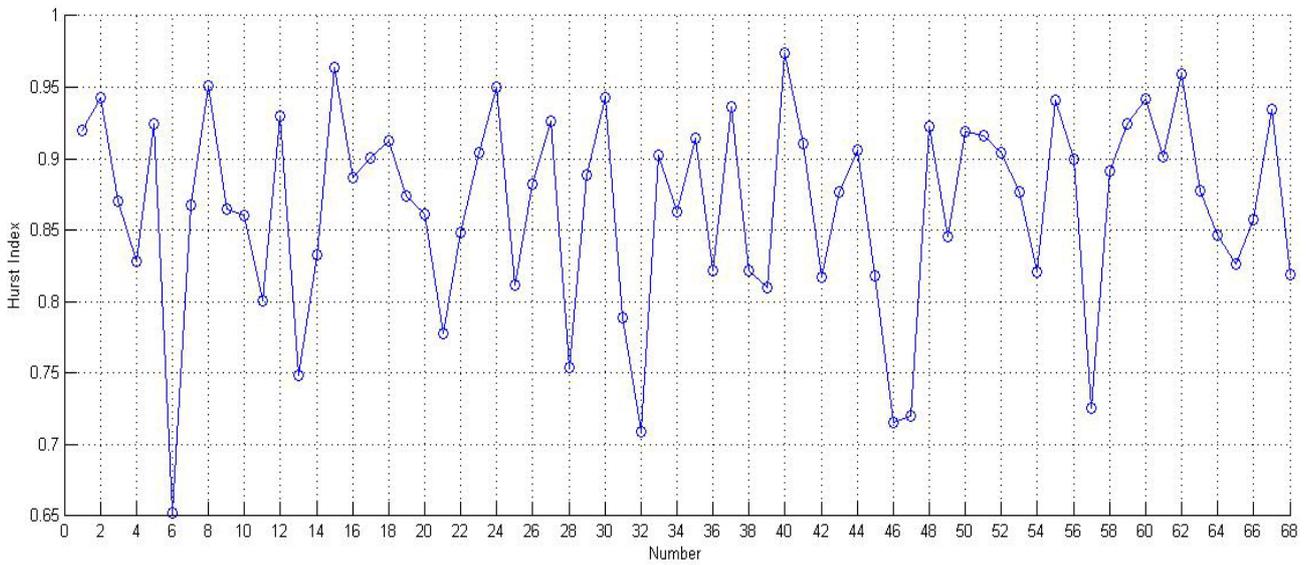
#### 3.3. Empirical Result

This paper test whether the housing markets in China and the United States are effective and the fractal structure of the market by calculating the Hurst index. Because of the insufficient sample size, we adopted the modified R/S analysis method to calculate the fractal index of each housing market. Later, the residual value in formula (5) was used for checking.

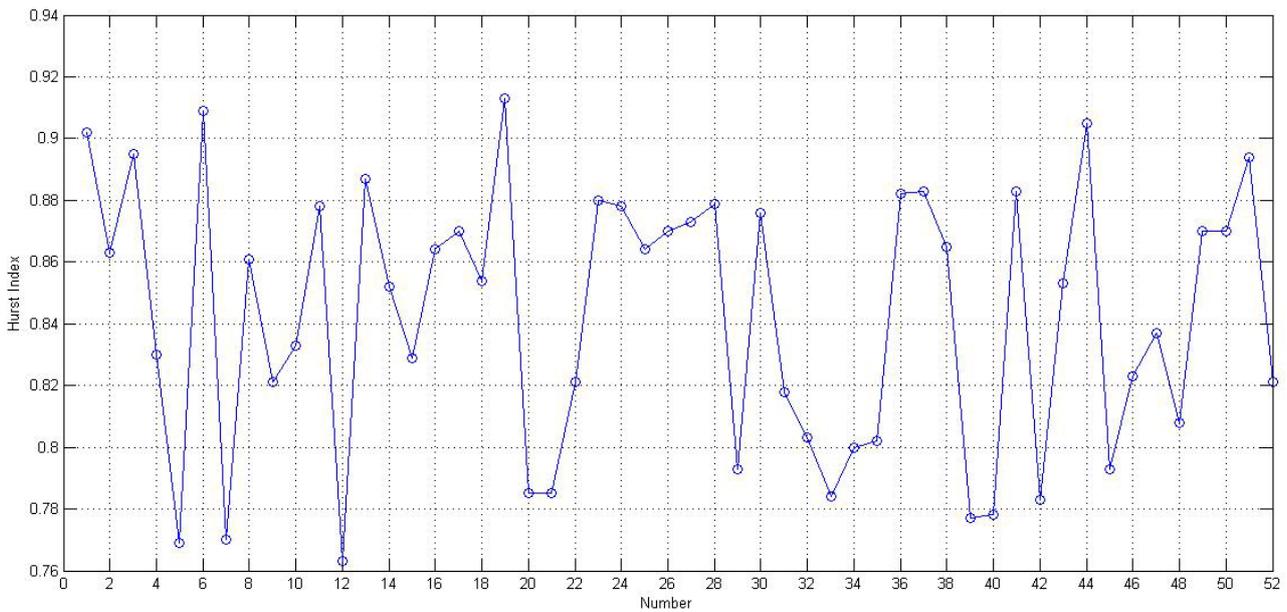
**Table 1.** Descriptive Statistics of Housing Fractal Index

	max	min	mean	median	standard deviation
China	0.9742	0.6525	0.8668	0.8771	0.0696
America	0.9132	0.7634	0.8424	0.8534	0.0432

Table 1 shows the descriptive statistics of fractal index of housing in China and the United States. Overall, the fractal structure index (Hurst index) of China is higher than that of the United States on average, indicating that the persistence feature of the Chinese market are more significant.



**Figure 1.** Fractal Index of Chinese Housing Market



**Figure 2.** Fractal Index of American Housing Market

For a more intuitive result, the Hurst index of each unit was plotted in Fig.1 and Fig.2. It can be found that the Hurst index of each subject is over 0.5 in both China and the United States. This demonstrated that the housing market of China and the United States is ineffective and even present long persistence. It further shows that the housing price of both countries has a long-term upward trend.

#### 4. Conclusion

According to the empirical results, it's clear that the housing markets have not achieved effective in both China and America, which shows that the information transmission mechanism of their housing markets is not perfect, but the market in the United States is slightly better than that in China. Thus, in the process of enhancing the efficiency of housing market in China, we can

selectively refer to the housing policy of the United States to meet the diverse needs of people with different living standards in the country, such as building a diversified housing supply system, controlling the rent and subsidizing low-income families. However, the primary task of China's housing market is to improve information transparency in the real estate industry and set up a public information disclosure system so as to reduce information asymmetry and the cost of searching for information. In addition, legislation should be strengthened. Whether buying or renting houses, it's necessary to establish a complete legal system as the basis to protect the interests of ordinary residents.

The imperfect of this paper is that although the Hurst index can distinguish whether the housing market is effective or not and measure its degree of persistence based on fractal structure theory, the assumption of this theory is flawed. Specifically, the calculation result may have some errors without considering that the complete random walk may exist positive persistence. In the future, we intend to combine other more effective methods to get more accurate conclusions.

## 5. References

- [1] Lo A W, Mackinlay A C. Stock Market Prices Do Not Follow Random Walks: Evidence from a Simple Specification Test [J]. *Review of Financial Studies*, 1988, 1(1):41-66.
- [2] Hamilton B W, Schwab R M. Expected appreciation in urban housing markets[J]. 1985, 18(1):0-118.
- [3] Larsen E R, Weum S. Testing the efficiency of the Norwegian housing market[J]. *Journal of Urban Economics*, 2008, 64(2):0-517.
- [4] Fama E F. Efficient Capital Markets: A Review of Theory and Empirical Work[J]. *The Journal of Finance*, 1970, 25(2):383-417.
- [5] Kodrzycki Y K, Gerew N . Using state and metropolitan area house price cycles to interpret the U. S. housing market[J]. *Public Policy Brief*, 2007.
- [6] Maier G, Heratfi S, Real Estate Market Efficiency: A Survey of Literature [J], *Urban & Real Estate Economics*. 2009, 07.
- [7] Robert K, James P, Anandi S, Random Walks and Market Efficiency: Evidence from International Real Estate Markets [J]. *Journal of Real Estate Research*. 2002, 24(3): 279-298.
- [8] Rayburn W, Devaney M, Evans R. A Test of Weak-Form Efficiency in Residential Real Estate Returns[J]. *Real Estate Economics*, 1987, 15(3):220-233.
- [9] Aimin P, Hongwei W, Inefficiencies of the Real Estate Market in China: Theory and Empirical Analysis [J]. *Financial Science*, 2008, 07:55-63. (In Chinese)
- [10] Keqiang W, Ying Z, Hongmei L, A Review of the Research on the Efficiency of Real Estate Market[J]. *China Land Science*, 2006, 20(5): 54-59. (In Chinese)