Market Efficiency and House Price Dynamics in Residential Real Estate Markets of China

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DECLARATION

I hereby declare that this thesis is my original work and it has been written by me in its entirety. I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

SUN Yajie

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CONTENT

Summary

The purpose of this paper is to test the efficiency of the residential real estate market and give a rational story to explain the rising housing prices in China. Firstly, we test the efficiency of the residential real estate market of China. Through observing the phenomena that housing prices cannot adjust to new information instantaneously, we illustrate that evidences do not obey the weak-form efficiency, using autocorrelation and fisher-type unit root test based on augmented Dickey-Fuller (ADF) test. More specifically, empirical results suggest that residential real estate markets in China are inefficient, and the degree of housing prices cannot reflect total information. Furthermore, we gain fundamental solutions for housing prices and price-to-rent ratios using the Lucas tree model. However, it fails to explain the dramatic fluctuations witnessed by actual data. Thus, we add bubble components in the asset pricing model, thereby successfully matching the trend of both housing prices and price-to-rent ratios.

Keywords: real estate markets, housing price, price-to-rent ratio, weak-form efficiency, Lucas tree model

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1 Introduction

Benefiting from the current policy of housing commercialization instead of central allocation, the Chinese real estate industry has experienced rapid development, serving as a major pillar of the Chinese economy. Changes in housing price are bound to influence household wealth and also the consumption behavior. As a result, fluctuations of housing price do have strong impacts on the whole economy, and it is particularly the case that the housing asset is the largest component of household wealth[1]. The Chinese real estate market has been in a boom over a decade. The size of the residential investment was only 211,794 million RMB in 1998, and it had grown to 6,435,215 million RMB by 2014. However, on account of rapid development, some serious problems have arisen, which hinder further development in the real estate industry and thereby act as an impediment to the national economy. The strong industry association is the reason that real estate markets become the main engine of economic growth. Thus, the market is engaged in something of a tightrope act. On one hand, if real estate markets can grow at a rational and healthy rate, related industries like the mining industry, the smelting industry, the transportation industry, etc. are bound to develop. On the other hand, if real estate markets have significant fluctuations and are always at a high level of risk, bubbles can be induced, and individuals can be in a panic, resulting in the detrimental impact on the national economy, as well as the society generally.

[1]Yu and Jin (2015) show that housing assets in China, which accounted for over 70 percent, are the largest component of household wealth.

To judge whether the real estate market is healthy, we can test the deviation of housing price from its true value. For the present situation in the real estate industry of China, due to the expected rise in housing prices, individuals are keen on investing in real estate markets. Even though national and local governments set up some policies aiming at restraining the high-speed rise in prices, over-investment and soaring housing prices still occur in many cities. Housing prices in some metropolises increase more than 20% in a year, which shows that it is of great importance to identify the determinants of housing price dynamics. Therefore, empirical investigations of the efficient market are necessary, being of critical significance in the evaluation and assessment of residential properties.

Testing of efficiency in security markets is popular and has been estimated by many previous studies. In security markets, efficiency means that market participants have equal and timely access to all related information. Meanwhile, in real estate markets, it implies that no individuals or companies can predict future housing prices depending on the past or current information. This distinction has been widely argued and applied among western countries decades ago.

The paper attempts to estimate the residential real estate market efficiency under the efficient market hypothesis (EMH), mainly focusing more on analyzing the historical housing prices and their related information. According to the EMH, there are three types of efficiency, which are weak-form efficiency, semi-strong-form efficiency, and strong-form efficiency. A market is defined to be weak-form efficient if it cannot earn an extra return by making investment decisions depending on historical information such as historical price data. Thus, the key problem is to test whether historical housing prices contain useful information to allow the prediction of future prices; that is to say, whether individuals can gain excess returns through access to related information. A widely used test of market efficiency analyzes whether residential real estate market indicators follow a random walk process. If it shows characteristics of a random walk, individuals cannot earn excess returns. Likewise, future prices cannot be predicted with the use of related information. On the contrary, if it does not show any characteristics of a random walk, individuals have the ability to predict housing prices. Thus, there exists the potential for excess returns. The efficiency test used in this part includes changes in the rates of excess return on its own lagged values, and then significant relationships are interpreted as evidences of market efficiency. Another empirical section applies the unit root test to the 30 provincial housing price panel data. It applies a Fisher-type test based on the augmented Dickey-Fuller test (D. A. Dickey and W. A. Fuller,1979). We find that real estate markets in China do not obey the weak-form efficiency, and results cannot provide support for the random walk hypothesis. That is to say, residential real estate markets are inefficient in China.

After analyzing the efficiency of the real estate market in China, we provide the explanation of the current pattern of the price-to-rent ratios and also housing prices in residential real estate markets of China. The study applies a Lucas tree asset pricing model, in which individuals own an asset, the house, and the asset can generate a stream of dividends, the rents. As for this Lucas tree model, houses are treated as financial assets and agents are regarded as investors. Rents here are analogous to the cash flow terms to dividends that stock market investors receive from holding stocks. A fundamental value of housing prices and price-to-rent ratios can therefore be calculated, and then it can be compared with the actual value. We solve the model under rational expectations, gain a solution for price-to-rent ratios, and then judge whether it can match the actual trend over the 1998-2015 sample. Results of the fundamental solution show that it cannot illustrate a trend similar to that of actual price-to-rent ratios. Thus, we consider applying the bubble component (Hunter, Kaufman, and Pomerleano, 2003) throughout historical data. Rational bubble models show that agents are able to realize the fundamental asset prices. However, they are willing to pay the extra prices. Thus final expectation values are the sum of fundamental solutions and bubble components. The findings show that expectation values in real estate markets of China are almost unanimous with actual values.

1.1 Background

The reform of the urban housing system began in the late 1980s[2], resulting in a general improvement in accommodation for most of the urban population in China. This part will trace the development of real estate industry in China from 1998 onwards. The year of 1998 is of great importance in the real estate markets of China.

In 1998, the government declared the policy about the abolition of all state-allocated housing and the establishment of residential mortgages, which is regarded as a

[2] These policies are gathered from the China Real Estate Association.

seminal moment in the Chinese real estate industry. The Asian financial crisis in 1997 caused an enormous impact on China, and the economic growth fell for the eight consecutive quarters. As a consequence, expanding domestic demand was a necessity to resolve the crisis and to curb the danger of further decline. The aim of the abolition of all state-allocated housing was to promote housing consumption. The government set up a series of policies to stimulate the real estate development. The most representatives were the abolition of the welfare housing policy as well as the start of housing mortgage loans, leading to the outbreak of demand in the short term, and maintaining a rapid growth in the real estate development.

During the period from 1998 to 2003, housing prices remained stable. Individuals purchased houses mostly for their living demand instead of investment. The real estate industry in this period gained policy incentives and credit support, directly improving and promoting economic conditions. For the next seven years from 2003 to 2010, real estate markets developed dramatically, and government land sales became an important source of income for local governments. The government established related policies, indicating that real estate industry has a high correlation with other industries, and became a major driver of the national economy. Moreover, scarcity of land resources was recognized, and auction-style land sales began, demonstrating that both supply and demand were fully commercialized. Housing prices started accelerating from 2003 at an unprecedented rate. Huge demand for investment and consumption demand could not be restrained, and investment continued to maintain a growth rate of 20% during that time span from 2003 to 2010.

Governments came to realize the existing problem, and they published successive policies to control the significant increase in housing prices. Nevertheless, these policies could not control the rapid increase in housing price, ending with failure. Although real estate markets along with the overall economic situation in China developed extremely fast, it exposed more problems with the industrial development of the country. For example, urban families bear high expenses in purchasing houses; purchasing a house might cost individuals' whole savings. Wealth inequality rose as a result of the increasing growth rate of housing prices. Redistribution led to social injustice, as well as social problems. Individuals who could not afford the high price began to complain, and then housing prices and the real estate industry became the focus of social concern.

The 2008 financial crisis in the United States decreased the quantity of sales and prices of houses, inducing a global economic recession. The demand for houses began to decrease; and thus, housing prices also maintained the same trend, which was the first fall since the policy of commercialization began in 1998. In order to ensure a healthy economic growth rate, the state conducted a more relaxed monetary policy, raising investments in real estate and reducing the cost of housing purchase. In September and October of 2008, the central bank cut the benchmark interest rate and housing provident fund loan interest rates, so as to solve the housing problems of the individuals, especially the low-income earners. The period is of great significance since both supply and demand had been commercialized. In addition, the real estate industry has been regarded mostly as a function of investment rather than living demand.

From 2011 onwards, housing price continued to rise. Some reports said the level of price-to-income ratio throughout China was even higher than that in New York, Tokyo and also other major cities around the world. Moreover, there existed a large number of vacant houses[3] for the reason that individuals regarded purchasing houses as a way to invest. At this stage, China's real estate market was characterized by uneven development. Imbalance in the market enlarged the inequality to a large extent. Housing prices in coastal areas were much higher than those in inland areas, and prices in urban areas were much higher than those in rural areas. Thus, the government needed to carry out some policies to reduce the disparity. In particular, housing restriction policy was published in certain areas, in which real estate markets yielded sudden huge profits.

At present, there are some challenges in the domestic economy. However, the government has not relaxed regulation and control. Therefore, this period could be regarded as a new development span. Real estate in various provinces develops with high disparities, thereby inducing different economic levels. Moreover, as purchasing houses has been a popular method to invest, individuals pay close attention to real estate markets. Innovation and appropriate policies are considered to ensure that the real estate industry adjusts and develops healthily. Accordingly, a thorough analysis of the current real estate market of China seems necessary.

[3] China Household Finance Survey and Research Center releases that the vacant housing rate was 22.4% in urban areas in 2013.

1.2 Literature Review

The paper is related to two strands of literatures, regarding the efficiency test and the asset pricing model. Some previous studies concentrate on testing the efficiency of real estate markets and explaining reasons of efficiency or inefficiency. Gau (1984) indicates that the market obeys weak-form efficiency using random walk hypothesis, and then further tests the semi-strong efficiency using an asset pricing model. The above literatures are empirical evidences in the United States real estate markets. Case and Shiller (1989) conduct the real estate market efficiency test. The paper performs tests of the market efficiency for single-family homes in various cities in America. And it holds the viewpoint that markets for single-family homes do not appear to be efficient in Atlanta, Chicago, Dallas, and San Francisco metropolitan areas, for the reason that information about real interest rates does not appear to be incorporated in price. Further, they utilize excess returns (Case and Shiller, 1990) to show that markets for single-family housing are not efficient. Richard Meese and Wallace (1994) use another method. They examine the efficiency of residential housing markets depending on Efficient Market Hypothesis (EMH) from the transaction database for Alameda and San Francisco Counties in Northern California. The conclusion is that the explanation for the short-run rejection of, but long-run consistency with the housing price present value is the high transaction cost. That is to say, the real estate market in the long-run is efficient in their study. Clapp, Dolde, and Tirtiroglu (1995) examine characteristics of housing price dynamics in residential housing in two areas in the US, and authors desire to document characteristics of housing price dynamics that may be consistent with rational learning and not simply irrational feedback trading. Dolde and Tirtiroglu (1997) study housing prices in residential real estate markets in Connecticut and San Francisco areas. The result is the same as that in Case and Shiller's (1989, 1990) study, which is the market does not obey weak-form efficiency at least in these particular areas. Myer, Chaudhry and Webb (1997) examine commercial housing price indicators in the US, Canada, and the UK. Their conclusions are that random walks exist in the three countries. Actually, researches illustrated above are related to the US market. Clayton (1998) investigates the extent to which condominium apartment prices in Vancouver, British Columbia, are set in an efficient asset market. Empirical results provide strong evidence to suggest that real estate markets are inefficient, and hence residential real estate returns are partly predictable based on the currently available information. Meen (2000) applies the framework of analyzing the efficiency of housing markets, detecting inefficiency in the UK. real estate markets by simulating housing cycles and housing models. Case, Goetzmann, and Rouwenhorst (2000) focus on the international real estate markets, and they find that correlations among international real estate markets are extremely high. In addition, Meen (2002) analyzes housing markets in the UK in much less detail compared with the US.

The second strand is related to the asset pricing model. Some studies have already applied the Lucas (1978) tree type model in the US real estate markets. Goswami and Tan (1984) estimate Euler equations associated with the gross housing returns inclusive of price appreciations as well as rents jointly for several metropolitan areas of the US. Benartzi (2001) analyzes data to illustrate how extrapolation of the most recent prices increase can determine asset allocation choices. Besides fundamental solutions under the Lucas tree model, the assumption of rational bubble components of the model shown in Kennelth and Maurice (1991), which exclusively introduces the presence of a specific type of rational bubble components can explain the behavior of prices depending on aggregate dividends. Van and Weill (2009) have presented and solved a spatial dynamic equilibrium model of the housing market. However, in their research, agents are influenced by wage shocks, rather than rent shocks. Granziera and Kozicki (2015) deal with the fundamental solution and find that the price-to-rent ratio series exhibit high volatility and persistence which are not exhibited in the fundamental solution. Then recent housing boom can be a bubble in fact. Yang Tang et al. (2016) investigates the rapid growth in the dispersion of housing prices across metropolitan statistical areas in the US. They find the calibrated model can match the rapid growth in the dispersion once incorporate rational bubble solutions. Most of the approaches we apply are from Lansing (2010) for the study of stock markets, which derives a general class of intrinsic rational bubble solutions in a Lucas type asset pricing model.

As for market efficiency in China, most of the literatures have focused on the security markets. In the field of real estate industry, some studies prefer to focus on the efficiency of the land market. Liang Peng and Thibodeau (2011) examine whether the government action mitigates the efficiency of the residential land market and introduces the relationship between the land lease prices and residential property prices from 2001 to 2007. Also, some studies focus on listed real estate companies. For example, Xian Zheng, Chau and Hu (2011) study measures performance and efficiency of listed real estate companies with three types of data envelopment analysis approaches. Researches in the housing market in China are much weaker, providing further motivation for a detailed analysis of this topic. In general, all previous researches on this topic have failed to reach a reliable consensus; thus, further research is crucial, in particular for markets in China. The following research aims to test the efficiency of real estate market based on monthly housing price indicators covering all provinces except Tibet.

The paper is organized as follows. Section 2 presents the methodology of testing real estate market efficiency in conjunction with the autocorrelation coefficient test and the random walk hypothesis, and also, the methodology of calculating fundamental solutions and bubble components. Section 3 describes the data applied in our study. Section 4 reports empirical results. Finally, Section 5 summarizes findings and conclusions.

2 Methodology

2.1 Methodology to Test Efficiency of Real Estate Market

Various methods can be applied to test market efficiency. This study chooses two different and efficient techniques to test weak-form efficiency in the real estate market in China: the autocorrelation coefficient test and the unit root test. The autocorrelation coefficient test is used to study the independence of housing prices, while, for unit root test, the study chooses a standard augment Dickey-Fuller Fisher test to study the randomness of housing prices. The two tests are introduced separately as follows.

The autocorrelation efficient test is a method to test the independence of asset prices under the null hypothesis of an efficient market. The efficient market hypothesis (EMH), one of the most well-studied propositions in economics, is a key proposition in this study. Test of markets' efficiency needs a time series of rates of return. In the discussion of market efficiency, it is classified as weak-form, semi-strong-form, and strong-form efficiency. Weak-form efficiency indicates that housing prices reflect all information shown in historical prices. Semi-strong-form efficiency implies that housing prices not only reflect the historical information but also reflect the current information; that is to say, housing prices can reflect new public information instantly. In terms of strong-form efficiency, it implies that all private information including hidden insider information is included in current market prices (Robert, James and Anandi, 2002). The sequence of testing market efficiency is not random. If a market is examined to be weak-form efficient, the semi-strong-form efficiency test can then be applied. Moreover, once the semi-strong-form efficiency is satisfied, the strong-form efficiency can be tested. Thus, if the weak-form efficiency does not succeed, there is no need to have further tests. In this paper, only weak-form efficiency is examined for the reason that results show that markets do not obey characteristics of weak-form efficiency.

Now we start with simple market efficiency tests, using the autocorrelation test. At the very beginning, we assume that the real estate market is a perfect asset market, which has no common expectations, no transaction cost and a competitive market for homogeneous assets. As economic participants are rational enough, prediction should also be rational. Thus, the asset price includes two separate but interrelated elements. One reflects the present value of all future dividends, and the other part reflects the expected future appreciation. For real estate market, if the market is efficient, price changes should be unpredictable, and the expected rate of return on investment in real estate should equal that on an alternative investment. Return of investment in real estate is a flow of income from housing services, which is rental price, plus expected appreciation. The paper denotes the nominal return available on alternative investment by *i* and then under efficient markets hypothesis (Clayton, 1998),

$$i_t = \frac{E_t(P_{t+1}|I_t) - P_t}{P_t} + \frac{R_t}{P_t} \;, \tag{1}$$

where E_t denotes expectation, P_t is housing price, R_t is rental income, denoting the flow of implicit rental services. Moreover, I_t is information set available to participants at the time when expectations of future housing prices are formed. Let us denote the excess return of housing to be the following expression

$$r_{t+1} = \frac{P_{t+1} - P_t + R_t}{P_t} - i_t \;, \tag{2}$$

where i_t[4] here can be regarded as risk free rate of return.

[4] The rate of demand deposit issued by the People's Bank of China is used to approximate it.

That is to say, residential real estate market efficiency can be examined by regressing excess returns by provinces for lags up to 24 months. A set of balanced panel data with national coverage is used from July 1998 onwards.

The paper uses autocorrelation coefficient test applying data divided at the provincial level. It reveals relationship for a variable under various periods; that is to test whether past behavior can have influences on present behavior. Using autocorrelation coefficient of excess returns in real estate market, the paper can test whether the coefficient is statistically significant. If it is, the null hypothesis of weak-form efficiency should be rejected.

The unit root test can be another method to test weak-form efficiency. The null hypothesis is that the real estate data carry a unit root and hence they are nonstationary. Statistical regulations may change as time passes by, and the mean function as well as variance function can be both constant and time-variant. This paper uses panel unit root test, which is the Fisher-type unit root test based on the ADF test, being an improvement based on the Dickey-Fuller test. There are several differences between the two tests. For ADF test, the error term can have autocorrelation, which suits most of economic data series. Nowadays ADF becomes an ordinary and popular way to test unit root, and hence the paper does not need to repeat the whole methodology here. The following equation is employed to estimate whether there exist any unit roots,

$$\Delta Z_{jt} = \alpha + \beta T_j + (\rho - 1) Z_{j,t-1} + \sum_{i=1}^{n} \theta_j \Delta Z_{j,t-j} + \varepsilon_{jt} \ , \qquad (3)$$

where T indicates that there is a time trend, Δ is the first difference operator, ε_{jt} denotes the error process with zero mean and constant variance, and Z_{jt} represents the normalized housing price, which is the logarithm of housing price divided by its mean, denoted as $Z_{jt}= log\frac{p_{jt}}{\frac{1}{n}\sum_{j=1}^{n}p_{jt}}$, where p_{jt} is the housing price in the period t for province j. In our sample data, n=30, the number of provinces applied in the paper. The null hypothesis is that all panels contain unit roots, which is $(\rho-1)=0$, while alternative hypothesis is $(\rho-1)<0$.

2.2 Lucas Tree Asset Pricing Model

We follow the approach developed in Lansing (2010) for the study of real estate markets. The Lucas tree asset pricing model is applied to gain a rational expectation value for price-to-rent ratios, and then we use the ratio to calculate housing prices. Just like the stock market, we treat houses as financial assets and rents can be regarded as an exogenous stream of consumption, which are dividends. In the Lucas model, agents always choose the consumption and the equity to maximize their utility. In particular, suppose agents maximize the following expected discounted utility given by

$$\max_{c_t,s_t} E_0 \sum_{t=0}^{\infty} \beta^t U(c_t) \quad , \tag{4}$$

subject to the budget constraint

$$c_t + p_t s_t = (p_t + d_t)s_{t-1} \text{, with } c_t, s_t > 0 \quad , \tag{5}$$

where E_0 is the agent's subjective expectations at time zero, c_t is the consumption in period t, s_t is the equity share purchased at time t, p_t is the price in period t, d_t is the dividend paid by the share in period t and $\beta \in (0,1)$ is the discount factor. Houses are treated as assets that can deliver rents, which are regarded as consumption. Then take the well-known first order condition of the maximization and get the Euler equation governing the agent's consumption choices

$$p_t = \beta E_t \frac{U'_{c_{t+1}}}{U'_{c_t}} (p_{t+1} + d_{t+1}). \tag{6}$$

Because there is no technology to store dividends, which is housing rents in this model, houses are available in fixed supply, for simplicity $s_t=1$ so that $c_t=d_t$ for any time t. Then apply this equilibrium condition in (6) and assume a CRRA utility function, i.e. $U(c_t) = \frac{(c_t)^{1-\alpha}-1}{1-\alpha}$, in which $\alpha>0$. Then we can get:

$$y_t = \frac{p_t}{d_t} = E_t[\exp\big((1-\alpha)x_{t+1}\big)\left(\frac{p_{t+1}}{d_{t+1}} + 1\right)] \ , \tag{7}$$

where α is the coefficient of relative risk aversion, and $x_t = log(\frac{d_t}{d_{t-1}})$, is the growth rate of dividends (rents).

To solve the model, a stochastic process for the growth rate of dividends is a necessity. Now suppose x_t obeys stationary autoregressive process, following a normal distribution. We use the following panel regression for the 30 provinces statistical areas from July 1998 to September 2015

$$X_{jt} = \bar{x}_j + \rho\big(x_{j,t-1} - \bar{x}_j\big) + \varepsilon_{jt} \ , \qquad |\rho| < 1, \varepsilon_{jt} \sim N(0, \delta_\varepsilon^2) \tag{8}$$

where $\overline{x_j}$ is the province $j's$ mean growth of rental price, ρ is the autocorrelation of rents growth rate and δ_ε is the standard error of rents' growth rate. Related values must be gained in this process.

2.2.1 The Fundamental Solution

This section introduces fundamental solution and its implications for price-to-rent ratios and housing prices. Then solve the model under rational expectations. We can cover an approximate solution which can be written as:

$$y_t^f = \frac{p_t}{d_t} = \exp(a_0 + a_1\rho(x_t - \bar{x}) + \frac{1}{2}a_1^2\delta_\varepsilon^2) \ , \quad (9)$$

where

$$a_1 = \frac{1-\alpha}{1-\rho\beta\exp[(1-\alpha)\bar{x}+\frac{1}{2}a_1^2\delta_\varepsilon^2]} \ , \quad (10)$$

$$a_0 = \log[\frac{\beta\exp((1-\alpha)\bar{x})}{1-\beta\exp[(1-\alpha)\bar{x}+\frac{1}{2}a_1^2\delta_\varepsilon^2]}] \ , \quad (11)$$

as long as $1>\beta exp[(1-\alpha)\bar{x}+\frac{1}{2}a_1^2\delta_\varepsilon^2]$.

See Proposition 1 of Lansing(2010) for the proof.

For the equation (9), if the value of parameter a_1 or ρ is zero, it illustrates that the value of y_t^f will be constant, and then there is no high volatility of price-to-rent ratios. Solutions show that price-to-rent ratios depend on the deviations from actual value and its mean. Then we can assign values to the parameters in the above equation and fundamental solutions can be gained.

2.2.2 Bubble Component

The fundamental solution shown in the part of empirical results illustrates that a rational expectation model cannot generate similar trend as actual price-to-rent ratio trend. We desire to find identical models to generate similar features of the real data. For the fundamental solution cannot reflect the high volatility in actual price-to-rent ratios, we apply a bubble component and then plus the two sections. That is to say, besides fundamental solutions, we still consider a rational bubble solution to the Lucas tree asset pricing model, which is firstly introduced by Froot and Obstfeld(1991), and then developed by Lansing (2010) using CRRA utility function.

The model desires to verify identical trend, and the price-to-rent ratio can be divided into two components. One is the fundamental solution which has been shown in the section 2.2.1, that is y_t^f. Moreover, the other is the rational bubble component, that is y_t^b defined in this part.

The expectation value y_t can be denoted as

$$y_t = y_t^f + y_t^b. \tag{12}$$

And the rational bubble component should satisfy the following expectational equation:

$$y_t^b = E_t(\beta \exp((1-\alpha)x_{t+1}) y_{t+1}^b). \tag{13}$$

Actually, the above condition is period-by-period condition and does not depend on time. The rational bubble component is considered to be intrinsic (Froot and Obstfeld(1991), because they derive all variables from exogenous economic fundamentals and none from extraneous factors. And solutions to the rational bubble component can be written as

$$y_t^b = y_{t-1}^b \exp(\lambda_0 + (\lambda_1 - (1-\alpha))(x_t - \bar{x}) + (\lambda_2 + (1-\alpha))(x_{t-1} - \bar{x})),$$

$$\text{with } y_0^b > 0, \quad (14)$$

where parameters λ_0, λ_1 and λ_2 satisfy following equlibrium equations.

$$\lambda_2 = -(\rho\lambda_1 + (1-\alpha)), \quad (15)$$

$$\frac{1}{2}(\lambda_1)^2\delta_\epsilon^2 + (1-\alpha)\bar{x} + \log(\beta) + \lambda_0 = 0, \quad (16)$$

and

$$\lambda_0 = (\lambda_1 + \lambda_2)\bar{x}. \quad (17)$$

Clearly the above three equations can be written as the equation

$$\frac{1}{2}(\lambda_1)^2\delta_\epsilon^2 + \lambda_1\bar{x}(1-\rho) + \log(\beta) = 0 \quad (18)$$

The proof can be found in Proposition 2 of Lansing (2010).

The bubble component with negative drift ($\lambda_0 < 0$) will eventually shrink to zero, implying that no bubble can occur in the future. We choose the solution with positive drift ($\lambda_0 > 0$). Equation (18) implies two solutions. One has positive λ_1, and the other has negative λ_1. Once λ_1 is chosen, parameters λ_0 and λ_2 can be easily solved.

3 Data

The data set that we use has obtained from the China Economic & Industry Data Database. It provides monthly data on housing prices, real estate rents and leasing price indices and bank deposit rates for common residences in every province across China. In the database, a part of rental price data comes from the National Real Estate Market Data Center of China; others are obtained from the real estate rents and leasing price indices. Furthermore, all the data sets are deflected by consumer price index and adjusted for seasonality.

Four data series are required to test the real estate market efficiency, including housing price indicators, rental prices, excess returns and price-to-rent ratios. We notice that, before 1997, houses for individuals were provided by their work units, so that pricing prices were below the market clearing price. It is noticeable that the year 1998 marked a turning point of housing commercialization nationwide. Thus, we assume that the market began to operate subsequently.

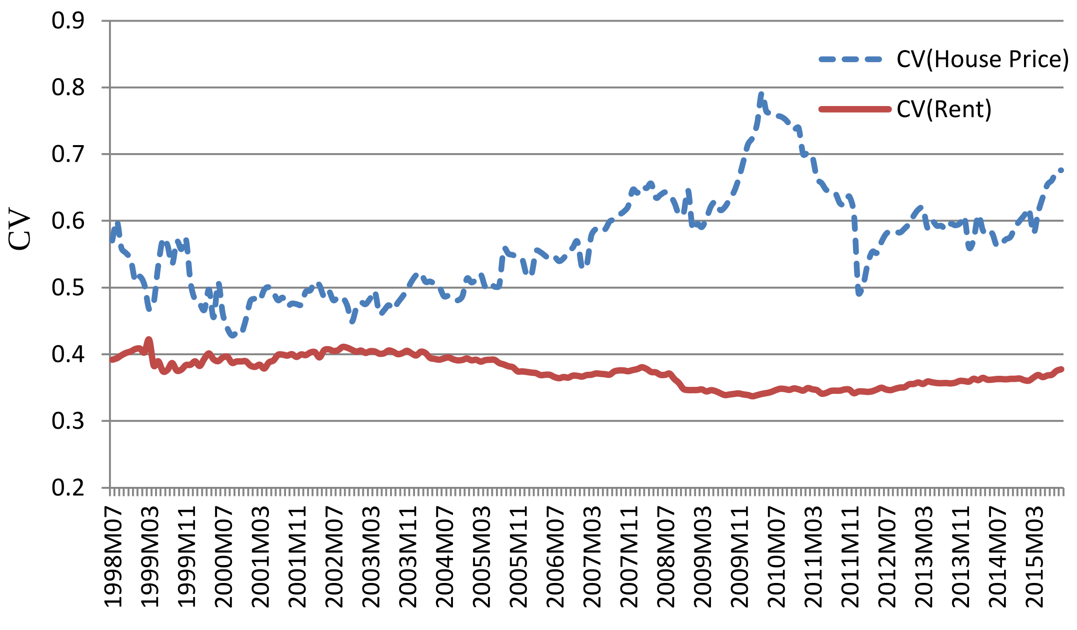
Table 1 presents summary statistics for monthly indicators at the national level between July 1998 and September 2015. It shows housing prices, rents, price-to-rent ratios and excess returns for common residences. From Table 1, we can find that housing prices range from 505.65 to 13,520.99 RMB per square meter over the period, illustrating that substantial differences exist across various provinces and time. It is rational that housing prices have increased significantly during the 17 years. The same applies to rental prices. We also calculate excess returns with given equations introduced in the methodology section, which range from -0.52 to 0.75. The mean is about 0.013, being positive. Standard deviations show the degree of volatilities in real estate markets in all provinces of China except the province of Tibet. A standard deviation of 7.43% indicates that excess returns are violent to some extent. Considering the lacking data of the market in Tibet, the paper actually abandons the province, which can increase the effectiveness and the validity of whole analyzes and results.

Table 1 Summary Statistics of Monthly Index 1998:7-2015:9

Variable		Mean (RMB)	Std. Dev.	Min	Max	Observations
House price	overall	2489.72	1814.49	505.65	13520.99	N =6115
	between		1375.01	1513.93	7383.29	n =30
	within		1201.97	1783.12	9052.42	T-bar=203.83
Rent	overall	17.53	6.37	8.40	43.84	N= 6179
	between		6.39	10.36	38.84	n = 30
	within		1.02	12.08	22.65	T-bar=205.97
Price-to-rent ratio	overall	139.58	67.94	23.14	519.35	N = 6088
	between		33.04	92.97	230.72	n = 30
	within		59.55	-38.77	428.21	T-bar= 202.93
Excess return	overall	0.0131	0.0743	-0.5209	0.7551	N = 6009
	between		0.0050	-0.0022	0.0245	n = 30
	within		0.0742	-0.5169	0.7507	T-bar= 200.30

In Figure 1, we show the coefficient of variation (CV) of housing prices and rentals in China. The CV measures the dispersion of the series of data, and is defined as the ratio of the standard deviation to the mean. In this paper, we use the across province variance in given periods. CV fluctuates around 0.6 in a long period. The CV of housing prices fluctuates largely before the year 2004, and then it increases with fluctuation but suffers a decrease in 2012. It is at a high level, explaining that prices among various provinces are really large. The CV of rents fluctuates around 0.4, smaller than that of housing prices, and more stable on the whole.

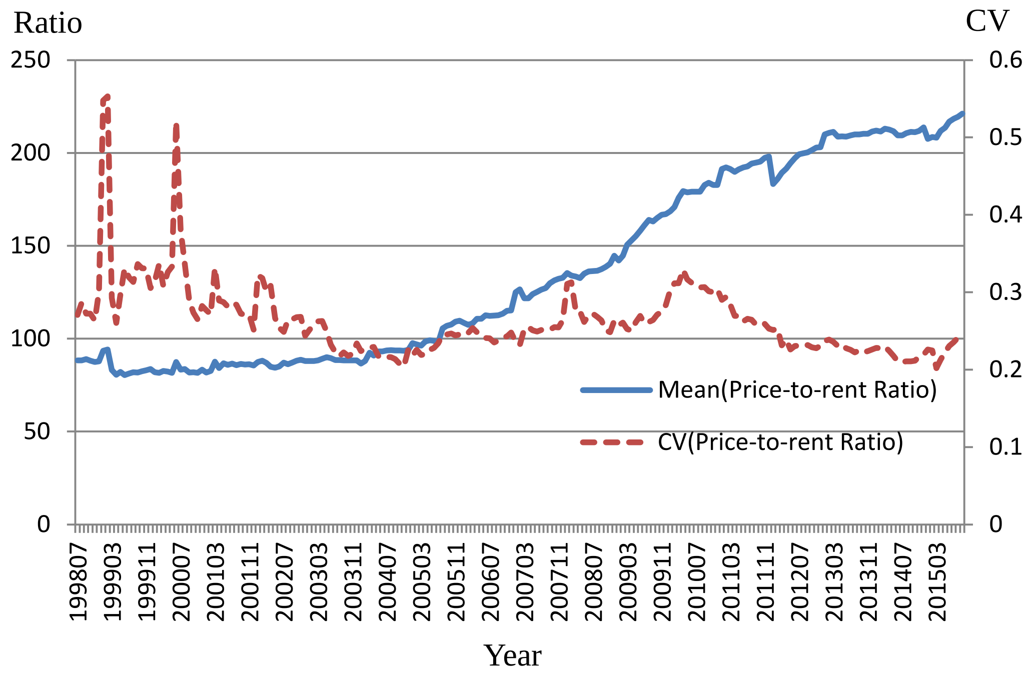
Figure 1 Coefficient of Variance of Housing Price and Rent



Notes: The figure is based on data from a balanced panel of 30 provinces. Both housing prices and rental prices are deflated by the consumer price index.

Figure 2 shows the mean and CV of the price-to-rent ratios from July 1998 to September 2015. The mean, which is 86 months, being already so high in the year 1998, still increases more than double to 224 months in the year 2015. As for the CV, the dispersion of price-to-rent ratios illustrates that it does not go up rapidly like the mean, but fluctuates significantly.

Figure 2 Mean and CV of Price-to-Rent Ratios



4 Empirical Results

We discuss the empirical results in this section. Section 4.1 is the estimation results for testing weak-from efficiency, which includes an autocorrelation coefficient function as well as a unit-root test (in ADF fashion). Section 4.2 is the estimation results from expectation solutions, which is the fundamental solution plus the bubble component.

4.1 Tests of Market Efficiency

4.1.1 Autocorrelation Coefficient

This section illustrates empirical results for testing weak-form market efficiency in the historical pricing data for given provinces. It evaluates the ability of past excess housing returns to predict future housing returns. The efficient market hypothesis in its weak-form version states that asset returns are not time-independent and thus are not autocorrelated. We examine autocorrelation structure of monthly excess returns, which are calculated as the capital gain adds rental income divided by initial price, minus the risk-free monthly rate. The autocorrelation functions (ACF) for the time series of excess returns are calculated at lags of 24 months,

$$\delta_i = \frac{Cov(r_t, r_{t-i})}{D(r_t)} \ , \tag{19}$$

where r_t is the excess return and *D(.)* denotes the variance.

Table 2 presents autocorrelation functions over a two-year span for the historical time series of each of the 30 provinces. To determine statistical significance, we compare autocorrelation values with their standard errors. Autocorrelation functions allow 24 lags in maximum. The table shows that autocorrelation coefficients around 75% (178/240) of orders are significant at various confidence levels. So to some extent, it reveals that the hypothesis of weak-form efficiency can be rejected in the real estate markets.

Table 2 Autocorrelations in Monthly Excess Return, 1998:7-2015:9

	Autocorrelation at Lags							
Province	3	6	9	12	15	18	21	24
Beijing	-0.0620	-0.0208	-0.0029	-0.0079	-0.0315	0.0539	-0.2071	0.2191
p-value	0.0017	0.0089	0.0576	0.1978	0.3247	0.4336	0.0582	0.0063
Tianjin	-0.0213	0.1320	0.0271	0.4478	-0.0391	0.1024	0.0403	0.1308
p-value	0.0107	0.0061	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000
Hebei	-0.1322	0.0083	0.0743	0.0885	0.0918	-0.0255	-0.0427	-0.0306
p-value	0.0007	0.0047	0.0159	0.0097	0.0108	0.0330	0.0614	0.0592

Liaoning	-0.0435	0.0114	-0.1007	0.7467	-0.0790	-0.0056	-0.1674	0.5533
p-value	0.0055	0.0310	0.0499	0.0000	0.0000	0.0000	0.0000	0.0000
Shandong	0.0275	0.0265	-0.0230	0.0529	0.0607	-0.0076	0.0663	0.3089
p-value	0.0002	0.0005	0.0028	0.0112	0.0306	0.0590	0.0902	0.0001
Shanghai	-0.0892	0.0465	-0.0579	0.0006	-0.0468	-0.0008	0.0091	0.0985
p-value	0.0616	0.2144	0.2646	0.2035	0.2049	0.2999	0.4444	0.3340
Jiangsu	-0.1001	0.0460	0.0658	0.1760	0.0186	0.0064	-0.0251	0.0835
p-value	0.3612	0.5525	0.4820	0.2001	0.3831	0.5680	0.6131	0.4800
Zhejiang	0.1056	-0.0347	0.1279	0.0328	0.0615	0.0469	0.0315	0.1424
p-value	0.1726	0.2462	0.0740	0.1243	0.1751	0.1134	0.1615	0.1100
Fujian	-0.0377	-0.0013	-0.0278	0.4918	-0.0086	-0.0031	-0.0922	0.3847
p-value	0.0094	0.0636	0.2012	0.0000	0.0000	0.0000	0.0000	0.0000
Guangdong	0.0473	0.0337	0.0323	0.1969	0.0882	0.0062	-0.0303	0.1925
p-value	0.0056	0.0326	0.0961	0.0043	0.0014	0.0019	0.0027	0.0004
Hainan	-0.0656	-0.0480	-0.0442	0.1540	-0.0197	-0.0271	0.0151	0.4162
p-value	0.1392	0.2726	0.2475	0.1280	0.2673	0.4486	0.5557	0.0000
Guangxi	-0.0240	-0.1483	-0.0190	0.0083	-0.0258	-0.0792	0.1619	0.2034
p-value	0.5468	0.0555	0.1060	0.0012	0.0019	0.0046	0.0012	0.0001
Jilin	0.0473	0.0155	-0.0435	0.1370	-0.1160	0.0109	-0.1304	0.0071
p-value	0.7319	0.6072	0.7470	0.5232	0.1856	0.2290	0.1998	0.3059
Heilongjiang	0.0438	-0.0156	0.0264	0.2565	0.0417	-0.0487	0.0745	0.1585
p-value	0.0148	0.0226	0.0193	0.0005	0.0016	0.0040	0.0047	0.0026
Anhui	0.0568	0.0188	0.0184	-0.0733	0.0486	0.0586	0.0119	0.3428
p-value	0.0036	0.0283	0.0700	0.0916	0.1319	0.0987	0.1589	0.0001
Jiangxi	-0.2598	0.0340	-0.1036	0.3317	-0.0539	0.0316	-0.0179	0.1219
p-value	0.0004	0.0025	0.0061	0.0000	0.0000	0.0000	0.0000	0.0000
Hainan	-0.0888	-0.0378	0.0880	0.3245	-0.0123	-0.0500	-0.0185	0.3245
p-value	0.0257	0.0172	0.0280	0.0000	0.0000	0.0000	0.0000	0.0000
Hunan	-0.0334	0.0067	-0.1932	0.3190	-0.0913	-0.0389	-0.1925	0.2306
p-value	0.0011	0.0132	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000
Chongqing	0.0643	0.0913	0.0930	0.2136	0.1139	0.0486	0.0794	0.3083
p-value	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
Sichuan	-0.0043	-0.0026	0.0226	0.1648	-0.0224	-0.0129	0.0852	0.4519
p-value	0.0000	0.0002	0.0012	0.0005	0.0022	0.0048	0.0051	0.0000
Guizhou	-0.1931	-0.0552	-0.1298	0.2742	0.0227	-0.0485	0.0002	0.0688
p-value	0.0001	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
Yunnan	0.1923	0.0489	0.1878	0.2083	0.1175	0.0239	0.1420	0.2220
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Henan	-0.0900	-0.0818	-0.0588	0.1721	-0.0761	-0.0451	-0.0721	0.2583
p-value	0.0199	0.0549	0.0609	0.0117	0.0233	0.0259	0.0501	0.0006
Shaanxi	-0.0414	-0.0656	0.0645	0.0368	0.0983	0.1012	0.0874	-0.0017
p-value	0.1793	0.1318	0.2699	0.1313	0.1784	0.1838	0.2342	0.3142
Shanxi	-0.0044	-0.0119	-0.0197	0.2460	-0.0105	0.0206	0.0313	0.1268

p-value	0.0246	0.1495	0.2616	0.0063	0.0155	0.0389	0.0733	0.0565
Inner Mongolia	-0.1605	-0.0197	-0.1273	0.2824	-0.1253	0.0282	0.0332	0.0557
p-value	0.0025	0.0205	0.0234	0.0004	0.0005	0.0019	0.0062	0.0149
Gansu	-0.0620	-0.0792	-0.0468	0.2483	-0.1088	-0.0194	-0.0014	0.0691
p-value	0.0717	0.1899	0.2894	0.0156	0.0256	0.0631	0.1185	0.1842
Qinghai	-0.0069	0.0157	-0.0164	0.1642	-0.0661	-0.1145	0.0491	-0.0217
p-value	0.6518	0.7420	0.8806	0.6533	0.7549	0.6221	0.6720	0.8135
Ningxia	-0.0883	0.0319	-0.0971	0.4490	-0.0485	-0.0598	-0.0999	0.3297
p-value	0.2249	0.4398	0.3211	0.0000	0.0000	0.0000	0.0000	0.0000
Xinjiang	-0.0330	0.0245	-0.0860	0.3282	0.0021	0.0151	-0.0757	0.4228
p-value	0.0029	0.0208	0.0434	0.0001	0.0004	0.0008	0.0021	0.0000

Notes: The data are drawn from China Economic & Industry Data Database during the period from July 1998 to September 2015 for all provinces in China expect Tibet. P-values are indices used to judge the significance level.

4.1.2 The Unit-root Test

Table 3 displays results of ADF-Fisher unit-root tests on housing prices. We allow a maximum of six lags. The test chooses optimal lags based on information criteria and individual ADF statistics. For each of the 30 provinces, the calculated t-statistics for the levels of z_t series, defined in the above section, are smaller than the critical value at all levels of significance. Moreover, the result shows that all of the p-values are zero at four decimal places, implying that the ADF test rejects the null hypothesis that weak-form efficient. The result provides no evidences to support the random walk hypothesis for residential real estate markets in China.

Table 3 ADF Test Results of Housing Prices

Lags	1	2	3	4	5	6
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes: The table presents the test statistic of ADF-fisher test results. The p-values are zero at four decimal places. Thus, the results reject the null hypothesis that there is an existence of unit roots in housing price panel.

4.2 Results for Fundamental Solution and Simulated Result

4.2.1 The Fundamental Solution

Table 4 reports parameters used in the calibration. As introduced above, parameters $\bar{x}$, ρ and δ_ε can be gained through the process (8). While as for α and β, they are chosen to match the sample average of the price-to-rent ratio for the provided data, within the reasonable range.

Table 4 Parameters Used in the Calibration

	Description	Value
$\bar{\mathbf{x}}$	Mean growth rate of dividends	0.002325
$\boldsymbol{\rho}$	Autocorrelation of rent growth rate	0.190706
$\boldsymbol{\delta_\varepsilon}$	Standard errors of dividends growth process	0.001036
$\boldsymbol{\alpha}$	Relative risk aversion	3.0
$\boldsymbol{\beta}$	Discount factor	0.9902

Parameters are calibrated to real estate markets in China over 1998-2015. α reflects individuals' risk attitudes, and it is set to be 3.0, which has been tried many a time to accord with the model. It is also within the reasonable range. β is the discount factor. Throughout the whole paper, β is set as 0.9902. Given all parameters and values of α and β, we then calculate all observations of the model and related results are shown in Figure 3 and Figure 4. Figure 3 compares actual price-to-rent ratios with fundamental solutions. Figure 4 is the actual data and expectations of the logarithm of housing prices. We calculate expectations of simulated price-to-rent ratios and real rents. Figures show that actual price-to-rent ratios keep increasing throughout the sample period while the simulated fundamental price-to-rent ratios are stable across time. To lessen the gap between the simulated results and the actual data, it would be necessary to observe a more violent or persisted growth process for the price-to-rent ratios.

Figure 3　Fundamental and Actual Price-to-rent Ratios

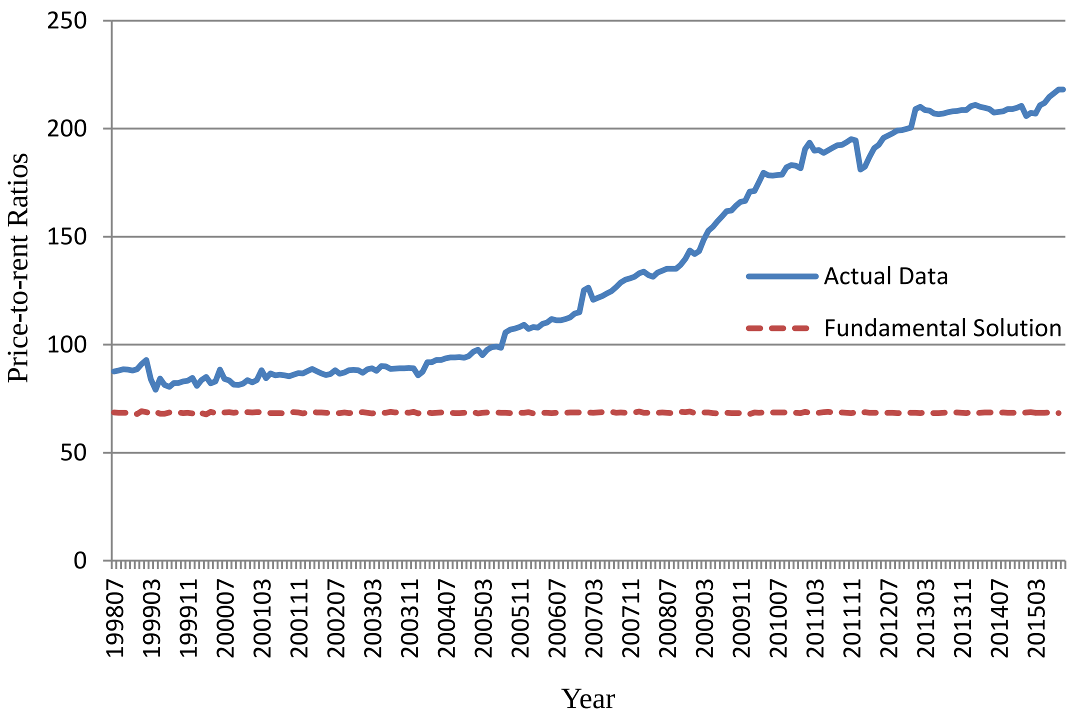
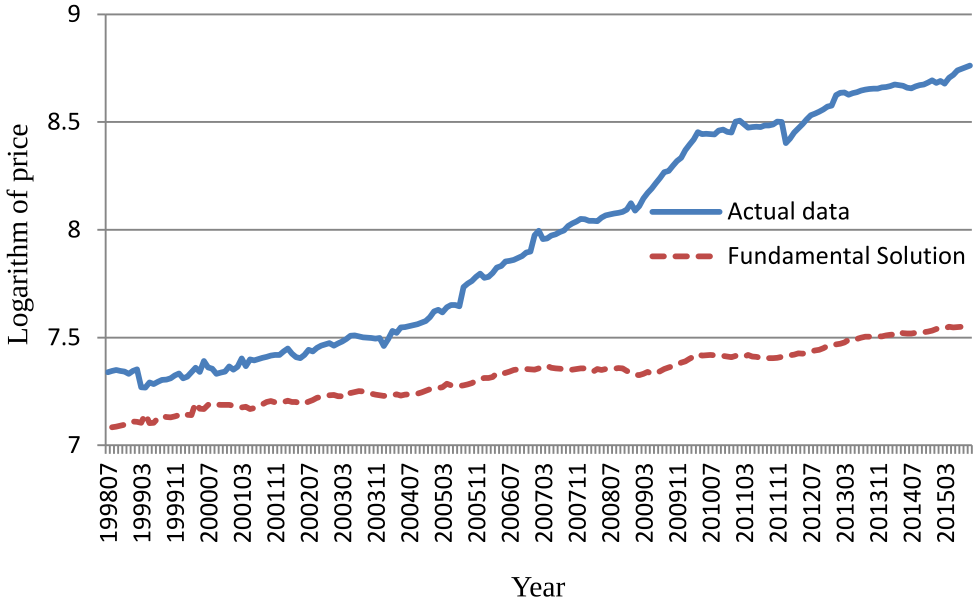


Figure 4 Fundamental and Actual Housing Prices[5]



4.2.2 The Rational Bubble Solution

This section discusses rational bubble solution applying related data using the model introduced in 2.2.2. The value of λ_0, λ_1 and λ_2 are 0.008924, 2.271799, and 1.566753 respectively. And then we calculate the value of y_0^b using equation (12). That is, $y_0^b = y_0 - y_0^f$, where y_0 is imputed by actual values of the initial price-to-rent ratio, and y_0^f is the fundamental solution which is gained from equation (9). The initial value y_0^b must be positive.

In Figure 5, we compare fundamental solutions, bubble components, and rational bubble solutions of price-to-rent ratios over the sample July 1998 to September 2015. The result shows that fundamental solutions are stable so that the trend of expectation values is nearly the same as that of bubble components. As shown in Figure 6,

[5] All the indicators showing in the graph are the logarithm of housing prices.

expectation values are improved and prompted after adding bubble components, though there are still small deviations from actual price-to-rent ratios. Moreover, as shown in Figure 7, the rational bubble solution also matches the rational bubble solution of housing prices, and also exhibits a similar trend as the actual values.

Figure 5 Fundamental Solution, Bubble Component and

Rational Bubble Solution of Price-to-rent Ratios

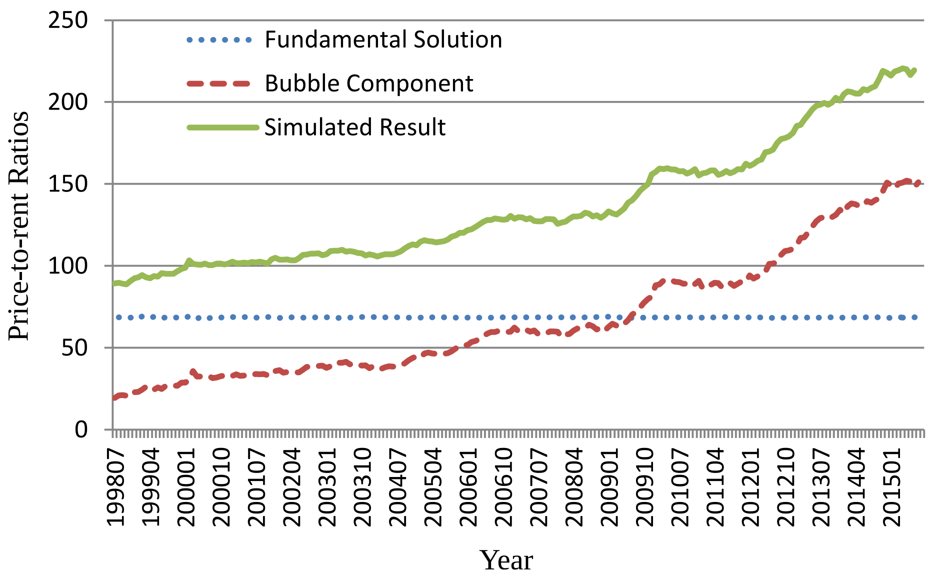


Figure 6 Rational Bubble Solution and Actual Price-to-Rent Ratios

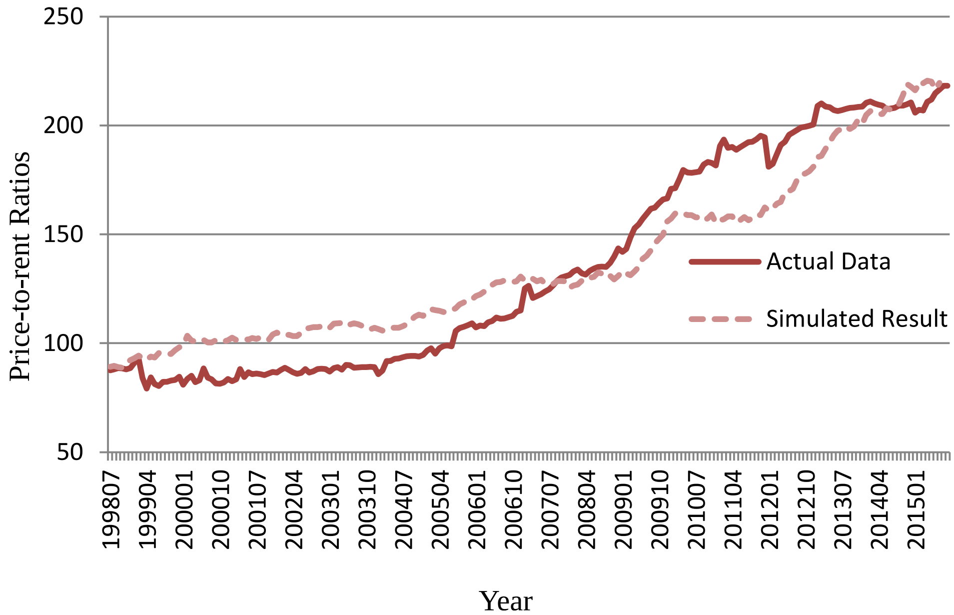
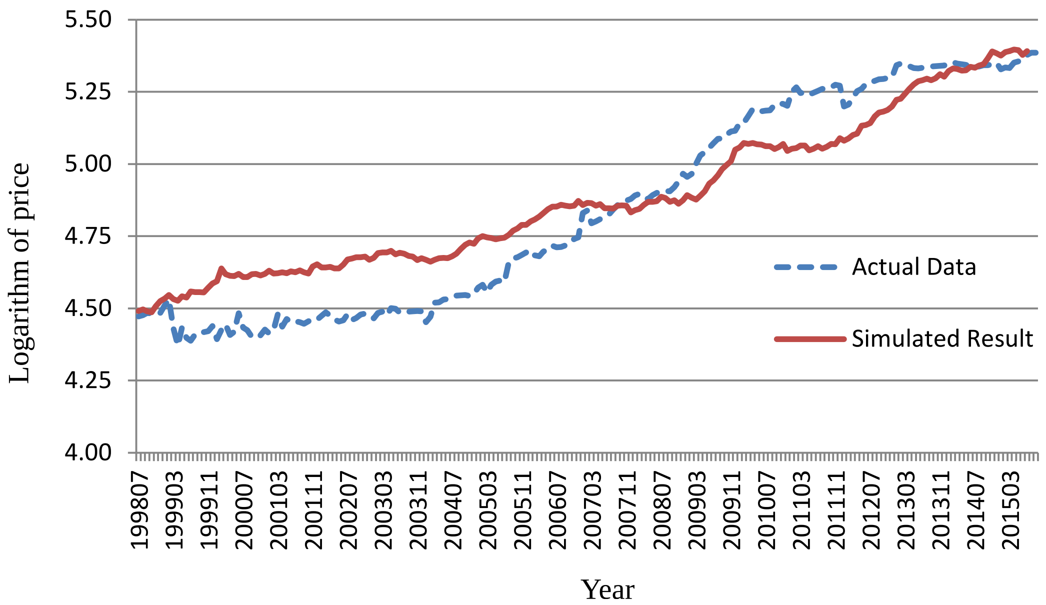


Figure 7　Rational Bubble Solution and Actual Housing Prices



Notes: We directly estimate the price-to-rent ration, and then calculate the housing price using the rental price of each province during given periods. The policy of housing commercialization is available since 1998. Thus we do not need to show before. The y-axis is in the logarithm scale.

The process above in the paper shares the similar framework as Lansing (2010). Just like the paper, we both apply rational bubble solutions instead of only the fundamental solution itself. However, there still exist differences. Lansing (2010) studies the price-dividend ratio of the stock market. Through this paper, we examine dispersion for housing prices and also price-to-rent ratios in the residential real estate markets in China.

5　Conclusion

We firstly test the efficiency hypothesis of the real estate market using monthly data of China and find empirical evidence that the real estate market of China is inefficient. Secondly, we investigate whether fundamentals can fully explain actual price-to-rent ratios and also housing prices. Furthermore, we find there exist bubble components for the housing prices. We utilize the behavior of data changes for 30 provinces for the period from July 1998 to September 2015.

We employ two various techniques to test the market efficiency. One is the autocorrelation coefficient test to test independence, and the other is the unit-root test (augmented Dickey-Fuller) in order to verify the randomness. These tests illustrate that housing markets in China are inefficient. Further excess returns are partly predictable based on the currently available information. In general, we can conclude that investors are able to earn excess returns by using past information in the real estate industry. We also provide more evidences to support that related information is useful in real estate markets. Subsequently, we regard houses as financial assets, and then apply the Lucas tree asset pricing model to explore the extent to which expectations can influence the evolution of housing prices and price-to-rent ratios. Fundamental solutions report that the model does not generate persisted, substantial and violent deviations from the mean, and it does not explain the protracted surge and subsequent downturn in house prices of the last decade. If taking bubble components into consideration, the expectation values maintain a similar trend and value as actual values calculated from the sample, and they show better results compared with fundamental solutions. The study successfully shows the existence of intrinsic rational bubble solutions, which potentially contributes to the literature by determining the features of residential real estate markets in China.

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Data Appendix Table: Variable Definitions and Sources

Variable	Definition
I_t	Risk free interest rate *Source: China Economics & Industry Data Database* *Source: National Real Estate Market Data Center of China*
r_t	Excess return. The index is the current value of houses adds the ability of further income minuses risk free return.
y_t	Price-to-rent ratio
x_t	Reflects growth rate of dividends. It is denoted as the logarithm of the growth rate of rental prices.
Z_t	Reflects housing price level. It uses log function of housing prices divided by its mean.
P_t	Housing price *Source: China Economics & Industry Data Database*
R_t	Rental price