What Drives Housing Markets: Fundamentals or Bubbles?

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Abstract

This study applies the dynamic Gordon growth model which is in the circumstance of rational bubbles to decompose log price-rent ratio into three parts, i.e., rational bubbles, discounted expected future rent growth rates and discounted expected future returns. The latter two terms represent housing fundamentals. The magnitudes of the components of price-rent ratio′s variance are estimated to distinguish the relative impact of the three parts on housing prices. Using time series data from the housing markets in the four largest cities in China (1991:Q1–2011:Q1 for Shanghai, Guangzhou and Shenzhen; 1993:Q2–2011:Q1 for Beijing), this paper presents a number of empirical findings: (a) the variance of rational bubbles is much larger than the variance of price-rent ratio, and rational bubbles contribute more fluctuations directly to price-rent ratio than the expected returns or the expected rent growth rates do; (b) the covariance between rational bubbles and expected returns or expected rent growth rates is also large; (c) the positive covariance of rational bubbles and expected returns implies that high expected returns coexist with bubbles, which differs from previous findings that lower expected returns drive asset prices; (d) the negative covariance of rational bubbles and expected rent growth rates indicates that the larger the bubbles are, the lower the expected rent growth rates are; (e) the positive covariance of expected returns and expected rent growth rates reveals underreaction of the housing markets to rents.

Keywords Price-rent ratio . Variance decomposition . Rationalbubbles . Return

Introduction

The asset price should be equal to the sum of discounted cash flows (i.e., rents). The movements of the asset price without bubbles should depend on two factors, i.e., future cash flows and discount rate, which determine the fundamental value of the asset. If bubbles exist, the asset price should be the combination of its fundamental value and bubbles. Therefore, there are two factors causing the fluctuations of housing markets, i.e., fundamental value and bubbles. In the housing markets, rent is considered as an important fundamental factor causing fluctuations of the housing prices (Hamilton and Schwab 1985; Meese and Wallace 1994; Himmelberg et al. 2005; Girouard, et al. 2006; Gallin 2008; Brunnermeier and Julliard 2008; Campbell et al. 2009; Plazzi et al. 2010; Cochrane 2011a; Ghysels et al. 2012; Engsted and Pedersen 2014; Gelain and Lansing 2014; Engsted, et al. 2016). Another factor is expected return. It is believed that the inflation of housing prices is caused by low expected returns or low risk premium (Case and Shiller 2003; Weeken 2004; Krainer and Wei 2004; Campbell et al. 2009; Favilukis, et al. 2013). However, Cochrane (2011b) arguesthat if the risk premium, which is part of the expected returns of risky assets, is low, this would drive the asset prices up, and it is not easy to separate this price rise from bubbles. In this paper, expected returns, expected rent growth rates and rational bubbles are included in the price-rent ratio decomposition framework,inorder tofindthe driving sources ofhousing markets infourChinese cities. This paper is different from previous studies of price-rent ratio or price-dividend ratio.
Himmelbergetal.(2005)applythestaticGordongrowthmodeltostudythedeterminantsof price-dividend ratio.Campbelletal. (2009), Plazzietal.(2010), Gelain andLansing(2014) followCampbellandShiller(1988)tousethedynamicGordongrowthmodeltodecompose the price-rent ratio into the expected rent growth rates and the expected returns in future, aiming to analyze the fundamental sources of fluctuation movements in the real estate markets.BrunnermeierandJulliard(2008)andCochrane(2011a)setupthedynamicGordon growth modelwith rationalbubbles to studythehousing markets. According totheir works and Balke and Wohar (2009), we set up the dynamic Gordon growth model with rational bubbles in order to decompose the price-rent ratio into the discounted expected future rent growth rates, the discounted expected future returns and rational bubbles. [2] What′s more, followingBrunnermeierandJulliard(2008)′sdesign,weusetheVARsystemtoestimateth e former two terms and then obtain rational bubbles, which are based on the decomposition formula of the price-rent ratio, in order to analyze the driving sources of price-rent ratio in Beijing, Shanghai, Guangzhou and Shenzhen in China. Brunnermeier and Julliard (2008) aim at the ways of inflation impact on the price-rent ratio. Cochrane (2011a) focuses on the

[2] Brunnermeier and Julliard (2008) suggest that the mispricing provided by the dynamic Gordon growth model captures bubbles.

predictabilityofthehousingmarkets.WhileBalkeandWohar(2009)estimatetheratio,i.e., the variance of the fundamentals or bubbles divided by the variance of the price-dividend ratio,tostudytherelativeinfluencesofthefundamentalfactorsandthebubblefactorsinthe stock markets. They do not consider the influences of the covariance between the fundamentals and bubbles. In this paper, we apply the variance decomposition method from Campbell (1991) not only to estimate the variances of the expected rent growth rates, expected returns and rational bubbles, but also to estimate the covariance among them to study their influences on the price-rent ratio. We find that the covariance is large and significantly reduces the volatility of price-rentratio.

The approach of this paper is also different from the return variance decomposition method common in the finance literature, which is the standard method to study what drives asset markets. Campbell (1991) first decomposes the unexpected returns′ variance into the variances of the discounted unexpected future dividend growth, discounted unexpected future returns and the covariance between them, and then measures the impact of those factors on the stock markets. The variance decomposition method has been widely applied to analyze the driving factors that affect asset prices in different markets subsequently.[3] Campbell et al. (2009), Hiebert and Sydow (2011), Engsted and Pedersen (2014) apply the variance decomposition method to study the fundamental factors that drive the housing markets. No matter in the housing markets or other asset markets, the studies which apply the variance decomposition method to study the fundamental factors driving asset prices do not consider the influence of bubbles. However, we consider the impact of asset price bubbles, and embed the rational bubbles into price-rent ratio variance decomposition. What′s more, we consider a problem that the state variables in the VAR system and the rational bubbles items might be nonstationary, if rational bubbles exist in the price-rent ratio. Therefore, we also make reference to the Bayesian estimation method used by Brunnermeier and Julliard (2008) to deal with the problem that variables are unsteady.

Based on the data in four Chinese cities′ housing markets, our empirical results show that the volatility of bubbles is larger than the price-rent ratio, and the rational bubbles have the largest independent impact on price-rent ratio. On the contrary, the effects of both expected rent growth rates and expected returns, which reflect the fundamentals, are smaller. The covariance between rational bubbles and expected rent growth rates or expected returns is larger and significantly reduces the volatility of price-rent ratio. The positive correlation between rational bubbles and expected returns means that the larger the expected bubbles are, the higher the expected returns are, showing that investors expect to get larger capital gains through the sharp rise in housing prices. We find that rational bubbles (sharp increases in asset prices) coexist with high expected returns, which is just opposite to the traditional view. That is to

[3] These studies include the overall bond markets (Campbell and Ammer 1993), the interaction between global stock (Ammer and Mei 1996), the influence of monetary policy on stock returns (Patelis 1997), the individual stocks (Vuolteenaho 2002), intertemporal CAPM model (Campbell and Vuolteenaho 2004a), inflation′s impact on the stock markets (Bekaert and Engstrom 2010), and so on.

say, the low expected returns are an important reason for the sharp increase in asset prices. In addition, the negative correlation between rational bubbles and expected rent growth rates means that the larger the bubbles are, the lower the expected rent growth rates are. Investors expect to get larger capital gains through the sharp increase in housing prices during the course of the bubbles, rather than by taking the rent to get higher returns. The covariance between expected returns and expected rent growth rates is smaller and the correlation is positive, which is consistent with Vuolteenaho (2002) and Campbell et al. (2009). This might likely indicate that the market is under-reaction. That is, when rent growth rates are expected to increase (and housing prices do not follow closely), investors′ expected returns will rise, with other conditions unchanged.

The rest of this paper proceeds as follows. In Section 2, we apply dynamic Gordon growth model with rational bubbles in order to decompose the price-rent ratio into the discounted expected future rent growth rates, the discounted expected future returns and rational bubbles, and decompose the price-rent ratio variance into the variance of those three factors and the covariance among them. Section 3 describes the data for this study. Section 4 sets up the estimation model of price-rent ratio decomposition based on the VAR system. Section 5 reports the price-rent ratio variance decomposition results and analyzes the main driving sources of the housing market movements, followed by a robustness test in Section 6. The final section provides the concluding remarks.

The Dynamic Gordon Growth Model With Rational Bubbles for Housing Markets

The total return of the housing price in period $t+1$ is defined as:

$$R_{t+1} \equiv \frac{P_{t+1} + V_{t+1}}{P_t} \tag{1}$$

where P_{t+1}, V_{t+1} are the real house price and the real rent respectively. Following Brunnermeier and Julliard (2008) and Cochrane (2011a), we consider the impact of bubbles on the dynamics of housing prices in relation to the Gordon growth model suggested by Campbell and Shiller (1988), and construct the price-rent ratio decomposition model. We multiply P_t/V_t on both sides of Eq. (1), rearrange it and have $P_t/V_t = R_{t+1}^{-1}(1 + P_{t+1}/V_{t+1})(V_{t+1}/V_t)$. Taking logarithm on both sides and applying Taylor approximation to the equation, we have:

$$p_t - v_t = k - r_{t+1} + \Delta v_{t+1} + \rho(p_{t+1} - v_{t+1}) \tag{2}$$

where $p_t \equiv \ln(P_t)$, $v_t \equiv \ln(V_t)$, $r_{t+1} \equiv \ln(R_{t+1})$, $\Delta v_{t+1} \equiv v_{t+1} - v_t$ and $\rho \equiv 1/(1 + \exp(\overline{v-p}))$, $\overline{v-p}$ is the sample mean of the log rent-price ratio, and k is a constant. Based on the information of period t, we take a forward iteration on Eq. (2) while ignoring the constant term, and then take the expectation on both sides. Equation (2) becomes:

$$p_t - v_t = E_t\left[\sum_{j=1}^{\infty} \rho^{j-1} \Delta v_{t+j}\right] - E_t\left[\sum_{j=1}^{\infty} \rho^{j-1} r_{t+j}\right] + E_t\left[\lim_{j\to\infty} \rho^j (p_{t+j} - v_{t+j})\right] \quad (3)$$

As in Brunnermeier and Julliard (2008), $E_t[\lim_{j\to\infty} \rho^j (p_{t+j} - v_{t+j})]$ would be zero with the transversality condition. Then from Eq. (3) we can get the fundamental price:

$$p_t^* = E_t\left[\sum_{j=1}^{\infty} \rho^{j-1} \Delta v_{t+j}\right] - E_t\left[\sum_{j=1}^{\infty} \rho^{j-1} r_{t+j}\right] + v_t \quad (4)$$

However, the actual housing price p_t isn't equal to the fundamental price p_t^*. Brunnermeier (2008) gives us an exact definition of a bubble: i.e. the asset price exceeds its fundamental value. Some scholars define the deviation between actual price and fundamental price as a bubble (Flood and Hodrick 1990; Kim and Suh 1993; Hou 2010; Ren et al. 2012).

Following the above assumption, we define a bubble as $b_t = p_t - p_t^*$. Set $\eta_{v,t} = E_t[\sum_{j=1}^{\infty} \rho^{j-1} \Delta v_{t+j}]$ and $\eta_{r,t} = E_t[\sum_{j=1}^{\infty} \rho^{j-1} r_{t+j}]$. Then we get the expression of a bubble:

$$b_t = p_t - p_t^* = p_t - E_t\left[\sum_{j=1}^{\infty} \rho^{j-1} \Delta v_{t+j}\right] - E_t\left[\sum_{j=1}^{\infty} \rho^{j-1} r_{t+j}\right] + v_t$$
$$= (p_t - v_t) - \eta_{v,t} + \eta_{r,t} \quad (5)$$

The bubble must satisfy the following equation (Blanchard and Watson 1982):

$$E_t[b_{t+1}] = b_t/\rho \quad (6)$$

The scholars take different forms of bubbles. For example, some set up bubbles as an explosive form (Tirole 1982), while some set up them as the form of switching among expanding, collapsing, and dormant regimes (Van Norden 1996; Brooks and Katsaris 2005). Without detracting from the forms of bubbles, this paper aims to analyze the effects of the bubbles and fundamentals on the price-rent ratio.From Eq. (5), we can find that the relationshipamongtheprice-rentratio,fundamentalsandbubbles.ThetwotermsofEq.(5), i.e., the expectation of sum of the discounted future rent growth rates and expectation of sum of discounted future returns represent market fundamentals, denoted by f_t as:

$$f_t = E_t\left[\sum_{j=1}^{\infty}\rho^{j-1}\Delta v_{t+j} - \sum_{j=1}^{\infty}\rho^{j-1} r_{t+j}\right] \tag{7}$$

On the basis of Eqs. (5) and (7), we have:

$$p_t - v_t = \eta_{v,t} - \eta_{r,t} + b_t = f_t + b_t \tag{8}$$

According to Eq. (8) and the definition of a bubble in Eq. (5), we can extract the bubble from price-rent ratio. With the absence of a bubble, it can be seen from Eq. (8) that the higher the expected rent growth rate (or the lower return rate is), the higher the current housing price-rent ratio will be. On the contrary, in the case that a bubble exists, a larger bubble can lead to a higher price-rent ratio.

The Variance Decomposition Model

Then we calculate the variance on both sides. The variance decomposition equation is as follows:

$$Var(p_t - v_t) = Var(\eta_{r,t}) + Var(\eta_{v,t}) + Var(b_t) - 2Cov(\eta_{v,t}, \eta_{r,t}) + 2Cov(\eta_{v,t}, b_t) - 2Cov(\eta_{r,t}, b_t) \tag{9}$$

Equation (9) shows that the price-rent ratio volatility consists of the variances of fundamentals and the rational bubble, as well as the covariance between them. This paper will calculate the magnitudes of the six individual components of the price-rent ratio′s variance, in order to gauge their relative contributions. As Fig. 1 suggests that the price-rent ratio increases while the rent decreases in the four housing markets during most of the time. Hence, it is expected that the magnitude related to the bubble

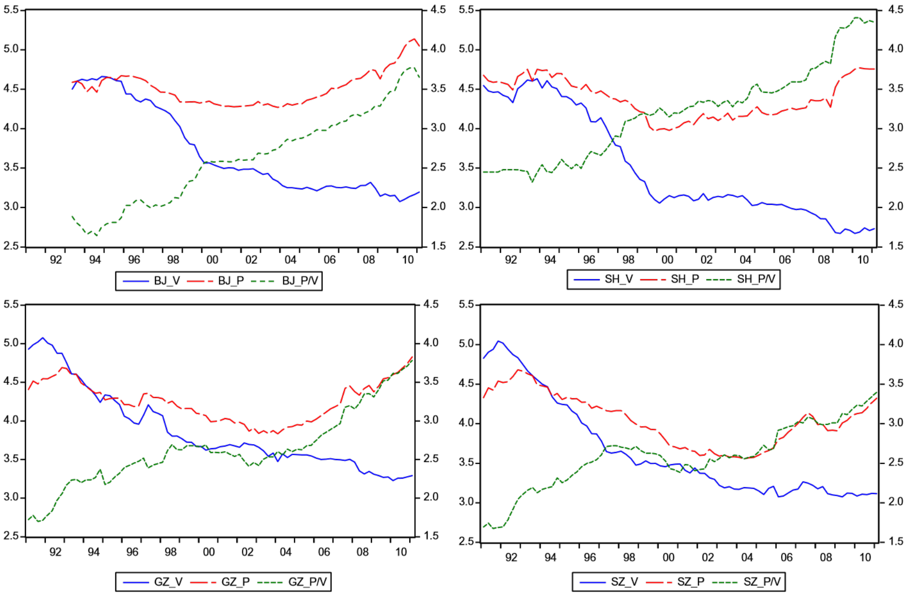

Fig. 1 Housing prices indexes, rent indexes and price-rent ratios. Source: DTZ Research. The left axis is for the log housing price indexes and log rental indexes while the right axis is for the log price–rent ratio. Both real house price indexes and rent indexes refer to 1993:Q3 as the base period, i.e. 100, and are adjusted for inflation. Three variables are treated with logarithmic form. BJ, SH, GZ and SZ stand for the housing markets in Beijing, Shanghai, Guangzhou and Shenzhen, respectively. P, Vand P/V represent the housing price index, the rent price index and the house price-rent ratio.

component might be larger than to other components, and bubbles might be the most important driving factor affecting the movements of the housing markets.

Data

House Price Indexes, Rent Indexes, and CPI

Both the housing price indexes and rent indexes for China's housing markets in Beijing, Shanghai, Guangzhou, and Shenzhen are taken from DTZ Index Chinese Mainland (DTZ Research 2011).[4] Hong Kong DTZ began to report the quarterly indexes of the real estate marketsinShanghai,GuangzhouandShenzhenin1991:Q1andinBeijingin1993:Q2.The indexes include office building rent and price indexes, housing rent and price indexes, etc.

[4] DTZ, a UGL company and one of the five famous international real estate consultants, has 26,000 permanent employees and 47,000 personnel including contractors, operating across 208 offices in 52 countries throughout Europe, the Middle East, Africa, Asia and the Pacific and the Americas. See the company's web site http:// www.dtz-ugl.com/content/corporate-Information.

The DTZ housing rent index and price index are a measure of rents/prices quoted in USD per square meter (gross) at the end of each quarter. In the index, housing prices are based on the prevailing open market value and housing rents are from newly-signed leases. The sample is selected from residential units of similar sizes, at around 100 square meters. The units are on the middle floor of good quality buildings located in prime residential districts. The indexes do not include other expenditures such as management fares, property taxes and maintenance costs. The rent-free period, fitting-out costs and other landlord subsidies are also excluded.

We use the indexes of house prices and rents, with 1993:Q3 as the base period. The time period is 1991:Q1–2011:Q1 in Shanghai, Guangzhou and Shenzhen, and 1993:Q2–2011:Q1 in Beijing.[5]

Using the consumerprice index (CPI) as the base, we convert the nominal price and rent indexes of the four cities into real indexes. The CPI data is taken from CEInet statistical database,withSeptember1993(inthethirdquarter)asthebaseperiod.Thenweusethedata in March, June, September and December each year as the quarterly CPI data for the corresponding quarter.

Log Price-Rent Ratio

The history of China's real estate market development is short. In order to extend the sample size, we follow the method of Campbell et al. (2009) to obtain the annualized data on the observation points at the end of each quarter.

The price-rent ratio cannot be obtained directly by calculation of DTZ indexes. However,ifone ofquarterly rental yields is known, wecan calculate other quarters' rental yields through thehouse price indexesandrentindexes. AccordingtotheresearchreportofChina international capital corporation in March 2008, BVolume is picking up, but prices are still onthehigh side^, we follow Chen etal. (2009) and consider2006:Q1 annualrental yield in (D_{2006Q1}) as the benchmark yields of Beijing, Shanghai, Guangzhou and Shenzhen, which are 5.1 %, 6.4 %, 3.1 % and 6.4 %, respectively, to calculate the log of the first quarter of each city's annual price-rent ratio. The estimation formula is as follows:

Vl2006Q1=Pl2006Q1 1 ! ð Þ pt−vt ¼ ln Vl=Plt D2006Q1 10 t

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[5] This data is up to 2011 because of the discontinuity of DTZ index data. The study of China's housing markets, and even the world housing markets is restricted to the time span of the data. The studies of China's housing markets often use the data from the National Bureau of Statistics of China. This data series started from 1998 (BDreger and Zhang 2011^ is cited in text but not given in the reference list. Please provide details in the list or delete the citation from the text. Dreger and Zhang 2011; Wu, et al. 2012) while Chinese housing markets prices increased sharply at that time. However, the data series do not go through an overall cycle. Therefore, it is difficult to determine whether there is a bubble in the markets (Wu, et al. 2012). Fortunately, from Fig. 1 in this paper, we can see intuitively that our data series has experienced both the increase and the decrease, and go through an overall cycle.

where P^I_t is the price index and V^I_t is the rent index in the housing markets.From Fig. 1, the rents almost dropped year by year over the past twenty years in the four Chinese cities: Beijing, Shanghai, Guangzhou and Shenzhen. However, since the millennium, the housing priceshaverisensharply,leadingtoapersistentincreaseinprice-rentratios.In2011:Q1,for example, the housing price-rent ratios in Beijing, Shanghai, Guangzhou and Shenzhen are 30, 39, 78 and 44 respectively. These figures are above the historical average level of 138.19 %, 165.22 %, 181.06 % and 109.98 % respectively, and they are much higher than that in the United States′ housing markets.[6] Some scholars find that price fluctuations in the Chinese housing markets might deviate from fundamentals like rent and income, and hence bubbles exist (Chen and Funke 2013; Hui and Yue 2006; Hui and Wang 2014; Hui and Wang 2015; Hou 2010; Dreger and Zhang 2011; Wu, et al. 2012).

From Table 1, the average price-rent ratio in Shanghai′s housing market is significantly higher than that in the other three markets. On the other hand, the volatilities of price-rent ratios in Beijing and Shanghai are greater than those in Guangzhou and Shenzhen.

Returns and Rent Growth Rates

The log of nominal annual return is calculated as follows: the annual growth rate of the nominal housing price index plus the quarter′s annual rental yield which is rent-price ratio, and 1, is the total nominal return, and then calculates its logarithm. The log of CPI is calculated as follows: the CPI in the t-th quarter divided by that in the same quarter last year on fixed base, and then calculates its log. The log of real annual return r_t is calculated as follows: the log of nominal annual return minus the log of CPI in quarter t. From Table 2, the average real returns of the housing markets in the four cities are all positive. The highest annual return (in Beijing) reaches 10.7 %. Shenzhen′s return is the lowest at 6.1 %. The return volatility level in Beijing′s housing market is significantly smaller than those in the other three markets.

Next, we calculate the log of the real rent index of quarters t and $t-4$. The former minus the latter is the log annual rent growth rate Δv_t. According to Table 2, the average annual rent growth rates in the four cities are all negative, and the rents had declined. Shenzhen′s rents fell by 9.5 % per year, which is the sharpest drop among the four cities. In comparison, Beijing′s rents fell by an annual rate of 8.2 %, which is the smallest among the four cities. The standard deviation of Shanghai′s rent growth rates is 13.9 %, which is the highest of the four cities.

[6] Campbell et al. (2009) find that the average rental yield (i.e., the house rent-price ratio) in a dozen of U.S. cities from 1975 to 2007 is 6.03 %, that is to say, the price-to-rent ratio is 16.58.

Estimation of the Price-Rent Ratio Decomposition

The discounted expected future rent growth rates, the discounted expected future returns and the rational bubbles in the price-rent ratio in decomposition Eq. (8) cannot

Table 1 Descriptive statistics of log price-rent ratio

Variable	Cities	Starting time	2011q1	Maximum	Minimum	Mean	Standard deviation	Observation
$p_t - v_t$	BJ	1993q2	3.652	3.776	1.643	2.615	0.588	72
	SH	1991q1	4.351	4.407	2.322	3.197	0.587	81
	GZ	1991q1	3.782	3.782	1.699	2.625	0.482	81
	SZ	1991q1	3.398	3.398	1.674	2.579	0.404	81

Table 2 Descriptive statistics of returns and rent growth rates

Variable	Cities	Starting time	Maximum	Minimum	Mean	Standard deviation	Observation
r_t	BJ	1994q2	0.320	−0.036	0.107	0.078	68
	SH	1992q1	0.438	−0.181	0.058	0.112	77
	GZ	1992q1	0.329	−0.204	0.081	0.121	77
	SZ	1992q1	0.336	−0.197	0.061	0.132	77
Δv_t	BJ	1994q2	0.129	−0.367	−0.082	0.108	68
	SH	1992q1	0.333	−0.416	−0.083	0.139	77
	GZ	1992q1	0.169	−0.351	−0.090	0.124	77
	SZ	1992q1	0.202	−0.345	−0.095	0.119	77

be observed directly. The former two terms represent the expected fundamental values and are often estimated by a VAR system (Campbell 1991; Brunnermeier and Julliard 2008; Hayunga and Lung 2011). Following this, we apply a VAR system to estimate the discounted expected future rent growth rates $\eta_{v,t}$ and the discounted expected future returns $\eta_{r,t}$. Referring to Campbell and Vuolteenaho (2004b), Brunnermeier and Julliard (2008), Campbell et al. (2009), we estimate two fundamental terms on the right side of Eq. (8) by a VAR system. Since the price-rent ratio on the left hand side of Eq. (8) is observable, the rational bubbles b_t can be calculated by $b_t = p_t - v_t - f_t$.

The selection ofstatevariablesiscriticalfora VAR system because the variablesplay an important role in estimation of the investors′ expectation. We select three variables: rent growth rate, return on housing and log price-rent ratio, as VAR system state variables to establish a VAR system with one lag as the benchmark model,[7] in order to estimate the discounted expected future rent growth rates and the discounted expected future returns. Define $Z_t \equiv (r_t, \Delta v_t, p_t - v_t)'$, where r_t is the log of total return and Δv_t is the log of rent growth rate, and $p_t - v_t$ is the log of price-rent ratio. A is the coefficient matrix of a firstorder VAR which contains three state variables. Define $e1' \equiv (1\ 0\ 0)$.Since $\eta_{r,t} =$
$E_t[\sum_{j=1}^{\infty} \rho^{j-1} r_{t+j}] = e1' \sum_{j=1}^{\infty} \rho^{j-1} A^j Z_t = e1' A(I - \rho A)^{-1} Z_t$, we have

[7] We construct the benchmark model of VAR system which contains three state variables, the same as Brunnermeier and Julliard (2008) and Hayunga and Lung (2011). What′s more, their structural VAR system variables contained inflation, because they need to test the inflation illusion assumption in the housing markets.

$$\eta_{r,t} = e1'\lambda Z_t \tag{11}$$

where $\lambda = A(I-\rho A)^{-1}$. Define $e2' \equiv (0\ 1\ 0)$. The discounted expected future rent growth rate can be estimated as follows:

$$\eta_{v,t} = e2'\lambda Z_t \tag{12}$$

According to Eqs. (11) and (12), the rational bubbles can be estimated indirectly in Eq. (5).

Results of Price-Rent Ratio Variance Decomposition

We estimate the discounted expected future rent growth rates and the discounted expected future returns with a first-order VAR system, which considers housing return, rent growth rate and house price-rent ratio as the three state variables. Based on the decomposition of price-rent ratio in Eq. (5), we can obtain the rational bubble term. We take the price-rent ratio variance decomposition by Eq. (9). We consider the first-order VAR system as a benchmark model.

Table 3 reports the results of price-rent ratio variance decomposition. Bubbles are the dominant factors in the price-rent ratio variance decomposition. The variance of rational bubbles exceeds that of price-rent ratio. In Shanghai, for example, the variance of rational bubbles is 5.53 times that of the price-rent ratio. In the four cities, the rational bubble contribution to volatility of price-rent ratio is bigger than the expected returns and the expected rent growth rates. Among its six variance components, the largest contribution to the volatility of the price-rent ratio arises from rational bubbles, except for Shenzhen.

The contribution of the three covariance terms related to bubbles to the volatility of the price-rent ratio is bigger than the covariance between expected returns and expected rent growth rates in BJ, GZ and SH. In general, low expected returns are supposed to be an important cause for the inflation of asset prices (Case and Shiller 2003). However, we find that the covariance between rational bubbles and expected returns is positive. This suggests that the larger the rational bubble, the higher is the expected return. This is consistent with the definition of a bubble, as the reason for the current price being too high and deviating from the fundamentals is that investors believe that the future price will be even higher (Brunnermeier and Oehmke 2013). On the other hand, the higher expected returns are along with bubbles. This infers that the higher expected returns among investors are attributed to their expectations that housing prices will increase. The covariance between rational bubbles and expected rent growth rates is negative, and it also greatly reduces the price-rent ratio fluctuations. This means that the larger a rational bubble, the lower rent growth rates are expected. This finding suggests that investors do not pay more attention to rental fundamentals, but are more concerned about capital gains arising from the increase in housing prices and bubbles.

The covariance between expected returns and expected rent growth rates is smaller and the correlation is positive, which coincides with the results of Vuolteenaho

(2002)′s and Campbell et al. (2009). To be specific, Vuolteenaho (2002) finds that the future premium of a company has a positive correlation to its expected dividend growth rates. Campbell et al. (2009) find that the future premium in housing markets has a positive correlation to the expected rental growth rates. On the contrary, Campbell (1991) finds that the future expected returns in the overall stock markets is negatively related to the expected dividend, which is opposite to our results. Our finding that expected returns have positive correlation to the rent growth rates might prove that the markets′ response to fundamentals from rent information is insufficient. While investors expect an increase in rent growth rates, the market does not respond adequately in time and housing prices do not reach a high enough level, the investors′ expected returns will increase.

Kim (1994) points out that under the Bayesian theorem, we can get the asymptotic normality of the Bayesian posterior in the case of the time series with a unit root, and the posterior distribution of parameters is asymptotically normal. As the time series is nonstationary, the estimated results might not be consistent. Fortunately, the estimation

Table 3 Variance decomposition for price-rent ratio

City	Numeric types	$Var(\eta_r)$	$Var(\eta_v)$	$Var(b)$	$-2Cov(\eta_r, \eta_v)$	$-2Cov(\eta_r, b)$	$2Cov(\eta_v, b)$
Panel A							
BJ	Original value	0.174	0.268	1.236	−0.028	−0.738	−0.591
	Median	0.201	0.313	1.346	−0.015	−0.770	−0.709
	Confidence intervals	[0.100,0.588]	[0.112,1.998]	[0.868,2.621]	[−0.907,0.327]	[−1.494,−0.249]	[−3.263,−0.159]
SH	Original value	0.313	0.807	1.834	−0.392	−0.71	−1.519
	Median	0.354	0.927	1.966	−0.430	−0.650	−1.710
	Confidence intervals	[0.114,1.983]	[0.310,6.936]	[1.122,5.171]	[−5.808,0.269]	[−1.904,1.746]	[−9.731,−0.327]
GZ	Original value	0.304	0.150	0.970	−0.097	−0.803	−0.323
	Median	0.328	0.185	1.023	−0.103	−0.816	−0.378
	Confidence intervals	[0.149,1.088]	[0.077,0.758]	[0.678,1.851]	[−1.020,0.230]	[−2.051,−0.362]	[−1.196,0.101]
SZ	Original value	0.447	0.236	0.589	−0.371	−0.718	−0.055
	Median	0.486	0.276	0.662	−0.350	−0.754	−0.131
	Confidence intervals	[0.205,1.683]	[0.096,1.333]	[0.372,1.920]	[−1.816,0.187]	[−2.732,−0.149]	[−1.498,0.387]
Panel B							
City	Numeric types	$\frac{Var(\eta_r)}{Var(p-v)}$	$\frac{Var(\eta_v)}{Var(p-v)}$	$\frac{Var(b)}{Var(p-v)}$	$\frac{-2Cov(\eta_r,\eta_v)}{Var(p-v)}$	$\frac{-2Cov(\eta_r,b)}{Var(p-v)}$	$\frac{2Cov(\eta_v,b)}{Var(p-v)}$
BJ	Original value	0.543	0.835	3.857	−0.086	−2.303	−1.845
	Median	0.627	0.975	4.200	−0.046	−2.404	−2.212
	Confidence intervals	[0.313,1.834]	[0.349,6.235]	[2.708,8.182]	[−2.830,1.020]	[−4.662,−0.777]	[−10.183,−0.496]
SH	Original value	0.943	2.432	5.528	−1.182	−2.143	−4.579
	Median	1.068	2.793	5.924	−1.295	−1.960	−5.154
	Confidence intervals	[0.343,5.976]	[0.936,20.902]	[3.383,15.583]	[−17.503,0.812]	[−5.738,5.261]	[−29.327,−0.986]
GZ	Original value	1.524	0.749	4.862	−0.488	−4.027	−1.619
	Median	1.646	0.928	5.125	−0.514	−4.087	−1.893

Table3 continued

City	Numerictypes	$Var(\eta_r)$	$Var(\eta_v)$	$Var(b)$	$-2Cov(\eta_r, \eta_v)$	$-2Cov(\eta_r, b)$	$2Cov(\eta_v, b)$
	Confidenceintervals	[0.749,5.449]	[0.385,3.797]	[3.398,9.271]	[−5.110,1.150]	[−10.274,−1.816]	[−5.992,0.508]
SZ	Originalvalue	3.475	1.834	4.577	−2.882	−5.580	−0.424
	Median	3.777	2.141	5.143	−2.719	−5.861	−1.018
	Confidenceintervals	[1.593,13.074]	[0.752,10.361]	[2.892,14.920]	[−14.109,1.452]	[−21.231,−1.161]	[−11.640,3.006]

Note:thistablereportstheoriginal resultsofprice-rentratiovariance decompositionbasedontheb enchmarkmodelandmedianvalueandits90%con fidenceintervalbasedon Bayesianmethodestimation.Thebenchmarkmodeluseafirst-orderVARsystem,includingthreestatevariables:housingreturn(r_t),rentgrowthrate(Δv_t)andlogprice-rentratio($p_t - v_t$).Weestimatethediscountedexpectedfuturereturnsby Eq. (11) andthediscountedexpectedfuturerentgrowthratesby Eq. (12).Basedonthe Eq. (5),wegettherationalbubbles, andobtaintheprice-rentratiovariancedecompositionthrough Eq. (9)

with the Bayesian method can solve the problem effectively. We follow Brunnermeier and Julliard (2008) and Hayunga and Lung (2011) to deal with the problems that the state variables in the VAR system and the rational bubble term might be nonstationary with the Bayesian method. The specific steps are as follows:

1. Based on the Bayesian theory of diffusion prior distribution, we set up the posterior distribution of the covariance matrix with a VAR system, and the posterior distribution obeys the distribution $\Sigma \sim IW_m(n\hat{\Sigma}; n-m)$, where IW is the inverse

   Wishart distribution and $\hat{\Sigma}$ is covariance matrix of VAR coefficient estimation residuals. The degrees of freedom are $n-m$, which is equal to the sample number minus the estimated parameters number of the VAR system in each equation.
2. We calculate the conditional distribution of the coefficient matrix in the VAR system. According to the Bayesian theorem, the posterior distribution of the coefficient matrix in the unrestricted VAR model is $B|\Sigma \sim N(\hat{B}; \Sigma \otimes (Z'Z)^{-1})$,

   where Z is the VAR system regression matrix and $\hat{B}$ is the original VAR system coefficient matrix.
3. Using the Monte Carlo sampling method, we draw a coefficient matrix B_i randomly from an unrestricted VAR model with the posterior distribution, and then put the simulation generation into the calculation of the coefficient matrices of the discounted expected future rent growth rates $E_t[\sum_{j=1}^{\infty}\rho^j \Delta v_{t+j}]$ and the discounted expected future returns $E_t[\sum_{j=1}^{\infty}\rho^j r_{t+j}]$. Next, we estimate the rational bubbles according to Eq. (5).
4. Applying variance decomposition, we calculate the contribution ratio of each component of decomposition to the variance of price-rent ratio.
5. Repeat Step 4 10,000 times to get 10,000 variance decomposition results and their contribution rates.

Applying the benchmark model based on the Bayesian method, Table 3 reports the median value and the 90 % confidence interval for compositions of the price-rent ratio variance decomposition and their proportion of price-rent ratio variance. From the results of the Bayesian method in Table 3, the signs of estimated parameters remain unchanged, and the estimation results do not vary much between the Bayesian estimation and the original one.

Robustness Tests

This section is to perform robustness tests. It will change the specification of the VAR system to take robustness tests of the results based on the benchmark model. The lag order number of the VAR system could affect the estimation of expected future rent growth rates and expected future returns. Model 1 in Table 4 reports a second-order VAR system′s estimation for each component of variance decomposition of the four housing markets. Table 5 reports the ratio of the components of variance to the variance of the price-rent ratio. Applying the Bayesian method, we obtain the median and the 90 % confidence interval for the components of price-rent ratio variance and their proportion of price-rent ratio variance in Model 1 in Tables 4 and 5. It suggests that the impacts of decomposition components on price-rent ratio fluctuation are almost identical to the results based on the first-order VAR systems in Table 3.

Campbell et al. (2010) argue that the variance decomposition results are more sensitive for the state variables in a VAR system. Although a VAR system includes the dividend yield, the changes of other state variables may also affect the results of variance decomposition. We take a robustness test by changing the selection of state variables for the benchmark model. We embed three more macroeconomic fundamentals in the VAR system as state variables, namely, the log growth rate of per capita disposable income, the log growth rate of employed population and the log growth of population.[8] At the same time, the per capita disposable income, employed population and population variables are also commonly used indicators for fundamentals of China′s house prices. For example, Shen and Liu (2004) point out that the per capita disposable income of urban households, total population, unemployment and so on, can partly explain the change in housing prices. Lv (2010) argues that the ratio between housing price and income is the most direct and accurate indicator for measuring the level of housing price bubbles.

Models 2 and 3 in Tables 4 and 5 report the variance decomposition results based on different state variables with a first-order VAR system as well as based on the Bayesian method in the same model. Whether it contains the price-rent ratio or the three macroeconomic variables in the VAR system, the rational bubbles are still the main driving source in the price-rent ratio. The conclusion almost remains unchanged.

In addition, from the variance decomposition with the Bayesian method, bubbles dominate the largest proportion of price-rent variance, and the (positive or negative) signs for the covariance among rational bubbles, expected future rent growth rates

[8] Hiebert and Sydow (2011) set up a VAR system which contains the growth rate of per capita disposable income as the macroeconomic state variable. Campbell et al. (2009) set up VAR system which contains growth rate of per capita disposable income, employment growth rate and population growth rate as the macroeconomic state variables. Engsted and Pedersen (2014) set up a VAR system which contains GDP growth, unemployment, and the spread between short-term and long-term interest rate as the macroeconomic state variables. In this paper, three macroeconomic variables data in the four cities are taken from the bureau of statistics web site in each city, but most of them are the annual data. In order to unify analysis, this paper refers to Campbell et al. (2009), assuming that the annual growth rate of per capita disposable income, the annual growth rate of employed population and the annual growth rate of population in the four quarters of the year is fixed.

and expected future returns do not change. In short, our empirical results are relatively robust.

Conclusion

No matter whether housing price appreciation comes from the influence of the fundamental factors such as the expected returns and expected rent growth rates, or from the impact of bubbles, their impacts are not easy to distinguish. Against this background, this paper has applied a dynamic Gordon growth model with rational bubbles and decomposed the price-rent ratio into discounted expected future rent growth rates, discounted expected future returns and rational bubbles. The former two terms represent the fundamentals of housing markets. In addition, applying the variance decomposition method for the price-rent ratio, we have successfully distinguished the effect of

$2Cov(\eta_v, b)$
−0.591
−0.709
[−3.263,−0.159]
−0.383
−0.463
[−1.272,−0.098]
−0.527
−0.712
[−12.121,−0.115]
−0.435
−0.583
[−3.342,−0.063]
−1.519
−1.710
[−9.731,−0.327]
−1.209
−1,437
[−9.113,−0.029]
−1.715
−1.978
[−64.500,−0.105]
−1.578
−1.808
[−11.454,−0.218]
−0.323
−0.378
[−1.196,−0.101]

$b)$	$2Cov(\eta, b)$
	−0.564
	−0.567
484]	[−1.195,−0.154]
	−0.261
	−0.312
222]	[−1.665,0.045]
	−0.188
	−0.217
439]	[−0.657,0.233]
	−0.055
	−0.131
149]	[−1.498,0.387]
	−0.076
	−0.146
156]	[−1.774,0.416]
	−0.179
	−0.230
73]	[−1.745,0.141]
	0.001
	−0.071
99]	[−1.784,0.370]

Models 1, 2, and 3, and also
the following state variables:
ate, price-rent ratio. Model 2
ies a first-order VAR system

$\frac{Cov(\eta_v,b)}{Var(p-v)}$
1.845
2.212
-10.183,−0.496]
1.240
1,499
-4.121,−0.317]
1.644
2.223
-37.833,−0.358]
1.357
1.820
-10.431,−0.196]
4.579
5.154
-29.327,−0.986]
3.681
4.373
-27.740,−0.087]
5.170
5.967
-194.389,−0.317]
4.757
5.449
-34.519,−0.657]
1.619
1.893
-5.992,0.[illegible]08]

	$\frac{2Cov(\eta_v,b)}{Var(p-v)}$
	−2.944
	−2.961
28]	[−6.239,−0.803]
	−1.308
	−2.411
13]	[−8.344,0.223]
	−0.944
	−1.087
0]	[−3.289,1.168]
	−0.424
	−1.018
61]	[−11.640,3.006]
	−0.639
	−1.233
12]	[−14.939,3.503]
	−1.393
	−1.787
]	[−13.558,1.098]
	0.006
	−0.553
]	[−13.865,2.874]

, and also reports the median

the three parts on the price-rent ratio. With the time series data from four housing markets, namely Beijing, Shanghai, Guangzhou, and Shenzhen, in China, our study has major empirical results as follows. First, rational bubbles have the largest impact on the price-rent ratio. Second, the covariance between rational bubbles and the expected returns (or the expected rent growth rates) has important impacts on the price rent ratio, and greatly reduces the volatility of the price-rent ratio. Third, whether changing the VAR system lag order, or adding the macroeconomic state variables in the VAR system, or using Bayesian method which is applied to solve the problem of variable stability, the robustness tests yield consistently almost the same results for the price-rent ratio variance decomposition. Fourth, the volatilities of rational bubbles are larger than that of the price-rent ratio. Likewise, in the price-rent ratio variance decomposition, the individual contribution of rational bubbles to the price-rent ratio is greater than expected returns and expected rent growth rates. In most cases, the contribution of the covariance related to bubbles to volatility of the price-rent ratio is greater than the covariance between expected returns and expected rent growth rates. In short, rational bubbles are the main driving sources in price-rent ratio fluctuations, while the influences of the two fundamental factors are much smaller.

More importantly, this study discovers that high expected returns coexist with rational bubbles (opposite to the opinion that lower expected return is an important cause for rising asset prices). The covariance between rational bubbles and expected returns is positive, implying that the larger the bubbles, the greater investors′ expected returns are. Paradoxically, this suggests that investors expect to get bigger capital gains through growth of bubbles, leading to an increase in housing prices. On the contrary, the covariance between rational bubbles and expected future rent growth rates is negative, meaning that when investors expect the bubbles to grow, the expected future rent growth rates would be lower. This shows that the bubble growth needs not to be supported by rental fundamentals. The covariance between expected rent growth rates and expected returns is positive. It is therefore likely that when good news is expected for rental growth, but the market price signal does not respond sufficiently enough, housing returns would be expected to increase.

Our findings have significant implications: academic, practical and policy. First, this study makes it clear that the dominating factor driving housing prices to stand high is the existence of bubbles. We hence suggest that future studies include and deal with adequately the bubble factor in modeling the dynamics of asset prices, in that the existing literature only focuses on the roles of fundamentals in asset pricing. Second, investors can benefit from the result showing that bubbles in asset prices always accompany high expected returns. When housing prices deviate from the fundamental values (signaling the formation of bubbles), investors could ride the bubble to earn excess gains from the housing price appreciation, rather than sell or short-sell the houses. Third, our study also has policy implication that benefits policy makers. Bubbles are found to drive housing prices up. To alleviate bubble formation, governments may put in place some monetary policies, such as raising interest rates. However, this might inadvertently send a country into recession, especially for China whose economy is quite vulnerable. As such, policy makers in China need to achieve a balance between mitigating housing price hikes and bubble formation, in avoidance of a recession. In this case, lowering loan to value ratio and/or higher down-payment can be useful tools to cool down the market. Finally, the variance decomposition method introduced in this paper can be applied not only to other sectors of the real estate market, but also to other markets such as stock and bond markets.

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