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Estimation of bubble dynamics in the Chinese real estate market: a State space model

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Abstract This paper analyses the existence of a bubble in the Chinese real estate market and examines its driving factors with a state-space model. The model considers macroeconomic and real estate time series variables as inputs and employs a Kalman filter to obtain an estimated fundamental price using demand and supply for Chinese real estate. We then measure the deviation between actual and estimated fundamental real estate prices to test for the existence of a bubble. We find evidence for the existence of a bubble especially post 2010, when the deviation ratio is found to be significantly higher with a peak of 80% in 2012. Our estimation of overvaluation is generally much higher than in other studies.

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1 Introduction

There have been many bubbles in the real estate market in different economies since the 1980s culminating in the bubble in the US real estate sector which resulted in the global financial crisis in 2008–2010. The Chinese real estate market has experienced rapid price rises particularly during the period end 2000 to end 2015 when the national house price index rose by 332%; with house price rises being driven by the strong growth and rapid urbanization of the Chinese economy, as well as lack of alternative investment opportunities. According to Bordo and Jeanne (2002) property booms and busts have been a fairly frequent occurrence in the global economy topic as compared to stock market booms and busts.

The issue of the possibility of a real estate bubble in China is an issue of increasing concern given the rapid price rises of recent years, for example, Zhang and Sun (2006) highlights the risks to Chinese banks of real estate credit exposure, the possible impact on local government finances and the dangers to foreign capital flows of large house price fluctuations. There are many ways in which to measure the existence of property bubbles, including using price to average income, price to rent and rental yield compared to the cost of mortgages. In this paper, we take a less direct approach and we regard the market value of a property as a state output variable changing over time; we similarly regard the economic factors determining the fundamental real estate price as changing inputs.

A key advantage of using a state space model is that it is able to process nonstationary time series while allowing for the addition of variables that cannot be observed. The variables that cannot be observed are referred to as state variables. A linear state space model is typically composed of two equations, a state equation and a signal equation. The state equation can be used to represent the relation between observable and unobservable variables, while the signal equation describes the trends of unobservable variables. In our case, the extent of overvaluations is an unobservable variable and we therefore use the state space model to avoid the issue of inappropriate model specification in order to predict the extent of the deviation between market prices and fundamentals in the Chinese real estate sector.

The structure of the paper is as follows. In section 2 we review some of the previous literature on bubbles in the real estate market. Section 3 provides an outline of the state space model used in our analysis. Section 4 outlines the state space model that we employ for our empirical analysis. Section 5 estimates demand and supply equations in order to calculate the unobservable fundamentals real estate prices and estimates the deviation of market prices from the fundamental. Section 6 attempts to link the deviation of prices to changes in the most important Chinese national policies and section 7 concludes.

2 The development of the Chinese real estate market

Up until 1980 China operated a centrally planned housing system but over time a number of reforms have changed the system to a much more market-oriented housing sector. Prior to 1980 urban housing in China was basically either owned by work units of State Owned Enterprises (SEOs) or housing management departments of local

governments. Residential housing was allocated to SEOs or housing management departments which in turn rented it to employees at very low rents with the State retaining the ownership of property. The central government played a significant role in determining the amount of housing investment and its allocation. The development of a private market in real estate in China began with reforms that were started in 1980 when the Chinese government implemented a variety of housing market commercialization policies. Those culminated in the 1988 central government document "Implementation Plan for a Gradual Housing System Reform in Cities and Towns", which marked the beginning of a major programme of nationwide housing reform. The reforms permitted public housing units to be sold to their existing tenants at substantially discounted prices. In addition, there was also a programme to raise the rents towards more market oriented levels, which had limited success as the new rents were often still insufficient to cover the maintenance.

A second reform effort started in 1994, when the Chinese central government issued "The Decision on Deepening the Urban Housing Reform." The reform tried to improve both the supply and demand sides to create a housing market. On the supply side there was provision of subsidized housing for low income groups, while high-income groups were expected to purchase regular market housing. On the demand side, a dual housing finance system was established using a combination of social savings and private savings. Further emphasis was given to privatize more of the public housing stock at more realistic market prices.

The most important set of reforms came with the 1998 notice: "Notification from the State Council on Further Deepening the Reform of the Urban Housing System and Accelerating Housing Construction." This notice banned SOEs from either building or buying new housing units for their employees, replacing it with a system of employee subsidies. It also encouraged the private sector to step into housebuilding and banks to lend to consumers with the object to create a proper functioning private market for housing. Over the period 1998–2002 there were a number of measures taken to stimulate the private housing market in China, including reductions in personal income tax, sales taxes and mortgage rates set at levels aimed at stimulating housing demand. It should be noted that revenues from land sales have become and an important source of local government revenues over this period, accounting for over 30% in Cities such as Beijing and Zhejiang.

The results of all these reforms means that some 80% of the Chinese housing stock is in now in private hands. The proportion of housing transactions as a percentage of GDP has risen from 4.1% in 2002 to 13.3% of GDP in 2016 and house price growth has averaged 9.4% per annum over this period. During the period 1998 to 2010 outstanding residential mortgage loans have grown 112 times to 4.76 Trillion RMB ($697 billion) and all outstanding real estate-related loans have grown 24 times to 7.33 Trillion RMB. For a fuller discussion of housing policy in China see Li (2016).

3 Literature review

Ultimately house prices are determined simply by the forces of supply and demand and the price will adjust over time with changes in the factors affecting the demand and supply. Bourassa et al. (2001) use selected fundamental variables such as real income

(employment and the real wage rate), real construction costs, and the real after-tax interest rate as key determinants of supply and demand when looking for house price bubbles in three major cities in New Zealand. Liang and Cao (2007) and Chen and Zhu (2008) identify rapid GDP growth, bank lending and the rapid urbanization of China, as people move from rural locations to the Cities, as key drivers of the demand side in China. Another important factor on the demand side is economic agents' expectations relating to future prices, with expectations of price rises or falls influencing the decision of whether to buy or sell. Prices can also be influenced by government policies such as the building of roads, transport links to other cities, schools, hospitals, greenspace and planning permission. Governments can also heavily influence housing demand through changes in taxes on income and property and through the amount of land that can be used for housing stock which affects both the demand and supply and hence the equilibrium price. Ahuja et al. (2010) note that central government and local government fiscal relations, land development policies and land prices are key determinants of the supply of housing in China. According to Lai (2017) using a user cost approach framework, a combination of high income growth, rapid credit expansion and low interest rates lies behind the rapid rise in prices in the Chinese housing market with demand persistently outstripping supply. The basic argument behind the user cost approach is that Chinese citizens have a choice between saving money at low interest rates or buying housing stock with a prospective higher rental yield and capital appreciation and this is the main explanation of the imbalance in the Chinese property market.

The monetary policy of central banks and credit conditions can have a large influence on the real estate market. Cesa-Bianchi et al. (2015) argues that real estate prices can be explained by global monetary liquidity conditions especially in emerging markets. In the case of the dramatic Japanese property bubble of 1985–1990 Okina and Shiratsuka (2004) argue that lax monetary policy by the Bank of Japan was a prime driver of the housing bubble. While McDonald and Stokes (2013) look at house price rises in 10 US cities over the period 1987–2010 using the Case-Shiller house price indices. Using the VAR modelling procedure and Granger causality tests they find that the reductions of interest rate by the Federal Reserve were a significant cause of the US housing bubble.

There are various fundamental approaches to valuing real estate, for example, Leamer (2002) points out that the fundamental price of property should be the present value of the future rent. Leamer argues that using large deviations of price to rental ratios from their historical norms can be a useful method of detecting housing bubbles. In their study, Björklund and Söderberg (1999) look at Swedish house prices over the period 1985 to 1994. They argue that a fundamental determinant of house prices is the Gross Income Multiplier (GIM). Their study finds that the ratio of house prices to rental income was too high and conclude that a bubble existed in the Swedish market. Ortalo-Magne and Rady (2006) use a life-cycle model of the housing market combined with a property market ladder to show that the income of young households is a prime determinant of their ability to afford a down-payment on a starter home. They show that, in such circumstances, changes in income may yield a housing price over-reaction with the house prices of trade-up homes exhibiting the most volatility. Their model also finds some empirical support when applied to the UK and US housing markets.

As well as fundamental determinants of house prices there is also the possibility of speculative activity pushing up the price driven by herding behaviour and irrational

expectations of future price rises which can lead to a significant deviation of prices from those justified by fundamental determinants. Caballero (2006) point out that an additional reason for house price inflation is that that in many countries, especially developing countries, there is a shortage of investment assets which, in turn, leads to over speculation in the real estate market and the frequent emergence of bubbles in the sector. Real estate is often the focus of investors in emerging markets because it generally has better property rights and legal protections in place for investors.

According to Herring and Wachter (1999) bank behaviour can lead to exaggerated movements in house prices. In a market with real estate prices rising, banks lend more loans for property purchases as rises in real estate prices increase the value of bank capital to the extent that banks own real estate. Banks may then perceive that there is a lower risk of real estate lending. As such, an increase in real estate prices can increase the amount of banking loan exposure to the real estate sector which in turn leads to further rises in real estate prices. Once prices of real estate peak, a fall in the price of real estate will lower the value of the banking sectors real estate assets and the value of loans collateralized by real estate. There may also be defaults, which further depletes banks capital, increasing the perceived riskiness of the real estate sector and in turn reduces the supply of credit to the real estate industry leading to further falls in prices and further reductions in loans to the real estate sector. Regulators may intervene to the weakening of bank capital positions by increasing capital requirements and instituting stricter rules for classifying and provisioning against real estate assets ultimately leading to even less activity in the real estate sector and lower prices.

Studies on the Chinese property market have grown in recent years. Liang and Cao (2007) investigate the relationship between property prices and bank lending for the case of China over the period 1999–2006, and find that there is unidirectional causality running from bank lending to property prices. Zhang et al. (2012) show that Chinese house prices can also be linked to changes in the macroeconomic variables using a non-linear autoregressive moving average with exogenous inputs approach combined with the vector error correction model over the period 1999–2010. Their estimations show that the mortgage rate, money supply growth rate, producer prices and the real exchange rate are key drivers of Chinese house prices while surprisingly they do not detect a significant role for personal disposable income, international trade or real incomes. Guo and Huang (2010) show that hot money from abroad has been a significant driver of the Chinese stock and property prices. While Liu and Wray (2010) argue that the liquidity driving the property prices in China is the result of massive intervention in the foreign exchange market by the Peoples Bank of China as reflected in the large increase in Chinese foreign exchange reserves. The increase in the Renminbi money supply resulting from the intervention means artificially low interest rates and high money supply and credit growth. Dreger and Zhang (2013) argue that that there was a large rise in the real estate market as a direct result of the fiscal stimulus package unleashed by the Chinese authorities as a result of the global financial crisis and also the very loose money market conditions permitted by the Chinese monetary authorities. Using a dataset covering some 35 major Chinese cities over the period 1998 to 2009, the authors apply a panel model along with cointegration techniques and find that Chinese real estate was some 25% higher than the equilibrium value implied by the fundamentals at the end of 2009, with the overpricing especially high in cities in southeast coastal areas and special economic zones.

Xu and Chen (2012) also argue that Chinese monetary policy actions are the key driver of real estate price growth in in China over the period 1998 to 2009. They examine the impact of monetary policy variables which includes the money supply growth rate, the long term bank loan rate and a mortgage credit policy indicator to analyse real estate price growth dynamics in China. Their empirical results show a two way causal connection, with a lower interest rate, higher money supply growth rate and a loosening of mortgage down payment requirements leading to rapid price rises for real estate. This then leads to even more loans to the sector and a further loosening of credit standards. Du et al. (2011) look at the connection between Chinese land policy and its impact on the dynamic relationship between the house prices and land prices in the Chinese real estate market. Using panel data sets for Beijing, Shanghai, Tianjin and Chongqing they demonstrate that there exists a long-run equilibrium between Chinese urban housing and land markets. Wu et al. (2012) show that price to rent ratios have risen substantially over time in China being over 40 in some cities. They also show that rises in land prices has been a major force in driving up real estate prices in China with land prices rising over 800% between 2003 and 2010. This has created bubble like conditions in certain Chinese cities.

The existence of housing bubble in China has previously been explored by Man Hui and Yue (2006) who use a macro based econometric model to detect the existence of a housing bubble in Beijing and Shanghai in 2003. Interestingly while they are not able to detect the existence of a bubble in Beijing they are able to detect one in Shanghai which is shown to be approximately 22% overvalued. While Ahuja et al. (2010) find that as of mid-2010 house prices in China were not significantly overvalued except in cities such as Shanghai and Shentzhen. Although, they also detect signs of overvaluations in the luxury segment in both Beijing and Nanjing.

In the following section, we use a state space model to examine the existence of a real estate bubble in China. A deviation of property prices from their market fundamentals involves estimating a variable that cannot be observed. To overcome this problem we choose a state space model. The state space model has been increasingly used in recent years economic research. See for example Bertus and Stanhouse (2001) who uses it to test for a bubble in the gold market. Lau et al. (2005) apply it to investigate the existence of rational stock market bubbles in the Asian economies. Man Hui and Gu (2009) use a state space model to analyse house prices in Guanzhou and find that house prices peaked with a 43% overvaluation in October 2007. Han et al. (2008) also use a state space model to measure the extent of overvaluation of the property market in Shanghai and show that the market become approximately 22% overvalued. While Teng et al. (2013) use the state space model to detect and estimate the size of housing market bubbles in both Hong Kong and Taipei.

4 State space modelling of real estate in China

For our analysis of the Chinese property market, we adopt a State Space Model (SSM), which is a powerful framework -widely used in physics, engineering and other sciences- for the analysis of dynamic systems. In many applications, the driving forces behind the evolution of economic variables are (at least partially) not observable or measurable. For example, at an individual level a person's income may depend on their

intelligence, special abilities, social skills, and so on. Similarly, at an aggregate level, economic theory suggests that macroeconomic variables such as economic growth are driven by unobservable factors, e.g. technological change or human capital accumulation. For this reason, SSMs have been applied in the econometrics literature to model unobserved variables such as; expectations, measurement errors, missing observations, permanent income, unobserved components (cycles and trends) and the non-accelerating rate of unemployment. Extensive surveys of applications of state space models in econometrics can be found in Hamilton (1994a, Chapter 13) and Harvey et al. (2004).

In the presence of both correlated and unobserved variables, adopting SSM represents an improvement upon standard regression analysis as a SSM can allow for *endogeneity*. While linear regression models use exogenous variables to distinguish the explained variation from the unexplained variation, a SSM relies on the dynamics of the state variables and the linkage between the observed variables and state variables to draw statistical inference about the unobserved states. In this respect, a SSM can represent an improvement also upon VAR techniques. Comparing SSM to standard VAR models when explanatory variables are not observable, standard VAR models can no longer be applied to study the evolution of the endogenous variables. However, it is easy to extend the VAR framework to analyse scenarios with unobservable explanatory variables by using SSM. In fact, a wide range of time series models, including the classical linear regression model and ARIMA models, can be written and estimated as special cases of a state space specification.

In this paper we use a SSM to analyse real estate demand, real estate supply and the unobservable overvaluation component. Modelling real estate demand and supply typically suffers from issues of omitted variables and endogenous, i.e. mutually correlated, variables. The first benefit of using a SSM is to be able to include non-stationary and endogenous macro-economic variables in the demand and supply equations. This improves upon a VAR technique, where only co-integrated variables can be included and a vector error correction model (VECM) should be imposed. The second benefit of using a SSM is to be able to estimate the unobserved overvaluation component by estimating a fundamental price through the Kalman filter, which is the standard estimation technique in SSM.

SSMs allow the researcher to model an observed (multiple) time series, $\{y_t\}_{t=1}^T$, as being explained by a vector of (possibly unobserved) state variables, $\{\xi_t\}_{t=1}^T$, which are driven by a stochastic process. A basic linear state SSM is formed by two equations. The first equation, called measurement equation, describes the relation between the observed time series, y_t, and the (possibly unobserved) state ξ_t:

$$y_t = \mathsf{A}\xi_t + \nu_t, \nu_t \sim N(0, \mathsf{R}) \, (measurement \quad equation). \tag{1}$$

In general, it is assumed that the data y_t are measured with error, which is reflected in the measurement error ν_t that enters the measurement equation. The standard approach is to model ν_t as a Gaussian error term normally distributed with zero mean and some given variance R.

The second equation, the transition equation, describes the evolution of the (possibly unobserved) state variables as being driven by the stochastic process of innovations ω_t:

$$\xi_t = \mathsf{B}\xi_{t-1} + \omega_t, \omega_t \sim N(0, \mathsf{Q})(transition \quad equation) \tag{2}$$

It is typically assumed that also innovations are normally distributed with zero mean and a given variance Q. State space models can also be formulated much more generally than this specification. For example, the system matrices A and B could depend explicitly on time, or one could introduce policy variables and constants in the specification. However, our model will be characterized by a simple formulation where state variables follow a random walk model, i.e. B is an identity matrix.

Generally, in practical applications the system matrices A and B together with the variances R and Q are unknown and have to be estimated. Whenever the explanatory variables are not observable Least Squares estimation is not the correct way to go. However, even in this case, one can apply likelihood based inference, since the Kalman filter allows to construct the likelihood function associated with a state space model. The SSM is therefore estimated by maximizing the estimated likelihood function through a numerical procedure. We apply this procedure by using the *Sspace* package in the EViews® software.

Our first step is to obtain consistent estimations of real estate demand and supply functions for China. To do this, we select a number of macroeconomic variables for each function. We verify their stationarity properties and co-integration. We opt to only include co-integrated variables in each function, even if in principle a SSM can handle variables that are not co-integrated. By doing this, we do not have to impose any structure on the functions and we can still obtain consistent estimations. In particular, we model that all macro variables evolve as a random walk, so that no stationarity in the estimated demand and supply is superimposed by the modelling assumptions.

After finding consistent estimations for demand and supply, we move to the second step of our analysis. We interpret that estimated demand and supply represent the fundamental forces beyond price movements and we estimate the unobserved fundamental price that would equate demand and supply through a new SSM iteration, by modelling the unobserved fundamental price as a random walk. As for the other macroeconomic variables, modelling a random walk process for the fundamental price is a natural choice because we do not want to impose any structure that could influence the fundamental price beyond the estimated factors. Finally, we compare the estimated fundamental price with the observed price, we compute their deviation ratio and analyse its properties.

Compared to other approaches in the literature reviewed in section 3, the novel contribution of our methodology is that the deviation ratio measures a purely irrational bubble component. In other words, our bubble component does not include price changes that are due to non-equilibrium between supply and demand, where demand includes not only the users' market but also investors' demand. This feature is important because real estate markets can be characterized by a fundamental mismatch between supply and demand which can take time to correct and by a component of demand that is investment driven and that is typically not decreasing in price.[1] A fair

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[1] See for example DiPasquale and Wheaton (1992).

account of the bubble component should therefore exclude those components. Moreover, in our analysis we do not consider rents on purpose, because those are co-determined in the economy with the observable market prices, whereas we want to have a measure of the fundamental unobservable real estate price that depends as much as possible on fundamental macro-economic factors.

5 Empirical analysis

The model is estimated by using 44 quarterly observations from 2004Q1 to 2014Q4 for various time series. The data are obtained from the National Bureau of Statistics of China. We consider the following variables:

1) SS: National Real Estate Selling Space
2) FS: National Real Estate Completion Space
3) P: Real Estate Sale Price reported in (reported in CNY/square meters)
4) GDP: Gross Domestic Product
5) PDI: Disposable income(reported in CNY/person)
6) MR: Loan Interest Rate (official 3 to 5 years interest rate)
7) CPI: Consumer Price Index
8) M1: Narrow Money Supply

As it is often the case with this type of macro variables, evaluating the data with Augment Dickey-Fuller test reveals that these variables are non-stationary in levels, but become stationary in first differences. We also adjust for seasonality with the Eviews Census X12 method and take the log of all variables to correct for heteroscedasticity. SS is our measure for real estate demand and FS is our measure for real estate supply. We carry out Johansen tests to select co-integrated variables for demand and supply. After that we estimate the two functions by a SSM.

5.1 Demand side

We include five variables in the demand equation: real estate sale space SS, sale price P, disposable income PDI, interest rate MR and consumer price index CPI. The variables are chosen on the basis of the Johansen test. Table 1 shows that there are five co-integrated relationship within the chosen variables of the demand equation. This implies that their relationship is stable across the sample period, indicating that the demand equation has economic meaning. The resulting demand equation is the following:

$$\ln(SS_t) = dv_{1t} \times \ln(P_t) + dv_{2t} \times \ln(PDI_t) + dv_{3t} \times \ln(MR_t) + dv_{4t} \times \ln(CPI_t) + \mu_t \quad (3)$$

Since each variable is in time series, they are subscripted with time sign-t before being transformed into the natural logarithm. The coefficients are also time-varying and are assumed to be random walk series in the signal equations:

$$dv_{1t} = dv_{1t-1} + \varepsilon_t^1; dv_{2t} = dv_{2t-1} + \varepsilon_t^2; dv_{3t} = dv_{3t-1} + \varepsilon_t^3; dv_{4t} = dv_{4t-1} + \varepsilon_t^4 \quad (4)$$

Table 1 Co-integration test for the demand equation

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value
None *	0.566740	91.26551	69.81889
At most 1 *	0.372167	56.13594	47.85613
At most 2 *	0.316227	36.58574	29.79707
At most 3 *	0.264359	20.62033	15.49471
At most 4 *	0.168020	7.725774	3.841466

Trace test indicates 5 cointegrating eqn(s) at the 0.05 level

*denotes rejection of the hypothesis at the 0.05 level

The residuals of the above five equations are assumed to have independent and identical distributions. Equations (3) and (4) form a SSM are estimated by Kalman filter using the Sspace analysis tools in Eviews7.0®. The estimated coefficients represent the long term and stable elasticity of sold real estate space with respect to each variables. Results are reported in Table 2 below.

We notice from Table 2 that the coefficient DV1 is positive and significant, this implies that demand for real estate increases in price. This apparently unusual positive relation of prices on demand is not uncommon in markets characterized by a strong investment, or speculation, motive. We notice that the coefficient DV2 is not significant and is excluded from the demand equation in the following steps of our analysis. Coefficients DV3 and DV4 are significant and they show a positive effect of interest rates and a negative effect of inflation. Similarly to what happens with the coefficient of price, the positive coefficient of interest rates, apparently a non-standard result, is due to the fact that Chinese national government policies have systematically raised interest rates in periods of strong demand as discussed in section 6. The negative coefficient of inflation is as expected and due to household budget constraints (Table 3).

5.2 Supply side

We repeat the same procedure in order to estimate the supply function.

We check that five co-integrated relationships exist also in the variables of the supply equation and we include the five variables in the supply equation: real estate

Table 2 Estimation of the parameters in the demand equation

	Final State	Root MSE	z-Statistic	Prob.
DV1	2.377801	2.298454	1.034522	0.0034
DV2	−0.154792	0.006288	−7.951273	0.8957
DV3	0.052206	0.053696	0.972257	0.0061
DV4	−0.351807	1.056569	−0.332971	0.0091

Table 3 Co-integration test for the supply equation

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value
None *	0.839862	128.2216	69.81889
At most 1 *	0.514890	64.11154	47.85613
At most 2 *	0.432954	38.79323	29.79707
At most 3 *	0.285672	18.71895	15.49471
At most 4 *	0.185068	4.20499	3.841466

Trace test indicates 5 cointegrating eqn(s) at the 0.05 level

*denotes rejection of the hypothesis at the 0.05 level

completed real estate space FS, sale price P, money supply M1, interest rate MR and GDP. The resulting supply equation is the following:

$$\ln(FS_t) = sv_{1t} \times \ln(P_t) + sv_{2t} \times \ln(M1_t) + sv_{3t} \times \ln(MR_t) + sv_{4t} \times \ln(GDP_t) + \eta_t \quad (5)$$

Also the coefficients are assumed to be random walk series with i.i.d. errors in the signal equations:

$$sv_{1t} = sv_{1t-1} + \xi_t^1; sv_{2t} = sv_{2t-1} + \xi_t^2; sv_{3t} = sv_{3t-1} + \xi_t^3; sv_{4t} = sv_{4t-1} + \xi_t^4 \quad (6)$$

In this case, eqs. (5) and (6) form a SSM are estimated by Kalman filter using the Sspace analysis tools in Eviews7.0®. The estimated coefficients represent the long term and stable elasticity of completed real estate space with respect to each variable. Results are reported in Table 4 below.

We notice from Table 4 that all coefficients are significant. SV1 is positive and this implies that demand for real estate increases in price as expected. We notice that the coefficient SV2 is positive implying that money supply increases real estate supply. Coefficients SV3 and SV4 show a negative effect of interest rates and a positive effect of GDP. The positive effect of money supply and the negative effect of interest rates are due to the fact that national policies have systematically used money supply and base interest rate to stimulate or alternatively curb real estate development activity. The positive effect of GDP on real estate supply is standard.

Table 4 Estimation of the parameters in the supply equation

	Final State	Root MSE	z-Statistic	Prob.
SV1	0.284715	0.425151	0.669680	0.0031
SV2	0.060843	0.068098	0.893456	0.0095
SV3	−0.598513	0.629294	−0.951086	0.0086
SV4	0.301307	0.686145	0.439130	0.0046

5.3 Equilibrium price

We use the results from the previous estimations and estimated demand and supply from the measurement equations, and we estimate the unobservable fundamental price (FP).

$$\ln(SS_t) = DV1 \times \ln(FP_t) + DV3 \times \ln(MR_t) + DV4 \times \ln(CPI_t) + \mu_t \qquad (7)$$

$$\ln(FS_t) = SV1 \times \ln(FP_t) + SV2 \times \ln(M1_t) + SV3 \times \ln(MR_t) + SV4 \times \ln(GDP_t) + \eta_t \quad (8)$$

As in the case of the estimation of demand and supply, in order not to super-impose assumptions, we model that the fundamental price follows a random walk in the signal equation:

$$\ln(FP_t) = \ln(FP_{t-1}) + \varepsilon_t \qquad (9)$$

where $\mu_t, \eta_t, \varepsilon_t$ are i.i.d.

The unknown series $\ln(FP_t)$ is then estimated as the unknown of the SSM formed by (7), (8) and (9) by Kalman filter. We interpret the difference between $\ln(P_t)$ - $\ln(FP_t)$ as it is the portion of price that is not explained by the dynamics of demand and supply, where the demand and supply have been estimated on the basis of broad macro-financial factors and not simply imposed to be at equilibrium. By standard results we obtain that:

$$ln(P_t) - ln(FP_t) \approx (P_t - FP_t)/FP_t \qquad (10)$$

Equation (10) defines the *deviation ratio* which is our measure of the irrational (i.e. bubble) component in the observed real estate price. We plot this ratio in Fig. 1.

As we can notice from Fig. 1, the deviation ratio is generally positive throughout the sample period and substantial in terms of magnitude. As a robustness check, we also perform an ADF test on the deviation ratio.

From Table 5, we notice that the deviation ratio is nonstationary in levels but becomes stable in first differences, therefore indicating that the deviation ratio is a I(1) series. This confirms that an irrational component exists in the real estate price and is significant. We also find evidence of a structural break in the deviation ratio at the end of 2010. After this period, the deviation ratio increases substantially. In the following section we analyse the dynamics of the deviation ratio over time and we relate those to policy changes.

6 Policy discussion

There is relatively limited research on Chinese housing policies published in English. The papers of Li and Chiang (2012) and Li (2016) are notable exceptions and
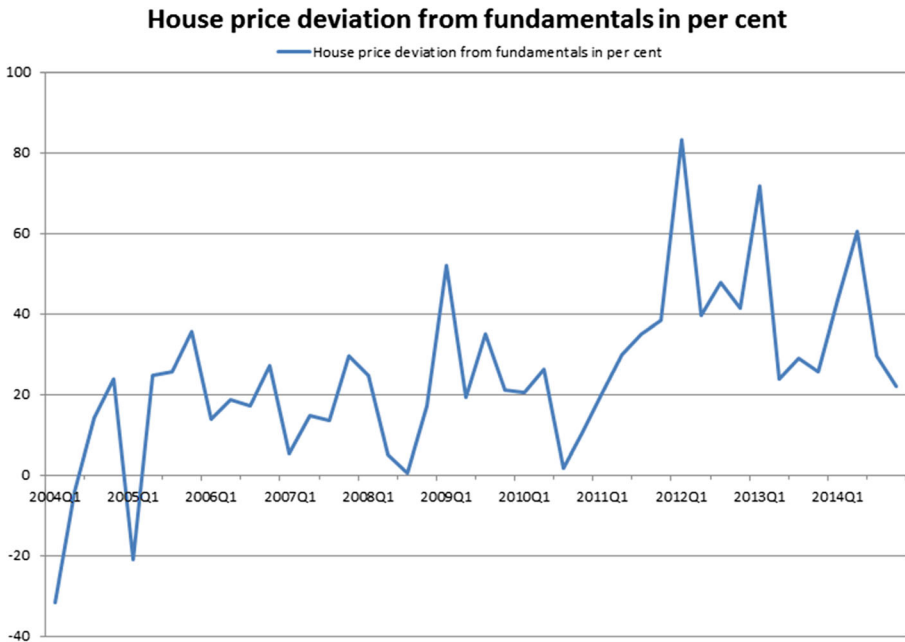
House price deviation from fundamentals in per cent

Fig. 1 Quarterly Deviation Ratio from end 2003 to end 2014

extensively review those policies over the last decade. They explain that the Chinese central government has substantially advocated three types of policies to cool down the property market and to curb potential housing bubbles over the past decade: restricted bank loan (*xiandai*), restricted sale price (*xianjia*) and restricted housing purchase (*xiangou*). Those policies have changed frequently, in an attempt to effectively control the market with objectives of promoting growth and stability. We can now analyze the dynamics of the deviation ratio with respect to the policy changes. There are various interesting features of the deviation ratio that are worth noticing in Fig. 1. First, we observe that the deviation ratio seems to have a cyclical behaviour over one calendar year; this behaviour, which is common to many western economies, can be explained by the fact that more properties tend to come on the market in the spring-summer period.

Looking at the deviation ratio from 2004 to 2006 shows the effects of some important policies introduced by the State Council in 2005 aimed at stabilizing property prices. The introduction of those policies in 2005 marks an important shift from the previous 2001–2004 period when State Council policies had as primary objective to sustain and promote the real estate market (see Li 2016). In particular, in a market

Table 5 Unit root test for the deviation ratio

	ADF test statistic	0.05 critical value	0.10 critical value	**conclusion**
deviation ratio	−1.897304	−2.931404	−2.603944	not stable
deviation ratio (first diff.)	−4.742939	−2.936942	−2.606857	stable

dominated by low interest rates, in March 2005 the People's Bank of China (PBOC) increased the minimum down payment ratio for homebuyers from 20% to 30%. We notice that the deviation ratio decreases from 35% in mid-2005 to 5% at the end of 2006, showing that the effect of the price-stabilizing policies while not immediate are quite powerful.

Next we notice that despite the cyclical behaviour, the deviation ratio in 2007 is much lower than in the previous years. Li and Chiang (2012) explain that from March 2007 to August 2008, the PBOC increased the residential loan rates 6 times and the deposit reserve ratio 13 times. These were extreme measures that the PBOC had never adopted before. Moreover, the Ministry of Housing and Urban-Rural Development increased the Housing Provident Fund (HPF) loan rates 6 times in a row.[2] Researchers have commented that those policies may have a distortive impact and unintended consequences. Moreover, the suppression on the bubble in the real estate market does not last long as the deviation ratio still reaches 30% in 2007, signalling that the real estate market is overheated and is little impacted by the by the monetary policy in short term.

With the financial crisis happening around the world in 2008, the real estate market in China became suddenly weaker. To avoid an economic recession, a series of new policies were formulated by the PBOC in October 2010. In particular, from October 27th the central bank decided to adjust the lower bound of the personal loan interest rate to 0.7 times the benchmark interest rate and revert the down payment portion back to 20%. There were five issuance of Notice on Lowering the RMB Benchmark Interest Rates for Loans and Deposit Reserve Rate of Financial Institutions. For low-cost housing, affordable housing and housing rental, policies provided tax free land for developers according to a defined portion of the total space. This welfare policy aimed at protecting the rigid demand of inhabitants while the loan interest and the subsidy are both unfavorable in this period. We notice that the trend of the deviation ratio is different in 2008 with respect to other years, as it reaches its bottom, rather than a peak, in the second quarter. In this period, due to the global economic recession, investors and speculators had less funds and confidence even in China, despite the still booming property market. Despite the global recession in 2008, the real estate market in China remains quite stable throughout 2009 mainly due to the effects of the favourable policies.

We then find evidence of a structural break in the deviation ratio from 2010 onwards. The behaviour is still cyclical but the average ratio from 2010 to 2014 is 35%, whereas it is 15% in the preceding sub-sample. Moreover, the magnitude of volatility is also higher after 2010. It can therefore be noticed that the real estate market of China recovers quickly from the recession but after the stimulating policy intervention sale prices rise quickly and significantly shift away from the estimated fundamental value. For this reason, April 2010 marks the start of a new set of policy measures aimed at restricting purchases and loans with the objective of limiting real estate appreciation and to keep the market stable. On 30 April 2010, the State Council issued the restrictive purchase policy (*xiangou*) to cool down the overheated property market. Restrictive

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[2] Chen and Deng (2014) explain that the HPF is self-funded circuit institution separated from the market-based financial system and it is a compulsory savings scheme to provide self-funded housing, where employers and employees of the public sector contribute 5% of employees' monthly incomes to individual HPF accounts.

purchases set purchase limits on the number of flats that could be sold to households. In 40 major cities, residents with local *hukou* (i.e., household registration) can buy up to two flats, nonlocal residents or foreigners can only buy one flat, and the interval for buying a second flat must be at least 2 years. Moreover, to control construction targets in an attempt to stabilize the market expectations, the central government required regional governments to issue property price controls in 2011 and by March 2011 608 cities in China issued policies to control real estate prices according to the Construction Department Database. Li (2016) comments that after the Chinese government implemented the restrictive purchase policy, none of the cities had any signs of housing bubbles in 2010/11. However, eight cities had bubbles detected in 2011/12 and most cities have shown signs of bubbles since 2012. We notice that despite the restrictive policies from 2011 to 2013, the deviation ratio peaks at 80% at the beginning of 2012 and stays at an average in excess of 40% thereafter.

7 Conclusions

Based on discussion and analysis above, we have employed the SSM as a means to detect a real estate bubble in the Chinese real estate market. By estimating the real estate demand and supply with a SSM using a broad number of macroeconomic and financial factors, we have been able to isolate the non-fundamental price component. We have then compared the market price to the fundamental price to calculate a deviation ratio, which is our measure of the extent of the bubble in the Chinese real estate market. Using the deviation ratio, we have described how the bubble component changes over time and we attempt to highlight how the deviation responds to changes in relation to policies of the Chinese authorities.

In line with some of the previous literature, we have found quite strong evidence of a bubble, especially after 2010, when the deviation ratio has an average value in excess of 40%. Compared to previous approaches in the literature, the novel contribution of our methodology is that the deviation ratio measures a purely bubble component. In other words, our bubble component does not include price changes that are due to non-equilibrium between supply and demand, where demand includes not only the users' market but also investors' demand. This feature is important because real estate markets are characterized by a fundamental mismatch between supply and demand, due to the time to develop property, and by a component of demand that is investment driven and that is typically not decreasing in price and a fair account of the bubble component should not include those components.

Looking at the dynamics of the deviation ratio with respect to policy changes broadly shows that stimulating monetary policies (especially post 2008) had strong positive effects on the bubble component, whereas policies that aimed to limit or reverse the bubble component had only limited and short lived effects. In line with Li (2016) we find evidence that interest rate policies or restricted housing purchase policies in specific cities post 2011 did not limit the bubble component at the aggregate national level. Given this evidence, we attribute a fundamental role in the inefficacy of interest rate policies to the role played by shadow banking. As the recent literature shows that bank lending is increasingly independent from the PBOC, it remains an open question whether shadow banking lending supports, weakens, or amplifies the

effects of monetary policy. Gabrieli, Pilbeam and Shi (2018 forthcoming) contribute to this recent debate by showing that Chinese Shadow Banking works independently from official monetary policy: it amplifies increases in the money supply but weakens the effects of restrictive interest rate-based monetary policy decisions. Given that virtually all of the official interest rate changes in the last decade have been motivated by policy objectives focussed on the real estate market, we conclude that the inability to curb the real estate bubble is very much related to the opposing role played by Shadow Banking. Future research could take a further step and specifically investigate the role of shadow banking in real estate price dynamics in China.

References

Ahuja A, Cheung L, Han G, Porter N, Zhang W (2010) Are house prices rising too fast in China? IMF Working Paper 10/274
Bertus M, Stanhouse B (2001) Rational speculative bubbles in the gold futures market: an application of dynamic factor analysis. J Futur Mark 21(1):79–108
Björklund K, Söderberg B (1999) Property cycles, speculative bubbles and the gross income multiplier. J Real Estate Res 18(1):151–174
Bordo MD, Jeanne O (2002) Monetary policy and asset prices: does 'benign neglect'make sense? Int Financ 5(2):139–164
Bourassa SC, Hendershott PH, Murphy J (2001) Further evidence on the existence of housing market bubbles. J Prop Res 18(1):1–19
Caballero RJ (2006) On the macroeconomics of asset shortages. No. w12753. National Bureau of Economic Research
Cesa-Bianchi A, Cespedes LF, Rebucci A (2015) Global liquidity, house prices, and the macroeconomy: Evidence from advanced and emerging economies. J Money Credit Bank 47(1):301–335
Chen J, Deng L (2014) Financing Affordable Housing through Compulsory Saving: The Two-Decade Experience of Housing Provident Fund in China. Hous Stud 29(7):937–958
Chen J, Zhu A (2008) The relationship between housing investment and economic growth in China: A panel analysis using quarterly provincial data. No. 2008: 17 Working Paper, Department of Economics, Uppsala University
DiPasquale D, Wheaton WC (1992) The markets for real estate assets and space: a conceptual framework. Real Estate Econ 20(2):181–198
Dreger C, Zhang Y (2013) Is there a bubble in the Chinese housing market? Urban Policy Res 31(1):27–39
Du H, Ma Y, An Y (2011) The impact of land policy on the relation between housing and land prices: Evidence from China. Q Rev Econ Finance 51(1):19–27
Gabrieli T, Pilbeam K, Shi B (2018). The Impact of Shadow Banking on the Implementation of Chinese Monetary Policy. Int Econ Econ Policy
Guo F, Huang YS (2010) Does "hot money" drive China's real estate and stock markets? Int Rev Econ Financ 19(3):452–466
Hamilton JD (1994) Time Series Analysis (Vol. 2). Princeton University Press, Princeton
Han DM, Liu LJ, Cao K (2008) Empirical analysis on real estate price bubble based on state-space model. J Financ Econ 1:126–135

Harvey A, Koopman SJ, Shephard N (2004) State Space and Unobserved Component Models. Cambridge University Press, Cambridge

Herring RJ, Wachter SM (1999) Real estate booms and banking busts: An international perspective (July 1999). The Wharton School Research Paper No. 99–27

Lai P (2017) China's housing market imbalance from 2003 to 2016: An analysis based on the user cost approach. Chin World Econ 25:44–59

Leamer E (2002) Bubble trouble. Your home has a P/E Ratio too, UCLA Anderson Forecast Quarterly

Li J (2016) Housing policies in Hong Kong, China and the People's Republic of China. Asian Development Bank Working Paper 566

Li J, Chiang YH (2012) What pushes up China's real estate price? Int J Hous Mark Anal 5(2):161–176

Liang Q, Cao H (2007) Property prices and bank lending in China. J Asian Econ 18(1):63–75

Liu X, Wray LR (2010) Excessive liquidity and bank lending in China: A modern money perspective. Int J Polit Econ 39(3):45–63

Man Hui EC, Gu Q (2009) Study of Guangzhou house price bubble based on state-space model. Int J Strateg Prop Manag 13(4):287–298

Man Hui EC, Yue S (2006) Housing price bubbles in Hong Kong, Beijing and Shanghai: a comparative study. J Real Estate Financ Econ 33(4):299–327

McDonald JF, Stokes HH (2013) Monetary policy and the housing bubble. J Real Estate Financ Econ 46(3): 437–451

Okina K, Shiratsuka S (2004) Asset price fluctuations, structural adjustments, and sustained economic growth: Lessons from Japan's Experience since the late 1980s. Institute for Monetary and Economic Studies, Bank of Japan

Ortalo-Magne F, Rady S (2006) Housing market dynamics: On the contribution of income shocks and credit constraints. Rev Econ Stud 73(2):459–485

Teng HJ, Chang CO, Chau KW (2013) Housing bubbles: A tale of two cities. Habitat Int 39:8–15

Wu J, Gyourko J, Deng Y (2012) Evaluating conditions in major Chinese housing markets. Reg Sci Urban Econ 42(3):531–543

Xu XE, Chen T (2012) The effect of monetary policy on real estate price growth in China. Pac Basin Financ J 20(1):62–77

Zhang X, Sun T (2006) China's current real estate cycle and potential financial risks. Chin. World. Econ. 14(4):57–74

Zhang Y, Hua X, Zhao L (2012) Exploring determinants of housing prices: A case study of Chinese experience in 1999–2010. Econ Model 29(6):2349–2361