REAL-TIME WARNING SIGNS OF EMERGING AND COLLAPSING CHINESE HOUSE PRICE BUBBLES

Xi Chen* and Michael Funke**

The recent increase in Chinese house prices has led to concerns that China is vulnerable to asset price shocks. In this paper, we apply recently developed recursive unit root tests to spot the beginning and the end of potential speculative bubbles in Chinese house price cycles. Overall, we find that except for 2009–10 actual house prices are not significantly disconnected from fundamentals. Thus, the evidence for speculative house price bubbles in China is in general weak.

Keywords: House prices; China; speculative bubbles; recursive unit root tests

JEL Classifications: C15; G01; G12; R31

1. Introduction

Issues related to Chinese house prices have become an international concern. China's extraordinary real estate boom began in the early 2000s and was further boosted in 2009 by China's huge financial crisis stimulus package. In the aftermath of the global financial crisis in 2008–9, the Chinese government urged banks to increase lending. Buyers took advantage of looser real estate lending terms and lower mortgage rates. Increasing rates of urbanisation, rising income, and rapid economic growth have also contributed to high real estate demand. Furthermore, the expansionary monetary policy stance has not only boosted house prices but has also generated a shift in house price expectations and spurred excessive risk-taking in the banking sector.[1] As a result, real estate in many cities has become unaffordable for broad sections of the population in China.

Ultimately, house prices have also become an important and topical issue for Chinese policymakers.[2] The property sector now makes up about 12 per cent of GDP. Furthermore, property is a sizable component of household and corporate balance sheets. Therefore, a sudden collapse in house prices may have negative spillover effects on the overall macroeconomic situation and may pose macroeconomic and financial stability risks.[3] Just as a quick reminder, the build-up of property price overvaluations triggered the Asian financial crisis of the late 1990s. In response to the sustained run-up in house prices, therefore, the Chinese government imposed in spring 2010 several market-cooling measures and restrictions intended to bring house prices down to a 'reasonable level'. In addition, the People's Bank of China benchmark mortgage lending rate was raised in summer 2011. As a result, multiple indicators suggested a slight market downturn in 2011. It must be pointed out that it remains an open question whether the latest market dip may be a short-term episode since high and rising real estate prices may be in line with market fundamentals.

Recent research has also focused on central banks' incentives. Kocherlakota and Shim (2007) demonstrate that the utility-maximising central bank's response to house price increases is conditioned on the real time probability of a future house price collapse. If this is high *ex ante*, proactive corrective action is optimal. Otherwise the central bank shows forbearance towards instability.

The uncertainties in defining a sustainable house price level and identifying emerging housing bubbles in real time have not lessened substantially in past decades.

*Hamburg University, Department of Economics. E-mail: xi.chen@wiso.uni-hamburg.de. **Michael Funke, Hamburg University, Department of Economics and CESifo, Munich University. E-mail: michael.funke@uni-hamburg.de. A previous version of the paper has been published as Bank of Finland BOFIT Discussion Paper No. 27-2012. The views expressed in the paper are those of the authors and do not necessarily reflect the views of the Bank of Finland.

Even worse, it may turn out not to be very useful to identify bubbles in real time. Even if statistically significant bubble characteristics are found and monetary policymakers are confident that a speculative housing bubble has emerged, the question of the timeliness of the policy response remains. The problem is the timing of the detection of the bubble relative to the timing of its collapse. The risk is that the subsequent interest and/or macroprudential policy response occurs not long before the bubble collapses on its own. Given the lags associated with monetary policy, the resulting contractionary effects of the proactive policy tightening would occur just when the bubble bursts, worsening rather than mitigating the effects of the bubble's collapse. Thus, those seeking to identify significant warning signs of future housing bubbles may turn out to be the Don Quixotes of housing research. Is it therefore time to call off the quest?

The plan of the paper is as follows. Section 2 reviews some theoretical and econometric issues related to housing valuation and bubble identification. Section 3 proceeds by discussing the data and the results of the econometric diagnostics. Section 4 draws some conclusions.

2. Theoretical and econometric considerations in relation to detecting property price bubbles

In the first stage, we need to define bubble periods. Based on this, we can then identify inflated house prices and bubble periods. Rational house price bubbles can arise because of the indeterminate aspect of solutions to rational expectations models. The house price that agents are prepared to pay today depends on the expected house price at some point in the future. But the latter depends on the expected house price even further in the future. The resulting process governing house prices does not pin down a unique house price level unless, somewhat arbitrarily, a transversality condition has to be imposed to obtain a unique solution. However, in general, the possibility that house prices may systematically deviate from their fundamental value cannot be ruled out. Even if risk-neutral agents are perfectly rational, the actual house price may contain a bubble element, and thus there can be a divergence between the house price and its fundamental value. The resulting real estate bubble is an upward house price movement over an extended range that then suddenly collapses.[4]

Our goal is to find how house prices evolve over time, given the behaviour of fundamentals. Time is discrete. In the modelling framework, fundamental house prices H_t can be represented as follows:

$$H_t = \left(\frac{1}{1+r}\right) E_t(R_t + H_{t+1}), \quad (1)$$

where E_t is the expectations operator, R_t is the rent, and r is the discount rate. To solve the model, we need to eliminate the term involving the expectation of the future value of the endogenous variable. It is straightforward to show that the fundamental house price H_t^F can be solved under rational expectations by repeated forward substitution. This implies

$$H_t^F = \Sigma_{j=1}^{\infty} \left(\frac{1}{1+r}\right)^j E_t(R_{t+j}). \quad (2)$$

The logic of equation (2) is that house market prices contain expectations of future rents. No specific assumptions are made about the process followed by R_t.[5] The rational bubble components B_t follow

$$B_t = \left(\frac{1}{1+r}\right) E_t(B_{t+1}). \quad (3)$$

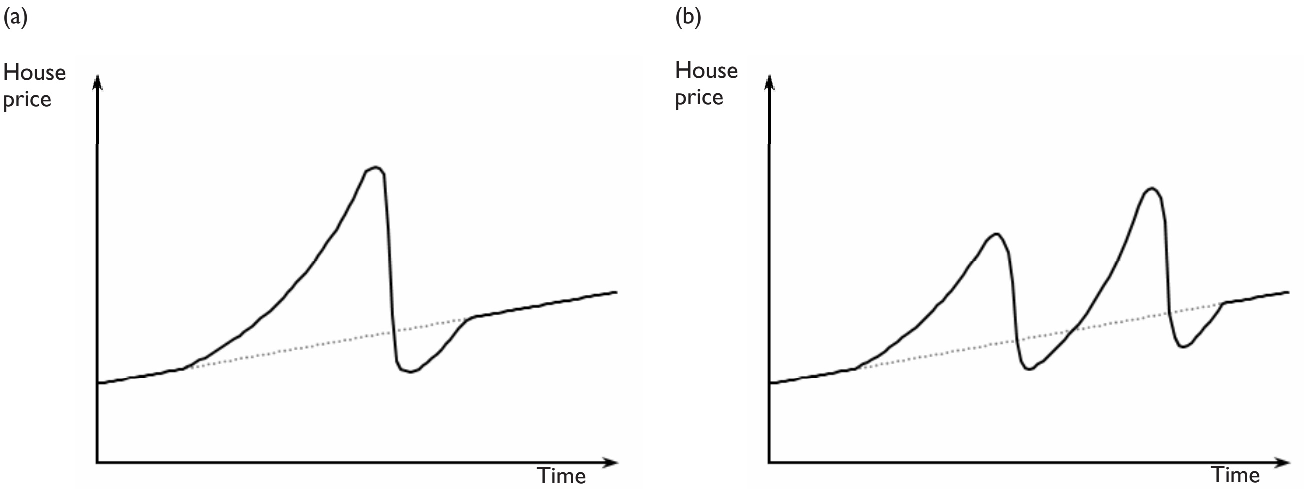
Solving for H_t finally yields

$$H_t = H_t^F + B_t. \quad (4)$$

Equation (4) breaks up house prices into a 'fundamental' and a 'bubble' component. Without a bubble, house prices equal the fundamental value H_t^F. Under bubble conditions house prices may show an explosive behaviour inherent in B_t.[6] What kind of house price bubble is B_t? Mathematically, the explosive bubble term is a *deus ex machina* arising as an alternative solution to the process governing house prices. The origin of the bubble cannot be explained, and only the dynamics of the bubble are given by the model. If a bubble is present in the house price, equation (4) requires that any rational investor must expect the bubble to grow. If this is the case, and if B_t is strictly positive, this builds the stage for speculative investor behaviour; a rational investor is willing to buy an 'overpriced' house, since he/she believes that through price increases he will be sufficiently compensated for the extra payment he has to make as well as the risk of the bubble bursting. In that sense, the house price bubble is a self-fulfilling expectation. Eventually, the bubble implodes, house prices fall with a sharp correction and deleveraging occurs.

Next we discuss how the theoretical framework can be linked to an econometric testing strategy. In the econometric literature, identifying a bubble in real time has proved challenging. In addition, severe econometric problems result from finite samples. Standard unit root

Figure 1. Stylised one-off bubble *vs* periodically collapsing bubbles



and cointegration tests may be able to detect one-off exploding speculative bubbles, as in panel (a) of figure 1, but are unlikely to detect periodically collapsing bubbles, as in panel (b) of figure 1. In other words, efforts to identify significant warning signs of future housing bubbles have been impeded by the necessity to spot multiple starting and ending points. The reason is that traditional unit root tests are not well equipped to handle changes from I(0) to I(1) and back to I(0). This makes detection by cointegration techniques harder, due to bias and kurtosis (Evans, 1991).

A nuanced and persuasive approach to identification and dating multiple bubbles in real time has recently been pioneered by Phillips and Yu (2011) and Phillips *et al*. (2012).[7] The idea is to spot speculative bubbles as they emerge, not just after they have collapsed. Their point of departure is the observation that the explosive property of bubbles is very different from random walk behaviour. Correspondingly, they have developed a new recursive econometric methodology interpreting mildly explosive unit roots as a hint for bubbles. If we consider the typical difference of stationary *vs* trend stationary testing procedures for a unit root, we usually restrict our attention to regions of 'no more than' a unit root process, i.e. an autoregressive process where $\rho \leq 1$. In contrast, Phillips and Yu (2011) model mildly explosive behaviour by an autoregressive process with a root ρ that exceeds unity but is still in the neighbourhood of unity. The basic idea of their approach is to calculate recursively right-sided unit root tests to assess evidence for mildly explosive behaviour in the data. The test is a right-sided test and therefore differs from the usual left-sided tests for stationarity. More specifically, consider the following autoregressive specification estimated by recursive least squares:

$$x_t = \mu + \rho x_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim iid(0,\sigma^2). \tag{5}$$

The usual H_0: $\rho = 1$ applies, but unlike the left-sided tests which have relevance for a stationary alternative, Phillips and Yu (2011) have H_1: $\rho > 1$, which, with $\rho = 1 + c/k_n$, where $c > 0$, $k_n \rightarrow \infty$ and $k_n/n \rightarrow 0$, allows for their mildly explosive cases. Phillips and Yu (2011) argue that their tests have discriminatory power, because they are sensitive to the changes that occur when a process undergoes a change from a unit root to a mildly explosive root or *vice versa*. This sensitivity is much greater than in left-sided unit root tests against stationary alternatives. But this is not all. It should be added that bubbles usually collapse periodically. Therefore, standard unit root tests have limited power in detecting periodically collapsing bubbles.[8] To overcome this drawback, Phillips and Yu (2011) have suggested using the supremum of recursively determined Dickey-Fuller (DF) *t*-statistics. The estimation is intended to identify the time period where the explosive property of the bubble component becomes dominant in the price process. The test is applied sequentially on different subsamples. The first subsample contains observations from the initial sample and is then extended forward until all observations of the complete sample are included. The beginning of the bubble is estimated as the first date when the DF *t*-statistic is greater than its corresponding critical value of the right-sided unit root test. The end of the speculative bubble will be determined as the first period when the DF t-statistic is below the aforementioned critical value.

Formally, Phillips *et al.* (2011, 2012) suggest calculating a sequence of DF tests. Let $\hat{\rho}_\tau$ denote the OLS estimator of ρ and $\hat{\sigma}_{\rho,\tau}$ the usual estimator for the standard deviation of $\hat{\rho}_\tau$ using the subsample $\{y_1,\ldots y_{[\tau T]}\}$. The forward recursive DF test of H_0 against H_1 is given by

$$\sup DF(r_0) = \sup_{r_0 \le \tau \le 1} DF_\tau \tag{6}$$

where $DF_\tau = \frac{\hat{\rho}_t - 1}{\hat{\sigma}\rho_t}$. Note that the DF statistic is computed for the asymmetric interval $[r_0,1]$. In applications, r_0 will be set to start with a sample fraction of reasonable size. The limiting distribution is

$$\sup_{r_0 \le \tau \le 1} DF_\tau \xrightarrow{D} \sup_{r_0 \le \tau \le 1} \frac{\int_0^\tau W dW}{\int_0^\tau W^2} \tag{7}$$

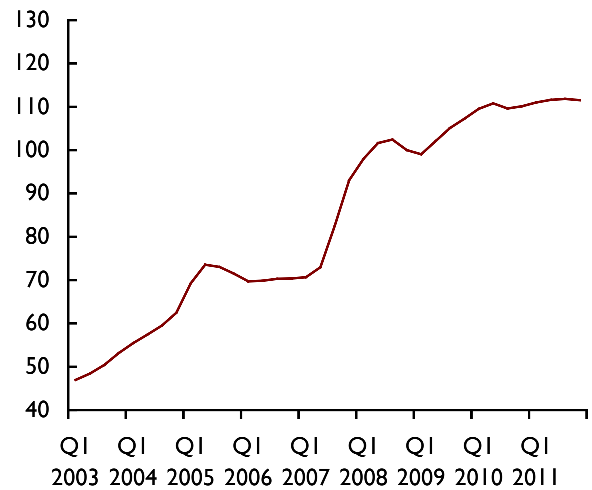
where '$\xrightarrow{D}$' denotes convergence in distribution and W is a standard Wiener process.

Analogously, the augmented supADF (SADF) test can be derived. In addition, Phillips *et al.* (2012) have suggested employing the 'generalised' supADF (GSADF) test as a dating mechanism. The GSADF diagnostic is also based on the idea of sequential right-tailed *ADF* tests, but the diagnostic extends the sample sequence to a more flexible range. Instead of fixing the starting point of the sample, the GSADF test changes the starting point and ending point of the sample over a feasible range of windows. Phillips *et al.* (2012) demonstrate that the moving sample GSADF diagnostic outperforms the SADF test based on an expanding sample size in detecting explosive behaviour in multiple bubble episodes and seldom gives false alarms, even in relatively modest sample sizes. The reason is that the GSADF test covers more subsamples of the data. In the next section of the paper we shall apply these two bubble dating algorithms to locate periodic explosive sub-periods.[9] They also show that the diagnostics perform accurately even with relatively small sample sizes. This gives us confidence in the potential applicability of the proposed testing strategy to Chinese house price data under real-time conditions, as shown below.

3. Data and estimation results

Prior to the econometric analysis, we briefly describe the data set. Our data set for mainland China covers nationwide nominal house prices (H_t) and the price-to-rent ratio (H_t/R_t) over the period 2003Q1–2011Q4. This period coincides with China's peak phase of urbanisation and the private housing market boom.[10]

Figure 2. Nationwide Chinese house price cycles, 2003Q1–2011Q4, seasonally adjusted index 2008Q4=100

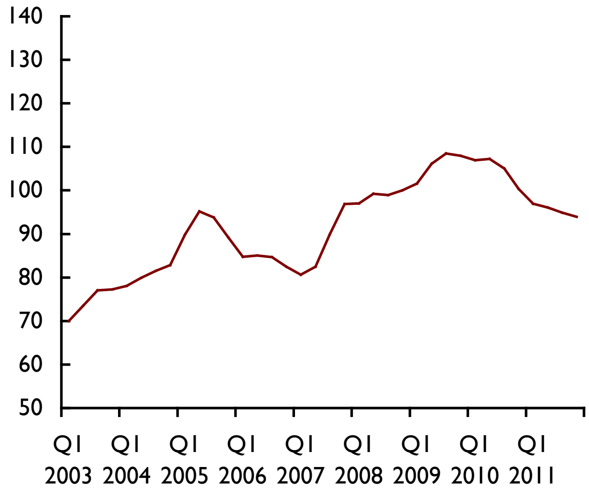


Source: Igan and Loungani (2012).

Figure 2 documents the magnitude of the nationwide surge in Chinese house prices. At first glance, the plot of the time series appears to justify the expression 'speculative housing bubble'. Chinese house prices rose rapidly until 2005. They accelerated again sharply in 2008, fuelled by the fiscal stimulus package, low interest rates and massive credit expansion.[11] Chinese house prices soon regained a steep upward trend until mid-2010 when, against the risk of a speculative bubble in the housing market, the Chinese government announced a number of measures to cool the market. The campaign intensified in 2011. The measures included (i) increasing downpayments for first-time buyers' mortgages from 20 per cent to 30 per cent, and for second homes from 50 per cent to 60 per cent; (ii) a total ban on mortgages for third home purchases; (iii) introduction of new restraints on house purchases by non-locals; (iv) introduction of new property taxes in Shanghai and Chongqing: between 0.4 per cent and 0.6 per cent in Shanghai, and between 0.5 per cent and 1.2 per cent on luxury homes in Chongqing; (v) elimination of mortgage discounts for first-time home buyers; and (vi) raising of the benchmark interest rate to 6.56 per cent in July 2011. Subsequently, the pace of house price increases began to slow.

In order to identify speculative house price bubbles, the fundamental part of house prices has to be separated from the speculative part. There are various ways to estimate

Figure 3. Nationwide Chinese price-to-rent ratio, 2003Q1–2011Q4, seasonally adjusted index 2008Q4=100



Source: Igan and Loungani (2012).

the fundamental value of house prices. The asset pricing equation (2) suggests looking at the Chinese price-to-rent ratio as a yardstick, i.e. house price changes should be in line with rent changes, given constant interest rates. A corollary of this is that the price-to-rent ratio (H_t/R_t) should be constant over time in the absence of a speculative bubble. When house prices are low relative to rent, future increases in house prices are likely to be high. Thus, the price-to-rent ratio (H_t/R_t) can be viewed as "an indicator of valuation in the housing market" (Gallin, 2008, p. 635).[12]

Figure 3 shows the Chinese nationwide house price-to-rent ratio from 2003Q1 to 2011Q4. A mere look at the plot of this time series indicates that the price-to-rent ratio increased until 2010 and has decreased since. It should be noted that a rising price-to-rent ratio is only a necessary but not a sufficient condition for speculative misalignment from fundaments. Below we therefore test for significant overvaluation using the recursive testing procedure suggested by Phillips *et al.* (2012).

Identifying speculative bubbles is no easy task even in mature markets with long time series. In China, time series for house prices and in particular for the price-to-rent ratio are short. Phillips *et al.* (2012) have demonstrated that higher-frequency data significantly improve the finite sample power of recursive tests. Taking this into account, we have first generated monthly price-to-rent ratios using the proportional Denton (1971) method.[13] Next we employ the recursive right-tailed *ADF* statistics

Figure 4. Recursive calculation of the SADF test for r_0=0.3

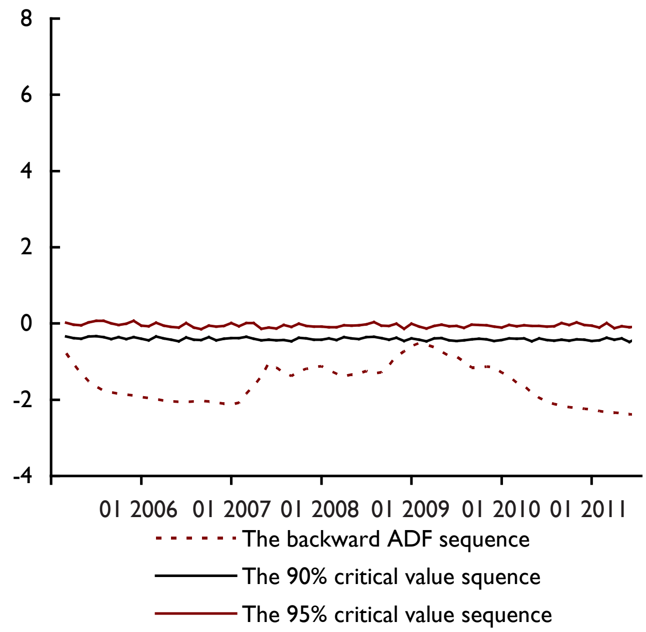


Figure 5. Recursive calculation of the SADF test for r_0=0.4

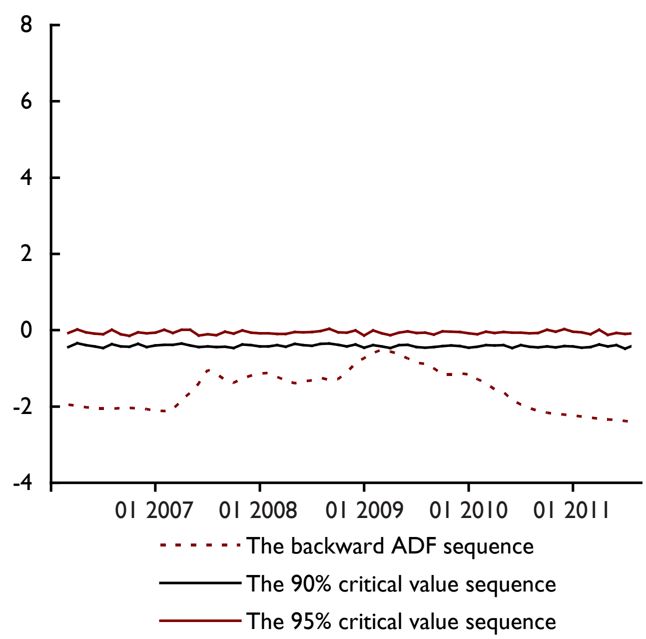


Figure 6. Recursive calculation of the GSADF test for r_0=0.3

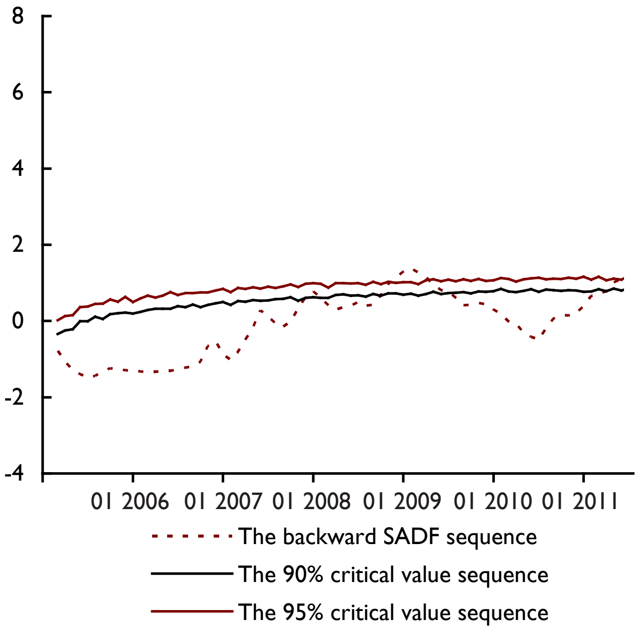
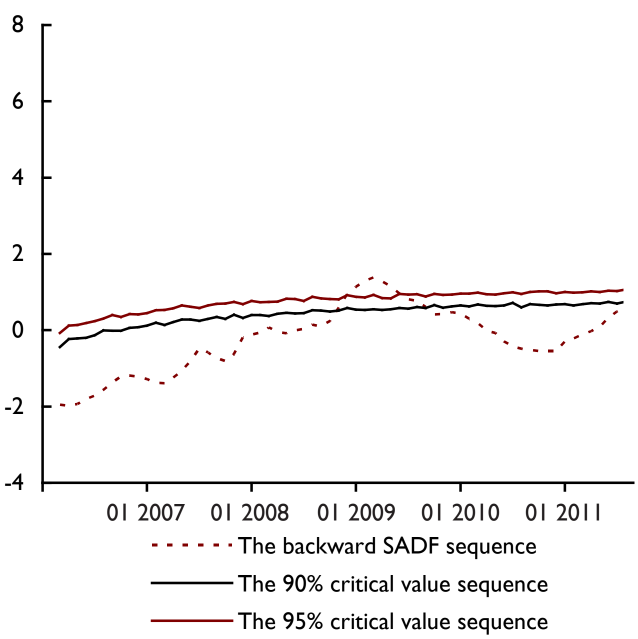


Figure 7. Recursive calculation of the GSADF test for r_0=0.4

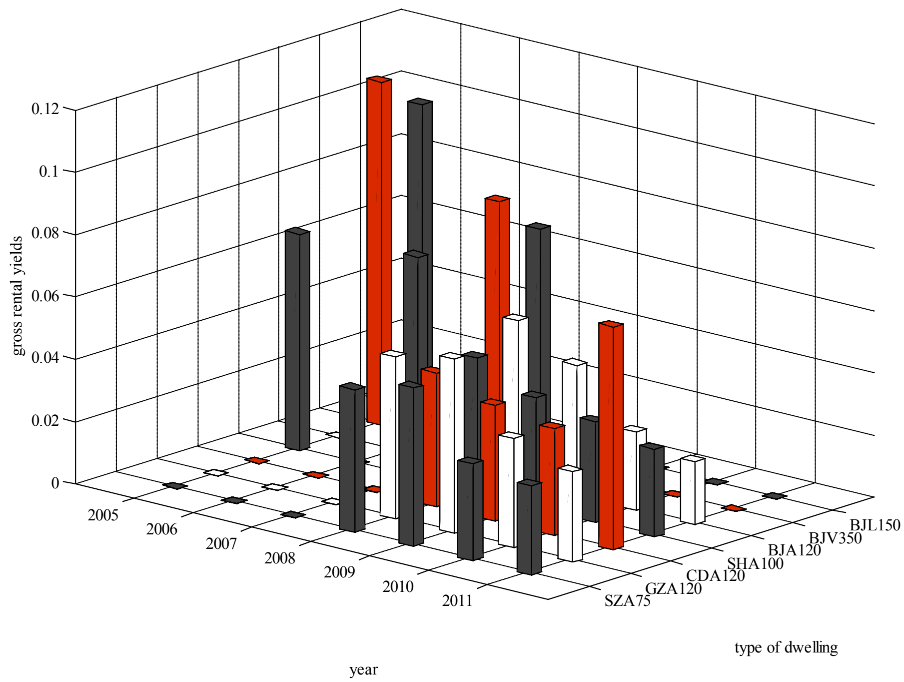


to scrutinise for speculative bubbles in Chinese housing markets. For the *SADF* and *GSADF* tests, r_0 has to be chosen. If the number of observations is small, r_0 needs to be large enough to ensure there are enough observations for initial estimation. In our application, we choose r_0 = 0.3 and r_0 = 0.4, respectively.[14] The finite sample critical values are obtained via Monte Carlo simulations with 2,000 iterations. Observations above the respective critical values signal a warning to policymakers as when to start to 'lean against the wind' in order to restrain undesirable and unsustainable trends. All computations were generated using a programme in MATLAB.

Figures 4–7 provide an overall picture of Chinese house price valuation over the sample period under consideration. The dotted red lines in figures 4–7 show the recursively calculated univariate backward *ADF* and *SADF* statistic sequences, respectively. The black and red solid lines show the associated critical values. The graphs lend themselves to several conclusions. Firstly, the *GSADF* tests flag a statistically significant periodic misalignment in 2009–10. The periodic bubble period is short but exceeds the minimum time span log(n) suggested by Phillips *et a*l. (2012), where n is the sample size. It is noticeable that this confirms the preliminary results from glancing at figure 2. Secondly, as expected, the *SADF* diagnostic turns out to be more conservative in detecting exploding sub-periods. Thirdly, except for that, sub-period house prices were not overly and significantly disconnected from fundamentals. Thus, the administrative measures to dampen house price inflation appear to be having the desired effect. Finally, it is an encouraging sign that the testing procedure is able to give warnings even when the speculative bubble period is short-lived.

It is worth emphasising that price-to-rent indices have obvious disadvantages and shortcomings. Certainly, it is true that the indices provide information about the dynamics of the price-to-rent ratio over time. However, they do not provide any information about the actual level of the price-to-rent ratio. Therefore, we additionally provide information about gross rental yields (R_t/H_t) across major Chinese cities and various market segments from 2005 to 2011. The gross rental yield is the rent over the course of one year, expressed as a percentage of the purchase price of the property. While this supplementary shorthand measure may not resolve all our interpretation difficulties, it may give us a better sense of where we are currently going in China. The disaggregated data also provide an important comparison with the nationwide trend and therefore round up the image.

Figure 8. Gross rental yields across major Chinese cities and market segments, 2005–11

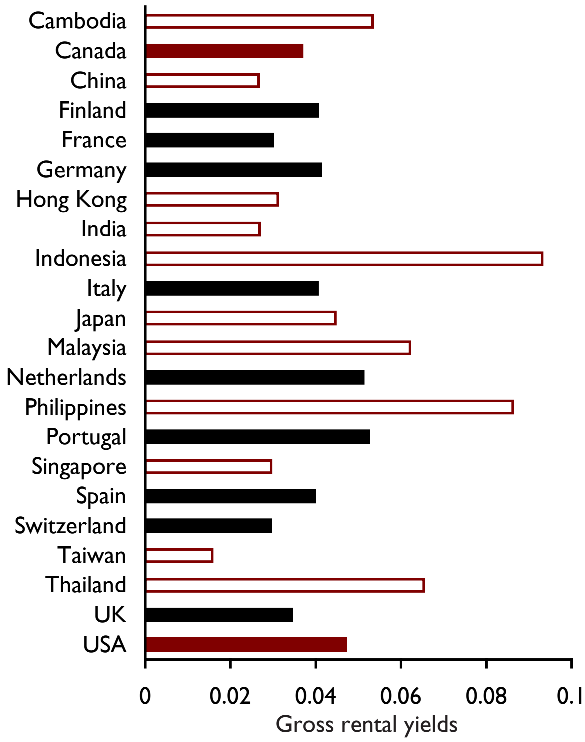


Source: *Global Property Guide Research* (http://www.globalpropertyguide.com).
Notes: The yield is defined as the gross annual rental income, expressed as a percentage of property purchase price. The yields are constructed by compiling and processing transaction-level data from a variety of market sources. Only resale apartments and houses are researched. Yields for newly built properties are not included. No data is available for the year 2006. BJL150: Beijing luxury apartments 150 m^2; BJV350: Beijing villas 350 m^2; BJA120: Beijing apartments 120 m^2; SHA100: Shanghai apartments 100 m^2; CDA120: Chengdu apartments 120 m^2; GZA120: Guangzhou apartments 120 m^2; SZA75: Shenzhen apartments 75 m^2.

Gross rental yields across cities have been quite heterogeneous, as is clear from the cross-city, cross-time data in figure 8.[15] Although yields are correlated across most cities, aggregate Chinese house price changes clearly mask sharp regional differences. In 2005, rental yields in all categories of Beijing property were above 9 per cent. In Shanghai, returns were lower than in Beijing, with gross rental yields ranging from 5.4 per cent to 7 per cent. In 2011, rental yields in Beijing were below 3 per cent, and in Shanghai below 3.5 per cent. The data send a clear message – during the period of study, property prices have been climbing steeply, while rents have not moved much.[16] The degree of price misalignment is particularly pronounced in the mass markets of a number of coastal cities like Beijing and Shanghai. The substantial heterogeneity in house prices and the house price-to-income ratio dynamics highlight the complexity of an appropriate policy response in situations where asset prices are not rising uniformly. The heterogeneity and idiosyncratic pattern may reflect the fact that city-level house prices include significant local variables. This is particularly true for so-called 'superstar cities', where local circumstances can result in a prolonged period of higher than average growth in house prices (see Himmelberg *et al*., 2005).

While there is no sign of significant nationwide overvaluation in figures 4–7 after introduction of the cooling measures in 2010–11, there are still signs that house prices in some coastal cities and market segments are disconnected from fundamentals. Overall, these results are consistent with the extant, rather scant empirical literature on the dynamics of Chinese city-level house prices. For example, Ahuja et al. (2010) have also concluded that, over the period 2000Q1–2009Q4, Chinese house prices were not significantly higher than would be justified by underlying fundamentals, while signs of overvaluation were present in some cities' mass-market and luxury segments. The balance of nationwide econometric and cross-city descriptive evidence points towards the conclusion that the period of market overheating cooled off in 2011 but remains at a high

Figure 9. Gross rental yields in 2011: an international comparison



Source: *Global Property Guide Research*.
Notes: The gross annual rental income for a 100–150m^2 apartment in a premier city location, expressed as a percentage of the purchase price. Only high-quality resale apartments and houses are included. The yields are constructed by compiling and processing transaction-level data from a variety of market sources.

level. But in light of the government´s corrective action, it is inconceivable that they will rise as fast as 2011.

Another natural temptation is to compare the gross rental yields in China to those of other countries. This can provide a more condensed picture of the Chinese housing market. Last, but not least, we therefore provide the cross-country gross rental yields for 2011 (figure 9). This may allow for a comprehensive picture and balanced assessment of the Chinese housing market.

Several descriptive results are obtained. The first thing to note is the considerable variation across countries. Yields below 3 per cent are usually considered to be a sign of an overvalued market, leading early warning signals to flash red. By international comparison, China had rather low rental yields in 2011. The same is true for Taiwan, where yields have reached unsustainably low levels. After three years of unbroken house price rises, gross rental yields are unusually low, at an average of 2.8 per cent. One trigger for rising Taiwanese property prices is speculation about future investment by mainland Chinese. At the other end of the scale are Indonesia and the Philippines. Despite high growth rates in recent years, the housing market in Indonesia has faltered. Some of the major factors that have made a decisive contribution to this development include high mortgage rates, high tax rates and restrictions on foreign ownership. Similarly, housing markets in the Philippines were held back by several obstacles, including high taxation, fake land titles and high transaction costs. Superficially, yields on property therefore look attractive. Property in the United States is now relatively inexpensive from an international perspective.[17] All in all, the evidence in figure 9 provides a more nuanced understanding of Chinese house price developments. The evidence also indicates that in several countries the ongoing housing downturn still has further to go.

4. Wrapping up: signalling Chinese house price bubbles with time series methods

Few areas have received the same amount of focus and scrutiny over the past couple of years as house prices. The collapse of the financial markets and the need for additional regulatory and macroprudential policies has overturned previously accepted wisdom about risk and self-regulation in a market economy. Monetary policymakers have two different strategies to deal with a possible asset price bubble: the 'conventional' strategy and an 'activist' strategy. A central bank following the conventional strategy does not attempt to use monetary policy to influence the speculative component of asset prices, on the assumption that it has little ability to do so and that any attempt will only result in suboptimal economic performance in the medium term. Instead, the central bank responds to asset price movements, whether driven by fundamentals or not, only to the degree that those movements have implications for future output and inflation. In contrast, an activist strategy takes extra action by tightening policy beyond what the conventional strategy would suggest. This requires that policymakers can identify emerging bubbles in real time with reasonable confidence.

In this paper we have employed the newly developed testing strategy pioneered by Phillips and Yu (2011) and Phillips *et al.* (2012) aimed at identifying explosive bubbles in real time. We believe that this new approach to identifying growing bubbles and their collapse will make a significant impact on the construction of early warning systems, and we have therefore used the method as a signpost for periodically collapsing Chinese housing bubbles.[18] The results flash a heightened probability of an emerging Chinese house price bubble in 2009–10. During other years, the Chinese housing market does not display significant signs of unsustainable overvaluation. Another contribution of this paper lies in its comprehensive approach. To measure and benchmark Chinese house prices, the paper presents and analyses several datasets and measures of house price overvaluation. In focusing on various measures, the paper provides empirical shape and substance to the multifaceted concept of house price bubbles. One conclusion is that the considerable house price variation across Chinese cities requires differentiated local policy responses to trigger price corrections.

NOTES

1 For the impact of the monetary policy stance on the banking sector, see Altunbas *et al.* (2010). Chinese banks are now much more exposed to the property market than they were in the early 2000s, with real estate loans now accounting for about 20 per cent of total loans.

2 There has been a considerable debate among economists on the evolution of Chinese property prices and the empirical evidence remains at best ambiguous, varying with the selected empirical methodology. For example, Wu *et al.* (2010) have argued that a real estate bubble has emerged in recent years, spurred by the fiscal stimulus after the great recession. In contrast, Ren *et al.* (2012) have found no evidence to support the existence of speculative price bubbles in China. The fragility of the results likely stems from the inherent difficulty of identifying bubbles. A review of traditional econometric tests for asset price bubbles is available in Gürkaynak (2008) and Mikhed and Zemcik (2009).

3 See Ciarlone (2011) and Chen *et al.* (2011).

4 Martin and Ventura (2011) have recently presented a rational bubble model with investor sentiment shocks and imperfect financial markets. In their framework, the size of the bubble depends upon investor sentiment. On the other hand, financial frictions allow efficient and inefficient investments to coexist. Introducing financial frictions can thus explain why bubbles can temporarily lead to expansions in the capital stock and in GDP although a bubble is nothing but a pyramid scheme. This happens when the bubble raises the net worth of efficient investors, allowing them to increase investment.

5 Much of the modelling appeal is clarity, not realism. Because of the complexity of the fundamental $E_t(R_{t+j})$ and the lack of agreement about its key ingredients, the frameworks stop short of being a fully specified model.

6 One implication of rational house price bubbles is that they cannot be negative, i.e. $B_t < 0$. This is because the growing bubble term falls at a faster rate than house prices increase and thus a negative bubble ultimately ends in a zero house price. Rational agents realise that and know that the bubble must eventually burst. By backward induction, the bubble must then burst immediately, as no investor will pay the ‘bubble premium’ in the earlier periods.

7 The diagnostic for multiple speculative bubbles modifies a previous method for identifying one-off bubbles suggested in Phillips *et al.* (2011). A different class of tests for identifying periodically collapsing bubbles based on Markov-switching models has been explored in Funke *et al.* (1994) and Schaller and van Norden (2002), among others.

8 Busetti and Taylor (2004), Kim *et al.* (2002) and Leybourne *et al.* (2006) have shown that traditional unit root tests have low power in the case of gradually changing persistence and/or the existence of persistence breaks.

9 Skipping, for the sake of brevity, further technical details, the interested reader is referred to the above-mentioned papers introducing the right-tailed unit root testing strategy. A technical supplement providing a complete set of mathematical derivations of the limit theory underlying the unit root tests is available at http://sites.google.com/site/shupingshi/TN_GSADFtest.pdf?attredirects=0&d=1.

10 Reliable Chinese house price indices are hard to come by. The official 70 cities house price index published by the Chinese National Bureau of Statistics (NBS) is mistrusted and has been widely criticised for underestimating house price inflation. Given the suspicion and criticism, the NBS suspended publication of the housing data in February 2011. See http://online.wsj.com/article/SB10001424052748703373404576147792827651116.html for more details. Therefore, we employ the house price and price-to-rent data in Igan and Loungani (2012). They pay particular attention to data coverage and computation leading to discrepancies among different data sources. Longer time series of Chinese house price data may not improve the results since China has experienced a regime shift in the housing market in the late 1990s. Indeed, until the late-1990s, the allocation of apartment units to most urban households was determined by employers, primarily government institutions and state-owned enterprises.

11 On the surface, the Chinese house price increases seem to share many of the features of the Japanese property price bubble in the 1980s. This does not in any way imply that a Chinese bubble, were it to exist, would collapse like the Japanese one. China is still years behind pre-bubble Japan and has abundant room for driving its maturing export-driven economy into one more geared towards consumption. Furthermore, Chinese banks are still majority-owned by the state and therefore policy restraints aimed at deflating bubble periods would be more effective in China than in Japan. Therefore, China is hardly a Japan in the making.

12 Also see Case and Shiller (2003) and Himmelberg *et al.* (2005).

13 The Denton procedure is a standard tool for compiling higher-frequency data. The technique generates monthly series which are both consistent with the quarterly data (i.e. the average of the monthly indices is equal to the quarterly indices) and as close as possible to the movements of a monthly reference series. The monthly house price index of the Chinese National Bureau of Statistics is used as the indicator series. The interpolation problem is nonlinear and can be solved using standard optimisation procedures, as discussed by Bloem *et al.* (2001) and Denton (1971).

14 In robustness checks, we used several r_0s and find that the results are not particularly sensitive to the precise choice. The qualitative results also remain unchanged when the logged price-to-rent ratio is used for the diagnostic tests.

15 At the city level, rental and price information for different market segments is even more limited and only selected annual data are available. Therefore, formal bubble tests cannot be employed.

16 Chengdu is an exception. For reasons unknown so far, yields appear healthy there. On the other hand, this may also represent just a statistical artifact.

17 However, house prices in the US were pushed up by consumers who borrowed heavily, while China´s house prices were pushed up by high savings and a lack of alternative investment. On the other hand, this may not resolve the problem in the long run since this is at least partially the result of distorted financial markets in China. So any liberalisation of financial markets may render high house prices unsustainable.

18 It is paramount to remember that we rely on limited observations. While the test results yield reasonable results, more work is needed to confirm our findings. Data availability limits the number of observations available for a more definitive evaluation. Further research with longer time series is therefore desirable to corroborate our assessment.

REFERENCES

Ahuja, A., Cheung, L., Han, G., Porter, N. and Zhang, W. (2010), 'Are house prices rising too fast in China?', IMF Working Paper No. WP/10/274, Washington, IMF.

Altunbas, Y., Gambacorta, L. and Marques-Ibanez, D. (2010), 'Does monetary policy affect bank risk-taking?', ECB Working Paper No. 1166, Frankfurt.

Bloem, A., Dippelsman, R. and Mæhle, N. (2001), *Quarterly National Accounts Manual: Concepts, Data Sources, and Compilation*. Washington, International Monetary Fund.

Busetti, F. and Taylor, A.M.R. (2004), 'Tests of stationarity against a change in persistence', *Journal of Econometrics*, 123, pp. 33–66.

Case, K.E. and Shiller, R.J. (2003), 'Is there a bubble in the housing market?', *Brookings Papers on Economic Activity*, 34, pp. 299–362.

Ciarlone, A. (2011), 'Housing wealth effect in emerging economies', *Emerging Markets Review*, 12, pp. 399–417.

Chen, Y.-F., Funke, M. and Mehrotra, A. (2011), 'What drives urban consumption in mainland China? The role of property price dynamics', Hong Kong Institute for Monetary Research, HKIMR Working Paper No. 15/2011, Hong Kong, Hong Kong Monetary Authority.

Denton, F.T. (1971), 'Adjustment of monthly or quarterly series to annual totals: an approach based on quadratic minimization', *Journal of the American Statistical Association*, 66, pp. 99–102.

Evans, G. (1991), 'Pitfalls in testing for explosive bubbles in asset prices', *American Economic Review*, 81, pp. 922–30.

Funke, M., Hall, S. and Sola, M. (1994), 'Rational bubbles during Poland's hyperinflation: implications and empirical evidence', *European Economic Review*, 38, pp. 1257–76.

Gallin, J. (2008), 'The long-run relationship between house prices and rent', *Real Estate Economics*, 36, pp. 635–58.

Gürkaynak, R.S. (2008), 'Econometric tests of asset price bubbles: taking stock', *Journal of Economic Surveys*, 22, pp. 166–86.

Himmelberg C., Mayer C. and Sinai, T. (2005), 'Assessing high house prices: bubbles, fundamentals and misperceptions', *Journal of Economic Perspectives*, 19, pp. 67–92.

Igan, D. and Loungani, P. (2012), 'Global housing cycles', IMF Working Paper No. WP/12/217, Washington.

Kim, T.-H., Leybourne, S. and Newbold, P. (2002), 'Unit root tests with a break in innovation variance', *Journal of Econometrics*, 109, pp. 365–87.

Kocherlakota, N.R. and Shim, I. (2007), 'Forbearance and prompt correction action', *Journal of Money, Credit and Banking*, 39, pp. 1107–29.

Leybourne, S.J., Kim, T.H. and Taylor, A.M.R. (2006), 'Regression-based tests for a change in persistence', *Oxford Bulletin of Economics and Statistics*, 68, pp. 595–621.

Martin, A. and Ventura, J. (2011), 'Theoretical notes on bubbles and the current crisis', *IMF Economic Review*, 59, pp. 6–40.

Mikhed V. and Zemcik, P. (2009), 'Do house prices reflect fundamentals? Aggregate and panel data evidence', *Journal of Housing Economics*, 18, pp. 140–9.

Phillips, P.C.B., Shi, S. and Yu, J. (2012), 'Testing for multiple bubbles', Cowles Foundation Discussion Paper No. 1843, Yale.

Phillips, P.C.B., Wu, Y. and Yu, J. (2011), 'Explosive behavior in the 1990s NASDAQ: when did exuberance escalate asset values?' ,*International Economic Review*, 52, pp. 201–26.

Phillips, P.C.B. and Yu, J. (2011), 'Dating the timeline of financial bubbles during the subprime crisis', *Quantitative Economics*, 2, pp. 455–91.

Ren, Y., Xiong, C. and Yuan, Y. (2012), 'House price bubbles in China', *China Economic Review*, 23, pp. 786–800.

Schaller, H. and van Norden, S. (2002), 'Fads or bubbles?', *Empirical Economics*, 27, pp. 335–62.

Wu J., Gyourko, J. and Deng, Y. (2010), 'Evaluating conditions in major Chinese housing markets', NBER Working Paper No. 16189, Cambridge (Mass.).