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DID BUBBLES MIGRATE FROM THE STOCK TO THE HOUSING MARKET IN CHINA BETWEEN 2005 AND 2010?

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Abstract. The speculative nature of both stock and housing markets in China has attracted the attention of observers. However, while stock market data are easily available, the low frequency and low quality of publicly available housing price data hampers the study of the relationship between the two markets. We use original hedonic weekly resale housing prices of a major Chinese housing market and study them in conjunction with Shanghai's stock market index in the second half of the 2000s. The use of the Phillips et al. (2015 a, b) recursive explosive-root test enables us to detect and date speculative episodes in both markets. We then implement the Greenaway-McGrevy and Phillips (2016) methodology to detect the presence of migration between the two types of bubbles. We detect significant migration from the stock to the housing market bubble in 2009 and a temporary spillover in 2007.

Keywords
Explosive root, bubble, migration, stock market, housing market, China

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1. INTRODUCTION

It is often argued that “Real estate markets are even more prone to bubbles than stock markets because these markets are dominated by unsophisticated households, short-sale constraints frequently bind, and often arbitrage is prohibitively costly” (Scherbina et al. 2014, p. 597). China’s markets provide a unique opportunity to test this hypothesis since its stock market is characterized by a dominance of inexperienced individual investors, binding short-sales constraints (lifted only in 2011), a small asset float (before the split-share reform of 2005-2006, see Beltratti et al., 2009) and heavy share turnover despite high transaction costs. Bailey et al. (2009) document that (the dominant) individual investors in China’s stock market are less informed and more subject to behavioral biases than institutional investors. In a similar way, individual investors dominate the residential resale housing market in China. Another major similarity between the real estate and stock markets in China is that the link with the prospective income on the respective market is tenuous. Indeed for many years Chinese listed firms hardly distributed any dividend, and the Chinese rental market for housing is very underdeveloped, in such a way that many investors in the housing market adopt a buy-and-hold strategy in which a lot of housing units are reported to be vacant. All these factors make very likely the presence of active speculative behavior in these two Chinese asset markets.

Detecting bubbles in asset markets has been an ongoing challenge, which empirical methods have for long been unable to meet. Such a challenge has been magnified in China due to the low quality of some asset price series. Giglio, Maggiori and Stroebel (2016) proposed a model-free test for no-bubble condition based on UK and Singapore housing markets data. Recently-developed recursive explosive-root (vs. random walk) tests (Phillips, Shi and Yu, 2015a, b, PSY) enable researchers to detect the rise and collapse of bubbles on a given asset market.[2] It is shown by Phillips, Shi and Yu (2015a) that the PSY method out-performs the recursive method of Phillips, Wu and Yu (2011) and the CUSUM strategy of Homm and Breitung (2012). In addition the former is much less computationally intensive and more effective than the Markov-switching ADF test of Hall et al. (1999). We apply the PSY method in a first step to the detection and dating of bubbles in China both in the stock

[2] The PSY procedure is based on the local explosive characteristic of bubbles (Diba and Grossman, 1988) and designed for positive bubbles. Diba and Grossman (1988) argues that given free disposal a negative rational-bubbles component cannot exist “because stockholders cannot rationally expect a stock price to decrease without bound and hence to become negative at a finite future date”.

and real estate markets. Most existing work using this or other methods (for surveys, see: Gurkaynak, 2008; Homm and Breitung, 2012; and Breitung, 2014) would only focus on one market in isolation without being able to examine the sequence of bubbles between different markets. However, in as much as other diversification opportunities for Chinese individual investors are very limited, it is expected that speculative pressure may move between these two markets. The recently developed methodology by Greenaway-McGrevy and Phillips (2016) enables us to examine in a second step for China the migration of bubbles from the stock market to a first-tier city real estate market (or vice versa). In order both to conduct a high-frequency study and to remedy the bias in official (low frequency) housing prices in China, we use an original weekly hedonic resale real estate price series of a major housing market in China, covering a sample starting before, and ending after, the Global Financial Crisis: from 2005 to 2010. Such a sample starts after a major step in urban housing reform in China (Yang and Chen, Chapter 2, 2014), and ends at the time of a major reform in the stock market associated with the introduction of stock index futures. Such reforms opened up diversification opportunities, out of the cash stock market, into the real estate market for the former and into the futures market for the latter.

A burgeoning literature has attempted to estimate the relationships between the returns or the volatility of China's government released real estate prices and stock prices (see section 2 below). However such work (often relying on vector autoregressive systems) typically excludes the presence of explosive behavior and simply models the first difference of prices. There is no existing literature on the relationship between stock and real estate bubbles in China.

The paper contributes to the existing literature by detecting bubbles both for high-frequency original hedonic resale housing market data for a first-tier city (Beijing) in China and the Shanghai stock market. We use for this purpose recently-developed recursive rolling explosive versus unit-root tests allowing for multiple bubbles. Near-explosive behaviour is detected for two non-overlapping main episodes for each of these markets. The use of bubble migration tests enables us to provide evidence that the "bubble" in the real estate market seems to have followed the stock bubble in 2009-10, with no reverse spillover.

The rest of the present paper will be structured as follows. The next section will review existing literature. The explosive-root detection, and the bubble migration methodologies, as well as the construction of the high-frequency hedonic resale housing price data used in the present paper will be introduced in section three. Section four will discuss the results of the application of the explosive-root detection and bubble-migration frameworks to the stock index and housing prices and provide interpretations. Section five will offer some conclusions.

2. LITERATURE ON CHINA'S STOCK AND REAL ESTATE BUBBLES

Speculation is a major candidate to explain the breakdown of the link between asset prices and fundamentals. Scheinkman and Xiong (2003) and Hong, Scheinkman and Xiong (2006) show that, in the presence of both heterogeneous beliefs and short sale constraints, investors may be induced to overpay for an asset if they expect to sell it to another investor who will be willing to pay even more in the future. Accordingly, asset prices may contain a sizeable speculative component. For surveys of the theory of asset market bubbles, see Scherbina and Schlusche (2014) and for housing market bubbles, Glaser and Nathanson (2014), and Scherbina, and Schlusche (2012). In China, the dominance of unsophisticated households, binding short-sale constraints, and often costly arbitrage are common to the stock (during our sample) and residential housing markets. Accordingly, it is likely that such markets would be characterized by their speculative nature. Recently Chen et al. (2014) thus proposed to model self-fulfilling housing bubbles, in the Chinese context, based on speculative arbitrage with anticipated future low return on capital and high expected future demand for housing.

Existing work on China's stock market provides us with evidence in support of its speculative character (Mei et al, 2009). However, a number of deep reforms, implemented in the last decade, may have lessened the speculative character of such a market. First, an expanding number of listed firms in China are increasingly representative of an economy with dominant non-state-owned firms in industrial activity, restructured state-owned firms, as well as reforms associated with entry into the World Trade Organization (WTO) in December 2001. Second, the split-share reform initiated in May 2005 and completed late 2006 (Beltrati et al., 2009), has reduced the sharp hiatus between the float and the capitalization of the stock market and its links with foreign markets have been gradually enhanced via the Qualified Foreign Institutional Investors (QFII) and the Qualified Domestic Institutional Investors' scheme (QDII) schemes. All these deep changes imply that the behavior of the Chinese stock market may have become closer to that of its peers in other large countries[3]. It is difficult to

[3] Within this perspective de Bondt et al. (2010) consider the influence of conventional fundamentals in the spirit of Shiller's (1981) present value model, including corporate earnings, a risk-free interest rate, and a proxy for the equity risk premium. They use their estimated long run stock price misalignments to date booms and

argue that parallel reforms in the real estate market could have contributed to lessen its speculative character.

It is well documented that developments in the real estate markets may not be independent from what happens in stock markets (Cocco, 2004; Campbell and Cocco, 2015). Indeed in as much as the portfolio of investors is composed of these assets, substitution between such investments may lead to a negative correlation of their returns (Shiller, 2014), while wealth effects may lead to positive correlations (Gyourko and Keim, 1992). Case, Quigley and Shiller (2005, 2013) in their highly influential papers found that households increase their spending when house prices rise, but they found no significant decrease in consumption when house prices fall. A potential collateral channel (Chaney, Sraer, and Thesmar, D., (2012); Kiyotaki and Moore, 1997; and within an housing-augmented CCAPM: Kwan and Dong (2013); Kwan, Leung and Dong, (2015)) could be generating a link between the real estate and stock markets. If a firm invests a large sum of money in the real estate market of a given city, this may not simply have an effect on the housing market, but also affect how corporations evaluate the real estate they already hold, and hence could affect the stock market price. Such collateral channel effects have been shown to matter in the US and Japan, but in the case of China Wu, Gyourko and Deng (2015), working with data on land values in 35 major Chinese markets and a panel of firms outside the real estate industry, estimate investment equations that provide no support for such a channel (see also Deng, Morck, Wu and Yeung, 2015). Their analysis further shows that debt in China is not characterized by the sort of frictions which were shown to lead to a collateral channel effect in other countries. The main reason is that in China borrowers who are financially constrained seem to be able to commit in a credible way to repay their debt. An alternative channel motivating the link between the real estate and stock markets, when controlling for fundamentals, may rely purely on an expectation formation effect. Among others, Chen, Cheng and Chu (2015) provide an illustration of the expectation formation effect in an asset market model.

Existing work on economies other than China has focused on low frequency relationships between stock returns and changes in real estate prices, conditioning on macroeconomic and monetary policy variables. Quan and Titman (1999), using a pooled sample of 17 countries, detect a substantial contemporaneous correlation between stock

busts, and show that equity market reforms and excess liquidity drive these stock price misalignments. They find evidence of stable relationships, though with episodes of sharp misalignments.

returns and real estate prices movements, and argue that this correlation may actually be driven by other factors than the usual current fundamentals. However, their study, which only uses annual data, is unable to determine whether what they detect as a contemporaneous correlation may not actually correspond to higher-frequency lags between movements in stock and real estate prices. Chang, Chen and Leung (2012), examine for Singapore the link between real estate prices and a vector of macro and international variables, including the domestic stock market, using quarterly data over two and a half decades, with regime switching techniques. Chang, Chen and Leung (2011), over three decades with quarterly data, examine the relative influence of monetary policy and macroeconomic variables on stock and REIT returns in the US. Such work is thus able to deal with misalignment of real estate and stock prices, but does not address the detection of bubbles with high frequency data and the speculative (lead-lag) link between these two markets.

In the case of China, Huang and Ge (2009) document only weak correlation between stock and real estate markets, though on a very short (monthly) sample (26 months from April 2006). With a longer sample (2003-2012) but a lower frequency (quarterly) and with a regional panel, Yuan et al. (2014) find opposite (positive) short-run and (negative) long-run effects of stock prices on housing prices. Guo and Huang (2010) document a positive impact of excess financial wealth on property prices as well as price volatility. By contrast Xu and Chen (2012) do not find any significance for such an impact when controlling for the effect of money supply growth.

While abundant empirical work has examined for China the relationship between prices and fundamentals, either for the stock or the real estate market, much more limited research has dealt with bubble detection, and hardly any attention has been granted to the study of the possible links between bubbles in the two markets.

The work which has attempted to detect bubbles in China's stock market reports only partially overlapping, and quite contrasted, results. Thus Jiang et al. (2010) use a faster-than-exponential (power law with finite-time singularity) increase in stock prices as the main diagnostic of bubbles over the May 2005 to August 2009 sample, and detect two bubbles from mid-2005 to October 2007 and from November 2008 to August 2009. In contrast, Asako et al. (2013), over the 1999-2010 period, only detect significant bubbles in April-May and August-October 2007, and Chang et al. (2016), over 1995 to 2013, find very short-lived bubbles early and late 2007. Only few papers specifically conduct formal tests for the presence of bubbles in China's housing price data (such as Ren et al, 2012, with durationdependence tests; and Liu et al., 2016, with city data) and the use of (biased) publicly available data restrict them to low frequencies (monthly, or yearly). Hui and Yue's (2006), for monthly house prices data from 1997 to 2003, using Granger causality tests and generalized impulse-response analysis detect speculative bubbles for Shanghai house prices in 2003 but not for Beijing. Using similar econometric techniques and quarterly data between 1996 and 2007, Hui and Ng (2009), find some mild evidence of a bubble in Shenzhen house prices. Chen and Li (2011) detect some risk of speculative bubble in several regional housing markets, especially in the eastern area, in as much as the convergence rate of the housing price towards the long-term equilibrium price is relatively slow in such regions.

3. METHODOLOGY AND DATA

3.1. Methodology

A new time-varying regression methodology to analyze the bubble characteristics of various time series was proposed by Greenaway-McGrevy and Phillips (2016; GMP). They build in a first stage on a technique proposed in Phillips, Wu, and Yu (2011) and Phillips, Shi and Yu (2015a, b; PSY) who provide a technology for identifying bubble behaviour with consistent dating of their origination and collapse. The tests serve as an early warning diagnostic of bubble activity and a new procedure is introduced for testing bubble migration across markets. In a second stage, they thus use the results of the explosive-root detection to test for the migration mechanism among the variables. They show the applicability of their methodology to establish the dating and sequence cum migration of bubbles in the New Zealand real estate markets. We follow this two-stage approach in the present paper.

3.1.2. Speculative Bubbles Detection

The asset price P_t consists of a market fundamental (F_t) and a bubble component (B_t) such that

$$P_t = F_t + B_t$$

The bubble component B_t is a sub-martingale process (Diba and Grossman, 1988) such that

$$E_t\left(B_{t+1}\right) = \frac{1}{\rho} B_t \text{ with } \frac{1}{\rho} > 1. \quad (1)$$

where ρ is the discount factor. The bubble process is explosive with an autoregressive coefficient of $1/\rho$. In the absence of bubble, the degree of nonstationarity of the asset price is controlled by the character of the rent (dividend) series and unobservable factors embedded in the market fundamental component F_t, where the rent (dividend) series and the unobservable factors are assumed at most integrated of order one. Therefore, empirical evidence of explosive behaviour in the asset price ratios (prices adjusted respectively for rent and dividend) may be used to infer the existence of bubbles.

The PSY procedure aims to detect the local explosive dynamics of speculative bubbles. The testing algorithm is based on a right-tailed unit root test (Phillips et al., 2014) with a unit root (market fundamental) null and an explosive (bubble) alternative. The regression equation for the unit root test is

$$\Delta y_t = \alpha + \beta y_{t-1} + \sum_{i=1}^{K} \gamma_i \Delta y_{t-i} + \varepsilon_t, \qquad (2)$$

where y_t is the asset price at period t, K is the lag order (set to one in the application), and ε_t is the error term. The null hypothesis is $\beta = 0$ and the alternative is $\beta > 0$. The ADF statistic is defined as the t-ratio of the OLS estimate of β.

The PSY test requires conducting subsample regressions. The purpose is to take care of any potential structure break or regime switching within the sample period. Let r_1 and r_2 be the fractional starting and ending points of a subsample regression, with the corresponding ADF statistic denoted $ADF_{r_2}^{r_1}$. The algorithm calculates the ADF statistic repeatedly on a sequence of backward expanding samples. Suppose r is the observation of interest. The ending points of all samples are fixed on r and the starting point of the samples varies from the first observation to $r - r_0$, where r_0 is the minimum window size required to initiate a regression. For practical implementation, Phillips et al. (2015a) suggest setting r_0 according to the rule $r_0 = (0.01 + 1.8/\sqrt{T})$ to reduce the probability of size distortion. The corresponding ADF statistic sequence is $\left\{ADF_{r_2}^{r_1}\right\}_{r_2=r}^{r_1 \in [1, r-r_0]}$. Inference of explosiveness for observation r is based on the sup value of the ADF sequence, denoted by $SADF_r$ and defined as

$$SADF_r = \max\left\{ADF_{r_2}^{r_1} : r_2 = r \text{ and } r_1 \in [0, r - r_0]\right\}.$$

We employ a wild bootstrapping procedure to obtain the finite-sample critical values. One prominent feature of weekly financial data is conditional/unconditional heteroskedasticity (Engle, 1982, and Bollerslev, 1986). The wild bootstrapping procedure replicates the pattern of heteroskedasticity in the original shocks and hence is expected to reduce the chance of size distortion (Harvey et al., 2015). See Milunovich et al. (2016) for details of this procedure.

3.1.3. Bubble Contagion

Suppose we are interested in the bubble spill-over effect from markets *A* to *B*. The contagion regression is based on the two β coefficient sequences for markets *A* and *B*, denoted by $\left\{\hat{\beta}_{A,t}\right\}_{t=w}^{T}$ and $\left\{\hat{\beta}_{B,t}\right\}_{t=w}^{T}$ obtained from moving window regressions of (2) with a fixed window size of *w*. The autoregressive coefficients form the basis of the PSY test and hence, to some extent, capture the degree of explosiveness.

Greenaway-McGrevy and Phillips (2016) specify a non-parametric regression as

$$\tilde{\beta}_{B,t} = \delta_{t,T}\tilde{\beta}_{A,t-d} + \varepsilon_t \tag{3}$$

where $\tilde{\beta}_{k,t} = \hat{\beta}_{k,t} - \frac{1}{T-w+1}\sum_{t=w}^{T}\hat{\beta}_{k,t}$ with $k = A, B$ are the demeaned coefficients, d is the lag order, ε_t is the error term, and $t = w+d,\ldots, T$. The regression analyses the relationship between the autoregressive coefficient of market B and the d-period-ahead autoregressive coefficient of market A, captured by the coefficient δ. Note that δ depends on the time period, implying that the relationship is time-varying. We find evidence of bubble migration when observing significant increases in the δ coefficient.

The time-varying coefficient δ may be estimated by local-level kernel regression such that

$$\hat{\delta}(r;h,d) = \frac{\sum_{j=w+d}^{T} K_{hj}(r)\tilde{\beta}_{B,j}\tilde{\beta}_{A,j-d}}{\sum_{j=w+d}^{T} K_{hj}(r)\tilde{\beta}_{A,j-d}^{2}} \quad \text{with } r = \frac{i}{T},$$

where $K_{hj}(r) = \frac{1}{h}K\left(\frac{j/T-r}{h}\right)$ with $K(.) = (2\pi)^{-1/2} e^{-\frac{1}{2}(.)^2}$ is the Gaussian Kernel, and h is a bandwidth parameter. The estimator $\hat{\delta}$ also depends on the selected lag order and band-width.

We set the bandwidth according to a cross-validation approach. For a given lag order *d*, the optimal bandwidth $\hat{h}_T(d)$ is estimated as

$$\hat{h}_T(d) = \arg \min_{h \in \left[T_0^{-1/2}, T_0^{-1/10}\right]} \sum_{i=w+d}^{T} \left\{ \tilde{\beta}_{B,i} - \hat{\delta}_i(r;h,d)\,\tilde{\beta}_{A,i} \right\}^2,$$

Where T_0 is the number of observations in the contagion regression (i.e. $T - w - d + 1$) and $\hat{\delta}(r;h,d)$ is replaced by the leave-one-out $\hat{\delta}_i(r;h,d)$ such that

$$\hat{\delta}_i(r;h,d) = \frac{\sum_{j=w+d,\, j\neq i}^{T} K_{hj}(r)\,\tilde{\beta}_{B,j}\tilde{\beta}_{A,j-d}}{\sum_{j=w+d+1}^{T} K_{hj}(r)\,\tilde{\beta}_{A,j-d}^2}.$$

The optimal lag order minimizes the MSE of the contagion equation such that

$$\hat{d} = \arg \min_{d \in \{0,1,\ldots,52\}} \sum_{i=w+d}^{T} \left[\tilde{\beta}_{B,i} - \hat{\delta}_i\left(r;\hat{h}_T(d),d\right)\tilde{\beta}_{A,i-d} \right]^2,$$

where $\hat{\delta}\left(r;\hat{h}_T(d),d\right)$ is the leave-one-out estimator with the optimal bandwidth.

3.2. Data

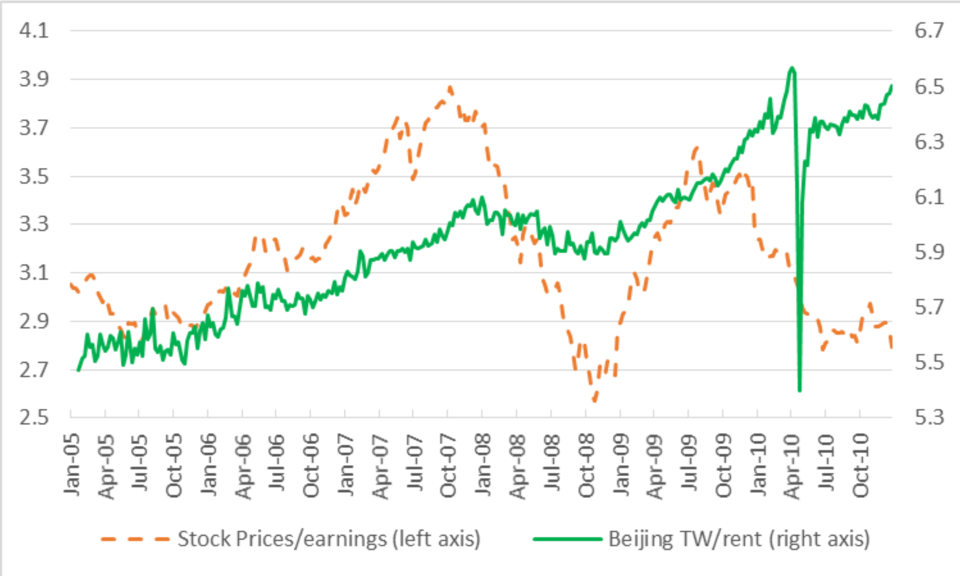
For both stock market and real estate data, we consider a daily sample from January 3rd 2005 through December 30th 2010. The Shanghai composite stock market index and its earnings are extracted from Bloomberg. Weekly data are calculated by taking the week's average from Thursday to Wednesday. Table 1 presents descriptive statistics on the price/earnings ratio, while Figure 1 shows the two periods of rising prices in Shanghai's stock market, from the Summer 2006 to November 2007, with an interruption in the Summer 2007, and from the end of October 2008 to the end of July 2009.

Table 1: Summary Statistics for weekly stock and real estate price ratios (in log)

Variable	Mean	STD	Skewness	Kurtosis
Weekly Shanghai composite Stock prices/earnings	3.183	0.304	0.427	2.245
Weekly prices of a major housing market/rent	5.948	0.274	0.229	2.199

Sample: Weekly data from 6th January 2005 to 30th December 2010.

Figure 1: Stock price index/earnings and Beijing resale hedonic housing price/rent (in log)



Publicly available monthly data on housing prices in China suffer from two major weaknesses. First these ignore the fall in complex-level quality over time: rapid urbanization pushes new buildings to the periphery (Deng, Gyourko and Wu, 2012), and permitted floor-area ratios rise. Second, these data suffer from a downward bias resulting from developers' opportunistic pricing strategy. Accordingly, we prefer to adopt a hedonic method to model one of the largest housing market (Beijing[4]) in China, in line with Deng, Gyourko and Wu (2012), and Wu, Deng and Liu (2014). The sources of data used in this analysis are the same as the daily housing transaction sample used in these two earlier studies. Such daily detailed micro-level housing-transaction data were collected from multiple leading residential real estate agencies and local government authorities' websites[5]. Appendix I provides a detailed description of the construction of the index. The sample covers the period from January 2005 to December 2010. Out of daily housing transaction data containing more than 360,000 transactions and leasing data, we focus on the subset of 77,577 resale housing transaction data to extract our sample. Weekly housing prices data are calculated by taking the

[4] The capital city may be representative of first tier coastal cities cities (Glaeser et al. 2017; Wu, Gyourko and Deng 2016; Fang et al. 2015), while cities in the interior and second or third tier cities may have behaved differently. Studies examining such issues include Peng, Tam and Yiu (2008), or Huang, Leung and Qu (2015), but they only focus on low frequency data.

transaction-weighted (TW) weekly average[6] from Thursday to Wednesday. No hedonic rent data is available to match our hedonic housing price data, however, monthly official rental data are available for Beijing from CEIC. We interpolate this series to obtain weekly observations which are then used to obtain the price/rent ratio. Descriptive statistics are provided in Table 1, while Figure 1 shows the two periods of rising housing prices, from March to December 2007, and even more durable from February 2009 to mid-Spring 2010.

As a by-product of the very successful reforms initiated in the late 1990s, home ownership in China is extremely widespread (87% of households in urban and 97% in rural areas) and substantially higher than stock ownership (only 6% in the late 2000s). However, households who buy new housing mainly do it (62% of them) for investment or speculative purposes, often in the form of a second or third housing unit. China's stock market is also often portrayed as highly speculative, as testified by the fact that the number of new household stock market accounts created every month often reaches several millions (households represent 80% of investors in China's stock market). Accordingly it is worth considering to what extent bubble migration may be at work between the real estate and stock markets, particularly for households in China whose only alternative (until the very recent gradual capital account opening) store of wealth is a bank account.

4. DETECTING BUBBLES AND THEIR MIGRATION

In this section we initially test for the presence of explosive behaviour in weekly Beijing housing prices/rent and the Shanghai Composite stock price index/earnings, in order to date the timeline of bubbles in each of these markets. Subsequently, we test for the presence of migration of bubbles from one market to the other**.**

4.1. Bubble Timeline: Detecting Explosive Behavior

Figures 2 and 3 show the identified bubble indicators, along with the log of the Shanghai composite stock price/earnings and log of the Beijing housing price/rent. The figures also highlight areas corresponding to periods of explosive behaviour as detected using 90% critical values obtained from wild bootstrapping procedures.

The stock market features (Figure 2) first a three-month long bubble: from Spring (6 April) to early Summer (6 July 2006). The second is a 4-month long bubble from (8 Mar

[6] In the case of the stock market, due to the very large number of daily transactions, the simple and transaction-weighted weekly averages are indistinguishable, so we only report the former.

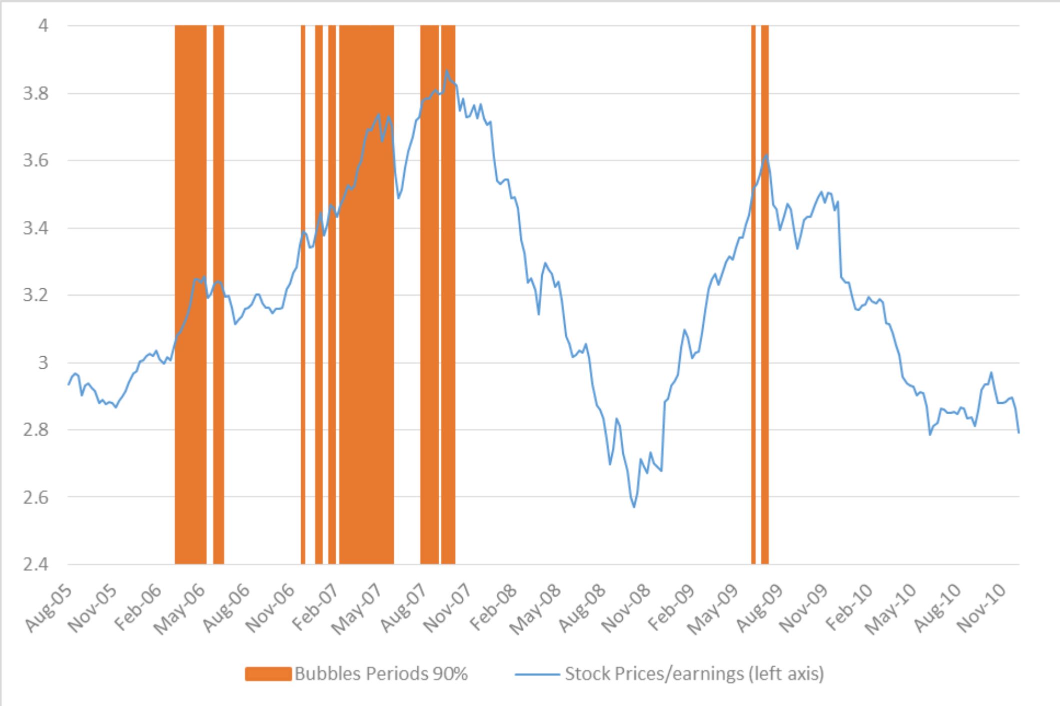
2007 to 21 Jun 2007), and from (23 Aug 2007 to 25 Oct 2007). It is noteworthy that in October 2007 the after-tax deposit interest rate started to exceed the price/earnings ratio (Li, 2015). The third bubble is a short lived one in the Summer (2 to 30th July) 2009. The procedure has falsely identified two episodes of market downturn in 2008 (13 March to 24 April 2008, and from 5 June to 27 Nov 2008), as bubble episodes and in June-July 2010 – the PSY procedure is designed for positive bubbles. Those periods are not highlighted in the figures.

The two bubbles, which took place or started in 2006, correspond to the full implementation in 2006 of the split-share reform (Beltratti et al. 2009), bringing the float closer to capitalization -initiated in the Spring 2005, following a long-lived bear market in the first half of the 2000s - accompanied by optimistic investor expectations (Li, 2015). However, earnings stopped validating such expectations in the early Autumn 2007. The bubble which arose and burst in the Summer 2009 marks the end of a long bull market as noted by Jiang et al. (2010).

The Beijing real estate market (Figure 3) features first a recurring but very short-lived bubble from 15 Feb to 1st Mar 2007, and from 5 Apr to 10 May 2007. The second bubble spans 11 October 2007 to 10 Jan 2008. The third episode lasts from 16 Apr to 21 May 2009, which is only six-week long in duration and quite weak, it disappears if a 95% level is chosen. Finally, the last bubble covers the period from 19th November 2009 to 15th April 2010.

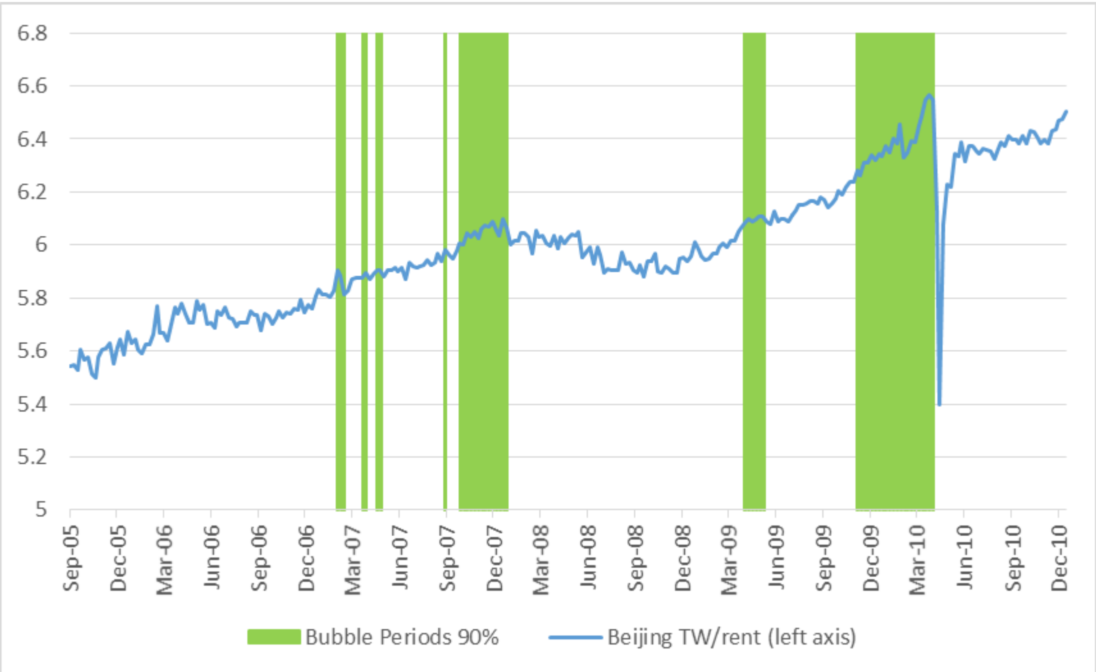
It is thus noteworthy that the real estate bubble episode from 15 February to 10 May 2007 arose approximately six months after the end of the 2006 stock market bubble. The second stock market bubble episode (8 March 2007 to 25 Oct 2007) not only was already well established but also continued after the collapse of the real estate bubble in May 2007. The second real estate bubble from 11 October 2007 to 10 January 2008 arose approximately seven months after the start of the second stock market bubble in March 2007. In contrast, last real estate bubble in our sample starts in mid-November 2009, three and a half months after the crash of the stock market bubble in late July 2009.

Figure 2: The identified bubble periods (shaded) and the log Shanghai composite price index/earnings



Note: The bubble periods are identified based on the SADF statistic sequence and the 90% wild bootstrapping critical value sequence.

Figure 3: The identified bubble periods (shaded) and the logarithmic Hedonic housing prices/rent



Note: The bubble periods are identified based on the SADF statistic sequence and the 90% wild bootstrapping critical value sequence.

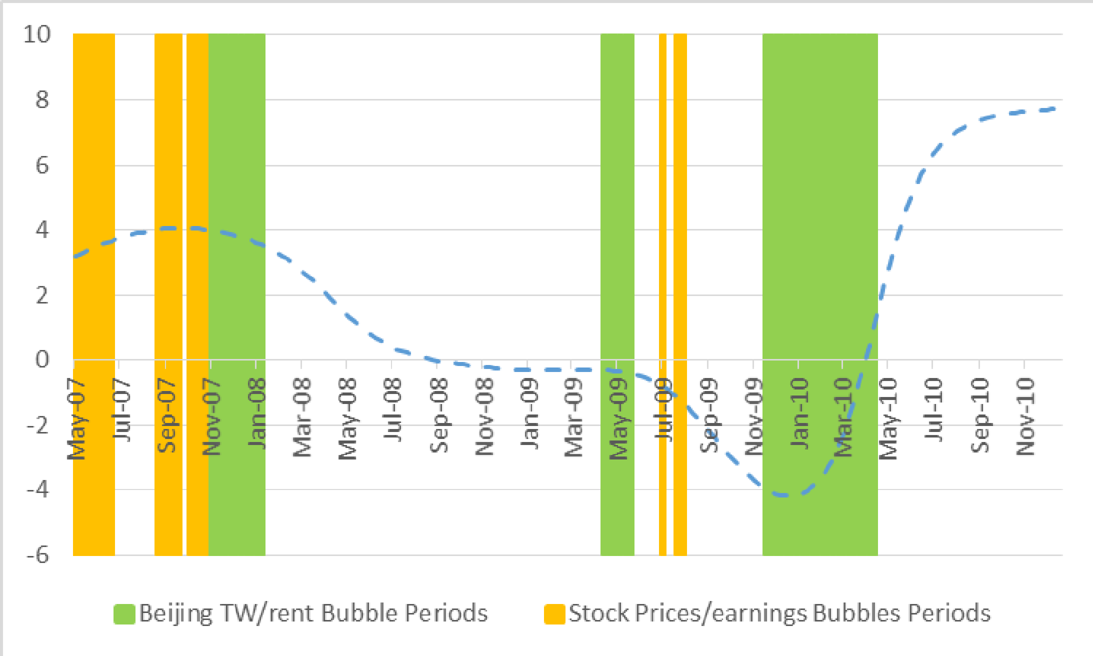
4.2. Bubble Migration

Given that real estate bubbles as detected in Figure 3 never precede stock market bubbles, we should rather focus on the reverse migration from stock to real estate bubbles of which there are some presumptions when confronting figures 2 and 3. We estimate rolling autoregressions of the form (2) for each of the series with a fixed window size of w = 70. This gives the slope coefficient estimates $\left\{\hat{\beta}_{A,i}\right\}_{i=w}^{T}$ and $\left\{\hat{\beta}_{B,i}\right\}_{i=w}^{T}$ where B stands for the Beijing real estate series/rent and A for the stock price series/earnings. We then estimate equation (3).

We find long lags (estimated to be 29 weeks, approximately seven months) at work in the migration of bubbles from the stock to the real estate market. In the real estate market the amount of time ("settlement period") elapsed between the exchange of contracts and the property settlement could be between one and three months. As such, a delay of 29 weeks for a stock market bubble to migrate to a real estate bubble may not be that surprising.

Due to the smoothing procedure used to estimate the migration coefficient, the rise of the sensitivity of one market to another can only manifest itself in a very gradual way. In other words, this coefficient has to be interpreted with care in as much as it is estimated over a rolling window and is thus more heavily influenced by past rather than current observations. On a given week, a rise in this coefficient does represent a sign that such sensitivity starts rising.

Figure 4: Bubble migration from stock to housing market: the estimated δ coefficient of eq. (3)



In Figure 4, the dashed line is the time varying coefficient of equation (3) above. The solid highlighted area shows the periods when there is evidence of a bubble at 10% in stock or real estate prices. The sensitivity of real estate to stock market bubbles rises during the period of upward movements in stock prices and falls sharply when the stock market bubble has exploded. It becomes negative in September 2008 and stays negative until April 2010. This implies that, over that period, real estate prices have an adverse reaction relative to the stock market prices. In the fall of 2009 (19 Nov 2009), three and a half months after the burst of an emerging short-lived stock market bubble (on the 30th July 2009), a real estate bubble arises. From April 2010 time varying coefficients become again positive, which means that real estate prices are sensitive to the stock market prices of, approximately, 7 months earlier. This sensitivity increases until the end of the sample. This finding aligns with the sequential hypothesis concerning bubble creation and collapse of Phillips and Yu (2011) for the US economy.

5. CONCLUSION

The growing concerns of a “bubble” in Chinese stock and housing markets in the second part of the first decade of the new millennium imply that skyrocketing increases in housing and stock prices may be generated by speculation. Existing literature has extensively studied this issue for these markets in isolation, but, in the case of housing, it has almost exclusively relied on publicly available real estate price indices and thus used low-frequency (i.e. monthly) data.

We proposed using a unique high-frequency, weekly, data set on hedonic residential housing prices in a major resale housing market in China, covering six years, combined with Shanghai composite stock market index data, to address such concerns. The hedonic data remedy the bias present in the Chinese 70-Cities Housing-Price Index. To analyse such data we used a two-step strategy to provide the first timeline of both real estate and stock market bubbles in China over the crucial period of the second half of the 2000s, and to test for bubble migration from one market to the other.

Our use of recently-developed recursive explosive versus unit-root tests implies that concerns about the presence of bubbles in China's stock and housing markets are vindicated even after conditioning on fundamentals of the stock and real estate markets such as earnings or rents respectively. These results align with the sequential hypothesis concerning bubble creation and collapse of Phillips and Yu (2011) for the US economy. Not only can near-explosive behaviour be detected for two main episodes for each of these markets, but also real estate bubbles seem to have followed stock market bubbles either temporarily, like in 2007, or durably like in the Summer 2009.

APPENDIX I

Hedonic housing price construction

The sample we consider corresponds to the period from January 2005 to December 2010. In the case of the housing data, our sample is extracted from 77,577 resale housing transaction data from a major market, out of a larger sample of daily housing transaction data containing more than 360,000 transactions and leasing data. For each detailed transaction information recorded involves the date, price (sale price), unit size, number of rooms, floor level at which the unit is located, and total number of floors of the building. We use the "*Soufun* Website-Based GIS" system [7] to match each transaction into over 6,000 neighbourhoods[8], as well as to compute the floor area ratio (FAR), and two distances: to the city centre, noted DCC, and to the nearest subway station, noted DSS, (See Ren, Wu and Deng, 2013, for further details on the compilation of the data set).

In order to properly measure house prices, it is necessary to disentangle observed movements in prices from the impact of quality changes on housing units sold in different periods (Malpezzi, 2002; Wu, Deng and Liu, 2014). The housing sector in Chinese cities is overwhelmingly composed of non-landed condominium units, each of them made of hundreds (thousands) of units located in multiple high-rise residential buildings on a given land parcel. Housing attributes should thus be distinguished into two groups: i) the complex-level attributes include the locational characteristics and neighbourhood amenities, as well as some physical characteristics (construction quality and building type); ii) the unit-level attributes refer to physical characteristics, usually unit size, floor level, and specific environmental attributes (such as noise, view, accessibility to sunshine, *etc*.). Within a given complex, housing units share the former attributes, but differ in the latter.

On the basis of the hedonic attributes of the residential units in each building and neighbourhood, we are able to construct hedonic housing price models for a major housing market in China. The hedonic specifications include: unit size, floor level, total number of floors in the building, total number of housing units in the building, as well as FAR, DCC and DSS.

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[7] The system can be accessed at map.soufun.com.

8 These 6,000 plus neighborhoods are located in eight urban districts in Beijing, namely, Chaoyang, Haidian, Fengtai, Xicheng, Xuanwu, Dongcheng, Chongwen and Shijingshan Districts. Among them, the Chaoyang District contains about 43% of the sample.

Based on such a framework, the hedonic model in the *resale* housing market can be expressed as:

$$P_{vst} = \lambda U_{vt} + \gamma C_{st} + \gamma_t D_{vst} + \upsilon_{vst} \quad \text{(A1)}$$

where P_{vst} is the transaction price of unit *v* in complex *s* sold at time *t*; U_{vt} and C_{st} are sets of unit-level and complex-level housing characteristics, respectively, all in natural logarithm; and υ_{vst} is an *i.i.d.* error term.

While other parameters might also be of interest in other contexts, the main task of house-price index construction consists in estimating accurately time dummies' coefficients γ_t. The hedonic method is able to incorporate the quality adjustment, directly based on the estimation results of equation (A1). The most frequently used, time-dummy, specification of the method, relies on the pooling of housing transactions from multiple periods into a single hedonic model in order to estimate the vector of time dummy coefficients γ_t, and subsequently to compute the house price index on the basis of γ_t (Kain and Quigley, 1970; Gourieroux and Laferrere, 2010).

A challenging feature of the hedonic method is associated with the intensive data requirement, which involves detailed housing-attribute information on top of the transaction price. Fortunately the required registration with local authorities in China of all housing-transaction contracts recently started making available data on housing attributes. Each transaction's key information, started to be recorded electronically by municipal-housing authorities in major cities ("Real Estate Market Information System") in 2003, and on a compulsory basis in 2006 (as mandated by the Ministry of Housing and Urban-Rural Development of China: MOHURD). Subsequently (April 2007), MOHURD prescribed the list, and defined the nature, and format, of variables to be reported. This official detailed recording represents a natural data source for the implementation of the hedonic method, even if it is unlikely that such data is exhaustive enough to encompass each and every complex- or unit-level attribute. However as long as the unobserved housing characteristics do not change monotonically over time this lack of exhaustiveness does not affect the reliability of the hedonic method (Wu, Deng and Liu, 2014).

APPENDIX II
Bubble detection with price/earnings and price/rent ratios

Since our bubble detection and migration tests were implemented on asset returns, one may wonder to what extent our results are robust when controlling for earnings (for stocks) and rent (for housing). Earnings are easily available at the index level for the Shanghai stock market (from Bloomberg), but no hedonic rent data is able to match our hedonic housing price data. However to the extent that (monthly) official rental data is available for Beijing (at CEIC), we tentatively use it (after weekly interpolation).

Figures A.1 and A.2 show recursive calculations of the SADF statistics for the log of the Shanghai composite stock price/earnings and log of the Beijing housing price/rent. The figures also highlight areas corresponding to periods of explosive behaviour as detected using 90% critical values obtained from wild bootstrapping procedures.

Figure A.1.: The identified bubble periods (shaded) and the log Shanghai composite price index/earnings

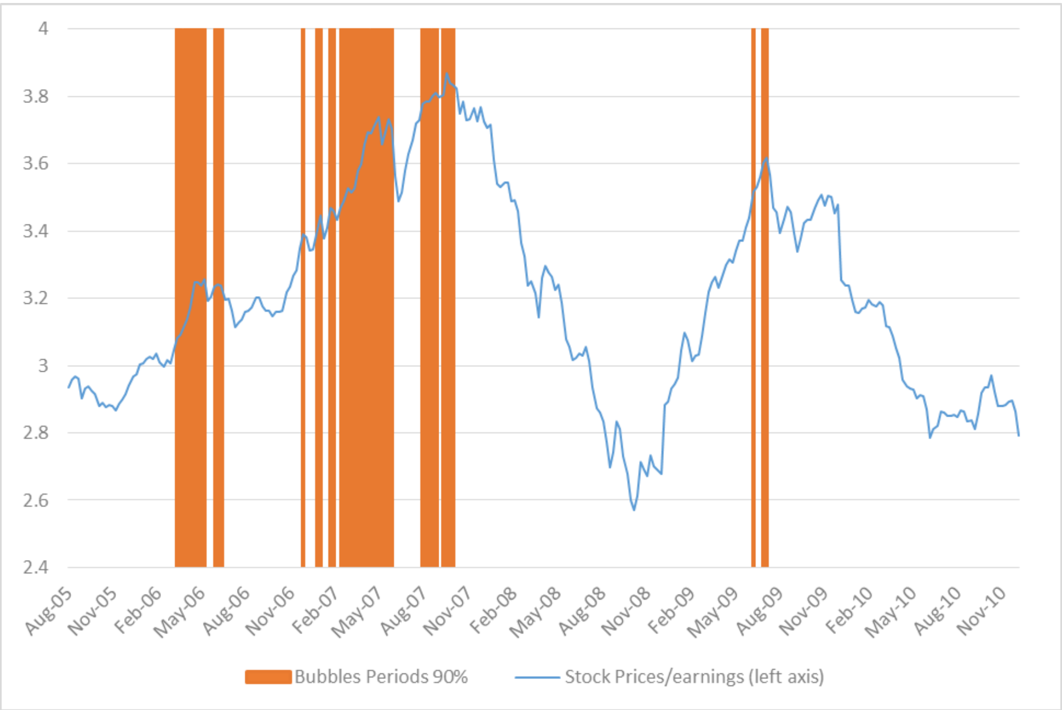
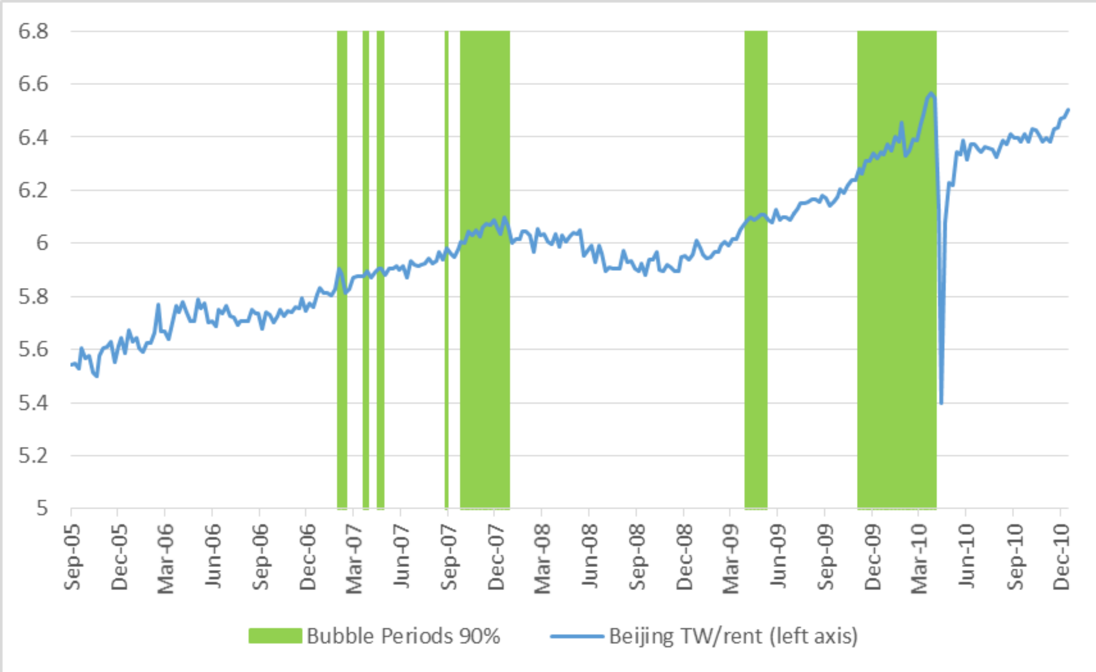


Figure A.2.: The identified bubble periods (shaded) and the logarithmic Hedonic housing prices

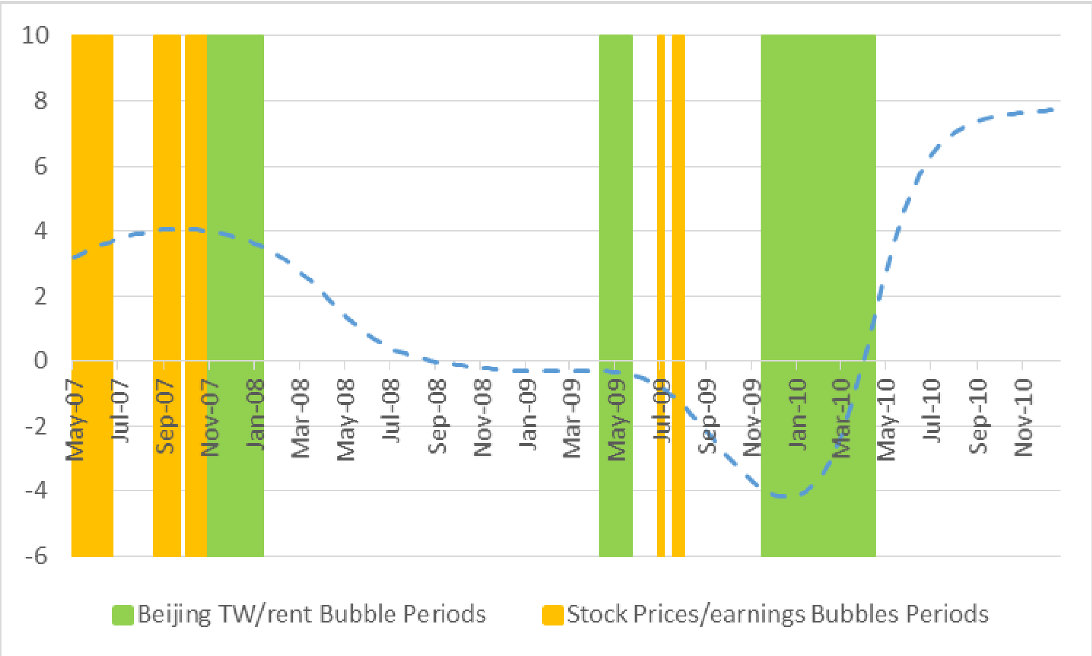


We find that over our sample the three detected bubbles each on the stock and housing markets obtained with the ratios match well the timing of the bubbles uncovered with the prices. Only in the case of the real estate market do we detect a fourth bubble, but a very short-lived one. Indeed the stock market features (Figure A.1.) first a three-month long bubble: from Spring (6 April) to early Summer (6 July 2006), slightly longer than the price series bubble, starting one week earlier and ending two weeks later. The second is a 4-month long bubble from (8 Mar 2007 to 21 Jun 2007), and one from (3 Aug 2007) to (25 Oct 2007), making more precise the bubble detection than with the price series which had an uninterrupted bubble for 16 months after late October 2006. It is noteworthy that in October 2007 the after-tax deposit interest rate started to exceed the price/earnings ratio (Li, 2015). The third bubble is a short lived one in the Summer (2 to 30th July) 2009, fully matching the timing of the price-series bubble. The procedure has falsely identified two episodes of market downturn in 2008 (13 March to 24 April 2008, and from 5 June to 27 Nov 2008), as bubble episodes and in June-July 2010 – the PSY procedure is designed for positive bubbles. Those periods are not highlighted in the figures.

The Beijing real estate market (Figure A.2) features first a recurring but very short-lived bubble from 15 Feb to 1st Mar 2007, and from 5 Apr to 10 May 2007, which was not detected with the price-series. The second bubble spans 11 October 2007 to 10 Jan 2008, and thus starts two months later and ends three weeks later than the price-series bubble. The third episode lasts from 16 Apr to 21 May 2009, which is only six-week long in duration and quite weak, it disappears if a 95% level is chosen. It replaces the later but equally short-lived bubbles detected with the price series over the Summer 2009. Finally, the last bubble covers the period from 19th November 2009 to 15th April 2010, and the timing is precisely the same as that of the price-series bubble.

Overall we thus conclude that our bubble detection on both the stock and real estate markets using prices is robust since it is matched by the timing obtained with ratios.

Figure A.3: Bubble migration from stock to housing market: the estimated δ coefficient of eq. (3)



In Figure A.3., the dashed line is the time varying coefficient of equation (3) above with a lag *d* equal to 29 weeks. The solid highlighted area shows the periods when there is evidence of a bubble at 10% in stock or real estate prices. The pattern of bubble migration from the stock to the housing market obtained with the ratios is very similar to the timing obtained with prices reported in Figure 4.

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