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Matthew S. Yiu and Lu Jin

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Matthew S. Yiu*
Hong Kong Monetary Authority

and

Lu Jin*
Hong Kong Monetary Authority

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Abstract

This study applies the newly developed bubble detection method (Phillips, Wu and Yu, 2011) to identifying asset bubbles in the Hong Kong residential property market. Our empirical results show that the method is capable of detecting the 1997 bubble and is able to reveal the corresponding origination and collapse, showing its superiority over the standard unit root and co-integration method. During the period between mid-2009 and early 2011, the method indicates strong upward price pressure in the mass segment and bubble-type behaviour in two short periods of time in the luxury segment. The results, however, show potential shortcomings of the method including: the high correlation between the price-rent differentials and t-statistics near the critical values, and the symmetric property towards explosive growth and precipitant fall of the time series.

Keywords: Asset Bubble, Residential Property Prices, Right-Tailed Unit Root Test, Explosive Behaviour, Price-To-Rent Ratio
JEL Classification: C22, G12, R31

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* Research Department, Author's E-Mail Address: msfyiu@hkma.gov.hk, ljin@hkma.gov.hk

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1. Introduction

Over the past one and a half decades, advanced and emerging economies suffered from severe financial crises, including the Asian financial crisis, the Dot-Com crisis and the global financial crisis. All these crises were triggered by the collapse of price bubbles in asset markets, such as in foreign exchange markets, equity markets and property markets. Given the adverse effects of these crises, economists and policymakers have been searching for ways to detect bubble formation empirically in order to take appropriate measures to deflate bubbles before they burst.

Bubble detection has been extensively studied in the financial economics literature. The most commonly used detection methods are developed based upon the present value model and rational bubble assumption. The present value model states that the price of an asset is the sum of all its discounted future incomes.[1] For example, in the absence of the bubble condition, the price of a stock is the sum of all the discounted future dividends. Similarly, the price of a property is the discounted sum of future rental incomes. This is often referred to as the fundamental part of the price of an asset. However, rational bubbles arise when investors are willing to pay more than the fundamental value to buy an asset when they expect that the asset price will significantly exceed its fundamental value in the future. When rational bubbles are present, the asset price is composed of the fundamental value and the bubble component.[2]

An earlier method of detecting bubbles, using the idea of rational bubbles, is the variance bounds test.[3] In the test, if rational bubbles exist, the variance of observed asset price will exceed the bound imposed by the variance of the fundamental value. However, this test is strongly criticised for having little structure on the bubble part and the indication of bubbles from the test could be ruled out by other reasonable factors.

Another earlier method is the two-step test proposed by West (1987) which requires a detailed specification of an underlying equilibrium model of asset prices. Basically, the test compares the respective estimates of the impact of fundamentals on the asset price in the underlying equilibrium model and in a simple linear model that assumes no bubble component. If the estimate from the linear model is similar to that of the underlying equilibrium model, it proves no existence of a bubble. In other words, if the two estimates differ, it is possible to attribute their discrepancy to the presence of a bubble component. However, the power of this test is affected by how well the equilibrium model is

[1] Gurkaynak (2008) shows that by solving consumers' optimisation problem and assuming no rational bubble and no-arbitrage, the price of a financial asset (e.g. the price of a housing property) is the present value of the future incomes (e.g. the future rental income stream).

[2] From a theoretical perspective, the "bubble" explanation of the housing price dynamics is not satisfactory, as argued by Montrucchio and Privileggi (2001) and in the survey paper by Leung (2004). Furthermore, part of the dynamics of "bubbles" can be explained by the regime switching process, such as in the works by Chen (2001) on the Taiwan data and Chang et al. (2011a, b) on the Hong Kong and Singapore data. Moreover, bubbles and switching processes are not easily distinguished as revealed by Driffill and Sola (1998).

[3] For details, see Shiller (1981).

specified and the rejection of the no bubble hypothesis could be attributable to the model misspecification instead of the existence of bubbles.

As both the variance bounds test and West's two-steps test have their own deficiencies, Campbell and Shiller (1987) propose an alternative method. In view of the observation that the gap between the asset price and the fundamental value will exhibit explosive behaviour during a bubble-formation process, Campbell and Shiller suggest using a unit root test as a first step to test the explosive characteristic and detect bubbles. If there is a bubble, the asset price and the fundamental value can be characterised by two possible cases:[4] in level, the asset price is non-stationary (i.e. not mean reverting) but the fundamental value is stationary; or, both the asset price and fundamental value are non-stationary. The second case, however, is not a piece of firm evidence for the presence of a bubble, and calls for a co-integration test as a second step. If a bubble is present, the asset price and its associated fundamental value will not be co-integrated (i.e. not having co-movement in the long run), assuming that they are both non-stationary in levels but stationary in first differences. As Diba and Grossman (1988) further point out, the identification of the explosive behaviour in the gap between the asset price and fundamental is equivalent to the bubble detection, and the unit root and co-integration tests are the tools for this. Since then, the standard unit root test (e.g. left-tailed Augmented Dickey-Fuller (ADF) test) and co-integration test on the price series and fundamental value series have been widely used for detecting asset bubbles because of their ease of implementation.

The unit root and co-integration tests have been applied to detect property market bubbles in different economies for the past two decades. For example, Drake (1993) uses this method to study the price boom in the mid-1980s in the UK property market and Arshanapalli and Nelson (2008) employ the co-integration test to verify the housing bubble in the mid-2000s in the US housing market. For Hong Kong, Peng (2002) uses this method to detect the 1997 bubble in the residential property market. The test has also been extended in different ways over time, such as using panel data and regime switching techniques.[5]

Although the unit root and co-integration tests are popular, the results from the tests need to be interpreted with caution. When the asset price and its fundamental value are found to be co-integrated, the null hypothesis of no bubble is confirmed. However, the reverse may not necessarily be true, because the presence of a rational bubble may be one of the many possible reasons. Other possible factors include, for example, the non-stationary nature of unobservable variables. Moreover, because the method utilises a linear model to detect any non-linear growth of the bubble component,

[4] There are four possible scenarios of the unit root tests on the asset price and fundamental value series: (A) asset price and fundamental value are both stationary in level; (B) asset price is stationary but fundamental value is non-stationary in level; (C) asset price is non-stationary and fundamental value is stationary in level; (D) asset price and fundamental value are both non-stationary in level. Scenario A indicates no bubble; Scenario B indicates an incorrect model; Scenario C suggests the presence of bubbles in the asset price; and Scenario D needs a co-integration test between asset price and its fundamental, assuming their first differences are stationary.

[5] For example, based on the panel unit root and co-integration tests, Mikhed and Zemcik (2009) use US metropolitan data and Tsai and Peng (2011) use data of four major cities in Taiwan to detect property bubbles.

the method's power of detecting explosive bubble behaviour and identifying the origination and collapse of a bubble, particularly the collapse, is very limited (this point will be shown below in the empirical results in Section 3).[6]

Given the limitations of the methods mentioned above, Phillips, Wu and Yu (PWY) (2011) propose a new method to detect bubbles. They use the right-tailed unit root test to directly detect the explosive pattern and devise the test to proceed in a forward recursive manner. Though in essence the PWY method is still an appliance of the unit root test, as argued in their paper, the right-tailed test is more powerful than the standard left-tailed test used by Campbell and Shiller in identifying explosive characteristics. Furthermore, the forward recursive procedure enables the test to identify the beginning and the collapse of an asset bubble. Applying the new method to the NASDAQ index, PWY (2011) successfully identify the start and the end of the IT bubble. The identification of the start of a bubble formation could help policymakers to consider appropriate measures if there is a risk of asset bubbles in their jurisdictions.

The objective of this study is to compare the PWY method with the standard unit root and co-integration tests by examining asset bubbles in the Hong Kong residential property market.[7] Hong Kong's property market is of interest because it experienced a pronounced bubble in 1997 which provides a good candidate for us to assess the performance of the methods. In addition, the Hong Kong property market has probably been facing the risk of asset-bubble formation since mid-2009.

This paper is arranged as follows. Section 2 explains the forward recursive right-tailed ADF unit root test of the PWY method. In Section 3, we apply the PWY method to the Hong Kong residential property market and compare the empirical results with those from the unit root and co-integration method. Finally, we provide a conclusion in Section 4.

2. Phillips, Wu and Yu (PWY) Method

Based on the present value model, rational bubble assumption and nonlinear explosive characteristic, PWY (2011) devise a procedure to identify the bubble-type behaviour in asset prices. The method uses the right-tailed ADF unit root test:

$$\Delta f_t = \mu + (\rho - 1) f_{t-1} + \sum_{j=1}^{k} \phi_j \Delta f_{t-j} + \xi_t \tag{1}$$

6 This also relates to the well-known deficiency of the unit root and co-integration method in detecting periodically collapsing bubbles (see Evans, 1991).

7 We refer to the private residential property market in Hong Kong only.

where f_t is the time series of the asset price which is the log real price-rent differential in this study and k is chosen such that the residual ξ_t from the regression is uncorrelated across time.[8] In the test, the null hypothesis is $H_0 : \rho = 1$ (unit root behaviour) and the alternative hypothesis is $H_1 : \rho > 1$ (mildly explosive behaviour). Unlike the standard left-tailed ADF test in which the null hypothesis is $H_0 : \rho = 1$ (unit root behaviour) against the alternative hypothesis $H_1 : \rho < 1$ (stationary behaviour), the PWY test looks directly for evidence of nonlinear explosive behaviour.

Another innovation of the PWY method is that it arranges the right-tailed ADF test to proceed in a forward recursive way in order to identify the origination and collapse dates of a bubble. The test in the first recursion uses $\tau_0 = [nr_0]$ observations, for some fraction $r_0 \in (0,1)$ as an initial period. Subsequent recursions employ this initial data set supplemented by successive observations giving a sample size of $\tau = [nr]$ for $r_0 \le r \le 1$. The origination of a bubble is dated as the first recursion for which the value of the t-statistic of the estimated ρ is equal to or larger than the right side critical value of the ADF test corresponding to a significant level, and the collapse date is identified as the first subsequent recursion for which the t-statistic drops back to or below the critical value.

3. Application to Hong Kong Residential Property Market

As shown in Figure 1, the Hong Kong residential property market experienced a bubble in early 1997 which collapsed several months later because of the onset of the Asian financial crisis. The collapse resulted in price deflation, recession and weak economic activities till 2003. In mid- and late-2008, the property market was severely hit by the global financial crisis and housing prices dropped considerably. However, since early 2009 the recovered market sentiment and strong capital inflows boosted a robust rally in property prices, which caused concern about the risk of asset-bubble formation.[9]

In the following, we will apply the PWY method to the Hong Kong residential property market. Unlike PWY (2011) who tested the price and fundamental series separately, we examine the differential between the property price and its fundamental, i.e. the rent, to detect bubble behaviour. The rationale for proceeding in this way is that the approach used in PWY (2011) will lead to an ambiguous conclusion regarding the presence of a bubble if both price and fundamental value exhibit explosive feature in a period (we will further elaborate this point in Section 3.4). On the other hand,

8 The estimate of ρ is subject to downward bias, since the least squares method which is used to estimate ρ is well known to produce downward biased estimates of first order autoregression.

9 It is natural to ask that, if capital inflows are the driving factor of the housing bubble, can the housing bubble period be interpreted as a period of time with “excess” capital inflows? Capital inflows can be viewed as a necessary condition for a housing bubble only, since capital inflows can go into other asset markets, e.g. Indonesia has been dealing with excess capital inflows into its sovereign debt market since 2009. Furthermore, because of its bounded territory, Hong Kong (as well as Singapore) is relatively likely to face housing bubbles due to the expectation of limited supply of housing.

the price-to-rent (p-r) differential, which is calculated as the log difference between the real property price index and real rent index of the Hong Kong residential property market, measures the deviation of the price from its corresponding fundamental.[10] The differential is expected to have an explosive feature if an asset bubble presents.

Figure 2 depicts the log p-r differentials of the overall Hong Kong residential property market as well as those of the mass and luxury segments.[11] The differentials as of March 2011 of both segments were higher than the peaks of those as of 1997, with a larger margin in the luxury segment.

3.1 The Bubble in 1997

We apply the PWY method (i.e. the right-tailed ADF test) on the p-r differential series of the overall market and also the mass and luxury segments from March 1993 to March 2011. Figure 3 plots the p-r differential and the t-statistics from the test with the 5% and 10% critical value lines for the overall market.[12,13] The results of the mass and the luxury segments are both very similar to those of the overall market and because of this they are not shown here. The t-statistics are well above the two critical levels for several months in 1997, which indicate the existence of a bubble in the residential property market. Specifically, the origination of the bubble is identified in February 1997 when the t-statistic for the first time exceeds both the 5% and 10% critical values. However, the collapse date of the bubble depends on which significance level is used. If the 5% significance level of the t-statistic is used, the end date was July 1997 when the real price dropped 4.1% from the peak in May 1997. On the other hand, if the 10% significance level is used, the end date was November 1997 when the real price fell 9.2% from the peak.

To compare with the results from the PWY method, we apply the standard unit root and co-integration tests in a forward recursive way to the Hong Kong overall residential property market. First, we conduct the standard left-tailed ADF test to test the stationarity of the log price and log rent series. The results show that in all sub-periods in the period from March 1993 to December 1998 the two series are non-stationary in levels but stationary in first differences.[14] This suggests that a further co-integration test is needed. Therefore, as the second step, we use the Engle-Granger co-integration test to investigate the co-integration relationship between price and rent for the sample period from

[10] Data on the housing price index and rent index are from the Rating and Valuation Department (R&VD) of Hong Kong SAR. CPI data used to deflate price and rent are from the Census and Statistics Department.

[11] The mass segment comprises of private domestic properties with saleable area less than $100m^2$ (Classes A to C according to the R&VD classification); and the luxury segment comprises of private domestic properties with saleable area larger than $100m^2$ (Classes D to E in the R&VD classification).

[12] For clear visualisation, we only plot the t-statistics from March 1996 to December 1998, and the t-statistics are well below the 10% critical value all the time afterwards.

[13] The first 37 months are used in the first recursion, thus the first t-statistic is available in March 1996.

[14] The first sub-period is the period from March 1993 to March 1996. Then one month is added to form the next sub-period till December 1998.

March 1993 to December 1998.[15] A p-value of the co-integration test above 0.05 or 0.1, depending on whether the 5% or 10% significance level is used, indicates no co-integration relationship between the price and rent series and implies the presence of a bubble. Figure 4 depicts the resultant p-values from the forward recursive co-integration tests over the period from March 1996 to December 1998. As shown, the p-values are in a range from 0.6 to 1.0, which suggest prices and rents are not co-integrated and there may be a bubble or bubbles in all the sub-periods from March 1996 to December 1998. These results seem not consistent with the historical observation that the 1997 bubble collapsed after a year. This shows that the co-integration test has little power, if there is any, in identifying the timeline of the bubble formation in 1997. The findings provide supportive evidence that the PWY method is superior in capturing explosive behaviour and finding the origination and collapse dates of bubbles.

3.2 Price Surge in 2009-2011

From early 2009, the Hong Kong property market quickly recovered from the 2008 global financial crisis and is now facing extreme buoyancy and very steep price rises. In light of this, we apply the PWY method to more recent property price data to test any bubble formation since 2009. Gilbert (2010) finds that the PWY method is not very effective to test multiple bubbles, in particular if the explosive behaviour is more pronounced in the first bubble.[16] Thus we exclude the 1997 bubble period from the test. In addition, we also exclude the period of a significant surge in the p-r differential in late 2003 to 2004 when the Hong Kong economy and the property market recovered from the deep recession. On the other hand, it is desirable to include as many months as possible in the sample period to ensure sufficient data for reasonable estimation. Considering both, we use June 2005, when the p-r differential is relatively stable, as the starting point. In order to ensure that the result is robust, we also test the months rolling from January to December 2005 as the starting point. The results are not much different.

Figure 5 shows the p-r differential and the PWY test results of the mass segment from June 2005 to March 2011.[17,18] There is no evidence of explosive behaviour in the p-r differential in the period from June 2005 to mid-2009, as the t-statistics stay below the 5% and 10% critical levels. However, since July 2009, the t-statistics move closely along the 10% critical value line, indicating strong upward price pressure. Furthermore, the t-statistics break the 5% critical value in the last three months of the sample period.

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15 Empirically, the co-integration test on the price and rent series should produce the same results as applying the left-tailed ADF unit root test on the price-rent gap series.

16 Gilbert (2010) applies the PWY method to commodity futures prices and discusses the method's power of multiple bubbles detection.

17 The results of the overall market are similar to those of the mass segment because the mass segment accounts for around 90% of the total private residential housing stock in Hong Kong.

18 The first 16 months are used in the first recursion, thus the first t-statistic is available in September 2006.

Regarding the luxury market, as shown in Figure 6, the t-statistics exceed the 10% critical value in 2009 Q3, March and April 2010 as well as January and February 2011, and are above the 5% critical value in August and September 2009. The indication of the explosive behaviour in the luxury segment echoes the documented buoyant property price development in the luxury segment,[19] attributable to the factors such as the favourable low-interest environment, strong capital inflows and favourable market sentiment. Since mid-2010, the t-statistics in the luxury segment have been hovering slightly below the 10% critical-value line, reflecting the risk of bubble formation even though the rent has increased with the rise in price in the luxury segment.

As in Section 3.1, we use the unit root and co-integration method to examine bubble behaviour in price and rent in the period from June 2005 to March 2011. Again, we first conduct standard left-tailed ADF tests on the log price and log rent series to test stationarity. The results show that the price and rent are non-stationary in level in all sub-periods, which satisfies the first condition to proceed to the co-integration test. However, their first-differences are not stationary in certain sub-periods, implying the price and rent series are integrated of different orders in different sub-period. This statistical property of price and rent makes the co-integration method not applicable any more. On the other hand, the PWY method which can test on the p-r differential directly has an appeal in this kind of situation.

3.3 Special Features of the PWY Method

Given the above results of the PWY method in detecting bubble behaviour, there are some features of the method worth noting.

Firstly, because of the symmetric property of the ADF test, the PWY test can detect both explosive growth as well as a precipitant fall of asset prices, just as the short-lived spike of the t-statistics in November 2008 shown in Figure 6, which actually corresponds to the period of asset prices plunge at the onset of the 2008 global financial crisis. The spike is due to the symmetric feature of the PWY test as noted by Gilbert (2010) when he identifies a negative 2008 bubble on the daily copper futures price. This appears to be an undesirable feature for bubble detection as looking solely at the t-statistics is unreliable and may lead to false alarms. This means that it is necessary to examine the underlying data and other related factors to reach a sensible conclusion about bubble formation.

Secondly, as illustrated in both Figures 5 and 6, the t-statistics tightly follows the movements of the p-r differentials, especially when the t-statistics are close to the critical levels. For the mass segment, the correlation between the t-statistics and p-r differentials is estimated to be at a high value of 0.92 since March 2009. Clearly, the upward break of the 5% significance level in January to March 2011 is due to the rapid surge of the p-r differentials in those months.

[19] See the HKMA Half-Yearly Monetary and Financial Stability Report, March 2010 and September 2010.

For the luxury segment, the t-statistics also follow closely the p-r differentials when they are around the critical levels as shown in the period from June 2009 to March 2011, in which period the p-r differentials show volatile movements around a stable level. The correlation between them in the luxury segment is also high at 0.79. The high sensitivity of the PWY test to the movement of the p-r differential makes the t-statistics fluctuate around the significance levels that could weaken the detecting power of the PWY test for identifying asset bubble formation.

3.4 Applying the PWY Test on Price and Rent Separately Versus Their Differential

In PWY (2011), their test is applied to the asset price series (NASDAQ Index) and the fundamental series (NASDAQ composite dividend) separately on the assumption that the fundamental series is stationary whereas the price series may have explosive behaviour in certain periods. However, this approach may not be applicable to the Hong Kong residential property market. Figures 7 and 8 show the t-statistics of the PWY test on the log real price and log real rent series of the mass and luxury segments from June 2005 to March 2011 respectively. The t-statistics indicate that the price and rent both have explosive-type behaviour during the period from mid-2007 to the end of 2008 in both segments.[20] Given the bubble-type behaviour in both price and rent, no conclusion can be made on the presence of bubbles based on the results from the PWY test. This also demonstrates that the use of p-r differential is appropriate for this study.

In principle, we could exclude the bubble-type behaviour period and apply the PWY test on the price and rent series separately in the more recent period, say the post-2008 global financial crisis period from January 2009 to March 2011. However, because of the short sample period, the estimated t-statistics will certainly have strong finite-sample downward bias (mentioned in Footnote 7 in Section 1), affecting the interpretation of the PWY test results.

4. Conclusion

We have applied the newly developed PWY method to identifying asset bubbles in the Hong Kong residential property market. The practical experience of the 1997 episode reveals that the PWY method is superior to the standard unit root and co-integration method. The PWY method is capable of detecting bubble-type behaviour and is able to identify the start and end of a bubble. In the post-2008 global financial crisis period, the PWY method is able to indicate strong upward price pressure in the mass segment and bubble-type behaviour in two relatively short periods of time in the luxury segment. The results show that the PWY method has good potential to be used for almost “real time” monitoring of bubble formation in asset markets.

Based on the empirical results, we reveal two special features of the PWY method which are potential shortcomings: (1) the high correlation between the p-r differentials and t-statistics near the critical

[20] The rapid rise of price in the period may be due to loosening monetary conditions and growing household income. The rent later rose quickly because property owners were trying to maintain acceptable rental yields.

values of the PWY test, that makes the t-statistics noisy, reduces the power of the test to give a clear signal of the existence of bubbles; and (2) the symmetric property towards explosive growth and precipitant fall of the time series may give false alarms.

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Figure 1. Real Price Index of the Hong Kong Residential Property Market (March 1993 to March 2011, 1999=100)

Source: Rating and Valuation Department and Census and Statistics Department of HKSAR

Figure 2. Log Price-Rent Differentials of the Hong Kong Residential Property Market (March 1993 to March 2011)

Source: Rating and Valuation Department and Census and Statistics Department of HKSAR

Figure 3. Price-Rent Differential and t-Statistics of the PWY Test of the Hong Kong Residential Property Market (March 1993 to December 1998)

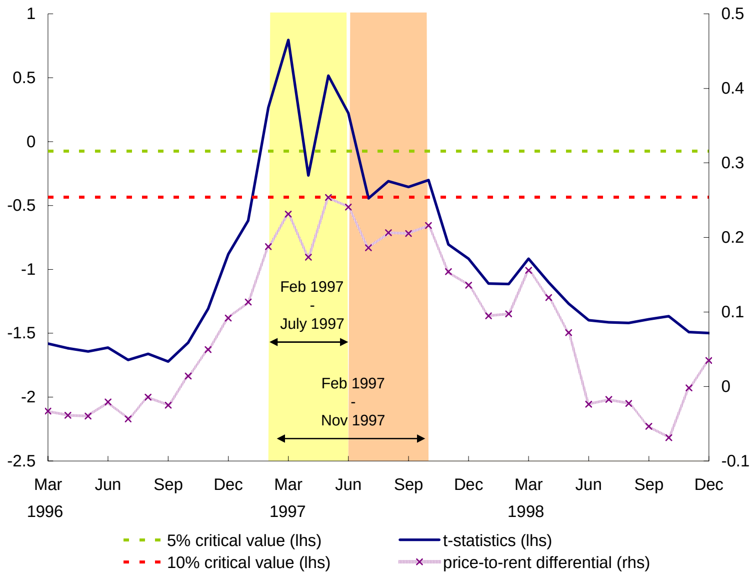

Figure 4. P-Value of the Co-Integration Test on P-R Differential of the Hong Kong Residential Property Market (March 1993 to December 1998)

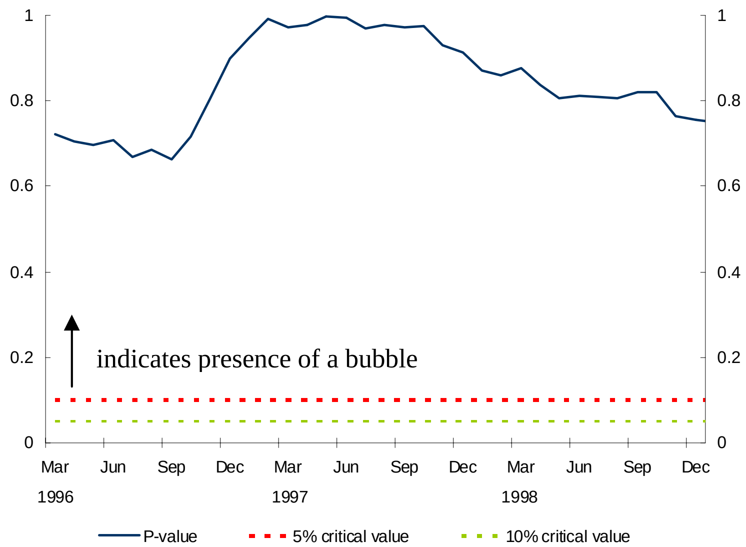

Figure 5. Price-Rent Differential and t-Statistics of the PWY Test of the Mass Segment of the Hong Kong Residential Property Market (June 2005 to March 2011)

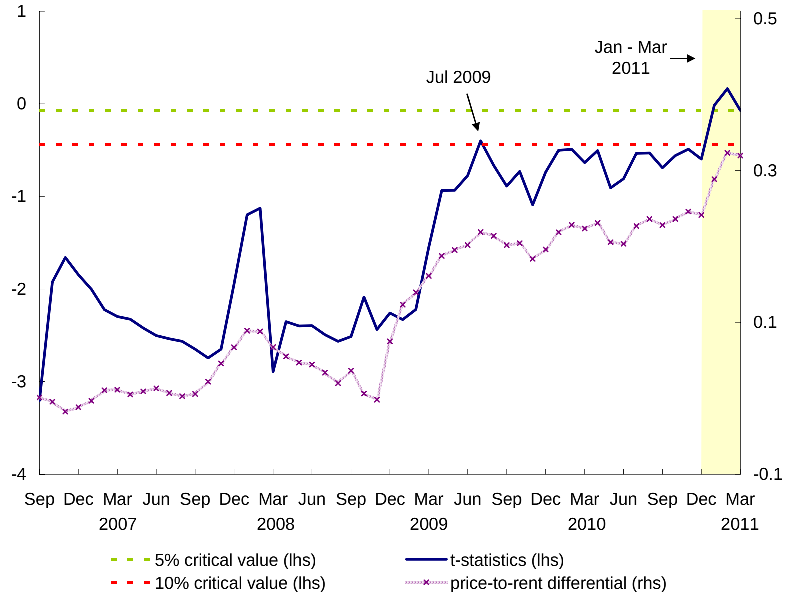

Figure 6. Price-Rent Differential and t-Statistics of the PWY Test of the Luxury Segment of the Hong Kong Residential Property Market (June 2005 to March 2011)

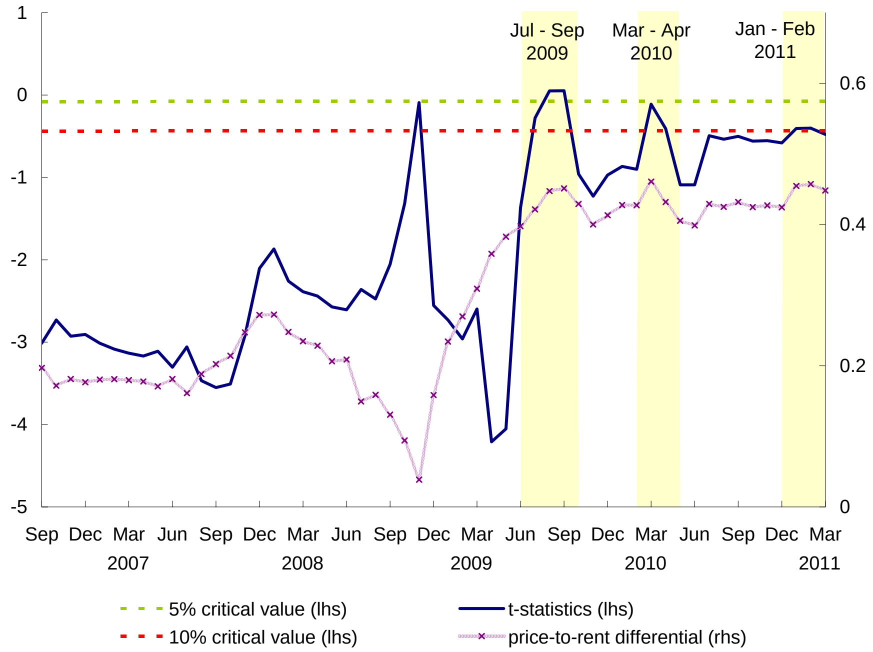

Figure 7. The t-Statistics of the PWY Test on the Price and Rent Series of the Mass Segment (June 2005 to March 2011)

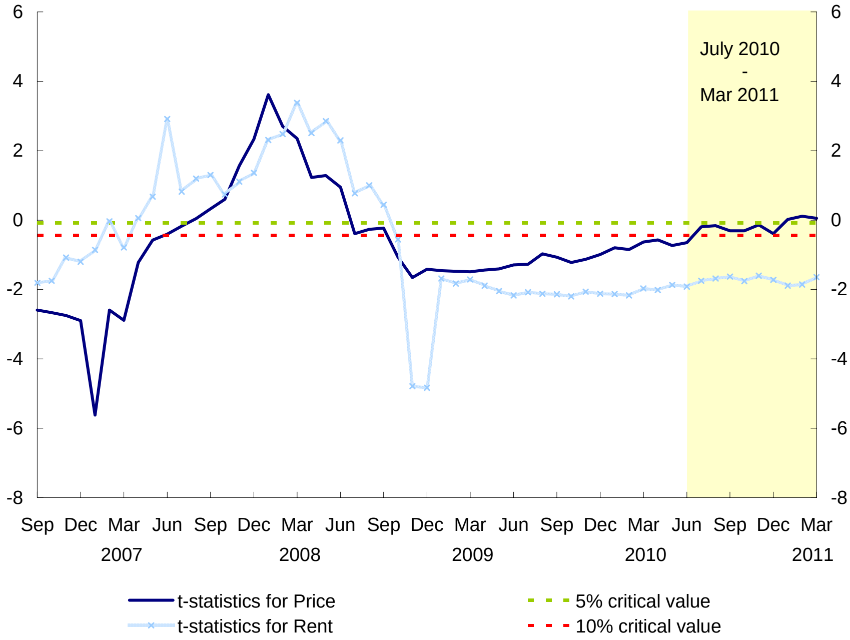

Figure 8. The t-Statistics of the PWY on the Price and Rent Series of the Luxury Segment (June 2005 to March 2011)