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Dating the timeline of house price bubbles in Australian capital cities

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Abstract:

House prices in some Australian capital cities have recently been on the rise to the extent that some describe this as an emerging bubble, but this claim remains formally untested to date. We apply a recently developed time series procedure to detect, and time stamp, bubbles in house price to rent ratios in Australian capital cities. The results show a sustained, yet varying, degree of speculative behaviour in all capital cities in the early 2000s. The onset of these bubbles were soon after the federal government introduced a major change to the capital gains tax law, and all of these bubbles collapsed with or before the global financial crisis. Recently, only Sydney and, with some delay, Melbourne have exhibited significant evidence of an exuberant rise in house prices compared to rents. We believe that the method that we apply has the potential to be a general early warning indicator to detect housing bubbles in other countries/markets. We provide the programming files to enable researchers to implement this test in other countries.

Keywords: Explosive bubbles; House prices; Rent; Australia.

JEL Classification Numbers: E31; R21; R39.

"*When you look at the housing bubble evidence, it is unequivocally the case in Sydney – unequivocally. .... Frankly, whatever the data says, just casual observation would tell you that's the case. ..... It does worry me that the very, very low – historically low – levels of interest rates are encouraging people to over-invest in housing*".

> John Fraser, Treasury Secretary, testimony before the House of Representatives Standing Committee on Economics, 2015 Inquiry into Home Ownership, Parliament of Australia.

"*A lot of people think it's a bubble, serious people think that and we agree this is a situation where the market is strong, it's overheated, it's a risky situation*".

> Malcolm Edey, Assistant Governor, Reserve Bank of Australia, testimony before the House of Representatives Standing Committee on Economics, 2015 Inquiry into Home Ownership, Parliament of Australia.

"*There is no bubble .... If housing was unaffordable in Sydney, nobody would be buying it*".

> Joe Hockey, then Treasurer of Australia (June 9, 2015).

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1. Introduction

As is well documented, the US housing market experienced a sharp increase, and then collapse, in housing prices, especially over the decade 2000 to 2010. This has led to much research on whether the house price increase in the boom phase was due to the existence of a bubble in the market (see e.g. Kivedal, 2013). More generally, the sizeable drop in house prices in the US between 2007 and 2009, and the role that falling house prices had as a catalyst for the global financial crisis (GFC), has generated considerable interest in understanding whether there are asset bubbles in housing markets. In addition to collapsing house prices in the US, declining house prices in parts of Europe, have fueled fears that other housing markets around the world that continue to experience rapid growth in housing prices, may also burst giving rise to recession. These fears have been reinforced by Reinhart and Roghoff's (2008) multi-country study of historical crises, which found that the US sub-prime crisis was very similar to previous crises, in that all have had a run up in house prices in the period leading to the bust.

Australian house prices have experienced strong growth since the middle of the 1990s. Based on the price to rent ratio, the OECD (2015) concluded that Australian house prices are overvalued by 48 per cent. According to the latest Annual International Housing Affordability Survey, housing in each of the five major metropolitan areas (Sydney, Melbourne, Brisbane, Adelaide and Perth) is considered "severely unaffordable", with the two largest cities (Sydney and Melbourne) rated the third and sixth least affordable city in the world respectively (Demographia, 2015). There have also been substantial consumption and wealth effects. Fisher et al. (2010) studied the response of non-housing consumption to permanent and transitory changes in housing wealth in Australia and found that large variations in housing wealth led to significant changes in the level of household wealth and consumption particularly after 2004.

The strong growth in housing prices has fuelled debate over whether Australia is experiencing a housing bubble. There is considerable difference of opinion on this point as reflected in the conflicting views of two of Australia's senior economic bureaucrats and Australia's immediate past Treasurer at the beginning of the paper. The most recent report of the Reserve Bank of Australia (as of October 2015), concludes that there will be a significant fall in house prices in the future, but the risks are manageable (Lannin, 2015a). Others are more pessimistic. For example, in a submission to the House of Representatives Standing Committee on Economics, 2015 Inquiry into Home Ownership, that was widely cited in the Australian media, David and Soos (2015, p.15) take it as a given that there is a bubble and it will burst:

> "Housing prices across all capital cities remain grossly inflated relative to rents, income, inflation and GDP. What event, or events, will trigger the beginning of the end of the housing bubble is not yet known. A bloodbath in the housing market, however, appears a near certainty due to the magnitude of falls required for housing prices to again reflect economic fundamentals".

In this paper we use the Phillips, Shi and Yu (2015a,b) (hereafter PSY) testing algorithm to examine whether the house price to rent ratio in the national capital, Canberra, and each of the state capital cities (Adelaide, Brisbane, Hobart, Melbourne, Perth, Sydney) has exhibited explosive behavior at any point in time over the period December 1995-August 2015. The PSY tests view asset bubbles in terms of mildly explosive growth in the time series of suitably normalized asset prices. This test is particularly apt for detecting bubbles in house prices. We believe that that the PSY procedure can be especially useful in providing real time information to inform investors and policy makers of the onset of an exuberant rise in house prices.

The results are important because our finding as to whether there is a housing bubble is a strong predictor of the possibility of a pending financial crisis. Shiller (2005, pp. xiii-iv) predicted the GFC, arguing that the rapid increase in house prices in the US in the late 1990s and early 2000s constituted a bubble that would lead to a recession as deep, and lasting, as Japan's “lost decade”. Much of the literature on whether there was a bubble in US housing markets, however, is retrospective. In other words, most studies have been conducted since the collapse in housing prices in the sub-prime crisis in an attempt to understand why the market burst. In those markets still experiencing strong growth in housing prices, such as Australia, China and the UK, there is the opportunity for investors and policy makers to *ex ante* avoid the fallout from a bubble. In this vein, we first need to determine whether there is, in fact, a bubble.

A second reason the results are important is that short episodes of housing bubbles can create significant and long-lasting waves of macroeconomic fluctuations in household consumption and GDP through wealth effects. When household leverage is high, incorporating “housing in a standard deleveraging model and allowing the debt limit of borrowers to tie to the market value of houses will amplify macroeconomic fluctuations under a credit shock, compared with the standard deleveraging model without housing and with exogenous debt limits” (Ngo, 2015, p.204). The early detection of housing bubbles is thus crucial for avoiding the spread of volatility to other key macroeconomic indicators. As Bloxham *et al.* (2011, p.1) put it:

> “The GFC has clearly demonstrated that a policy of ‘cleaning up the mess’ after a collapse in asset prices is problematic, especially if the collapse is associated with significant damage to financial institutions. This strengthens the case for taking early action in order to avoid a damaging correction later on.”

We make the following contributions to the literature. This is the first study to formally test for an asset bubble in the Australian housing market. Three previous studies for Australia to which our contribution is related are Costello et al (2011), Fox and Tulip (2014) and Fry et al. 2010. Costello et al. (2011) use a VAR model to ascertain the fundamental component of house prices and examine the extent to which the non-fundamental component spill over between states, while Fox and Tulip (2014) address the question, whether it costs more to own or rent. Fry et al. (2010) examine the extent of overvaluation in house prices in Australia during the period

2002-2008 by studying the effects of alternative housing demand and supply shocks. They find evidence that real house prices in Australia are overvalued and attribute such an overvaluation to demand shocks and wealth effects arising from equity markets. We differ from these studies in that we use the recently proposed PSY test to formally examine whether there is any evidence of explosive bubbles or exuberant behavior in the house price to rent series.

Second, as Anundsen (2013, p.2) notes, in the fallout from the US sub-prime crisis, there is a need "to develop an 'early warning system' to robustify the institutional framework and to prevent such events from repeating in the future". We use monthly house prices, sourced from SIRCA's (2015) CoreLogic RP online database which is updated each month. Thus, we also contribute by illustrating the application of tests that identify, and date, exuberant behavior in house prices, which, because the dataset is updated monthly, can serve as a leading indicator of asset bubbles in housing markets. We also provide the programing codes in Matlab for application in future studies aimed at detecting bubbles in any types of housing and non-housing assets with varying frequencies. This should prove particularly useful in detecting housing bubbles in other markets in which prices have been rising, such as China (Bian & Gete, 2015).

Our contribution is one of only a few studies that seek to identify asset price bubbles using formal statistical methods. Phillips, Wu and Yu (2011) (hereafter PWY) use a similar approach to date the NSADAQ stock market bubble in the US in the 1990s. Phillips and Yu (2011) use a modified version of the PWY test to date bubbles in house prices, crude oil prices and bond prices in the US. PSY (2015b) date several asset bubbles in the S&P 500 over 150 years. The only other application of the PSY (2015a,b) tests of which we are aware is Greenaway-McGrevy and Phillips (2015) who apply it to identify, and date, housing bubbles in New Zealand over the period 1993 to 2014, finding a current housing bubble in Auckland.

2. Econometric methodology

If the significance of a house was limited to the shelter that it provided, one would expect that its price would not deviate persistently from the expected value of the future stream of housing services that it provided over its physical life. This would mean that house prices would have the same trend as rents, i.e. they were cointegrated with rents, and the price to rent ratio would be stationary. However, the value of a house is not limited to the housing services that it provides. In Australia, owning an investment property has significant income tax implications unrelated to the value of housing services that it provides. These tax implications have undergone significant changes in the past 30 years. As a result, it is quite plausible to expect highly persistent deviation of house prices from the expected value of all future rents in the past 30 years, i.e. it is reasonable to expect that price to rent ratio has a unit root. Moreover, it is reasonable to expect that this ratio may also exhibit local drift as house prices transit from an old equilibrium to a new one following changes in tax policy that affects house prices, but not rents.

The time series dynamics described above, however, do not characterize dynamics of an asset price with "periodically collapsing rational bubbles" (Evans, 1991). These are self-feeding explosive components that appear in asset prices and last as a result of self-fulfilling expectations and then collapse randomly. Evans (1991) shows that it would be impossible to detect such behavior in time series observations using standard unit root tests.

Recently, PSY (2015 a,b) have developed a new test that can detect such periodically collapsing bubbles. They have also developed an algorithm for time stamping the beginning of a bubble in real time, which we will refer to as the PSY procedure hereafter. Their work improves upon the dating algorithms in PWY (2011) and Homm and Breitung (2012), in particular when the sample period is likely to include multiple episodes of explosive bubbles, which is likely in this application. Hence, we use the PSY procedure to examine whether the house price to rent ratio in Australian capital cities has exhibited explosive bubbles (behaviour) using all available monthly observations (1995m12-2015m8) from SIRCA's CoreLogic RP online dataset.

The PSY procedure is based on a test statistic that is designed to have power to detect mildly explosive behavior in a time series. The null hypothesis is that the time series contains a random walk with possibly local drift, which is a reasonable null for house price to rent ratio as explained in the first paragraph of this section. This null hypothesis can be specified as:

$$H_0: y_t = kT^{-\eta} + y_{t-1} + \varepsilon_t, \tag{1}$$

with constant k and $\eta>1/2$, where y_t is the price-to-rent ratio at period *t* in any given capital city, ε_t is the error term, and *T* is the sample size. The alternative hypothesis characterizes the mildly explosive behavior, which is a reasonable depiction of periodically collapsing bubbles as described above in the second paragraph of this section, with the following specification:

$$H_A: y_t = \delta_T y_{t-1} + \varepsilon_t, \tag{2}$$

where $\delta_T = 1 + cT^{-\alpha}$ with c>0 and $\alpha \in (0,1)$. The main ingredient of the PSY procedure is the augmented Dickey-Fuller (ADF) test statistic, which is the *t*-statistic of the coefficient of y_{t-1} in the regression:

$$\Delta y_t = \alpha + \beta y_{t-1} + \sum_{i=1}^{K} \gamma_i \Delta y_{t-i} + \varepsilon_t. \tag{3}$$

Equation (3) includes an intercept but no time trend and *K* is the optimum lag length which is determined by the Bayesian information criterion (BIC).

For each observation y_τ, the procedure uses all information before time τ to determine if there is sufficient evidence to reject the null that y_τ belongs to the martingale null in favor of the mildly explosive alternative. The algorithm calculates the augmented Dickey-Fuller (ADF) statistic repeatedly on a sequence of backward expanding samples. The ending points of all samples are fixed on time τ and the starting point of the samples varies from the first observation to τ-τ_0+1, where τ_0 is the minimum number of observations needed to estimate equation (3). The corresponding ADF statistic sequence is shown as:

$$\{ADF_{\tau_1}^{\tau_2}\}_{\tau_2=\tau}^{\tau_1\in[1,\tau-\tau_0+1]} \tag{4}$$

Inference of explosiveness for observation τ is based on the maximum value of the ADF sequence, denoted by $BSADF_{\tau}$ and defined as follows:

$$BSADF_{\tau} = max\{ADF_{\tau_1}^{\tau_2}: \tau_2 = \tau \; and \; \tau_1 \in [1, \tau - \tau_0 + 1]\} \tag{5}$$

PSY (2015b) derive the asymptotic distribution of this test statistic under the null. If the value of the $BSADF_{\tau}$ statistic is larger than the right tail critical value of this distribution, then y_{τ} is classified to be from a bubble episode.

In our application, we set τ_0 to 30 based as recommended in Phillips, Shi and Yu (2015a). They suggest this value to be set to a proportion close to $0.01 + 1.8/\sqrt{T}$ of the sample size to reduce the probability of size distortion. We obtain the finite sample critical value sequences for the $BSADF_{\tau}$ test statistic from a Monte Carlo simulation with 2,000 replications.

3. Data

All currently available monthly house prices (December 1995-August 2015) have been sourced from SIRCA's (2015) CoreLogic RP online database. SIRCA adopts a hedonic imputation methodology across both time and space (Goh et al., 2012) which takes into account observed housing characteristics and the average price changes in repeat sales of the same properties. The Australian Bureau of Statistics (ABS, 2015a, Cat. 6416, Table 8) published established house price indices for all capital cities from June 1986 to June 2005. However, after September 2005 the ABS (2015a, Cat 6416, Table 2) has adopted a different methodology and published and backdated established house price indices only from March 2002. Combining both incompatible series (ABS, 2015a, Tables 2 and 8) would give us a total number of 117 quarterly observations, spanning from June 1986 to June 2015 which is the most recent available quarter. However, the use of the CoreLogic RP data not only doubles the number of observations from 117 quarters to 237 months (1995m12-2015m8), it also provides more accurate, consistently defined and timely data with which we examine the formation of explosive bubbles in the housing market. Therefore, the estimated time varying $BSADF_{\tau}$ can serve as an easily replicable monthly early warning signal, measuring the pulse of the property market.

As to the second variable, only quarterly capital city rent indices can be obtained from the ABS (2015b, Cat 6401.0, Table 11) as one of the sub-groups of the Consumer Price Index during the period September 1972-June 2015, totaling 172 quarterly observations. However, given the fact that quarterly house prices are available for the period June 1986-June 2015, the adjusted sample size for both variables constitutes only 117 quarterly observations. Thus, we have two choices: either use 117 quarterly inconsistent observations or change the frequency of the rent indices from quarterly to monthly and work with 237 observations.

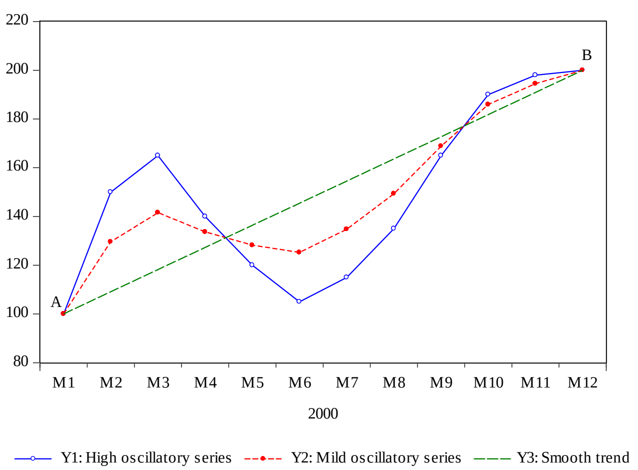

Fig. 1. Plot of three hypothetical series in 2000.

If the rent series had exhibited oscillatory behavior through time like the hypothetical Y1 and Y2 series in Figure 1, such frequency conversion would introduce measurement errors. However, if we know *a priori* that a series follows a non-oscillatory and relatively smooth trend like Y3, the resulting interpolation would still provide reliable estimates because finding the path between two hypothetical points A and B in Figure 1 is rather straightforward to predict.

Over a 12-month period actual rent indices are more likely to resemble Y3 than Y1 (see Figure 2). As can be seen from the Appendix table, we have adopted two totally different approaches in converting quarterly data to monthly observations: (a) linear frequency conversion (with first observation matched to the source data); and (b) cubic spline frequency conversion (with first observation again matched to the source data). The results in the Appendix table show that the two converted monthly series are so similar that if we were to draw them in a single graph they would have been indistinguishable. We also undertook the quadratic low to high frequency conversion method and the results (not reported but available upon request) were almost identical to those two shown in the Appendix table. Hence, in this study, we use the monthly rent indices resulting from the cubic spline conversion method which are shown in Figure 2, exhibiting a relatively smooth trend over the sample period (1995m12-2015m8).

Figure 3 shows the logarithmic difference between house prices and rent indices in all major capital cities for the period (1995m12-2015m8). As expected, the mean of the house price to rent index ratio (on logarithmic scales) during the sample period was highest in Sydney (1.89) followed by Canberra (1.63), Melbourne (1.55), Perth (1.54), Brisbane (1.40), Adelaide (1.25) and Hobart (1.03). While in Hobart and Adelaide this ratio has always been less than that of the other capital cities, the same cannot be said about the rest. For example, in the midst of the 2006 mining boom this ratio in Perth temporarily exceeded all other capital cities including Sydney. Moreover, while both Brisbane and Melbourne had the same ratio at the beginning of the sample period, the price to rent ratio in Melbourne exceeded that in Brisbane by 2005. In terms of the standard deviation, Hobart (0.345) and Melbourne (0.335) had the most volatile price to rent ratio, whereas Sydney (0.210) and Canberra (0.278) enjoyed the lowest volatility levels.

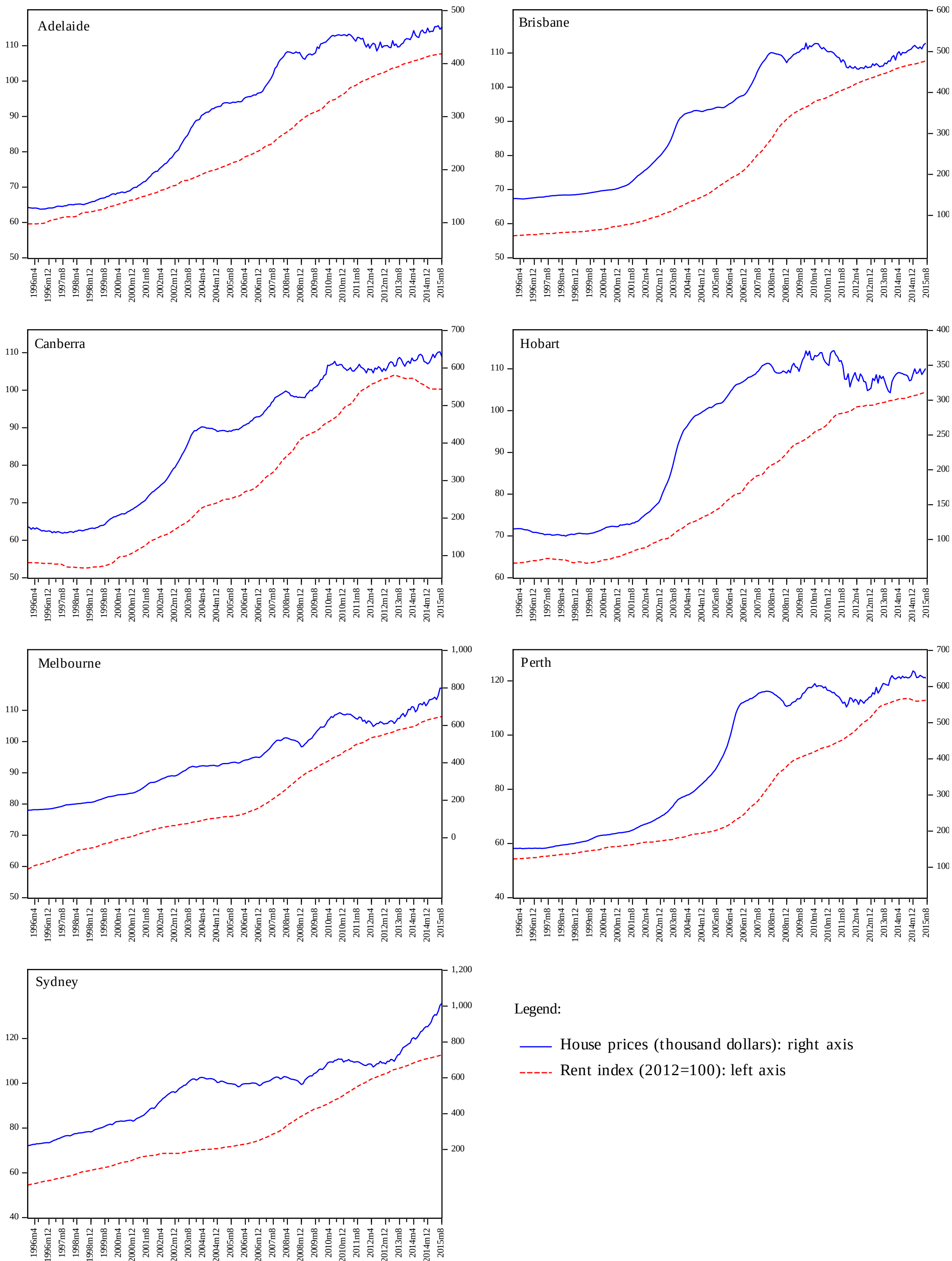

Fig. 2. House prices and rent indices in major capital cities (1995m12-2015m8).

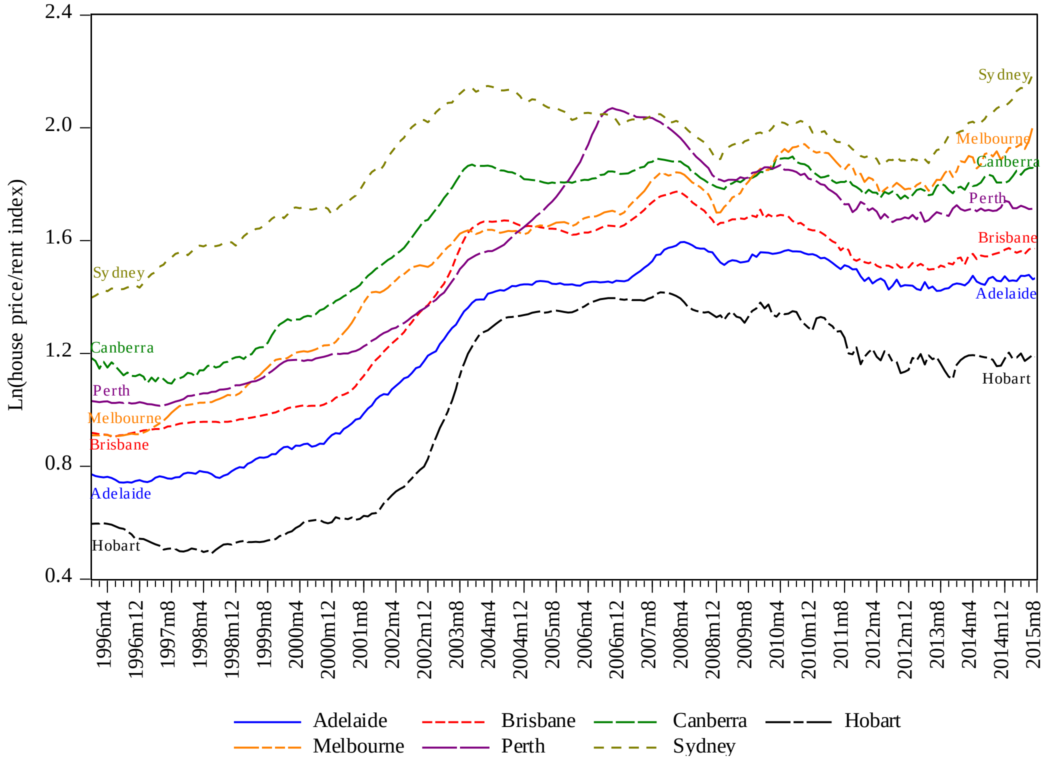

Fig. 3. House price to rent ratios in major capital cities (1995m12-2015m8).

4. Empirical results and policy implications

For each monthly observation we estimated the $BSADF_\tau$ statistics by using equation (5) and imposing a minimum window size equal to 30 months. This means that the ADF test statistic sequence commences after the 31st observation (i.e. 1998m5) rather than the beginning of the sample (i.e. 1995m12). In order to make robust inferences regarding the timing of speculative bubbles, we conduct a Monte Carlo simulation with 2,000 replications to generate the $BSADF_\tau$ statistic sequences and the corresponding critical values at the 90%, 95% and 99% levels. The bubble detection test results are displayed in Figure 4 during the period 1998m5-2015m8 for all seven capital cities.

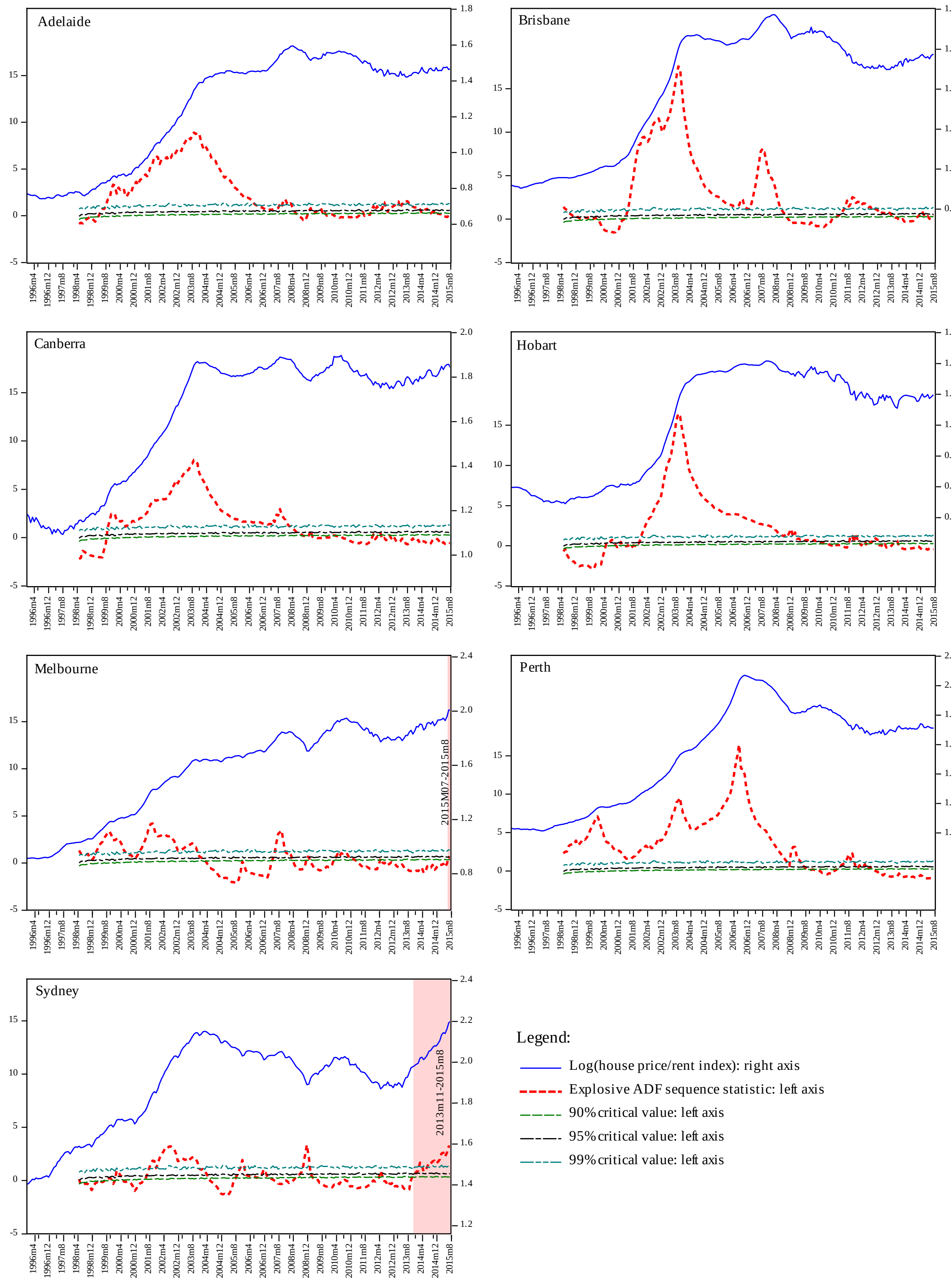

Fig. 4. Chronology of the explosive bubbles in the house price to rent ratio(1998m5-2015m8).

Note: The latest significant explosive bubbles (>95%) are shaded in pink

Based on Figure 4, we observe an explosive bubble in Adelaide, Canberra, Melbourne and Sydney, commencing in 1999 or 2000 and one year later in Brisbane and Hobart. These bubbles last until 2004 (Sydney), 2006-07 (Adelaide, Brisbane and Canberra) and 2008-09 (Hobart). Over these dates, the $BSADF_{\tau}$ statistics in these cities consistently exceeded the three critical values. Broadly, these bubbles correspond with the housing boom in Australia over the first half of the 2000s. The commencement of these bubbles either coincide with, in the case of Adelaide, Canberra, Melbourne and Sydney, or follow with a lag, in the case of Brisbane and Hobart, Federal Government changes to capital gains tax in September 1999. The changes to capital gains tax provided property investors with a 50 per cent discount on tax payable if they hold their property for one year. As can be seen in Figure 4, these changes were the precursor to the considerable upswing in property price to rent series in the first half of the 2000s.

The sharp increase in the housing price to rent ratio in the first half of the 2000s was mainly on the back of the policy change induced boom in rental property investment. The overall number of rental property investors, and the proportion who are negatively geared, has risen sharply since 2000 with a structural break around 2000 or 2001 (ACOSS, 2015). By 2003, 45 per cent of new housing loans were for investment purposes, compared with around 25 per cent at the end of the 1990s (Bloxham et al., 2011). By 2013 two-thirds of investors were negatively geared, compared with one half in the 1990s (David & Soos, 2015). And most (over 90 per cent) investment in negatively geared housing stock is in existing properties (Eslake, 2014). Lending for investment in new construction has been negligible and flat since the 1980s; however, lending for investment in existing dwellings increased from approximately $A2 billion in 1999 to $A7 billion in 2004 (ACOSS, 2015; Department of Social Services, 2014).

The housing bubble in Perth was already in full swing when the changes to the capital gains tax provisions were introduced in 1999. In terms of duration, Perth experienced the longest and most sustainable house price bubble from May 1998 until December 2008. For about two-thirds of the detection window, Perth experienced a more chronic, sustained and longer lasting explosive bubble in house prices than any other capital city. The housing price bubble in Perth was due to a significant boom in the mining sector. Western Australia, which has considerable mineral resources, has been the epicenter of Australia's commodity boom. Western Australia's minerals and petroleum industry grew by an average 15 per cent annually over the period 2003 to 2013, built largely on exports of iron and ore to China. The commodities boom generated an influx of interstate and foreign workers to Perth and substantially higher wages, pushing up house prices (Steele, 2014).

As can be seen from Figure 4, the same applied to Brisbane, which also benefited from the mining boom, but to a lesser extent. That both cities were major beneficiaries of the mining boom, contributed to both cities remaining in the speculative housing bubble zone longer than other cities. The housing bubble in both cities ends around the GFC, which coincides with slower economic growth in China. Both cities have experienced varying degrees of price to rent ratio adjustments since 2008.

Both Sydney and Melbourne house prices have been subject to more frequent, but shorter, bubbles (in terms of duration) than the other capital cities. The bubble at the beginning of the 2000s ended much earlier in Sydney than other cities. In the lower income suburbs of western Sydney, house prices declined between 5 per cent and 20 per cent in 2004 (Bloxham et al., 2011). Based on the 99% time-varying critical values shown in Figure 4, an explosive, sustained and rising bubble formed in Sydney in November 2013. There is no evidence of current explosive bubbles in any of the other capital cities, except Melbourne, which only surfaced in July 2015 based on the ADF 95% critical value. This result provides some support for the findings in other studies of Australian housing markets, employing alternative methodologies, that the Sydney market, and to a lesser extent, Melbourne market, behave differently to the other capital cities (see eg. Akimov. et al., 2015; Costello et. al., 2011; Valadkhani & Smyth, 2015). In Melbourne and Sydney, housing prices have been driven by strong growth in demand for inner city housing, both from negatively geared domestic investors and from foreign investors from Asia and, in particular, China (Birrell & Healy, 2013; Valadkhani & Smyth, 2015).

That Sydney, and more recently, Melbourne, have exhibited significant evidence of an exuberant rise in house prices compared to rents, is consistent with views, such as that expressed by Treasury Secretary John Fraser, quoted at the start of this paper, that Sydney house prices are "unequivocally" in a bubble. The results for Sydney also accord with comments made by Reserve Bank of Australia Governor, Glenn Stephens who stated in a speech in June 2015 that Sydney property prices were "crazy" (Morgan & Janda, 2015). House prices in Sydney have increased 30 per cent since 2012, while income and rent have remained relatively stagnant (Lannin, 2015b). Expensive property, relative to potential earnings in rent in Sydney, can be explained, at least in part, by sustained market exuberance that has produced a bubble in the housing market since late 2013. This result is similar to the findings of Greenaway-McGrevy and Phillips (2015) for the Auckland property market in New Zealand since 2013.

An obvious question is whether the current bubble in Sydney, and more recently, Melbourne, in housing prices will continue. Application of the PSY tests is unable to answer this. To answer this question requires a generative mechanism for the bubble with driver variables as predictors (Greenaway-McGrevy & Phillips, 2015). While Greenaway-McGrevy and Phillips (2015) and Phillips and Yu (2011) offer some preliminary ideas about how such a model could be constructed, no such model yet exists in the literature. Nevertheless, we can still speculate. In this respect, that in Sydney, and to a lesser extent, Melbourne the current housing boom is being driven by the demand for inner city units is potentially problematic, given the growing oversupply of inner city units (Yardney, 2015). This suggests that the upswing in prices in both cities observed at the end of the sample period might end and prices begin to fall. This view is consistent with recent findings in Valadkhani and Smyth (2015) that the boom in house prices in these two cities may come to an end or exhibit more moderate growth.

Much of the concern about a housing bubble more generally in Australian markets seems overstated. In the same speech in June 2015, Glenn Stephens also stated that while “Sydney's property price boom is ‘acutely concerning’, …. most other capital city property markets were not rising strongly” (Morgan & Janda, 2015). Our results are consistent with this view. In their widely cited submission to the 2015 Inquiry into Home Ownership, David and Soos (2015, p.15) argue that there is a housing bubble and that “Melbourne is primed to become the epicenter of a legendary housing market crash”. While there is the beginning of a housing bubble in Melbourne very late in our sample period, it is too early to refute or confirm such a claim.

5. Conclusions

The US sub-prime crisis has focused attention on the need to develop early warning mechanisms to detect the existence of asset bubbles in housing markets. There are, however, very few formal statistical tests for the existence and timing of asset bubbles and even fewer applications to housing markets. In this paper we have applied the latest statistical test of asset bubbles, proposed by PSY (2015a, 2015b), to the house price to rent ratio in Australia using monthly data for the last two decades. The Australian housing market represents an interesting laboratory in which to test for asset bubbles because it has experienced almost two decades of relatively sustained growth in prices that has largely withstood the GFC downturn.

We find evidence of asset bubbles in several capital cities of differing duration. Many of these coincide broadly with the housing boom in the first half of the 2000s that followed changes in the capital gains tax for investment properties implemented in September 1999. The housing bubble in Perth, and to a lesser extent Brisbane, was much longer and was sustained mainly by the commodities boom. We also find evidence of a current asset bubble in the Sydney housing market since December 2013 and Melbourne since July 2015. Given that our results suggest that the current bubble is focused on one or two cities, they are consistent with the position of the Reserve Bank of Australia that while prices will fall, the risks are manageable (Lannin, 2015a).

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Appendix

Monthly rent indices (2012=100) based on the linear and cubic spline frequency conversion methods.

Months	Adelaide		Brisbane		Canberra		Hobart		Melbourne		Perth		Sydney	
	Linear[(a)]	Cubic[(b)]	Linear[(a)]	Cubic[(b)]	Linear[(a)]	Cubic[(b)]	Linear[(a)]	Cubic[(b)]	Linear[(a)]	Cubic[(b)]	Linear[(a)]	Cubic[(b)]	Linear[(a)]	Cubic[(b)]
1995M12	59.60	59.61	56.43	56.44	54.03	54.01	63.47	63.47	59.27	59.20	54.23	54.24	54.47	54.47
…														
1999M01	63.10	63.10	57.60	57.60	52.80	52.80	63.80	63.80	66.00	66.00	56.60	56.60	61.30	61.30
1999M02	63.23	63.24	57.63	57.62	52.83	52.84	63.73	63.78	66.17	66.13	56.73	56.74	61.47	61.48
1999M03	63.37	63.39	57.67	57.65	52.87	52.87	63.67	63.70	66.33	66.29	56.87	56.88	61.63	61.65
1999M04	63.50	63.50	57.70	57.70	52.90	52.90	63.60	63.60	66.50	66.50	57.00	57.00	61.80	61.80
1999M05	63.57	63.55	57.77	57.76	52.97	52.94	63.57	63.53	66.73	66.75	57.07	57.08	61.93	61.94
1999M06	63.63	63.59	57.83	57.83	53.03	53.01	63.53	63.49	66.97	67.00	57.13	57.13	62.07	62.07
1999M07	63.70	63.70	57.90	57.90	53.10	53.10	63.50	63.50	67.20	67.20	57.20	57.20	62.20	62.20
1999M08	63.93	63.91	57.97	57.97	53.23	53.22	63.57	63.55	67.30	67.31	57.30	57.30	62.37	62.35
1999M09	64.17	64.17	58.03	58.04	53.37	53.35	63.63	63.63	67.40	67.39	57.40	57.41	62.53	62.51
1999M10	64.40	64.40	58.10	58.10	53.50	53.50	63.70	63.70	67.50	67.50	57.50	57.50	62.70	62.70
1999M11	64.50	64.53	58.13	58.14	53.73	53.66	63.77	63.75	67.73	67.70	57.57	57.55	62.93	62.91
1999M12	64.60	64.61	58.17	58.17	53.97	53.88	63.83	63.81	67.97	67.95	57.63	57.61	63.17	63.15
…														
2003M01	70.60	70.60	62.70	62.70	63.20	63.20	69.20	69.20	73.20	73.20	61.00	61.00	68.70	68.70
2003M02	70.97	70.94	62.90	62.92	63.50	63.51	69.27	69.27	73.33	73.34	61.10	61.10	68.77	68.72
2003M03	71.33	71.36	63.10	63.13	63.80	63.82	69.33	69.31	73.47	73.49	61.20	61.21	68.83	68.78
2003M04	71.70	71.70	63.30	63.30	64.10	64.10	69.40	69.40	73.60	73.60	61.30	61.30	68.90	68.90
2003M05	71.77	71.84	63.47	63.44	64.37	64.35	69.70	69.62	73.63	73.64	61.37	61.35	69.10	69.10
2003M06	71.83	71.87	63.63	63.59	64.63	64.60	70.00	69.94	73.67	73.65	61.43	61.40	69.30	69.32
2003M07	71.90	71.90	63.80	63.80	64.90	64.90	70.30	70.30	73.70	73.70	61.50	61.50	69.50	69.50
2003M08	72.10	72.04	64.13	64.12	65.33	65.27	70.63	70.67	73.87	73.84	61.70	61.69	69.57	69.60
2003M09	72.30	72.26	64.47	64.48	65.77	65.71	70.97	71.01	74.03	74.03	61.90	61.92	69.63	69.64
2003M10	72.50	72.50	64.80	64.80	66.20	66.20	71.30	71.30	74.20	74.20	62.10	62.10	69.70	69.70
2003M11	72.70	72.71	65.00	65.03	66.70	66.71	71.53	71.54	74.27	74.29	62.17	62.19	69.83	69.81
2003M12	72.90	72.90	65.20	65.21	67.20	67.22	71.77	71.76	74.33	74.34	62.23	62.23	69.97	69.95
…														
2007M01	80.60	80.60	76.40	76.40	75.40	75.40	82.20	82.20	79.20	79.20	71.70	71.70	74.90	74.90
2007M02	80.97	80.98	76.97	76.93	75.90	75.93	82.60	82.68	79.53	79.53	72.40	72.44	75.23	75.22
2007M03	81.33	81.38	77.53	77.49	76.40	76.45	83.00	83.05	79.87	79.86	73.10	73.16	75.57	75.55
2007M04	81.70	81.70	78.10	78.10	76.90	76.90	83.40	83.40	80.20	80.20	73.80	73.80	75.90	75.90
2007M05	81.87	81.87	78.73	78.76	77.20	77.23	83.73	83.79	80.57	80.55	74.30	74.30	76.27	76.27
2007M06	82.03	81.99	79.37	79.41	77.50	77.51	84.07	84.15	80.93	80.92	74.80	74.76	76.63	76.64
2007M07	82.20	82.20	80.00	80.00	77.80	77.80	84.40	84.40	81.30	81.30	75.30	75.30	77.00	77.00
2007M08	82.67	82.59	80.47	80.48	78.27	78.18	84.50	84.48	81.70	81.70	76.10	76.00	77.33	77.33
2007M09	83.13	83.09	80.93	80.91	78.73	78.65	84.60	84.53	82.10	82.10	76.90	76.82	77.67	77.65
2007M10	83.60	83.60	81.40	81.40	79.20	79.20	84.70	84.70	82.50	82.50	77.70	77.70	78.00	78.00
2007M11	83.97	84.02	82.07	82.01	79.83	79.82	85.20	85.11	82.90	82.89	78.57	78.57	78.47	78.39
2007M12	84.33	84.38	82.73	82.71	80.47	80.47	85.70	85.66	83.30	83.28	79.43	79.44	78.93	78.85
…														
2011M01	96.70	96.70	97.50	97.50	95.60	95.60	97.60	97.60	97.00	97.00	96.10	96.10	95.20	95.20
2011M02	97.20	97.20	97.77	97.77	95.83	95.87	98.03	98.09	97.23	97.26	96.43	96.41	95.67	95.69
2011M03	97.70	97.75	98.03	98.04	96.07	96.05	98.47	98.55	97.47	97.44	96.77	96.76	96.13	96.14
2011M04	98.20	98.20	98.30	98.30	96.30	96.30	98.90	98.90	97.70	97.70	97.10	97.10	96.60	96.60
2011M05	98.40	98.46	98.53	98.55	96.87	96.74	99.03	99.11	98.13	98.11	97.40	97.40	97.10	97.09
2011M06	98.60	98.62	98.77	98.78	97.43	97.33	99.17	99.23	98.57	98.59	97.70	97.69	97.60	97.60
2011M07	98.80	98.80	99.00	99.00	98.00	98.00	99.30	99.30	99.00	99.00	98.00	98.00	98.10	98.10
2011M08	99.13	99.10	99.20	99.20	98.60	98.68	99.40	99.39	99.17	99.24	98.40	98.36	98.53	98.56
2011M09	99.47	99.46	99.40	99.40	99.20	99.31	99.50	99.49	99.33	99.37	98.80	98.76	98.97	98.99
2011M10	99.80	99.80	99.60	99.60	99.80	99.80	99.60	99.60	99.50	99.50	99.20	99.20	99.40	99.40
2011M11	100.00	100.04	99.83	99.81	100.07	100.12	99.77	99.72	99.77	99.71	99.67	99.66	99.80	99.79
2011M12	100.20	100.23	100.07	100.05	100.33	100.36	99.93	99.88	100.03	99.98	100.13	100.12	100.20	100.18
…														
2013M01	102.90	102.90	102.80	102.80	103.20	103.20	101.30	101.30	102.60	102.60	107.50	107.50	104.60	104.60
2013M02	103.17	103.19	103.00	102.99	103.43	103.42	101.43	101.41	102.73	102.73	108.30	108.33	105.03	105.03
2013M03	103.43	103.48	103.20	103.20	103.67	103.69	101.57	101.56	102.87	102.84	109.10	109.17	105.47	105.50
2013M04	103.70	103.70	103.40	103.40	103.90	103.90	101.70	101.70	103.00	103.00	109.90	109.90	105.90	105.90
2013M05	103.80	103.81	103.57	103.58	103.87	103.97	101.77	101.78	103.23	103.23	110.30	110.45	106.10	106.16
2013M06	103.90	103.88	103.73	103.75	103.83	103.92	101.83	101.83	103.47	103.49	110.70	110.83	106.30	106.33
2013M07	104.00	104.00	103.90	103.90	103.80	103.80	101.90	101.90	103.70	103.70	111.10	111.10	106.50	106.50
2013M08	104.27	104.24	104.07	104.05	103.63	103.64	102.03	102.03	103.80	103.82	111.30	111.31	106.77	106.73
2013M09	104.53	104.53	104.23	104.21	103.47	103.46	102.17	102.17	103.90	103.90	111.50	111.50	107.03	107.01
2013M10	104.80	104.80	104.40	104.40	103.30	103.30	102.30	102.30	104.00	104.00	111.70	111.70	107.30	107.30
2013M11	104.93	104.97	104.63	104.62	103.23	103.18	102.37	102.37	104.17	104.16	111.97	111.95	107.57	107.56
2013M12	105.07	105.09	104.87	104.86	103.17	103.11	102.43	102.42	104.33	104.35	112.23	112.23	107.83	107.82
2014M01	105.20	105.20	105.10	105.10	103.10	103.10	102.50	102.50	104.50	104.50	112.50	112.50	108.10	108.10
2014M02	105.37	105.35	105.30	105.32	103.10	103.15	102.63	102.64	104.60	104.59	112.70	112.74	108.43	108.43
2014M03	105.53	105.53	105.50	105.53	103.10	103.19	102.77	102.79	104.70	104.66	112.90	112.94	108.77	108.77
2014M04	105.70	105.70	105.70	105.70	103.10	103.10	102.90	102.90	104.80	104.80	113.10	113.10	109.10	109.10
2014M05	105.83	105.84	105.83	105.84	102.77	102.83	102.90	102.91	105.10	105.05	113.20	113.22	109.37	109.38
2014M06	105.97	105.97	105.97	105.97	102.43	102.46	102.90	102.89	105.40	105.37	113.30	113.32	109.63	109.64
2014M07	106.10	106.10	106.10	106.10	102.10	102.10	102.90	102.90	105.70	105.70	113.40	113.40	109.90	109.90
2014M08	106.27	106.25	106.23	106.24	101.87	101.84	103.03	103.00	105.97	106.00	113.40	113.48	110.17	110.18
2014M09	106.43	106.42	106.37	106.38	101.63	101.63	103.17	103.15	106.23	106.26	113.40	113.50	110.43	110.46
2014M10	106.60	106.60	106.50	106.50	101.40	101.40	103.30	103.30	106.50	106.50	113.40	113.40	110.70	110.70
2014M11	106.77	106.78	106.60	106.60	101.10	101.09	103.40	103.41	106.70	106.72	113.13	113.15	110.87	110.88
2014M12	106.93	106.95	106.70	106.70	100.80	100.77	103.50	103.50	106.90	106.92	112.87	112.85	111.03	111.04
2015M01	107.10	107.10	106.80	106.80	100.50	100.50	103.60	103.60	107.10	107.10	112.60	112.60	111.20	111.20
2015M02	107.20	107.22	106.93	106.93	100.43	100.35	103.73	103.73	107.23	107.26	112.60	112.50	111.40	111.40
2015M03	107.30	107.32	107.07	107.07	100.37	100.29	103.87	103.87	107.37	107.39	112.60	112.52	111.60	111.61
2015M04	107.40	107.40	107.20	107.20	100.30	100.30	104.00	104.00	107.50	107.50	112.60	112.60	111.80	111.80
2015M05	107.47	107.48	107.30	107.31	100.33	100.33	104.10	104.11	107.57	107.57	112.67	112.68	111.93	111.95
2015M06	107.53	107.54	107.40	107.41	100.37	100.37	104.20	104.21	107.63	107.63	112.73	112.75	112.07	112.07
2015M07	107.60	107.60	107.50	107.50	100.40	100.40	104.30	104.30	107.70	107.70	112.80	112.80	112.20	112.20
2015M08	107.63	107.64	107.60	107.60	100.40	100.41	104.40	104.40	107.80	107.79	112.83	112.84	112.37	112.35

Notes: (a) Linear frequency conversion (with first observation matched to the source data). (b) Cubic spline frequency conversion (with first observation matched to the source data).

Source: The authors' calculations and ABS (2015b).