1 Introduction

Movements in house prices in the last few years have sparked considerable debate about the factors driving those changes. For example, Smith and Smith (2006), Himmelberg et al. (2005), Krainer and Wei (2004) and McCarthy and Peach (2004) examine the price of houses in the U.S. relative to various fundamentals, such as per capita personal income, historical prices, population density and long-term interest rates. Their analyses suggest there was no overall evidence of bubbles except, possibly, in a few coastal states. These results indicate that fundamentals can explain both the patterns and the geographical dispersion of U.S. house prices, as well as why some areas seem more likely to experience house price booms than others. Other studies have disputed this view and argued that a bubble was present (e.g., Krugman, 2005; McCarthy and Peach, 2005; and Shiller, 2005).

Asset price bubbles are difficult to define and even more difficult to detect. A consensus view is that a state where investors hold the asset only for the expected capital gain rather than the dividend (or rent, or utility from occupancy of a house in this case) would constitute a bubble.[1] The detection of bubbles is more contentious and in this paper we take the route of analyzing the univariate time series properties of regional and aggregate U.S. house prices. Evidence of explosiveness in those series could be associated with the presence of a bubble term in the data generating mechanism of the price if one is ready to rule out explosive behavior in any of the fundamentals.[2]

Once the periods where prices reflect factors other than fundamentals have

[1] Case and Shiller (2003) widely discuss the term housing bubble as well as presenting evidence on the relationship between home prices and fundamentals. Arces and Lopez-Salido (2010) develop a life-cycle model that provides theoretical underpinnings to the existence of bubbles in the housing market.

[2] Or indeed assume that, e.g., switching fundamentals are not observationally equivalent to explosive behavior in the price series (see Flood and Hodrick (1986) in the context of variance bounds tests). In that sense we refer to the term bubble with caution.

been identified, the effect of such deviations upon household behavior can be investigated. Some theoretical models suggest that only the 'non-fundamental' component of real house prices/housing wealth has an impact on non-housing consumption (e.g. Buiter, 2008). We address this issue by augmenting the consumption model of Lettau and Ludvigson (2001, and 2004) with a variable that captures the acceleration(deceleration) in house prices. In order to analyze such effect this paper proceeds sequentially. First, we test for explosive behavior in house prices and second, we examine their effect on consumption.

2 Temporary Explosive Behavior in House Prices

There are different ways to test for the presence of bubbles in asset prices (see Gurkaynak, 2005, for a comprehensive review). We follow the more recent methodology of Phillips et al. (2007) because it enables us to identify the starting and finishing date of the explosive behavior of a series. This will be useful when trying to interpret the effect of house prices on consumption. According to Phillips et al. the house price would be classified as a bubble when the null of a unit root can be rejected against the alternative of an explosive series using the following regression

$$s_t = \mu + \phi s_{t-1} + \sum_{j=1}^{J} \xi_j \Delta s_{t-j} + \varepsilon_{s,t}, \quad \varepsilon_{s,t} \sim NID(0, \sigma_s^2), \tag{1}$$

where s_t is the asset price, the null hypothesis is $H_0 : \phi = 1$, and the alternative $H_1 : \phi > 1$. Phillips et al. (2007) propose two tests, a right-side and a *sup* Augmented Dickey–Fuller (ADF) test based on the recursive estimation of (1).[3] Under the null, the corresponding test statistics, denoted by ADF_r and

[3]Recursive estimation is implemented by fitting (1) to a fraction of the sample, r_0, and sequentially increasing this fraction by including successive observations. Phiilips et al. (2007) claim that their test can detect bubbles à la Evans with a parameter π in Evan's process as low as 0.25.

$\sup_{r\in[r_0,1]} ADF_r$, are

$$ADF_r \Rightarrow \frac{\int_0^r W dW}{\int_0^r W^2}, \tag{2}$$

$$\sup_{r\in[r_0,1]} ADF_r \Rightarrow \sup_{r\in[r_0,1]} \frac{\int_0^r W dW}{\int_0^r W^2}, \tag{3}$$

where W denotes a Brownian motion, and $r \in [r_0, 1]$ a fraction of the sample.[4] We apply these tests to twenty U.S. metropolitan areas and two aggregate monthly S&P/Case-Shiller house price indices over the period January 1987 to June 2008. We also examine the quarterly house price index from the Office of Federal Housing Enterprise Oversight (OFHEO) from 1975.Q1 to 2007.Q4, which we will denote by HPI.[5]

The results in Table 1 show rejection of the null hypothesis of a unit root, suggestive of explosive behavior, in the case of 9 metropolitan areas house price indices, the Composite-20 index, and the HPI. Figure 1 plots the recursive $supADF_r$ statistic and suggests that the bubble type behavior originated in 2003, and burst at the end of 2006 and 2007 for the Case-Schiller Composite-20 and HPI aggregate indices, respectively. At the regional level, bubbles originating between late 1990s and 2001 and ending around 2005 can be found for Atlanta, Chicago, Detroit, Las Vegas, Miami, Minneapolis, Phoenix and Seattle. Whilst the presence of a house price bubble in the Miami and Tampa areas has also been documented in Mikhed and Zemcik (2007) and Lai and Van Order (2009), our results, with an extended sample, suggest that a larger number of areas exhibited house price explosive behavior.

[4] The lag length J in Equation (1) is selected on the basis of the Akaike Information Criterion and r_0 is set to 0.25. If the null hypothesis is rejected then confidence intervals for the parameter ϕ can be constructed on the basis of the work by Phillips and Magdalinos (2007) regarding the asymptotic distribution theory for mildly explosive processes.

[5] All series are deflated by the consumer price index, obtained from the International Financial Statistics database. Note that some of the Case-Shiller indices do not cover the whole period from January 1987 to June 2008. For a more detailed description of the data see www.homeprice.standardpoors.com and www.fhfa.gov.

2.1 Power of the Phillips et al. (2007) test for a composite index

House prices are often analyzed at an aggregate level, e.g., a nationwide index such as the ones used here provided by S&P Case/Shiller and OFHEO. We examine the power properties of the Phillips et al. (2007) test when applied to an index that has been constructed by averaging a number of different individual series, e.g., regional house prices. The index will exhibit a bubble if any of its constituents does contain one. The issue is therefore whether the power of the test depends on the number of series displaying explosive behaviour or a bubble.

We run a Mote Carlo experiment with 10 simulated series that enter the index equally weighted. The number of series exhibiting bubble type behaviour therefore ranges from 1 to 10. The bubble is generated using the process proposed by Evans (1991) for different parameter values of π, the probability of the bubble not collapsing. We run 1,000 replications, each with a sample size of 100. The results displayed in Table 2 show that the power of the test does indeed depend on the number of processes that contain a bubble. In order to have good power a value of of $\pi \geq 0.95$ is needed. It is also worth noting that for $\pi \leq 0.85$, on average, no more than 5 series would be considered to display explosive behaviour even though all ten series display a bubble à la Evans. This finding suggests that it is not very likely to detect explosive behaviour in a composite index unless many of the series that form the index contain a bubble or the ones that have one, burst very infrequently.

3 The Impact of House Prices on Consumption

Lettau and Ludvigson (2001) demonstrate and provide empirical evidence that a wide class of optimal models of consumer behavior imply that the log of real non-durable consumption, c, is cointegrated with the log of real wealth, w, and the log of real labour income, y. In order to investigate the possible impact of real house price inflation on real consumption, we estimate an error correction model employing updated data from Lettau and Ludvigson supplemented with real house prices.[6] We apply a "general to specific" model selection procedure and end up with the following specification

$$\Delta c_t = \beta_0 + \sum_{i=1}^{3} \beta_i \Delta c_{t-i} + \beta_4 \Delta w_{t-1} + \beta_5 \Delta y_{t-1} + \beta_6 (\Delta rhp_{t-1} - \Delta rhp_{t-2}) + \epsilon_t, \quad (4)$$

where Δ represents first difference, and rhp the log of real house prices (HPI).[7] The term that distinguishes our specification from the general form estimated by Lettau and Ludvigson is $\Delta rhp_{t-1} - \Delta rhp_{t-2}$, which measures the acceleration (deceleration) in real house prices.

Table 3 reports the results of our estimation of the error correction mechanism over the full sample period, 1975.Q1 to 2007.Q4, and for various subsamples suggested by the findings regarding the presence and timing of a house price bubble discussed above. Since the Jarque-Bera test of the OLS regressions indicates non-normality, we complement the OLS estimates with Least Absolute Deviations, LAD, estimates.[8] The acceleration (deceleration) in the rate of change of real house prices is significant and this finding is robust to the estimation method used.[9] Furthermore, the coefficient of the real house price acceleration (deceleration) term in the consumption equation exhibits only a

[6] Case et al. (2005) employ a panel of 14 countries with data on consumption, income and wealth. They report a significant effect of housing wealth on consumption.

[7] The data for c, w, and y is the updated version of that used in Lettau and Ludvigson (2004) available at: http://www.econ.nyu.edu/user/ludvigsons/. House prices are represented by HPI.

[8] In Table 3, column one, we also report the result including the cointegrating residual from the consumption, wealth, and labour income relationship, denoted by cay_{t-1}, which is insignificant for the full sample, 1975Q1-2007Q4. A similar result was obtained by Lettau and Ludvigson.

[9] To check the robustness of our results, we obtained significance levels based on the wild bootstrap suggested, inter alia, by Davidson and Flachaire (2008), which replicates any het-

small variation in value across the samples considered, ranging between 0.070 and 0.097 for the OLS estimates and between 0.098 and 0.122 for the LAD estimates. As illustrated by model (3) in Table 3, omission of this term results in a drop of four percent in the explanatory power of the consumption model considered for the full sample.[10]

In order to investigate further the effect of the possibly identified bubble part of house prices on consumption we estimate the error correction mechanism recursively. We start with an initial sample of ten years, 1975.Q1 to 1985.Q4, and iteratively add an extra observation until the end of the sample. Figures 2 and 3 show the way in which the coefficient of the house price acceleration term, β_6, and its t-statistic evolve. They suggest that the significance of the acceleration term is largely driven by the period of explosive house prices as indicated by the Phillips et al. test. This is also the period of highest sensitivity of consumption to real house price changes. These findings are consistent with the analysis of Buiter (2008) who demonstrates that a pure wealth effect on consumption from a change in house prices can only exist if it reflects a bubble.[11]

To gain more insight on the impact of house prices on consumption, we consider the extreme values of the acceleration(deceleration) in real house prices for the period before and that after prices peaked (that is, before and after 2006.Q4). By multiplying these values by the point estimate of the coefficient linking the rate of change of consumption to the rate of change of real house inflation (with a value of 0.083 for the full sample period considered), we can determine, *ceteris paribus*, the maximum impact that the acceleration(deceleration) in real house

eroskedasticity and non-normality in the residuals of the estimated regression. The results, not reported here for brevity, are available upon request from the authors, and are consistent with the results reported here.

[10] We also note that our results corroborate the argument in Piazzesi and Schneider (2009).

[11] Alternative rationales for the impact of house prices could include relaxation of borrowing constraints, as argued by Campbell and Cocco (2007); arguments from behavioural economics, such as those presented in Shefrin and Thaler (1988); but also by empirical evidence as in De Veirman and Dunstan (2008).

inflation has exerted upon the rate of change of consumption during the period of explosive behavior.

Our calculations indicate that this impact reached a maximum value of 0.188% per quarter when prices were explosively increasing, and 0.186% when declining. This may be considered as further evidence in support of our assertion in line with Buiter (2008). A pure wealth effect of changes in house prices on consumption can be unveiled if it represents a manifestation of a bubble, with consumption (almost) returning to the level before the origination of the bubble after its collapse.

4 Conclusion

We apply the Phillips et al. (2007) unit root test to a number of regional and aggregate house price indices in the U.S. Our results indicate that a country aggregate index as well as a number of U.S. cities experienced explosive behavior in their housing market. To analyze their impact on aggregate consumption we extend the Lettau and Ludvigson (2001, and 2004) model and find evidence that real house price acceleration(deceleration) affect consumption only when they display bubble type behavior.

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Table 1. Test for bubbles. Phillips et al. (2006) statistics (2) and (3)

City	$\sup ADF_r$	ADF_1	City	$\sup ADF_r$	ADF_1
Phoenix	2.07^{**}	-2.656	Minneapolis	1.52^{**}	-2.97
Los Angeles	-1.21	-4.412	Charlotte	1.14	-0.79
San Diego	0.30	-3.289	Las Vegas	2.66^{***}	-2.87
San Francisco	0.19	-2.521	New York	-0.90	-3.28
Denver	0.09	-2.406	Cleveland	0.15	-1.05
Washington	-0.27	-4.682	Portland	0.41	-2.19
Miami	1.51^{**}	-5.292	Dallas	0.49	0.49^{**}
Tampa	1.23^{*}	-4.262	Seattle	1.75^{**}	-2.02
Atlanta	1.67^{**}	-2.347	Aggregate Index		
Chicago	1.50^{**}	-1.906	Composite–10	-0.30	-4.76
Boston	-1.37	-2.637	Composite–20	2.80^{***}	-2.43
Detroit	2.56^{***}	-1.178	HPI	1.32^{*}	-1.26

Notes: ***,**and *indicate significance at 1%, 5% and 10% significance levels

Table 2. Aggregation of series and Power of the Phillips et al. (2007) test

#Bubbles	1	2	3	4	5	6	7	8	9	10
$\pi = 0.25$										
Rej Rate	0.248	0.284	0.295	0.312	0.322	0.310	0.333	0.322	0.335	0.359
#Stocks A	1.290	1.553	1.749	1.821	1.997	1.990	2.156	2.323	2.227	2.521
#Stocks B	0.581	0.697	0.803	0.901	0.904	0.955	0.985	0.997	1.015	1.028
$\pi = 0.50$										
Rej Rate	0.305	0.373	0.371	0.406	0.394	0.416	0.415	0.438	0.435	0.464
#Stocks A	1.380	1.700	1.962	2.180	2.335	2.442	2.636	2.913	3.090	3.200
#Stocks B	0.623	0.853	0.949	1.005	1.036	1.043	1.055	1.105	1.074	1.127
$\pi = 0.75$										
Rej Rate	0.341	0.469	0.518	0.512	0.537	0.552	0.551	0.552	0.558	0.568
#Stocks A	1.663	1.866	2.124	2.420	2.628	2.947	3.225	3.569	3.810	4.125
#Stocks B	0.765	0.938	1.033	1.104	1.106	1.138	1.192	1.225	1.247	1.268
$\pi = 0.85$										
Rej Rate	0.397	0.501	0.556	0.594	0.658	0.654	0.677	0.686	0.731	0.716
#Stocks A	1.572	1.922	2.291	2.589	2.982	3.245	3.685	3.969	4.326	4.682
#Stocks B	0.781	1.034	1.112	1.173	1.239	1.292	1380	1.373	1.482	1.524
$\pi = 0.95$										
Rej Rate	0.596	0.755	0.829	0.872	0.912	0.933	0.956	0.963	0.959	0.972
#Stocks A	1.654	2.150	2.690	3.257	3.833	4.328	4.935	5.507	6.174	6.699
#Stocks B	0.926	1.164	1.397	1.586	1.849	1.994	2.208	2.438	2.640	2.825
$\pi = 0.99$										
Rej Rate	0.770	0.930	0.971	0.993	0.996	0.997	0.999	1.000	1.000	1.000
#Stocks A	1.642	2.444	3.211	4.062	4.808	5.625	6.453	7.190	7.985	8.871
#Stocks B	1.003	1.610	2.178	2.910	3.471	4.063	4.700	5.231	5.901	6.579

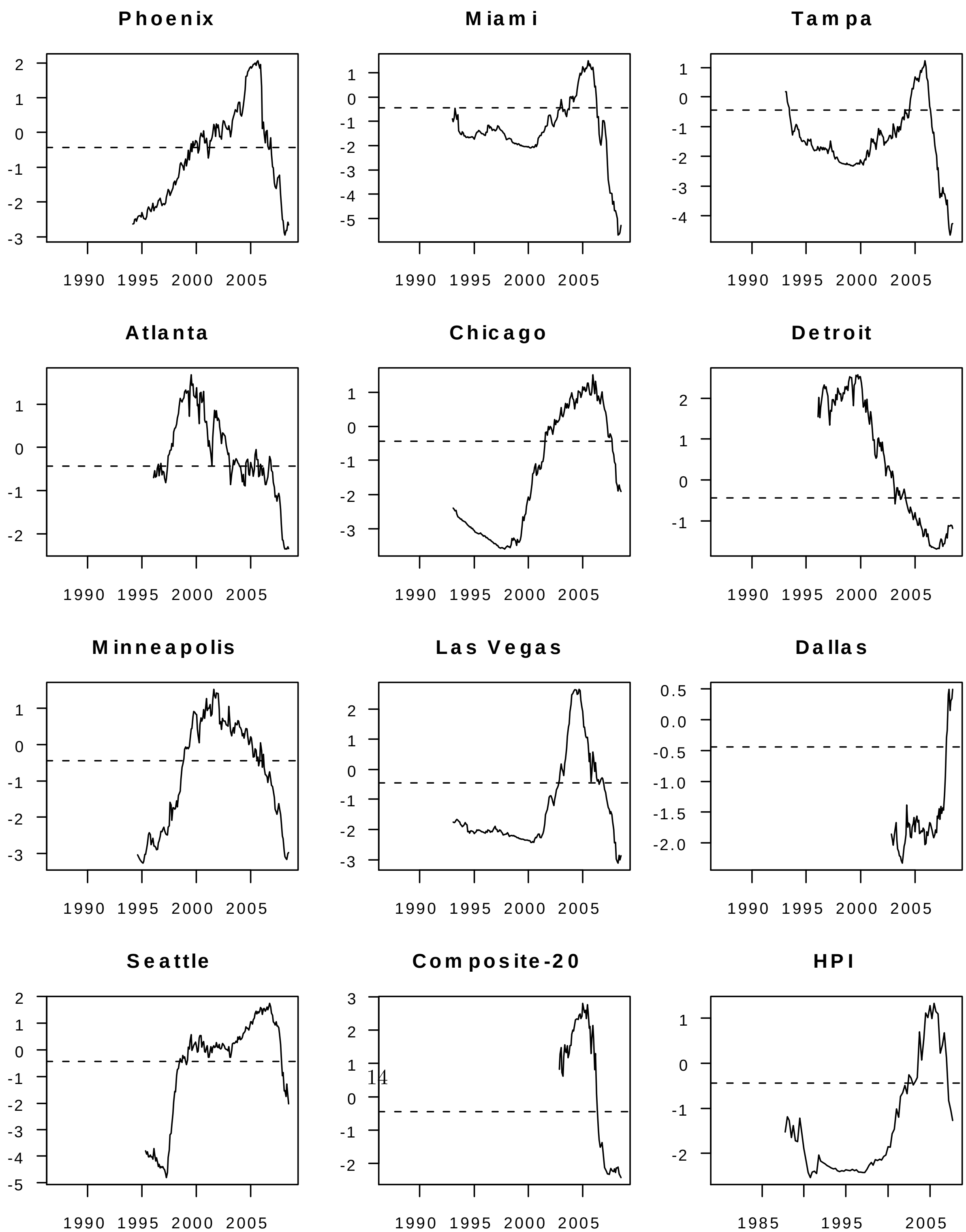
The total number of series is 10. #Bubbles indicates the number of simulated series with a bubble. Rej Rate is the percentage of times that the sup test of Phillips et al. rejects the unit root behaviour of the aggregate series in favourof the alternative of explosiveness. #Stocks A denotes the average number of individual series for which the sup test rejects the null. #Stocks B denotes the average number of individual series for which the null is rejected at the time the aggregate t-statistic reaches its maximum.

Table 3: The impact of real house prices on consumption.
Regression (4) where the dependent variable is real consumption growth ($\Delta cons_t$)

	1975.Q1-2007.Q4				1980.Q1-2007.Q4		1990.Q1-2007.Q4		2000.Q1-2007.Q4		1975.Q1-2000.Q4		1975.Q1-2005.Q4	
		OLS		LAD	OLS	LAD	OLS	LAD	OLS	LAD	OLS	LAD	OLS	LAD
	(1)	(2)	(3)											
β_0	0.002***	0.001***	0.001***	0.002***	0.001**	0.002***	0.001**	0.002**	0.002***	0.002***	0.001**	0.003***	0.001***	0.002***
	(3.119)	(2.867)	(2.768)	(3.820)	(2.513)	(2.638)	(2.239)	(3.223)	(2.911)	(1.816)	(2.345)	(3.965)	(2.770)	(4.230)
	[0.000]	[0.000]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.000]	[0.001]	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]
β_1	0.201***	0.203***	0.209***	0.093	0.194**	0.111	0.083	-0.064	0.062	-0.094	0.206**	0.060	0.200***	0.071
	(2.874)	(2.842)	(2.568)	(1.195)	(2.604)	(1.246)	(0.632)	(-0.437)	(0.600)	(-0.379)	(2.345)	(0.664)	(2.721)	(0.910)
	[0.069]	[0.071]	[0.081]	[0.078]	[0.075]	[0.089]	[0.132]	[0.148]	[0.103]	[0.248]	[0.083]	[0.090]	[0.073]	[0.078]
β_2	0.061	0.065	-0.029	0.139	0.110	0.176*	0.149*	0.162	0.220**	0.289	0.276	0.129	0.055	0.131
	(0.664)	(0.704)	(-0.318)	(1.491)	(1.157)	(1.662)	(1.684)	(1.534)	(2.089)	(1.693)	(0.234)	(1.115)	(0.579)	(1.375)
	[0.092]	[0.092]	[0.091]	[0.093]	[0.095]	[0.106]	[0.089]	[0.105]	[0.105]	[0.171]	[0.118]	[0.116]	[0.095]	[0.095]
β_3	0.232***	0.237***	0.301***	0.229***	0.214***	0.218**	0.264***	0.208*	0.074	0.031	0.267***	0.216**	0.241***	0.246***
	(3.265)	(3.240)	(3.659)	(2.852)	(2.858)	(2.561)	(3.867)	(1.810)	(0.669)	(0.145)	(3.435)	(2.113)	(3.273)	(2.895)
	[0.071]	[0.073]	[0.082]	[0.080]	[0.075]	[0.085]	[0.068]	[0.115]	[0.111]	[0.216]	[0.078]	[0.102]	[0.073]	[0.084]
β_4	0.105***	0.117***	0.132***	0.089***	0.107***	0.078**	0.104***	0.090**	0.069**	0.090	0.144***	0.083*	0.126***	0.078**
	(3.580)	(3.772)	(4.105)	(2.577)	(3.644)	(2.198)	(3.081)	(2.043)	(2.213)	(1.289)	(3.270)	(1.840)	(3.684)	(2.197)
	[0.029]	[0.031]	[0.032]	[0.034]	[0.029]	[0.035]	[0.034]	[0.044]	[0.031]	[0.070]	[0.044]	[0.045]	[0.034]	[0.036]
β_5	0.033**	0.037***	0.040***	0.033***	0.039***	0.039**	0.043***	0.039***	0.040***	0.040**	0.030	0.030	0.038***	0.036**
	(2.553)	(2.917)	(3.027)	(2.053)	(3.036)	(2.344)	(3.765)	(2.768)	(3.977)	(2.216)	(1.433)	(1.150)	(2.884)	(2.069)
	[0.013]	[0.013]	[0.013]	[0.016]	[0.013]	[0.017]	[0.011]	[0.014]	[0.010]	[0.019]	[0.021]	[0.026]	[0.013]	[0.017]
β_6	0.085***	0.083***	-	0.108***	0.091***	0.106***	0.097***	0.130***	0.089***	0.098**	0.070	0.122***	0.085***	0.104***
	(2.968)	(2.889)		(3.986)	(2.833)	(3.444)	(3.076)	(2.966)	(4.356)	(2.282)	(1.637)	(2.897)	(2.655)	(3.382)
	[0.028]	[0.028]		[0.027]	[0.032]	[0.031]	[0.031]	[0.044]	[0.020]	[0.043]	[0.043]	[0.042]	[0.032]	[0.031]
cay_{t-1}	-0.026	-	-	-	-	-	-	-	-	-	-	-	-	-
	(-1.568)													
	[0.120]													
$\overline{R^2}$	0.342	0.339	0.304	0.209	0.337	0.215	0.415	0.260	0.638	0.320	0.318	0.180	0.338	0.204
JB	26.747	25.735	27.437	36.698	30.939	43.010	13.976	35.094	0.683	0.072	16.358	24.384	21.617	37.318
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.710]	[0.965]	[0.000]	[0.000]	[0.000]	[0.000]
$ARCH(1)$	0.228	0.340	0.272		0.472		5.646		1.403		0.135		0.254	
	[0.634]	[0.561]	[0.603]		[0.493]		[0.020]		[0.246]		[0.715]		[0.615]	
$ARCH(4)$	0.239	0.277	0.248		0.138		4.965		0.388		0.280		0.257	
	[0.915]	[0.892]	[0.910]		[0.968]		[0.001]		[0.815]		[0.890]		[0.905]	

Notes: t-statistic in (),Newey-West robust standard errors in [ ].***,**and *indicate significance at 1%, 5% and 10% levels, $JB$is the Jarque-Bera test for normality. $ARCH(1)$and $ARCH(4)$are heteroskedasticity tests for residuals. For the JB, $ARCH(1)$and $ARCH(4)$statistics, p-values are reported in [].

Figure 1: SupADF$_r$ statistic of Phillips et al. (2006) for different city and aggregate U.S. real house prices



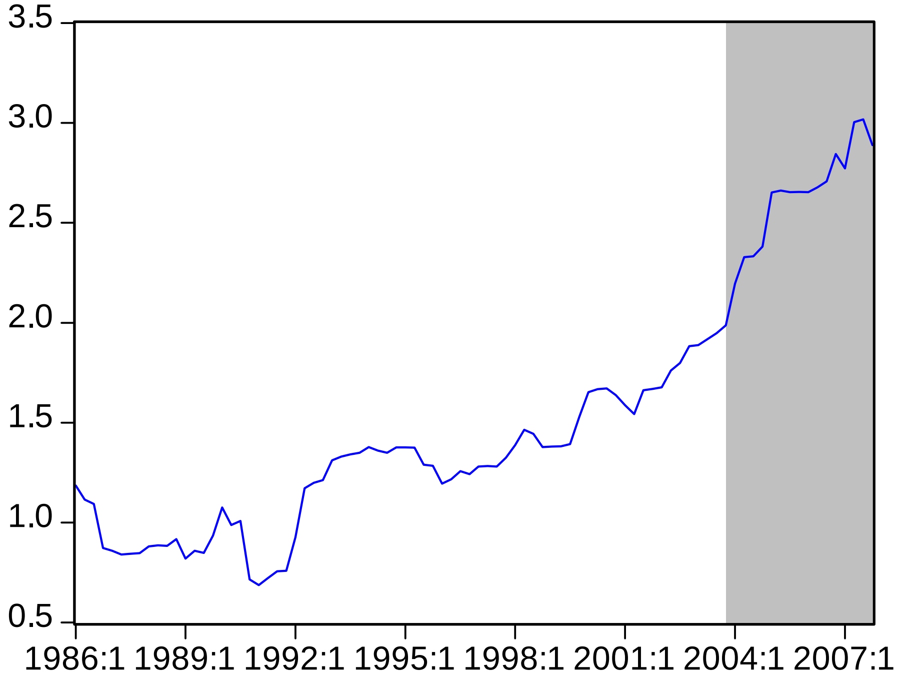


Figure 2: Recursive t-statistic of the sensitivity of changes in consupmtion to real house price acceleration, β_6. Shaded area denotes explosive behavior in HPI according to Phillips et al. (2007) test.

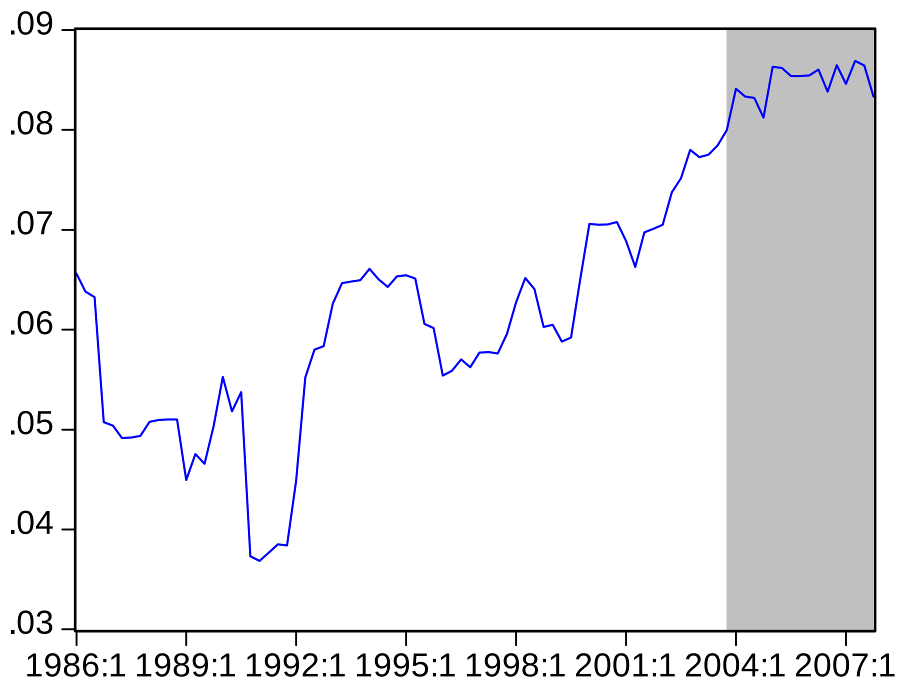


Figure 3: Recursive point estimate of the sensitivity of changes in consumption to real house price acceleration, β_6. Shaded area denotes explosive behavior in HPI according to Phillips et al. (2007) test.