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Testing for bubbles in EU and US property markets

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Abstract

This study detects explosive behavior and bubbles in US and EU property markets, specifically the EU countries which were examined are United Kingdom, Finland, Italy, France, Denmark, Germany and Spain. The methodology used to test for bubbles is the **Phillips, Shi and Yu** (2011) and **Phillips, Wu and Yu** (2011). These tests are applied to the datasets of OECD of real house prices, nominal house prices to rent ratio and nominal house prices to income ratio for the time period from 1980 to 2014. The results of the second methodology are shown to be more powerful and used to detect and to date the origin and the end of the bubbles. The findings coincided with many bubble episodes which have been reported in the literature.

Keywords: Bubble, house prices, SADF, GSADF, right-tailed unit root tests, date-stamping bubble periods, price-to-rent ratio, price-to-income ratio

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1. Introduction

1.1 Why detecting a house bubble is important?

During latest decades many countries have experienced dramatic changes in their house prices, especially from 1985 to 2006 there was a strong rise in their prices but since then many countries faced large drops. Specifically, in the US from late 1990s, a major housing bubble emerged and due to the insufficient risk management, lack of transparency and increasing leverage this bubble resulted in a boom through the sub-prime mortgage market collapse which came to the surface with Lehman Brothers bankruptcy in September 2008. So a crisis started and triggered a series of panic over Europe mainly through the channel of confidence in the financial sector.

Generally the formation of the housing bubbles concerns the policy makers and this is totally justified as the bursting of a bubble induces serious consequences in the economy. Commonly in the analysis of a bubble can be used the **Blanchard and Watson** (1982) model which defines the fundamental value of an asset at the present value of future incomes by solving consumers' optimization problem, assuming no rational bubble and no-arbitrage. This model adjusted to house prices, as equation 1.1 shows, equates the fundamental house price P_t as the future rents R_{t+k} divided with a constant discount factor d **.**

$$P_t = \sum_{k=0}^{\infty} \left(\frac{1}{1+d} \right)^{k+1} E_t \left(R_{t+k} \right) \qquad 1.1$$

where $E_t\left(r_{t+k}\right)$ is the expected rent paid at time $t+k$ with the available information at t.

The constant discount factor typically is the sum of a reference rate and a risk premium which investors demands in order to invest in a security. The definition of the bubble will be discussed more in detail in the next unit but broadly it can be said that is when the prices are constantly and significantly increasing and this change cannot be attributed to a fundamental change. So when the prices ballooned the policy makers should facilitate the situation by increasing the reference rates in order to exert an opposite power in the prices. However if the increase of the house prices is accompanied with a reduction in the risk premium then there is not a bubble but a logical response from the market. In that case if the policy makers intervene by increasing the reference rates the investments would be discouraged and then the GDP growth will be interrupted. So the existence or not of a bubble is playing a determinant role in the actions of policy makers and a wrong estimate could induce negative aspects to the economy.

Another linkage is between asset prices and the overall stability of the financial and banking system. To be more specific the bursting of a bubble induces diminishing house prices which in turn drops the value of property collaterals and harms the bank's balance sheets. In turn the bank loans are being reduced so as the investments and the consumption making the banking system to fail and generally creating negative expectations of the economy.

Finally bubbles in housing markets are more important than bubbles in stock market. Historically, housing price indexes collapses less frequently but the consequences last longer and cost a lot (IMF World Economic Outlook (2003)). So the ability to identify a bubble in the real time is very important and has several benefits as it protects the economy of the catastrophic consequences of the bursting of the bubbles and at the same time warns the regulators when they should intervene.

1.2 Bubble definition

A bubble according to **Kindleberger** (1992) is "a sharp rise in price of an asset or a range of assets in a continuous process, with the initial rise generating expectations of further rises and attracting new buyers – generally speculators, interested in profits from trading in the asset rather than its use or earning capacity". Also a bubble becomes noticed after it bursts as **Mishkin and White** (2002) stated clearly "when you see it, you know it". So alternatively we can say that a bubble is characterized by a deviation from the observed asset's price and its fundamental value which will lead to an unsustainable boom. According to **Kunicova and Komarek** (2011) the fundamental value could be affected by the following factors: a) the expected flows of returns b) the expected flows of returns of holding of alternative assets, c) the expected price realized on the future sale of the asset and d) the relative and liquidity risk associated with holding the asset. Most authors agree with the above definition but others specifies more what should the condition in order a bubble to occur. For example, **DeMarzo, Kaniel and Kremer** (2007) define the bubble by specifying three components: 1) the market price of an asset is higher than the discounted sum of each expected cash flows, with the discount factor being equal to risk free interest rate, 2) cash flows have a no negative correlation with aggregate risk and 3) risk averse investors rationally choose to hold the asset, despite their knowledge of 1) and 2).

1.3 Colorful adjectives for bubbles

In the literature bubbles have been characterized by many adjectives such as speculative (J. Hamilton 1986), rational ((R. J. Shiller 1981) and (LeRoy and Porter 1981)), irrational (Vissing-Jorgensen 2003), churning (Allen and Gorton 1993) informational (Grossman and Stiglitz 1980), intrinsic (Froot and Obstfeld 1991)**,** fads ((R. Shiller, Stock Prices and Social Dynamics 1984), explosive (Evans 1991) periodically collapsing (Evans 1991)**,** negative bubble (R. Shiller 2000) etc. Most of the times authors are describing the same thing but in some cases they point out some important differences. These different types of bubbles could be separated into eight types of bubbles: speculative, rational, irrational, churning, intrinsic, periodically collapsing and negative bubbles.

Speculative bubbles purchased under the belief that the price will appreciate further based on no objective changes in fundamentals.

Rational bubbles are a subcategory of speculative bubbles, as **Xie and Chen** (2014) stated. Rational bubbles are consistent with the rational expectations hypothesis and with no arbitrage opportunities

An intrinsic bubble could be treated as a subcategory of rational bubbles and according to **Froot and Obstfeld** (1991) is driven exclusively –albeit nonlinearly-by the exogenous fundamental determinants of asset prices (e.g. aggregate dividends) and not by extraneous factors such as fads, time and variable discount rates. Fads and intrinsic bubbles can generate departures that are highly persistent but an important theoretical distinction between the two is that the former entail short term speculative profit opportunities whereas bubbles alone do not. For example, **Phillips and Yu** (2011) showed that the pricing errors could be emerging due to the sensitivity caused from the changes in the discount rates to the fundamentals price. Moreover, these bubbles can cause asset prices to overreact to changes in fundamentals.

Irrational bubbles according to **Meltzer** (2002) defined as "a rise in the price of an asset or asset class that generates additional increases, a rapid upward price movement based on exaggerated beliefs about the potentials of a new technology or organizational structure to generate earnings, and followed by a collapse." In other words bubbles occur and crash in the absence of a significant increase in fundamental values because investors act against their inside information and follow the herd.

A churning bubble, which was mentioned in **Allen and Gorton** (1993), involves asymmetric information between investors and portfolio managers. When there is asymmetric information bubbles will arise. The bad traders will trade assets which are deviate over the fundamental value motivated by their profits against their investors as they ignore the crash of a bubble.

Evans (1991) separated rational bubbles which can take the form of explosive processes when there is a significant chance that they will collapse after reaching high levels with periodically collapsing bubbles which are always positive but periodically collapse.

All the above bubbles were consisted of positive bubbles, in which prices are constantly rising. But there are also negative asset price bubbles, which occur when market prices are undervalued compared to the fundamentals and in these bubbles feedback occurs in a downward direction.

1.4 Conditions of emergence and classification

Another classification of bubbles according to **Kunicova and Komarek** (2011) is based on the way of their emergence. The first category assumes the existence of rational investors and that bubbles follow an explosive path. Second category involves rational investors but they are asymmetrically informed. Third category is related to behavior finance theory. Specifically, bubbles persist over time and limits in arbitrage inhibit rational investors from the elimination of pricing impact caused by behavior traders-investors who can make systematic mistakes. Last category assumes that bubbles emerge under heterogeneous beliefs of investors about fundamental values, based on psychological biases.

This thesis focuses on the first category of bubble emergence. In other words, analyzes rational bubbles which assume the existence of rational investors and symmetric information. Moreover one technique to test explosive behavior is by applying empirical methods and models. These empirical methodologies of rational bubble can be separated into direct and indirect tests. A direct test specifies the bubble formation process and tests for the no-bubble hypothesis by econometrics method such as unit root tests, cointegration test. For example **Taipalus** (2006) applied unit root testing by constructing a rolling sub-sample Augmented Dickey Fuller (ADF) indicator to test log rent-price ratio for the existence of real estate bubbles for Finland, USA, UK, Spain and Germany. The direct test of the bubble detection is designed to confirm or refute the existence of the bubble while indirect tests contrasts the actual with the fundamental house price and then claim if there is evidence of a bubble. For example this could be tested through volatility tests such as Variance-bound tests ((R. J. Shiller 1981)**,** (Kleidon 1986)**,** (Gilles and LeRoy 1991)**,** (Brooks, et al. 2001)**)** and Newey West's Two-Step Test **(** (Newey and West 1987)).

The remaining of the paper proceeds as follows; Section 2 is the literature review on the methodologies used to detect bubbles, with an emphasis in econometric methodologies, Section 3 describes the bubble test of the method which was applied, in

Section 4 the data used are presented, in Section 5 the technical details of the bubble test are reported, in Section 6 the results are analyzed, and in Section 7 the empirical evidence is contrasting with similar researches while Section 8 concludes.

2. Literature review

Based on **Gurkaynak** (2005) survey as well as on the methodologies encountered in the literature for bubble detection afterwards, there are eight different econometric methodologies and a mathematical one that have been used to identify bubbles across markets: Variance-bound tests, Newey‑West's Two-Step tests, the intrinsic bubbles concept, cointegration based tests, MTAR based model, the concept of a bubble as an unobserved variable, regime switching models tests, a mathematical definition-based model and recursive unit root tests.

2.1 Variance bound tests

R. J. Shiller (1981) and **LeRoy and Porter** (1981) based on the simple present model examine the variance bounds on stock prices. The idea is that, if a rational bubble exists, the variance of the observed asset price will exceed the bound imposed by the variance of the fundamental value. **R. J. Shiller** (1981) has based this test on present value model as equation 1.1 shows. The hull hypothesis is that the actual price is the expected rational price and the alternative is the opposite. In addition the difference between the real price and the expected one is equal to the forecast error must be uncorrelated with the forecast in order the forecast to be objective. So the variance of the ex post rational price should be the sum of the variance of ex post rational price and the variance of the error term. It is expected that the variance of the error term should not to be included in the variance of the price so the variance of the ex-post rational price should be at least more than the variance of the real price and that is an upper bound of the ex-pos rational price.

R. J. Shiller (1981) and intent was not to identify bubbles but merely to test if the efficient market hypothesis and the present value model hold in practice. If the variance of ex-post rational price does not exceed the variance of the fundamental price then present value model (Equation 1.1) does not hold and a bubble exists.

Empirically it is difficult to find the right ex post rational price because the value of the dividends should have a terminal value. **R. J. Shiller** (1981) denoted the sample average of the stock prices as the terminal value and examined the variance bounds assuming a constant discount rate.

He made volatility comparisons using annual data 1871-1979 on Standard and Poor´s Composite Stock Price Index and modified Dow Jones Industrial and found that the measures of stock price volatility appeared to be far too high to be attributed to new information about future real dividends; however he did not make an argument about bubbles.

Flood and Hodrick (1990) criticized variance bounds tests because under the assumption that the real price has a bubble component he proved that the again the variance of the new ex-post rational price should be at least more than the variance of the real price. Later **Cochrane** (1992) tested the existence of bubbles using the variance of the price/dividend ratio. He did not assume a constant discount rate and assumed a random walk for the dividends.

2.2 West test

The **Newey and West** (1987) is testing two alternative hypotheses of how asset prices are formed.

The null hypothesis tests if the prices are following the standard model of (Myers and Brealey 1981) which does not include a bubble component while the alternative hypothesis is that the prices are following the (Blanchard and Watson 1982)formula.

West (1987) compared two alternative estimators of the parameter needed to calculate the expected present discount value in order to test separately for the presence of bubbles and model misspecification.

One can directly be estimated by performing a straightforward linear regression of stock prices on lagged dividends. The other estimator is constructed by estimating the discount rate from the observable no-bubble Euler equation follows. The determination of the market price is estimated through OLS method. If the first estimator for the expected present discount value is similar to the constructed one, suggests that no bubble exists.

In the case of the constant rate **West** (1987) rejected the no bubble hypothesis analyzing Standard and Poor´s Composite Stock Price Index, annual data 1871–1980 and the modified Dow Jones index 1928–1978. However, when he assumed a dynamically discount rate West did not find any bubble in the sample. A problem with this procedure **West** (1987) is that the test is not consistent. Under the alternative hypothesis that a bubble is present, the probability that the test will reject the null does not go to unity asymptotically. This is a direct consequence of the explosiveness of prices under the alternative.

Dezbakhsh and Demirguc (1990) also used **West** (1987) method by applying a modification as they observe size distortions in small samples. They criticize the use of Hausman test with which **West** (1987) rejected the null hypothesis of equal coefficients and used other tests with better fit in small samples. Their results were completely different from West's as they find no bubble by examining the S&P500 from 1871 to 1981.

2.3 Intristic bubble

Froot and Obstfeld (1991) created a new category of bubbles different from rational bubbles. The intrinstic bubble is driven nonlinearly only by functional form (e.g the level of dividends) and not by extraneous factors.

The basic equation of testing bubbles equals the observed price with the sum of the fundamental price and the bubble component and an error term where the bubble process is a non linear relationship between bubble and dividends.

Under the null hypothesis there is no intrinsic bubbles and under there is a no linear relationship between the stock prices and the dividends which implies an intrinsic bubble.

Froot and Obstfeld (1991) examined Standard and Poor's stock price and dividend indexes from the security price index record over the period 1900-1988 and they showed that the simple present value model does not hold as there is an overreaction in stock prices from the changes in dividends. They stated that with the available data it might be impossible to conclude if deviations from present-value prices are stationary (no bubble) or non-stationary (bubble) or if they existed at all it would be because of time varying discount rates or dividends growth.

Driffill and Sola (1998) went further and assumed that the underlying stock pricing model being nonlinear. They proposed a regime switching model of dividends instead of **Froot and Obstfeld** (1991) who assumed that log dividends follow a random walk with drift. **Driffill and Sola** (1998) verified that this formulation of the dividend process fits that data better and then test the model with regime switching fundamentals. **Driffill and Sola** (1998) demonstrated the lack of identification in bubble testing by concluding that switching fundamentals match the data equally well in the context of a possible intrinsic bubble.

2.4 Cointegration tests

Cointegration based tests are indirect tests which do not reject the no-bubble hypothesis if the price is cointegrated with the fundamental value. For example if the house price to rent ratio is stationary or house price is cointegrated with the fundamental price then the no bubble hypothesis cannot be rejected.

Most of the bubble detection papers test the existence of stock market bubbles using traditional unit-root tests to the price–dividend ratio on the data of the S&P 500 composite index. For example, **Campbell and Shiller** (1987) tested for rational bubbles using annual data for the S&P 500 from 1871 to 1986, obtaining persistent deviations of stock prices from the present-value model, and thus, rational bubbles.

Diba and Grossman (1998) observed that a rational bubble cannot start, thus if it exists now, it must always have existed and proposed a way to empirically test the absence of bubbles. This claim is based on lack of arbitrage opportunities and inability of negative prices.

The test pointed out that there is evidence of the existence of a bubble if the dividends are stationary but not the prices, no matter how many differences are taken in the data series.

Then the way to test the bubble existence is to take as many differences as needed in order to make the dividends stationary and then see if the stock prices are stationary too. Under the null hypothesis of no bubbles in stock prices, the dividends and stock prices should be cointegrated. Using Dickey–Fuller tests, found that both dividends and stock prices were integrated in levels, but were not cointegrated. So **Diba and Grossman** (1998) found that stock prices did not contain explosive rational bubbles, when analyzing data of S&P 500 index for 1871–1986.

Evans (1991) pointed out that cointegration tests are not capable of detecting periodically collapsing bubbles. For example, it is possible a sudden collapse of a bubble to be mistaken for mean reversion or rejecting the no bubbles hypothesis due to time variation in some component of the present value model. He assumed that the bubble process depend on a threshold value. It is important to note that **Evans** (1991) did not show the existence of bubbles in stock prices; he only showed that unit root tests are not adequate to reject this hypothesis

Another method to overcome **Evans** (1991) criticism was **Scacciavillani** (1994) test based on fractional differencing. Specifically, the difference between the two variables is considering in a wider variety of I(d) models, with d not necessarily constrained to be 0 or 1. **Koustas and Serletis** (2005) analyzed 1871–2000 annual US data series performing tests for fractional integration in the log dividend yields. The tests based on fractional integration focuses on possible nonlinearities in variance of log dividend yield and show no bubble existence. **Cunado, Gil-Alana and Perez de Gracia** (2005) use also a methodology based on fractional processes. They studied the order of integration of the stock prices and dividends in the NASDAQ index. The results were mixed, in monthly data the unit root null hypothesis cannot be rejected suggesting the existence of a rational bubble but in daily and weekly data, the order of integration suggested that a certain degree of fractional cointegration existed between the two variables.

2.5 MTAR unit root test

Another way to test periodically collapsing bubbles is adopt the momentum threshold unit root test (MTAR), proposed by **Enders and Siklos** (1998). In the threshold autoregressive (TAR) model the degree of autoregressive decay depends on the variable state. In the MTAR model allows also for positive and negative changes in the variable's autoregressive decay, thus capturing its possible asymmetric movement. **Xie and Chen** (2014) employed MTAR and MTAR with the logistic smooth transition in trend (LNV-MTAR model) which allowed for the possibility of a regime shift between two different trend paths over time but also permits a structural break to occur gradually not instantaneously. **Xie and Chen** (2014) examined periodically collapsing bubbles in four real estate investment trust (REIT) classifications in the US by employing the MTAR model and LNV-MTAR model in order to take the possibility of non-linear trends into consideration. Their findings examining the dividend–price ratios were that are not periodically collapsing bubbles in the US REIT markets.

2.6 Switching regime tests

The literature in order to treat bubble expansion and contraction as results of two different regimes developed the Markov-regime switch models. These models tried to identify periodically collapsing bubbles by capturing discrete shifts in the generating process of time series data and were introduced by **J. D. Hamilton** (1989).

Funke, Hall and Sola (1994) added in Markov-switching regime model the probabilities of the bubble in each period to grow or to collapse which were assumed to be constant overtime. The probability of the collapsing scenario obeys a first-order Markov process. In their bubble test they examined whether stock prices switch between stationary behavior and explosive growth. So the test will identify a bubble if one stage is stationary whereas the other stage is not stationary.

Hall, Psaradakis and Sola (1999) proposed a Markov-switching Augmented-Dickey-Fuller test which treated each component of a simulated bubble process as a separate Markov-regime with constant transition probabilities between the regimes. Their test suggested the existence of bubbles in the S&P 500.

Van Norden and Vigfusson (1998) disagreed with the existence of bubbles in the S&P500 which **Hall and Solá** (1993) found as the van Norden test which models the switching probabilities as functions of the size of the bubble does not indicate the presence of a bubble in the same data set. Van Norden defined a bubble as a positive or negative deviation from the fundamental value. Accordingly, the bubble ranged between two stages (regimes). In one stage the bubble continued growing, whereas in other stage the bubble collapses partially or completely.

2.7 Unobserved variable

A slightly different approach developed by **Wu** (1997) who characterized the bubble as an unobserved variable. Based on the present value model, he produced a linear process on the bubble component. Particularly, he assumed that differenced dividends follow an AR process and estimated the bubble as an unobserved variable subject to the no-arbitrage condition using a Kalman filter. The Kalman filter is a recursive procedure for computing the optimal estimate of the bubble at each time period, based on the structural economic model and the observed data. In addition this model often shows negative bubbles. His result estimated bubble components accounted for a substantial proportion of real S&P500 and real dividends during 1871–1992.

Al-Anaswah and Wilfling (2011) also treated the bubble as an unobservable variable but extend his framework by allowing the bubble to switch between alternative regimes, one in which the bubble survives and one in which it collapses. **Al-Anaswah and Wilfling** (2011) used a state-space model with Markov-switching to detect speculative bubbles in stock-price data and find that their Markov-switching approach is able to detect the majority of bubbles in their artificial Evans-processes as well as in their real-world data sets.

2.8 Mathematical definition based model

All the above methodologies are based on the definition of the market price as the sum of the fundamental and a bubble component. So the above bubble tests are based on the underlying model where the existence of the bubble maybe connected to the misspecification of the model **Flood and Garber** (1991). So another way of detecting bubbles is without any calculation of the fundamental value through another mathematical definition.

The work of **Johansen and Sornette** (2001) introduced a specific functional form to describe bubbles and crashes by considering the end of the bubble as a spontaneous singularity occurring at certain critical time. Particularly they found that a crash will occur if economic indicators grow faster than an exponential function. However, this method cannot describe the start of the bubble.

Watanabe, Takayasu and Misako (2007) solved this problem by giving a mathematical definition of bubbles and crashes which can detect the beginning of the bubble and its end. In general they tried to identify an exponential behavior in historical data. The equation of describing this exponential fitting is an autoregressive (AR) model of historical prices which estimated the parameter characterizing the exponential behavior each period and the base line of exponential divergence. If the price is more than one is either exponentially increasing or decreasing while if the price is equal to one then it follows a random walk and there no bubble trend and if the parameter if less than one the price is convergent to the base line.

In order to date the origin and the end of the bubble they estimated the minimum period using an AR model of the price difference, under this condition the parameter should be less or equal to 1.0. Then for each horizon of the minimum period they characterized if the time steps in each horizon is exponential or convergent. After that they calculated again the parameters which are characterizing the exponential behavior each period and the base line of exponential divergence and observed the price trend. When the exponential trend diverges upwards they called it bubble, when it diverges downwards it is called crash and when the trend curve converges they called it convergence.

Watanabe, Takayasu and Misako (2007) examined the YHOO stocks from 07 January 1998 to 28 December 2001 at a frequency of every 30 seconds. They detected the bubble starting from the January 1999 and after January 2000 there model detected no crashes.

Later **Hui, Zheng and Wang** (2010) used the methodology of **Watanabe, Takayasu and Misako** (2007) to detect bubbles and crashes in the property security market. However they improved the model by changing the optimal time scale for observing the exponential behavior from constant to dynamic as it is more suitable when the data frequency is limited.

Moreover one more change they applied was that the formula describing the bubble and the crashes were instead of an AR (1) model they used an AR (2) in order to achieved a better fitting.

In the property markets they examined daily GPR 250 Property Security Index on five national markets, the United States, the United Kingdom, Japan, Hong Kong and Singapore from January 2000 to October 2008. They found that the most property markets passed through a bubble period during 2003 to 2007.

2.9 Recursive unit root tests

The bubble testing based on traditional unit roots had some severe limitations. Firstly, it could not function well under persistent changes from non stationary processes to stationary on and secondly was unable to detect multiple starting and ending points of these changes. The bubble detection was then needed to locate multiple starting and ending points of unit root periods from continuous data. So a new approach was developed by **Leybourne, Taylor and Kim** (2007) purpose testing for and dating multiple changes in the order of integration of a time series between trend stationary I(0) and difference-stationary I(1) regimes, based on sequences of doubly-recursive implementations of regression-based unit root statistics.

Another idea to solve the initial problem was to use shorter and rolling samples which could help the exit from persistence changes. **Taylor** (2005) use rolling and recursive samples of Augmented Dickey–Fuller **(ADF, hereafter)** test and **Taipalus** (2006) analyze the use rolling subsamples in the application ADF to search for bubbles.

Phillips, Wu and Yu (2011) **(PWY, hereafter)** used a sup Augmented Dickey–Fuller (DF) (SADF) test repeatedly on a forward expanding sample sequence to test for a structural change from a random walk to an explosive regime providing real time estimates of the origination date and the termination date of a bubble.

Phillips and Yu (2011) investigated bubble characteristics in the U.S. house price index from January 1990 to January 2009, the price of crude oil from January 1999 to January 2009 and the spread between Baa and Aaa bond rates from January 3, 2006 to July 2, 2009. Their methods relied on PWY methodology meaning forward recursive regressions coupled with sequential right-sided unit root tests. They tested for unit roots period by period against the alternative mildly explosive alternatives. Mildly explosive processes were modeled through an autoregressive model with a root ρ which is more than the unity but near. There are three differences from the PWY methodology. Firstly, the initial condition is not fixed to be the first observation in the full sample as previously but is selected based on the Bayesian information criterion. The information criterion allows a better identification of the origin of the bubble and thus may not be included all the observations. The second difference is that they emphasized in bubble transmission mechanism, so a test was developed for that and a new limit theory is provided for the new procedure. Lastly, the main is the different examining time period. The results were that a bubble arises in housing prices between February 2002 until December 2007, in oil from March 2008 to July 2008 and in Baa/Aaa from 22 February 2008 to 20 April 2009.

A limitation in the PWY methodology is that it is designed to analyze a single bubble episode. **Phillips, Shi and Yu** (2011) **(PSY, hereafter)** showed that if there are two bubbles in a time series and the duration of the second bubble is less than that of the first one, the PWY procedure cannot consistently estimate the origination date and the termination date of the bubble. They proposed the generalized sup augmented Dickey–Fuller **(GSADF, hereafter)** test which has the advantage that detect multiple periodically collapsing bubbles instead of the PWY test. The difference is letting the starting and the ending point change but from the new starting point several different forward expanding sequences are used to form samples instead of keeping fixed the starting point of the sample in the sup Augmented Dickey–Fuller **(SADF, hereafter)** case. Another difference of the GSADF is in the way of dating the origination and the termination of the bubble. For the GSADF, they compared the backward sup ADF **(BSADF,**

hereafter) statistic sequence which is obtained from implementing the right-tailed ADF test on backward expanding sample sequences with critical values for the SADF statistic. Comparing with the PWY procedure, the PSY procedure covers more subsamples of the data and has greater flexibility in choosing a subsample that contains a bubble episode.

The main difference with the **Taipalus** (2006) methodology is that she also allows the starting and the ending point to change but move constantly forward by one step at time with fixed length while **Phillips, Shi and Yu** (2011) GSADF test relies on a rolling approach but with several different forward expanding sequences begins from the starting point.

Taipalus (2006) criticized **Phillips, Wu and Yu** (2011) method of be unable to identify negative bubbles. **Taipalus** (2006) developed a rolling sub-sample ADF indicator to test the log rent-price ratios for the existence of real-estate ratio bubbles for Finland, USA, UK, Spain and Germany and the results suggests that in almost all these countries a bubble existed.

Gutierrez (2011) based on a bootstrap methodology computed the finite sample probability distribution of the asymptotic tests proposed in **Phillips, Wu and Yu** (2011) in Nasdaq stock price index and Case-Shiller house price index. He found exuberance in house prices which was started in October 2003 and then collapsed in May 2006, for a total of 30 months.

Yiu and Jin (2012) applied the method of PSY to identifying asset bubbles in the Hong Kong residential property market. Their results showed several positive bubbles in the Hong Kong residential property market, including one in 1995, a stronger one in 1997, another one in 2004, and a more recent one in 2008. In addition, the method identified two negative bubbles in the data, one in 2000 and the other one in 2001.

Phillips, Shi and Yu (2014a) examined appropriate ways of formulating regressions for right-tailed unit root tests to assess empirical evidence for explosive behavior. They used the SADF distributions and figured out that when the smallest window size decreases both SADF asymptotic distributions move sequentially to the right. In addition they found that the critical values are sensitive to smallest window size. Also, the finite sample SADF distribution is invariant to the localizing parameter when it is more than 0.5 but varies significantly with less than 0.5.

Chen and Funke (2013) applied the GSADF unit root tests in actual house prices in order to detect speculative bubbles in Germany over the sample period 1987Q3 – 2012Q4 and find no evidence of house price bubbles. They also calculated the test statistics for Ireland, Spain, the Netherland, the UK, and the U.S in order to assess the validity and reliability this test and accept their conclusion. In all countries were findings of bubbles which showed the fundamental suitability of the GSADF house price bubble as an early warning indicator. Specifically, from the plots reported some approximately concussions are the followings. Spain experienced bubble between 1987 and 1991 and another between 2003 and 2008, UK experienced two bubbles between 2003 and 2008 and US experienced a very huge bubble between 2001 and 2008.

Pavlidis, et al. (2013) applied the GSADF test developed by **Phillips, Wu and Yu** (2011) and **Phillips, Shi and Yu** (2011) to the data from the Dallas Fed International House Price Database. They monitored all the available countries but paid more attention in United States, the United Kingdom and Spain housing markets. Their results suggested that these three countries experienced a period of exuberance in housing prices during the late 90s and the first half of the 2000s that cannot be attributed solely to the behavior of fundamentals.

3. Model and specification test

Our model is based on the econometric bubble detection mechanism proposed by **Phillips, Wu and Yu** (2011) and **Phillips, Shi and Yu** (2011).

The underlying theory is described in following asset pricing equation:

$$P_t = P_t^f + B_t = \sum_{i=0}^{\infty} \left(\frac{1}{1+r_f}\right)^i E_t(D_{t+i} + U_{t+i}) + B_t \qquad 3.1$$

The after-dividend price of the asset P_t is the sum of the market fundamental component P_t^f and the bubble component B_t.The r_f denotes the risk free interest rate, D_t denotes the payoff from the asset received, U_t represents the unobservable fundamentals and B_t satisfies the following equation:

$$E_t(B_{t+1}) = (1+r_f)B_t \qquad 3.2$$

when $B_t = 0$ the stationarity is affected by the payoff from the asset received and the unobserved fundamentals. If one of these factors is an $I \sim (1)$ process then the asset price follows at most an $I \sim (1)$ process. On the other hand, in the presence of bubble the asset price would be explosive.

The empirical regression model is the following:

$$\Delta y_t = a + \beta y_{t-1} + \sum_{i=1}^{k} \phi_i \Delta y_{t-i} + \varepsilon_t, \varepsilon_t \sim NID(0, \sigma^2) \qquad 3.3$$

$H_0 :\ \beta = 0$ a unit root, $H_1 :\ \beta \prec 0$ stationarity

3.1 The PWY test

The PWY test relies on repeated estimation of the 3.3 on a forward expanding sample sequence and the test is obtained as the sup value of the corresponding ADF statistic sequence. In the recursion the r_w is the window size of the regression and runs from r_0 to 1, where r_0 is the smallest sample window width fraction and 1 is the largest one (total sample). The starting point r_1 is fixed at zero so the end point r_2 runs from r_0 to 1.

$$SADF(r_0) = \sup_{r_2 \in [r_0,1]} ADF_0^{r_2} \qquad 3.4$$

The t-statistic is denoted corresponding to the null hypothesis as:

$$ADF_{r_1}^{r_2} = \frac{\hat{\beta}_{r_1,r_2}}{s.e.(\hat{\beta}_{r_1,r_2})}$$

The limit distribution of the $\sup_{r\in[r_0,1]} ADF_r$ is given by:

$$\sup_{r\in[r_0,1]} ADF_r = \sup_{r\in[r_0,1]} \frac{\int_0^r W dW}{\int_0^r W^2} \qquad 3.5$$

The W denotes the standard Brownian motion. The ADF statistic is being computed recursively from each regression and the sup ADF statistic is then used to detect the presence of bubble. They defined the origin date of the bubble to be the smallest value of $r \in [r_0, 1]$ for which ADF_r is larger than the critical value. The Illustration 1 shows the procedure of SADF test graphically.

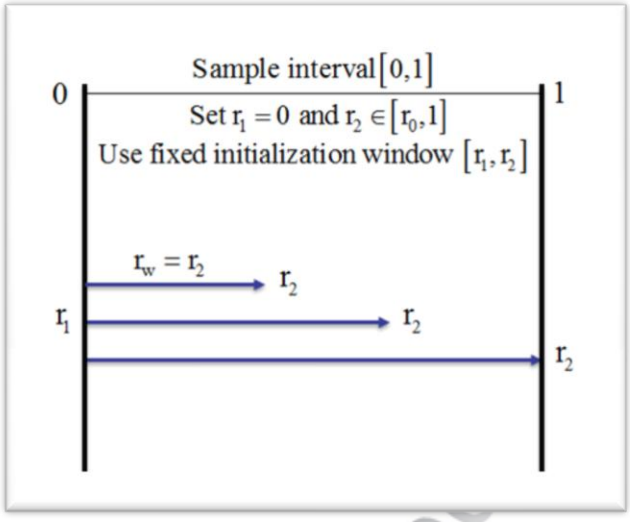


Illustration 1 SADF test

3.2 The PSY test

The GSADF test relies on repeated estimation of the 3.3 in a rolling approach but with several different forward expanding sequences. Specifically the GSADF test varies both the starting point r_1 to change with a feasible rang e.g. $r_2 - r_0$ and the ending point r_2 runs from r_0 to 1. The GSADF statistic is defined to be the largest ADF statistic over the feasible ranges of r_1 and r_2, denotes as $GSADF(r_0)$:

That is

$$GSADF_{r_2}(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} ADF_{r_1}^{r_2} \qquad 3.6$$

Again, rejection of the unit root hypothesis in favor of explosive behavior requires that the test statistic exceeds the right tailed critical value from its limit distribution. **Phillips, Shi and Yu** (2011) derived the limit distributions for of the GSADF statistic which is a nonlinear function of r_0 and Brownian motion which is denoted under the null hypothesis as:

$$\sup_{r_2 \in [r_0, 1], r_1 \in [0, r_2 - r_0]} \left\{ \frac{\frac{1}{2} r_w [W(r_2)^2 - W(r_1)^2 - r_w] - \int_{r_1}^{r_2} W(r) dr [W(r_2) - W(r_1)]}{r_w^{1/2} \left\{ r_w \int_{r_1}^{r_2} W(r)^2 dr - [\int_{r_1}^{r_2} W(r) dr]^2 \right\}^{1/2}} \right\} \qquad 3.7$$

Using this result and monte carlo simulation methods it is possible to compute the asymptotic and finite sample critical values. The asymptotic values are calculated from **Phillips, Shi and Yu** (2011) for the cases r_0 as the smallest window size be 0.4, 0.2 and 0.1**.**

The Illustration 2 shows the procedure of GSADF test graphically.

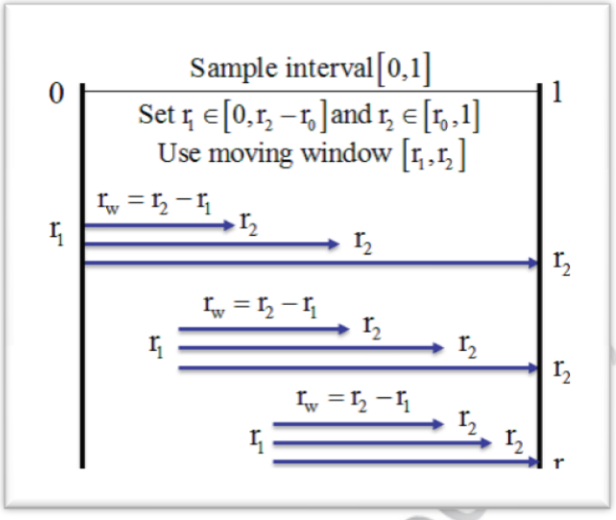


Illustration 2GSADF test

3.3 Date stamping methodology

The strategy to identify the starting and the ending point of a bubble is to perform a double recursive test procedure which is called backward sup ADF test (BSADF). The ending point of this sequence is fixed at r_2 and the starting point varies from 0 to $r_2 - r_0$.

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} ADF_{r_1}^{r_2} \qquad 3.8$$

The origination date of the bubble would then be defined when it would be firstly observed that the BSADF statistic exceeds the critical value of the BADF statistic.

$$\hat{r}_e = \inf_{r_2 \in [r_0,1]} \left\{ r_2 : BSADF_{r_2}(r_0) > scu_{r_2}^{\beta_T} \right\} \quad 3.9$$

The termination date of the bubble would be calculated as the first observation after $\lfloor Tr_e \rfloor + \delta \log(\mathrm{T})$ whose BSADF statistic falls below critical value of the BADF statistic. T is the sample size, r_e is the starting date of the bubble, $\lfloor . \rfloor$ gives the integer part of the argument and δ is a frequency dependent parameter.

$$\hat{r}_f = \inf_{r_2 \in [r_0,1]} \left\{ r_2 : BSADF_{r_2}(r_0) < scu_{r_2}^{\beta_T} \right\} \quad 3.10$$

where $scu_{r_2}^{\beta_T}$ is the 100 β_T% critical value of the sup ADF based on $r_2 T$ observations and β_T is the chosen significance level.

When the BSADF statistic exceeds the finite sample critical values of the SADF, the empirical evidence suggests that the time series displays explosive behavior. Because the distributions of the SADF(r_0) and GSADF(r_0) are non-standard, critical values have to be obtained through Monte Carlo simulations. The Illustration 3 shows the procedure of GSADF test graphically.

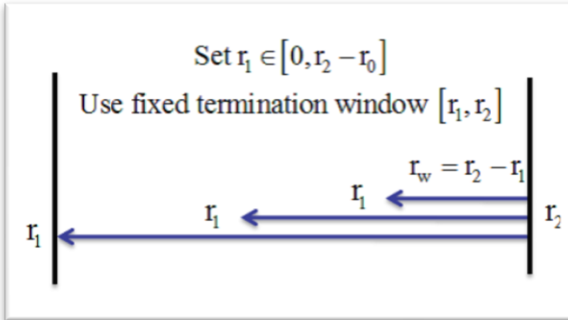


Illustration 3 BSADF test

4. Data

The price of an asset is in general the discounted sum of its future incomes. So an increase of the price-to-rent ratio shows the expectation that rent would be appreciated. If the indicator deviates persistently and significantly from its long-term average, this can be read as a sign of a bubble. The price-to-rent ratio data were provided from the OECD database in order to reach some commensurability. Quarterly data from the first quarter of 1980 to the last quarter of 2013. Specifically, the nominal price houses were taken for United States and some countries of the Euro zone which are Finland, Italy, France, United Kingdom, Denmark and Germany. The nominal house prices were provided from each country's national statistics and the rent prices were provided from the OECD. Table 4 in appendix describes the data used for the nominal house prices series in more detail.

5. Technical details

The computation of the SADF statistic, GSADF statistic and the corresponding finite critical values has been executed in the Matlab programming environment. There were assumptions about the ADF equation, the lag length and the minimum window size.

The ADF equation was assumed to be with a constant but without a trend as the graph of the returns of the data used was not had an upward trend and the mean was not reverting through zero. The partial autocorrelation of the returns has shown that the most information is described in two to four lags for all countries. The ADF calculated with fixed four lag length and not with an application of an information criterion because the computation cost would be high despite the fact that the results would be more accurate.

Following the proposal of **Phillips, Shi and Yu** (2014 b), the minimum size window was chosen based on the down rounded result given by the formula:

$$SWindow = \left(0.01 + \frac{1.8}{\sqrt{T}}\right) * T \tag{5.1}$$

Particularly all the datasets was assumed to be 22 meaning five years and 2 months, as the total observations of each country are 136. The size window should be neither too small in order to avoid miscalculations nor too large as it would produce wrong results. This methodology is quite sensitive to the window size; the more it is increased the more the critical values are reduced and then may produce more exuberance episodes. Moreover, the finite critical values are calculated through Monte Carlo simulations by generating 2000 random walk processes with N (0, 1) errors.

6. Empirical evidence

This section investigates the explosive behavior of United States, Germany, United Kingdom, France, Italy, Finland, Spain and Denmark by examining the real house prices, the nominal house prices to rent ratio and the nominal house prices to income ratio obtained from OECD from 1980Q1 until 2013Q4.

The Figure 1 displays the evolution of the quarterly time series for the real house prices from 1971Q1 to 2013Q4 with the 1971Q1 be the base line. In the total period house prices of Germany have remain approximately the same and below the base line during the financial crisis (2007-2012). All the other countries appear to have changes in their house prices from 1971. In general an obvious and large appreciation has started from approximately 1986 for United Kingdom and Spain and from 1998 a less large for United States, Italy, France, Finland and Denmark. In general the increasing prices in house property market is mainly due to the low interest rate level as people are more willing to accept large debts in order to buy a house. The peak period of all the series apart from Germany seems to be between 2007 and 2009. However when the series were stable does not mean that they did not experience a bubble and when they have a downward movement may experience a negative bubble as it will be shown later.

The Figure 2 displays the evolution of the quarterly time series for the nominal house prices to rent ratio from 1971Q1 to 2013Q3 with the 1971Q1 be the base line. It is expected that when house prices are low relative to rent, future increases in house prices are likely to be high. There is an obvious a co movement with the Figure 1 with the Spain again to exhibit the largest change in this ratio but the United Kingdom be in a lowest level instead of the previous figure. Italy also comes first at the beginning of the analysis as it exhibits a significant increase but then after 1986 comes second.

The Figure 3 displays the evolution of the quarterly time series for the nominal house prices to income ratio from 1980Q1 to 2013Q3 line as there was not previous available data and with the 1980Q1 be the base. In general this graph has more variations than the Figure 1 which has only upward movements from the base line expect for Germany. The Spain again is the first having the largest house price to income ratio and this time follows again the United Kingdom but with the Denmark be also in the same levels. In addition, United States and Germany has a diminishing price to income ratio from 1980 which shows that in both countries especially US have increased their income substantially.

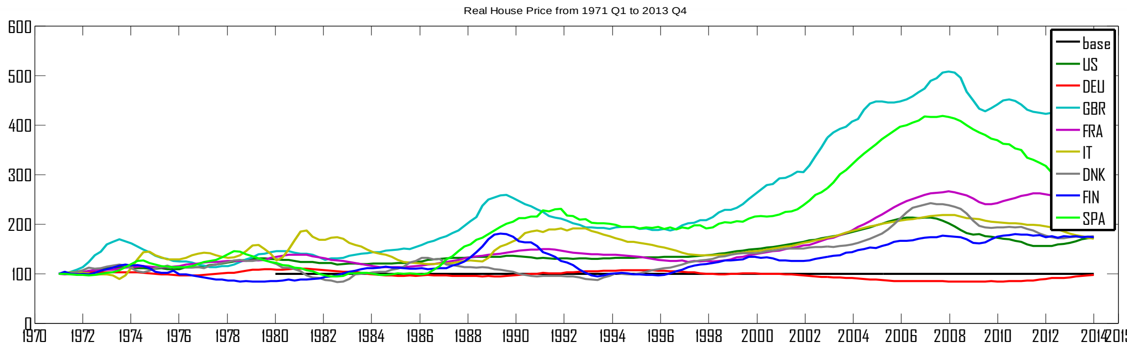


Figure 1 Real House Prices from 1971Q1 to 2013Q4

Source: OECD data

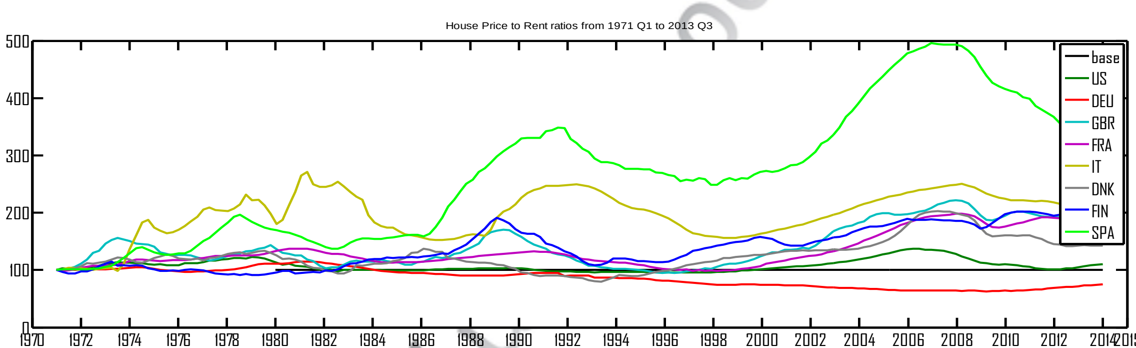


Figure 2 Nominal House Prices to Rent ratio from 1971Q1 to 2013Q4

Source: OECD data

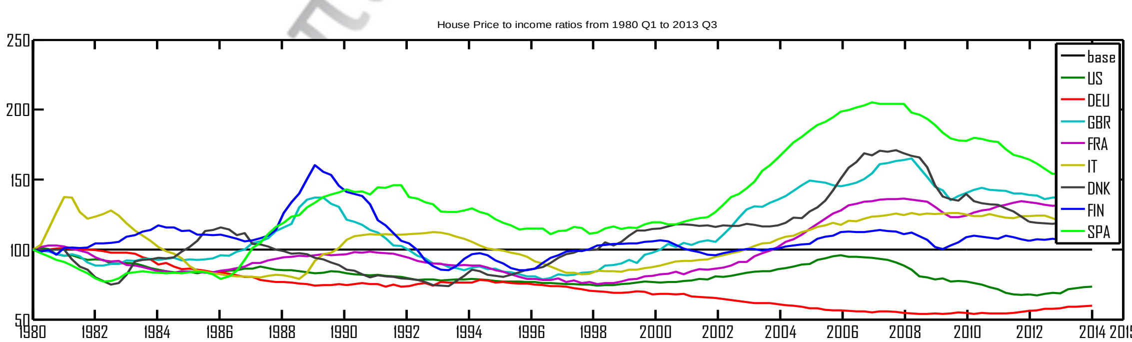


Figure 3 Nominal House Prices to Income ratio from 1980Q1 to 2013Q4

Source: OECD data

In the Table 1 in Panel A are sided the results for the SADF and GSADF statistics for all the countries and for all datasets and in Panel B their corresponding finite critical values. In order to reject the null hypothesis in favor of explosive behavior the test statistic should exceed the critical value. The total observations for all datasets are the same so are the critical values too.

Panel A: Test statistics

Country	Real House Prices		Nominal House Price-to-Rent Ratio		Nominal House Price-to-Income Ratio	
	SADF	*GSADF*	*SADF*	*GSADF*	*SADF*	*GSADF*
USA	2,25	3,2	-0,44	2,81	1,32	4,57
GER	-0,11	2,1	-0,07	4,25	-1,35	3,46
UK	2,06	3,9	1,61	3,21	-0,39	2,92
FRA	0,57	4,8	-0,83	2,51	0,41	3,49

IT	0,51	4,1	1,15	3,19	0,05	3,23
DNK	1,66	4,4	0,65	4,36	0,65	4,25
FIN	1,38	2,2	-0,17	2,00	0,80	4,93
SPAIN	1,16	3,5	0,49	3,73	1,63	3,22
Panel B: Critical values						
90%	1,37	2,94	1,37	2,94	1,37	2,94
95%	1,75	3,27	1,75	3,27	1,75	3,27
99%	2,58	4,17	2,58	4,17	2,58	4,17

Table 1 SADF and GSADF statistics and the corresponding finite critical values

Source: author's calculations

In the Table 2 are sided the comparisons of the SADF and GSADF statistics with the corresponding critical values for the three datasets. The Panel A includes the dataset of real house prices and shows explosive behavior for the most countries. Particularly at 5% confidence level the GSADF statistic exceeds the corresponding critical value for all countries apart from US, Germany and Finland instead of SADF which capture explosiveness only in US and France. So it is obvious the power of GSADF methodology against SADF. Moreover the Panel B includes the dataset of nominal house price to rent ratio and in this case the GSADF at 5% confidence level results a house bubble only for Germany, Denmark and Spain while SADF does not show any explosiveness. Finally in the Panel C which includes the nominal house price to income ratio the GSADF shows explosiveness at 5% confidence level for all countries except France, Italy and Spain. Again the SADF shows no signs of explosiveness in any country at the same confidence level.

Panel A: Test explosiveness for Real House Prices								
				Test explosiveness 10%				
	US	GER	UK	FRA	IT	DNK	FIN	SPAIN
SADF	Explosive	No	No	Explosive	No	Explosive	Explosive	No
GSADF	Explosive	No	Explosive	Explosive	Explosive	Explosive	No	Explosive
				Test explosiveness 5%				
SADF	Explosive	No	No	Explosive	No	No	No	No

GSADF	No	No	Explosive	Explosive	Explosive	Explosive	No	Explosive
Test explosiveness 1%								
SADF	No	No	No	No	No	No	No	No
GSADF	No	No	Explosive	No	No	Explosive	No	No

Panel B: Test explosiveness for Nominal House Price-to-Rent Ratio

Test explosiveness 10%								
	US	GER	UK	FRA	IT	DNK	FIN	SPAIN
SADF	No	No	No	Explosive	No	No	No	No
GSADF	No	Explosive	No	Explosive	Explosive	Explosive	No	Explosive
Test explosiveness 5%								
SADF	No	No	No	No	No	No	No	No
GSADF	No	Explosive	No	No	No	Explosive	No	Explosive
Test explosiveness 1%								
SADF	No	No	No	No	No	No	No	No
GSADF	No	Explosive	No	No	No	Explosive	No	No

Panel C: Test explosiveness for Nominal House Price-to-Income Ratio

Test explosiveness 10%

	US	GER	UK	FRA	IT	DNK	FIN	SPAIN
SADF	No	No	No	No	No	No	No	Explosive
GSADF	Explosive	Explosive	Explosive	No	Explosive	Explosive	Explosive	Explosive
Test explosiveness 5%								
SADF	No	No	No	No	No	No	No	No
GSADF	Explosive	Explosive	Explosive	No	No	Explosive	Explosive	No
Test explosiveness 1%								
SADF	No	No	No	No	No	No	No	No
GSADF	Explosive	No	No	No	No	Explosive	Explosive	No

Table 2 Test explosiveness for all datasets in 10%, 5% and 1% confidence levels

Source: author's calculations

United States:

Figure 4 displays the real house prices for the US from 1980Q1 to 2014 and the corresponding backward SADF sequence with the SADF critical value at 95% confidence level. The vertical shaded lines are for the identified bubbles.

Figure 5 displays the nominal house prices to rent ratio for the US from 1980Q1 to 2014 as there was the only available data for all datasets and the corresponding backward SADF sequence with the SADF critical value at 95% confidence level.

Figure 6 displays the nominal house price to income ratio for the US from 1980Q1 to 2014 and the corresponding backward SADF sequence with the SADF critical value at 95% confidence level.

This analysis is analogous for all the rest countries meaning Germany, United Kingdom, France, Italy, Finland, Spain and Denmark.

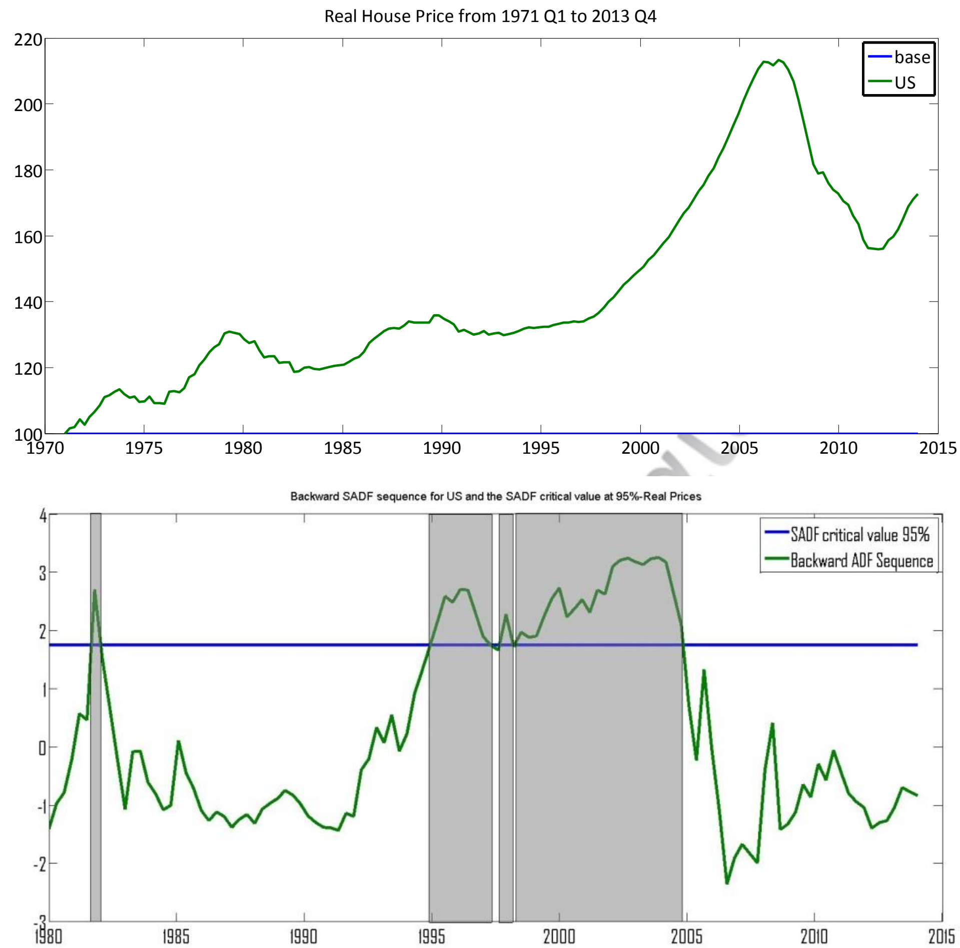
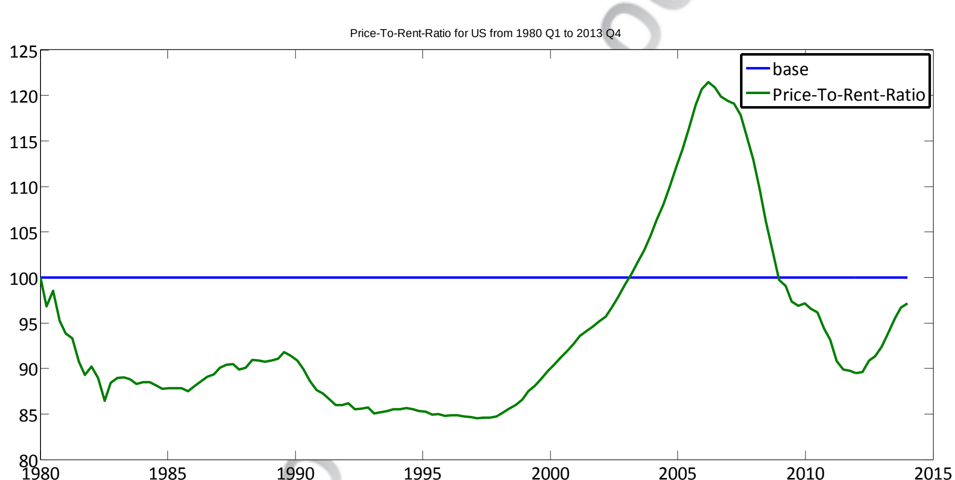


Figure 4 US real house prices index with the 1971Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

First looking at the US real house prices graph it can be observed a constantly growth from 1971Q1 until 2007 when the property bubble was collapsed. According to Federal Housing Finance Agency (FHFA) House Price Index in its latest report the US compound annual growth rate from monthly house prices is from January 1991 to September 2014 3.3% with a total increase of 111%. The BSADF sequence on real house prices signals one major bubble which includes the period from mid 1995 to 2005 with a small interruption at 1998Q3 and another at 1982Q2. It seems that the dating of bubble-signals fits well with the periods when there has been a strong arise in the real house prices. From the comparison of the two graphs above it is concluded the power of the GSADF methodology as it could provide early warnings signs of bubble bursting.



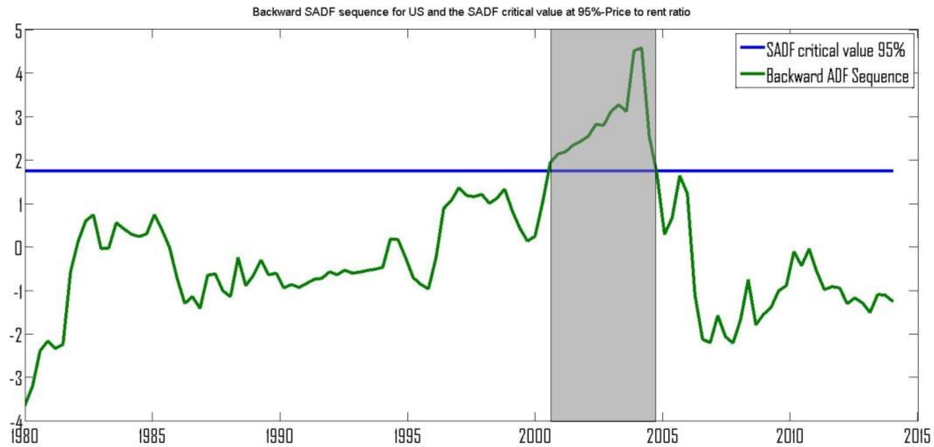
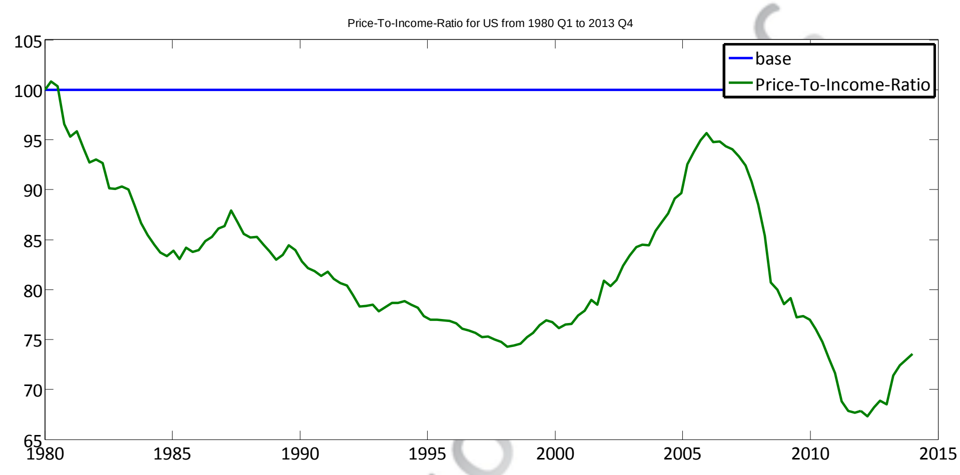


Figure 5 US nominal house prices to rent index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The US house price to rent ratio was downward since 1980 but there was a significant increase from 1995 to 2006. The nominal house prices to rent ratio dataset show a bubble between 2000Q4 to 2004Q3 which coincides too with the first dataset but capturing a smaller duration and again the BSADF methodology acts as early bubble indicator. According to **Taipalus** (2006) who applied unit root testing with rolling windows in monthly rent to house price data spotted bubbles previously than 1995Q1 and show the bubble with some interruptions. Specifically, she identified bubbles at the end of 1986 and lasts until the autumn 1987, in the beginning of the year 1995 and in the autumn 1998 lasting until the end of 2001 and reappearing again in the autumn 2003 until 2006. **Taipalus** (2006) apart from the different methodology used other dataset and convert the quarterly observations to monthly. So the differences of the results could be attributed in many things but recursive unit root testing can show a consistence of the bubble episodes instead of the traditional unit root test with rolling windows which can spot only small explosives periods.



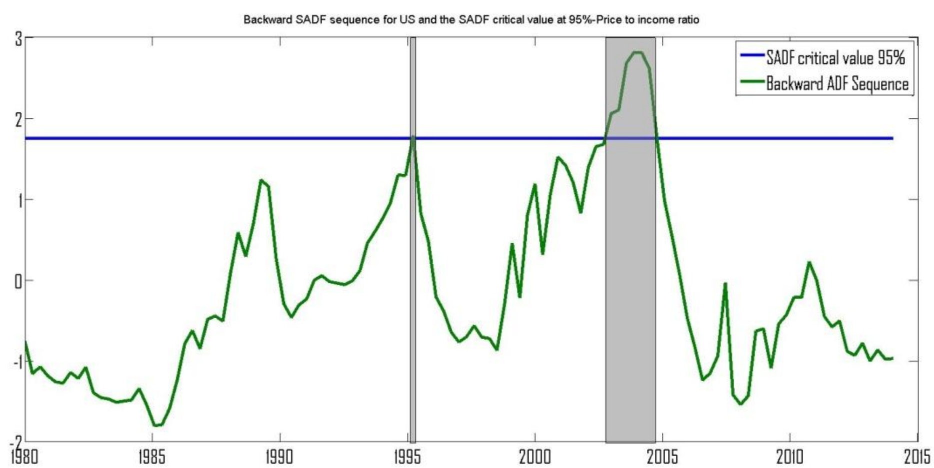


Figure 6 US house prices to income index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The house price to income ratio has also a downward movement from 1980 until mid 1995 when it was increased until 2006. The nominal house price to income ratio dataset signals two bubbles and both of them have less duration than the first dataset meaning 1995Q1 and 2002Q4 to 2004Q3.

Germany:

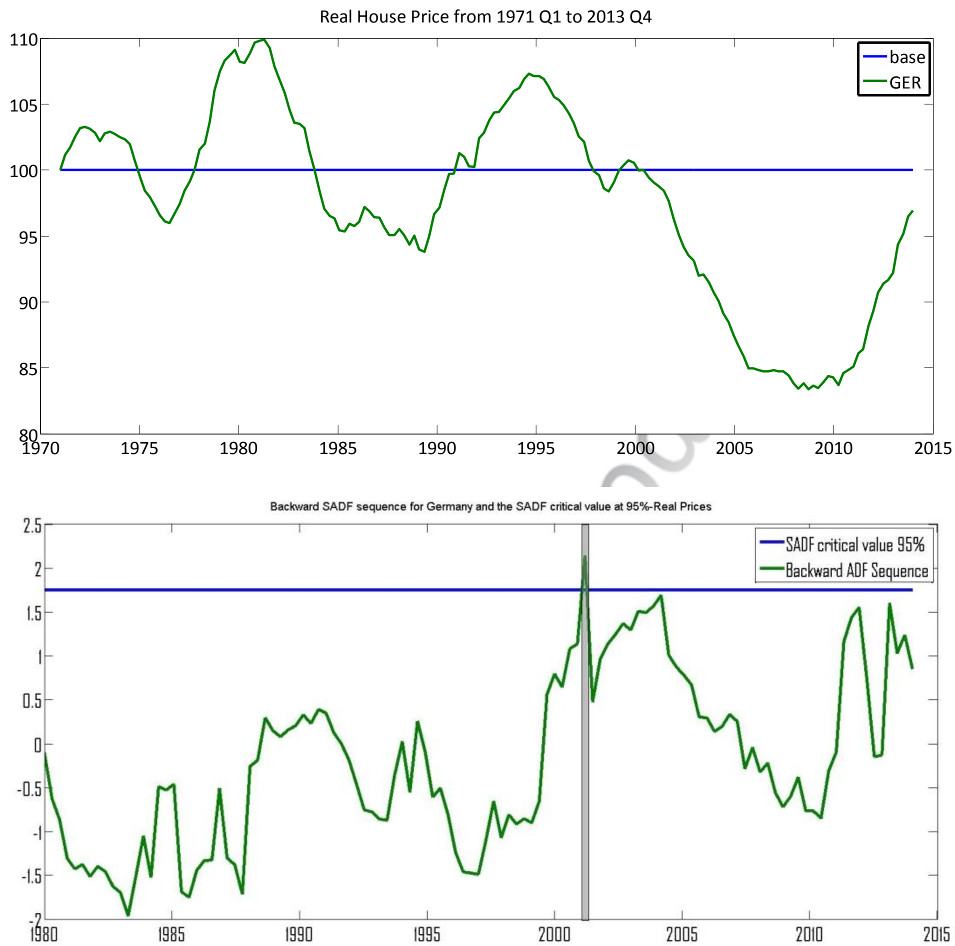
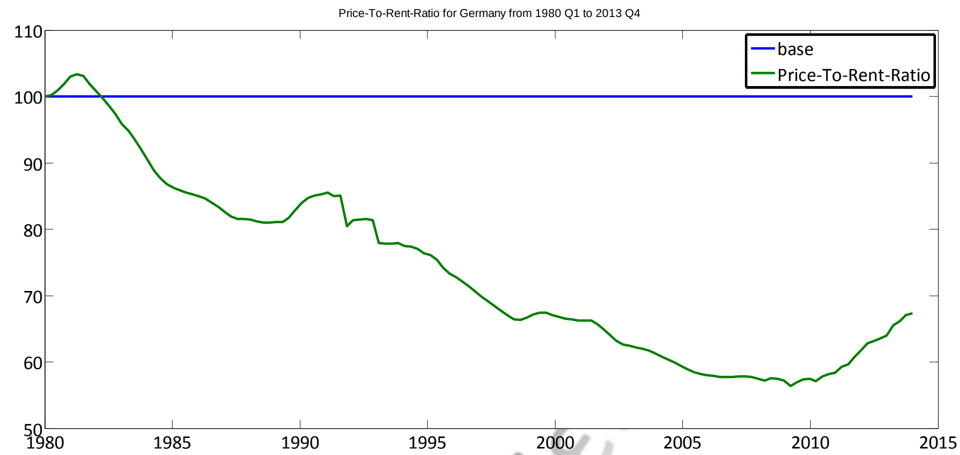


Figure 7 Germany real house prices index with the 1971Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

Looking at Figure 7 real house prices in Germany spot two periods with quicker growth one during 1978 to 1981 and the second from 1989 to 1996. The BSADF technique in real house prices does not signal any bubble apart from a small explosive behavior in 2002Q2 which is justified as Germany is commonly very stable during last decades.



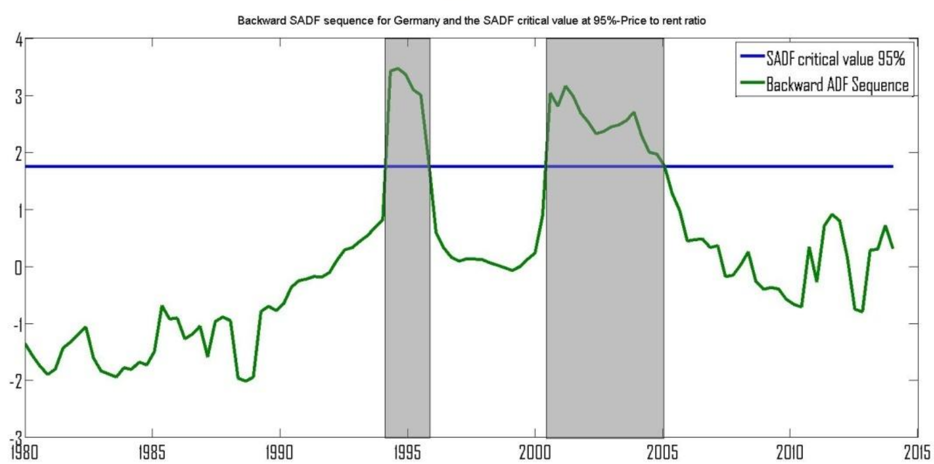


Figure 8 Germany house prices to rent index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The house price to rent ratio is falling since 1981 which could be attributed to rent raises or to house prices reductions depending on the examining period. The Figure 8 shows two bubbles between 1994Q1 to 1997Q1 and 2001Q2 to 2005. Therefore as the real house prices are diminishing in this period these signs could be held as negative signs bubbles. According to **Taipalus** (2006) methodology indicates three periods as bubbles by examining the price to rent ratio which coincides with the results of the price to rent ratio of this study but with capturing only small spots of the total period. Particularly, the **Taipalus** (2006) results show explosive behavior starting from summer 1978 until the end of 1978, early 1997 as well as the period starting from summer 2003 and lasting until the end of 2003. Moreover, the strong upward movement in the 1989 to 1996 period as **Taipalus** (2006) reported is related to the substantial increase in housing demand due to the high rise in immigration.

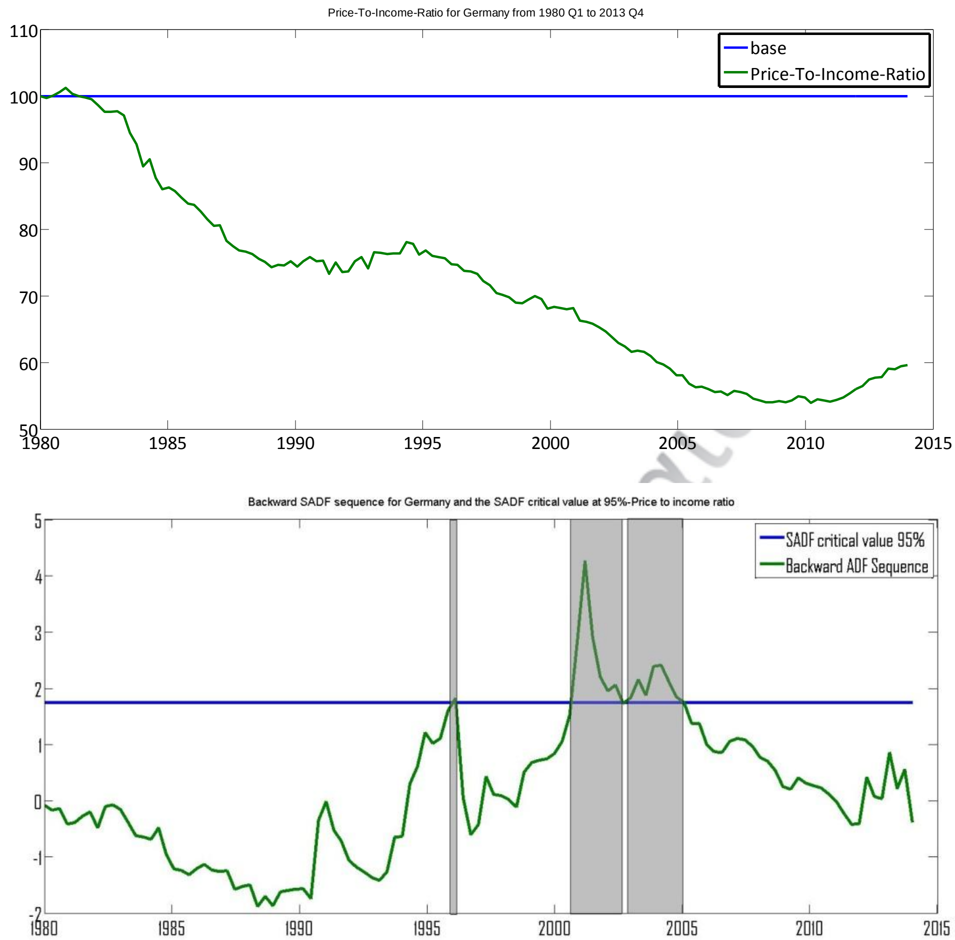


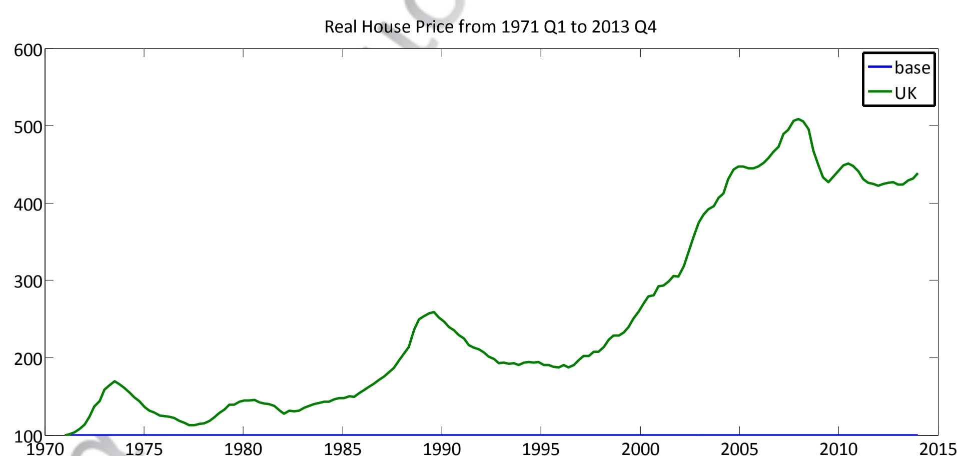
Figure 9 Germany house prices to income index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The house price to income ratio follows the same path with the house price to rent ratio which means that the rents and the income in Germany follows the same direction. However, the nominal house price to income ratio dataset signals two bubbles meaning 1996Q1, 2000Q4 to 2005 except the period 2002Q4.

Lastly there is a fear that the Germany maybe forming a property bubble as the real house prices have been rising steadily since 2010. However, based on the findings in this report, there is not such a danger. In general, Germany is by far at the lower end of the scale of price increases compared with the property price bubbles in the United States, Finland, Italy, France, United Kingdom, Denmark and Spain. In addition indicators, such as the price-to-income ratio and the price-to-rent ratio, do not indicate any significant overheating in the German housing market.

United Kingdom:



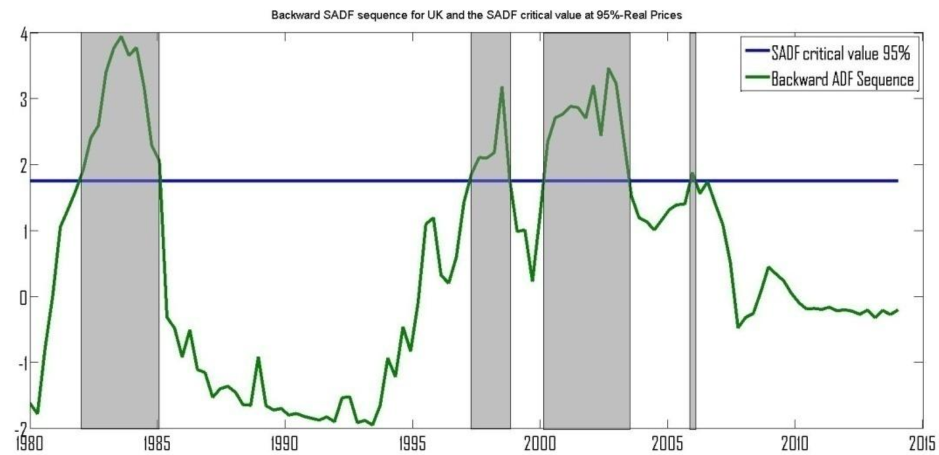
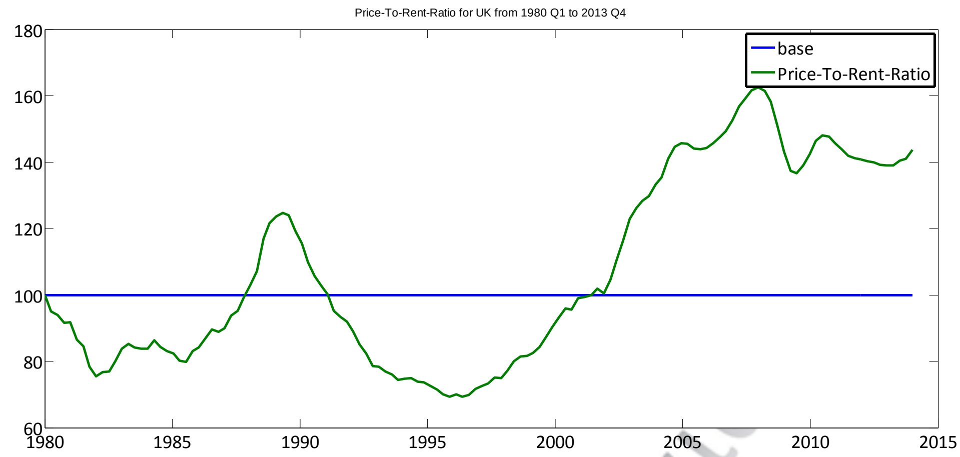


Figure 10 UK real house prices with the 1971Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

In the real house prices graph it can be observed that the index is constantly rising from 1971Q1 to 2013Q4. According to the GSADF methodology, the real house prices in total signals four bubbles which are included in the period from mid 1982 to 1985, 1997Q3 to 1998, 2000 to 2003Q3 and 2006Q2. It seems that the dating of the bubble signals dates well with the periods that real house prices experience a strong rise.



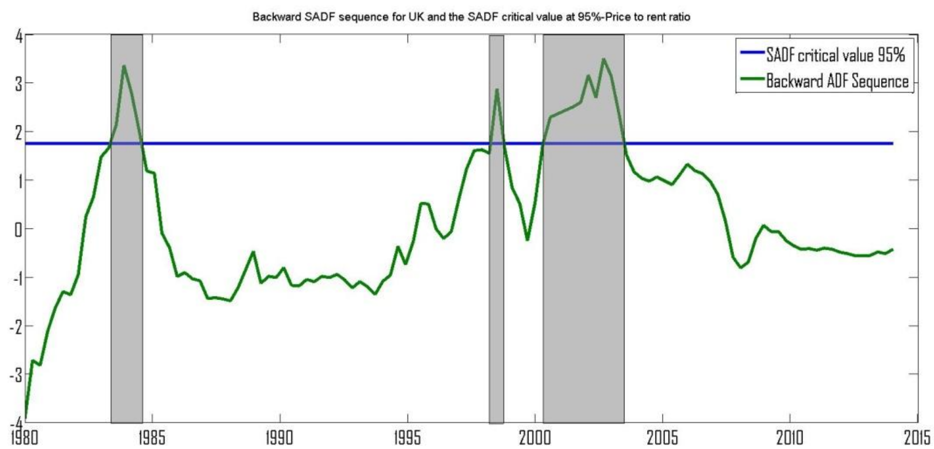
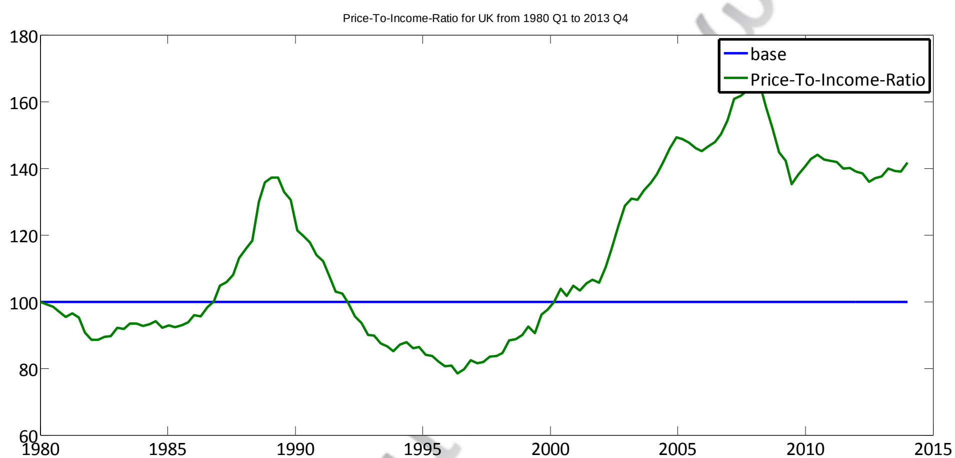


Figure 11 UK house prices to rent index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The house price to rent ratio shows a strong rise from 1995 to 2007. The BSADF technique shows two bubbles from 1983Q3 to 1984Q3 and 2000Q2 to 2003Q3 and an explosive behavior in 1998Q2 to 1999Q1. **Taipalus** (2006) applied unit root testing with rolling windows in rent to house price data and did not detect explosive behavior from 1984 to 1985 but she identified 2002Q2 to 2003Q1 period.



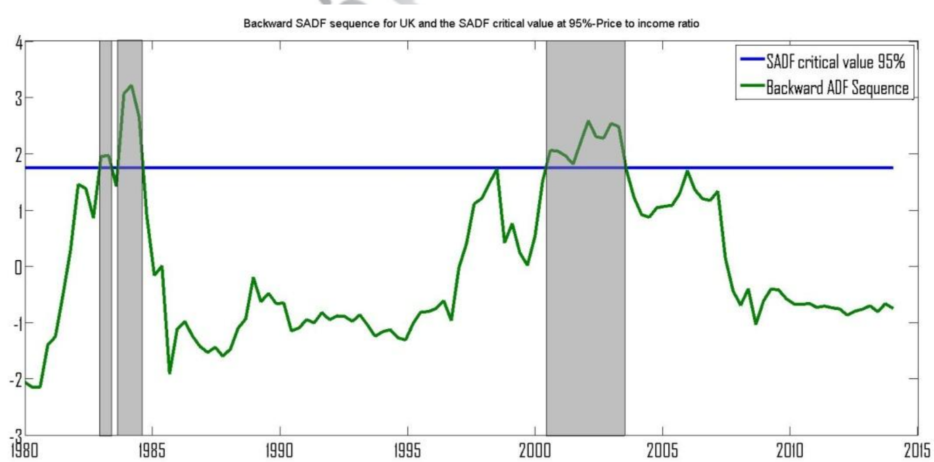
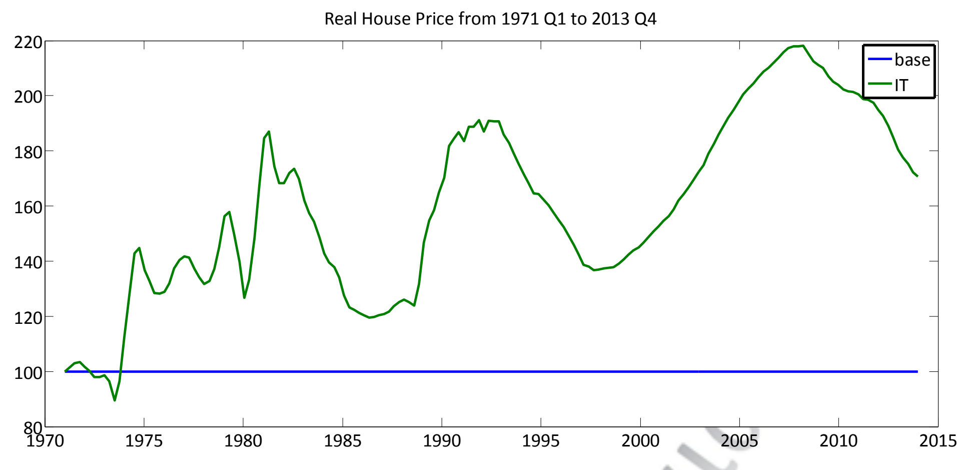


Figure 12 UK house prices to income index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

In addition, the nominal house price to income ratio dataset signals two bubbles meaning 1982Q4-1984Q3 apart from a small pause around 1983Q2 and the other in 2000Q2-2003Q3. There is an obvious matching in bubble signals with upwards movements in price to income ratio.

Italy:



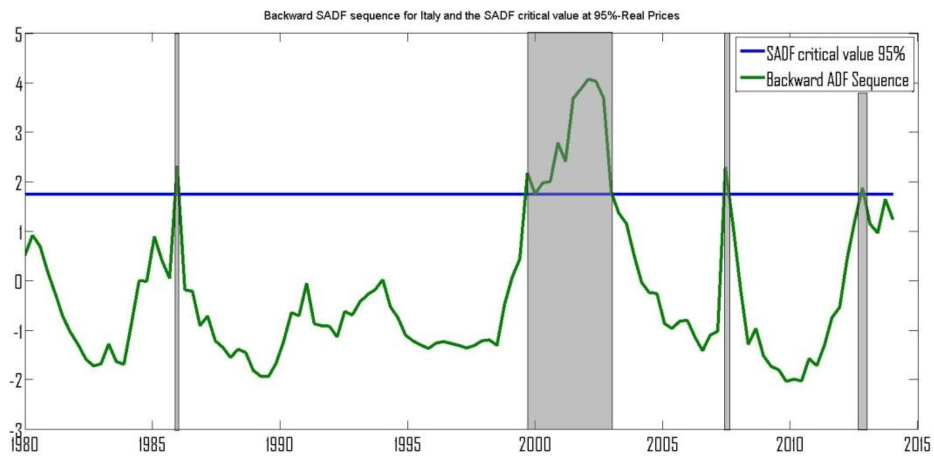


Figure 13 Italy real house prices index with the 1971Q1=100 UK and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The graph of the real house prices is observed to be upward since 1971Q1 but with making long cycles and reach its peak at mid 2007 to mid 2008. The graph of real house prices in total signals one major bubble which includes the period from 1999Q3 to 2003Q2 and faintly explosiveness in 1985Q2, 2007Q2 and 2013Q3.

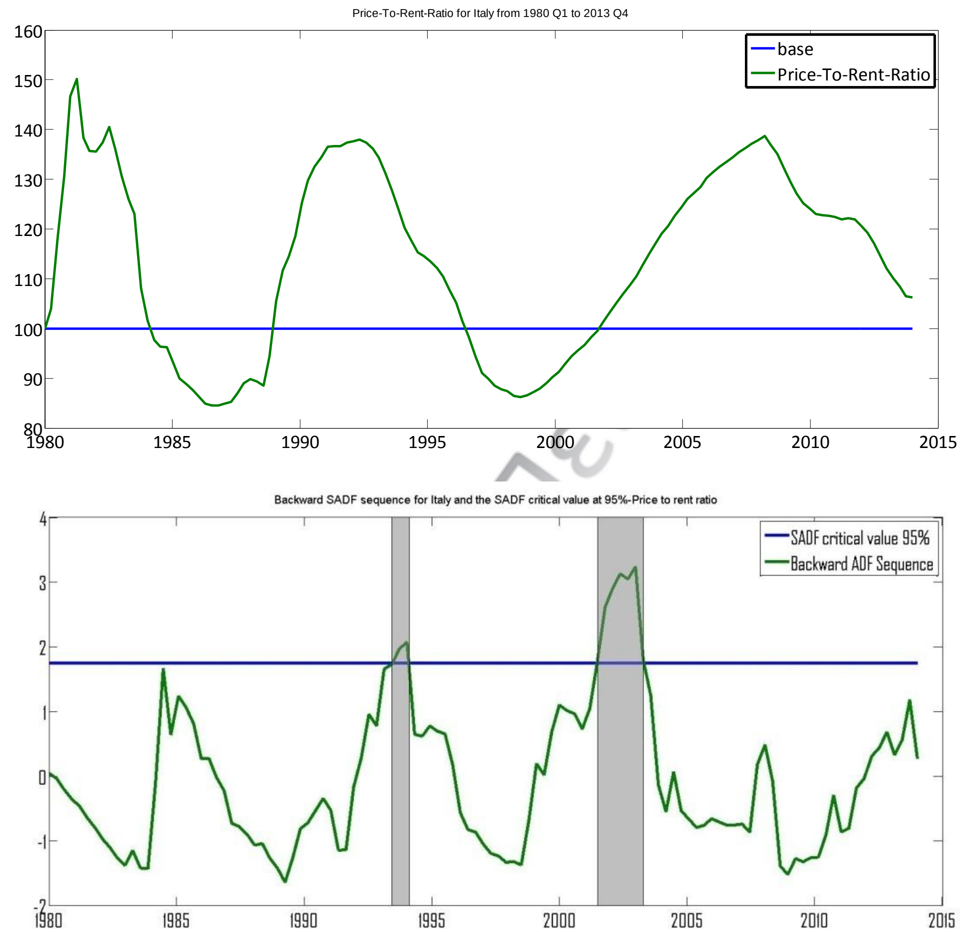


Figure 14 Italy nominal house prices to rent index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The house price to rent ratio in Italy seems to make long cycles and also experience a strong rise from mid 1995 to 2007. The BSADF methodology shows explosive behavior from 1993Q2 to 1994Q1 and 2002 to 2003Q1.

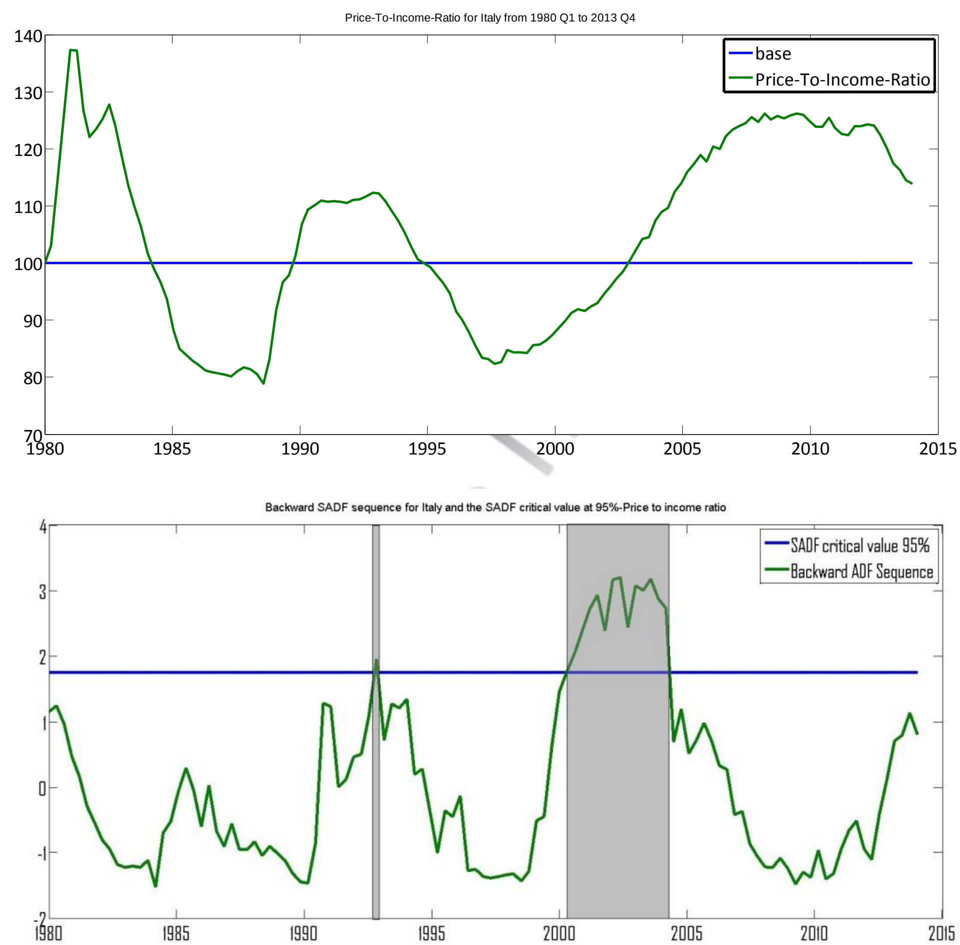


Figure 15 Italy nominal house prices to income index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

As previously, the house price to income ratio seems to make long cycles and experience a rise from mid 1995 to 2007. In addition, the nominal house price to income ratio dataset signals explosive behavior in 1992Q4 and from 2000Q1 to 2004Q1.

France:

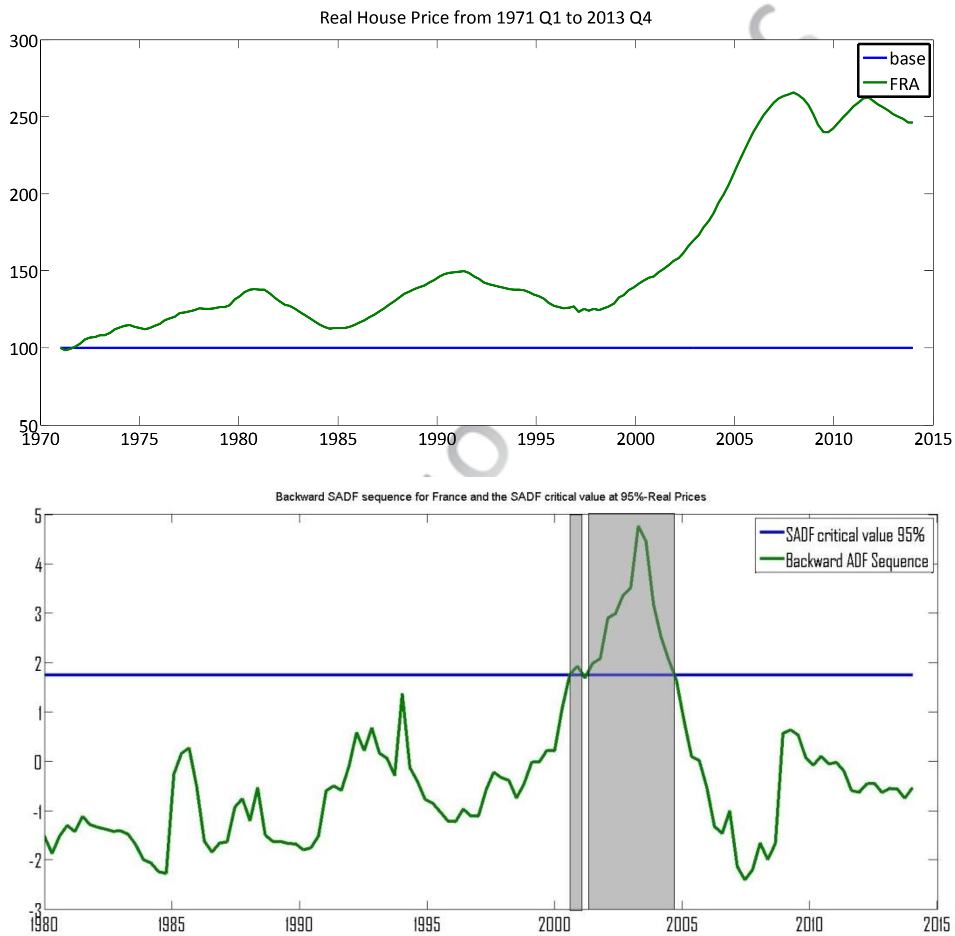


Figure 16 France real house prices index with the 1971Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

First looking at the France real house prices graph it can be observed a constant growth from 1971Q1 until 2007 when the property bubble was collapsed. However, this shock in 2007 seems not to affect the France in a big degree as it raised again in 2010. The BSADF methodology in real house prices signals in total one bubble which includes the period from 2001Q1 to 2004Q3 with a small pause in 2002Q2.

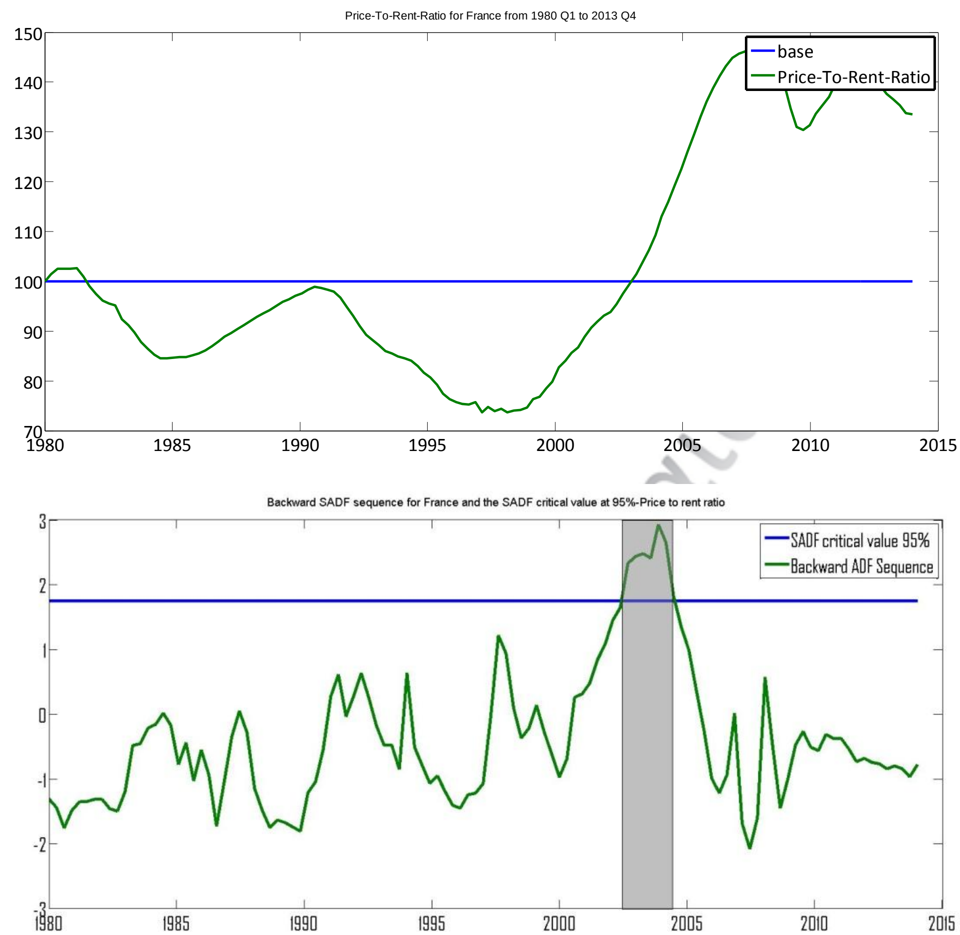


Figure 17 France nominal house prices to rent index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The house price to rent ratio seems to experience a large growth from mid 1995 to 2006. The BSADF technique shows explosive behavior in 2003Q1 to 2004Q2 which coincides with the first dataset but with smaller duration.

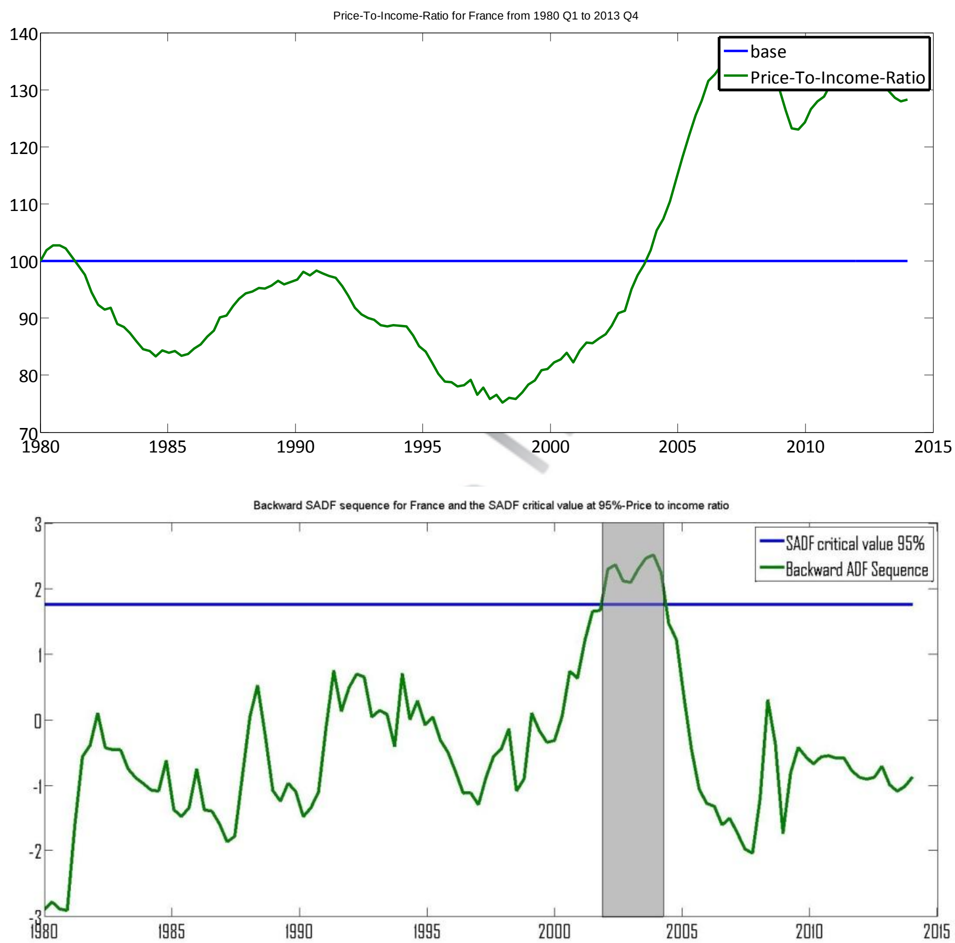
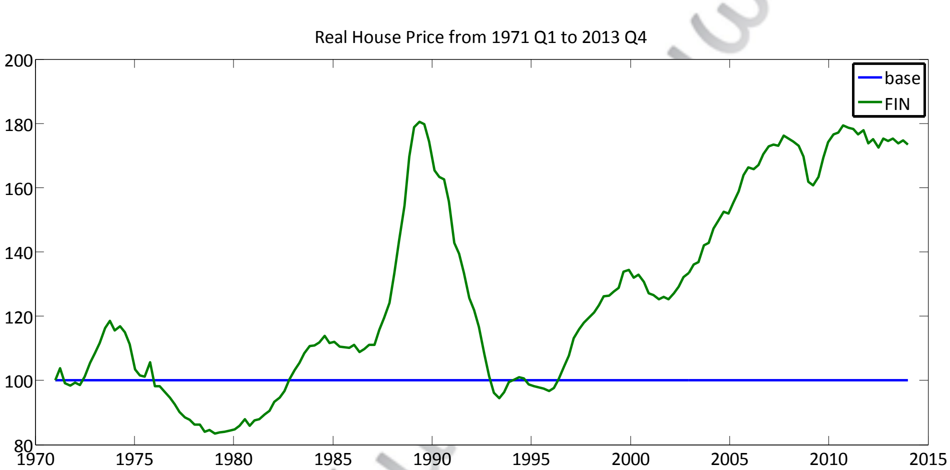


Figure 18 France nominal house prices to rent index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The house price to income ratio follows the same path as the house price to rent ratio. In addition, the BSADF technique in the nominal house price to income ratio dataset signals explosive behavior from 2002 to 2004Q1.

Finland:



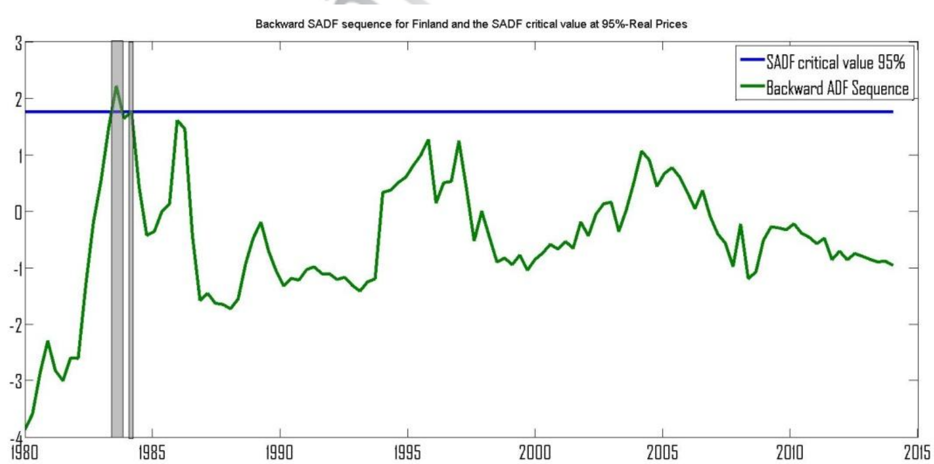


Figure 19 Finland real house prices with the 1971Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

Looking at the Finland real house prices graph it can be observed many fluctuations from 1971Q1 and a big rise from 1986 to 1990 following a big drop. Also from 1996 to present there is constant rise with only a small reduction in 2009. On the contrary for other countries Finland does not seem to be affected from the financial crisis. The BSADF technique of real house prices signals almost no major bubble but two small explosive periods which are included in the period from 1983 to 1983Q2 and 1983Q4 and could be signed as a negative bubble as the real house prices this period follows a downward movement.

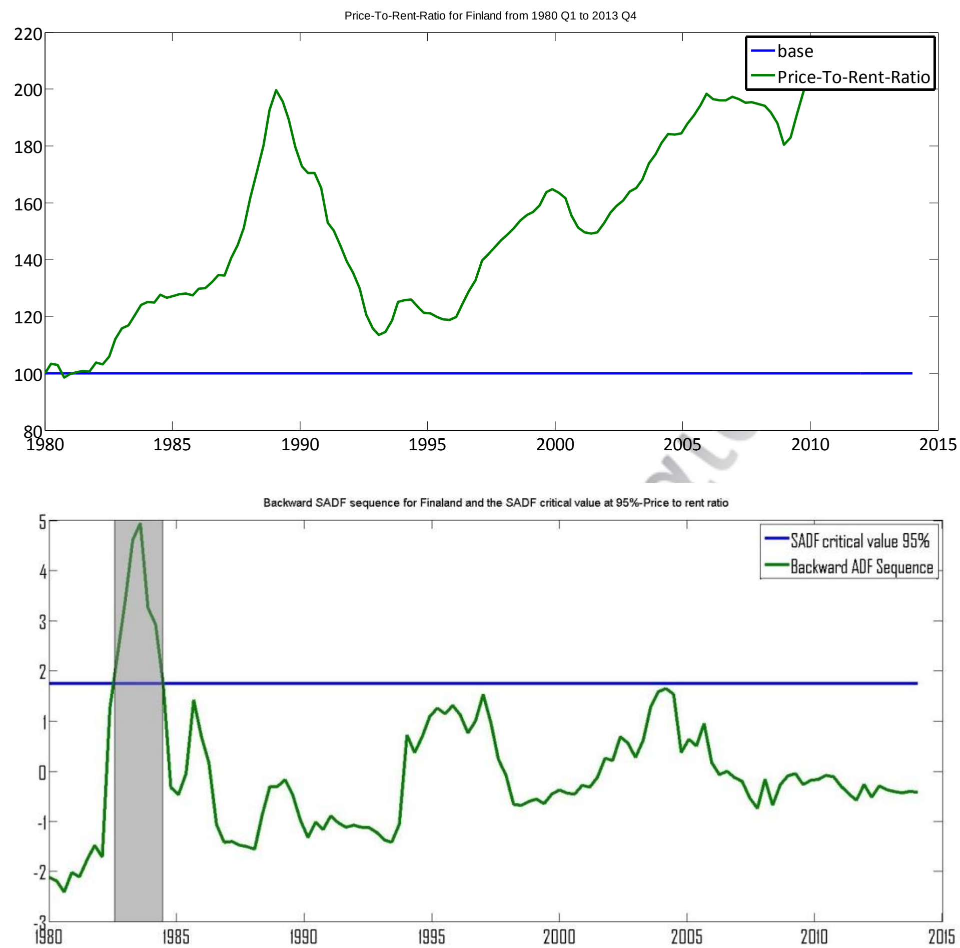
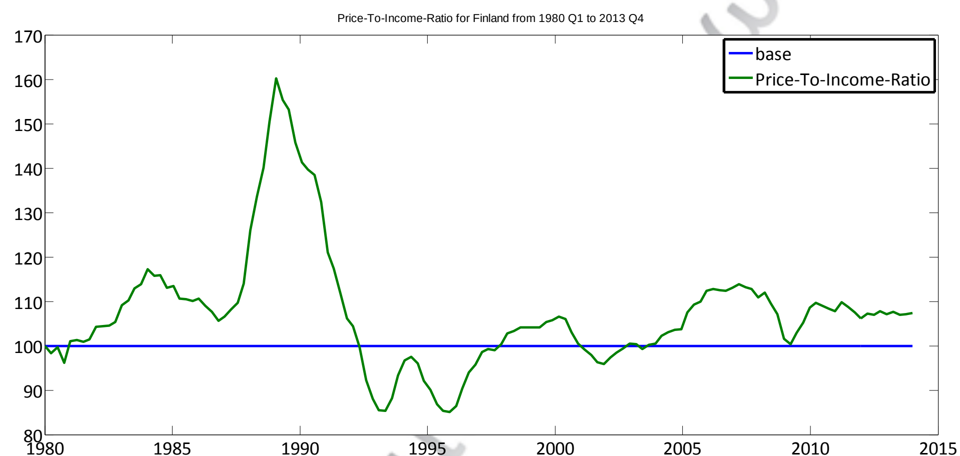


Figure 20 Finland nominal house prices to rent index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The house price to rent ratio seems to have a common movement with the real house prices. The BSADF technique shows, in house price to rent ratio, explosive behavior from

1982Q2 to 1984 which coincides with the first dataset but has a coherency. **Taipalus** (2006) detects more signs of explosive behavior apart from the period this analysis found examining the logarithm of rent to price ratio but with a small intensity. Particularly she identified explosive behavior from late 1983 until the early 1984 from autumn 1987 until early 1989, from spring 1992 until early 1993 and finally a period that starts somewhere round autumn 2003.



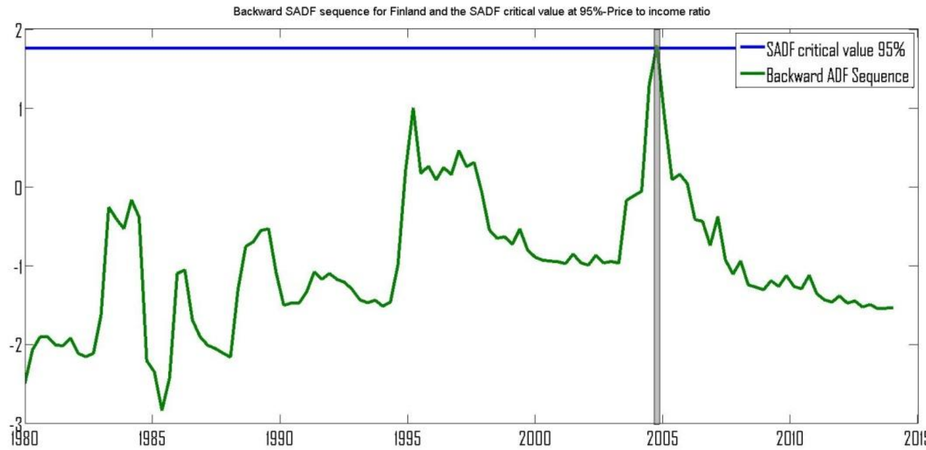
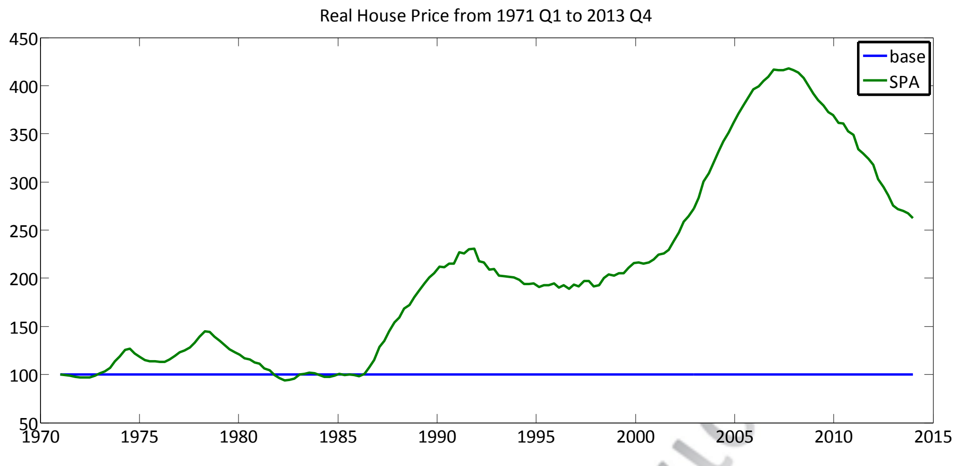


Figure 21 Finland nominal house prices to income index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The house price to income ratio makes a strong rise from 1986 to 1989 and then after 1995 follows experience variances. The BSADF methodology in the nominal house price to income ratio dataset spots almost no explosive behavior apart from a small sign in 2004 summer.

Spain:



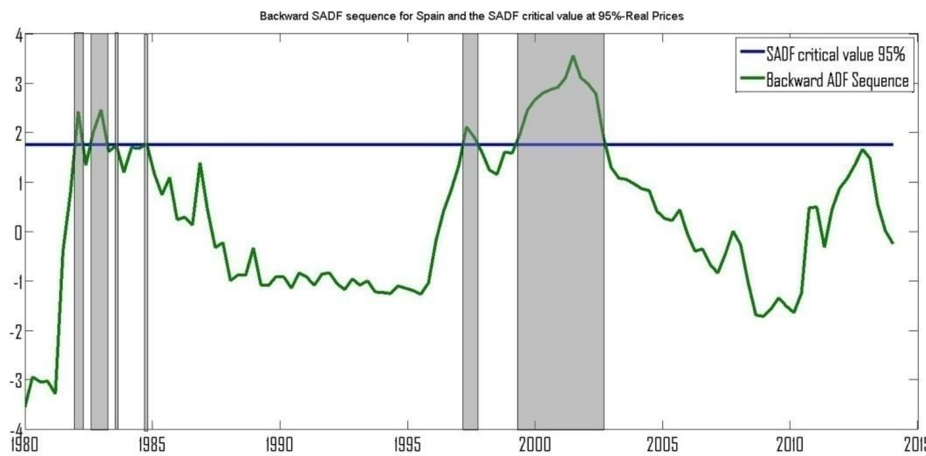


Figure 22 Spain real house prices index with the 1971Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The Spanish data shows an upward trend in period from 1987 to 1991 when the real estate prices experienced an expansionary phase, then flat growth in period from 1992 until 1997, a period from 1998 to 2007 which was featured with strong expansionary growth and finally a downward movement from the peak in 2007 to present. According to BSADF methodology, Figure 22 conclude that there was one major bubble in the real house prices from 1999Q3 to 2003 and three small explosive periods which include the period from 1982Q3, 1983Q2 to 1983Q3 and 1998Q3 to 1998Q4.

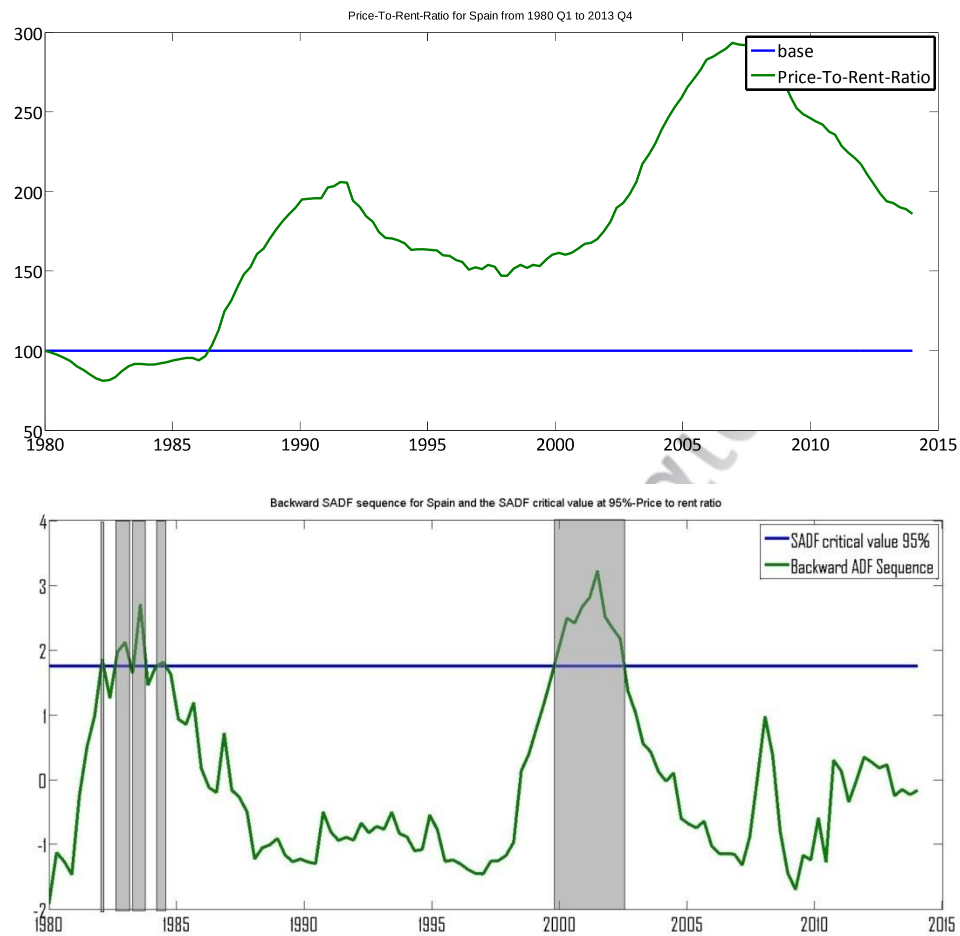


Figure 23 Spain real house prices to rent index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The nominal house prices to rent dataset shows explosive behavior from 1982Q4 to 1984 with some pauses as in the first dataset and a bubble from 1999Q4 to 2003.

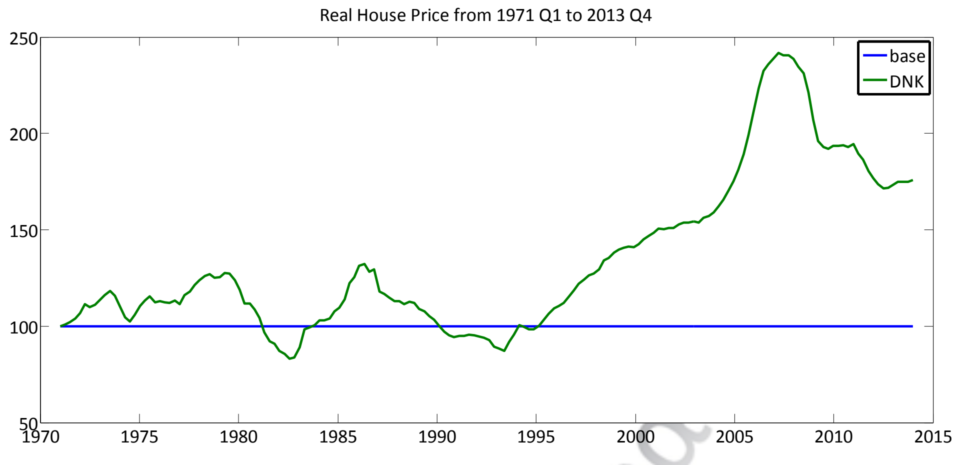
Figure 24 Spain real house prices to rent index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

In addition, the figure of the nominal house price to income ratio dataset spots faintly explosive behavior in 1982Q4 and a bubble in the mid 1999 to mid 2002.

On the other hand, **Taipalus** (2006) detects some period of explosive behavior completely different for this analysis and includes the same second period of price to rent ratio but with longer duration. Particularly identifies strong explosive behavior which starts around the beginning of the 1997 and lasts until autumn 1997 and a little smaller one which starts in the beginning of 2000 and lasts all the way until 2006.

Denmark:



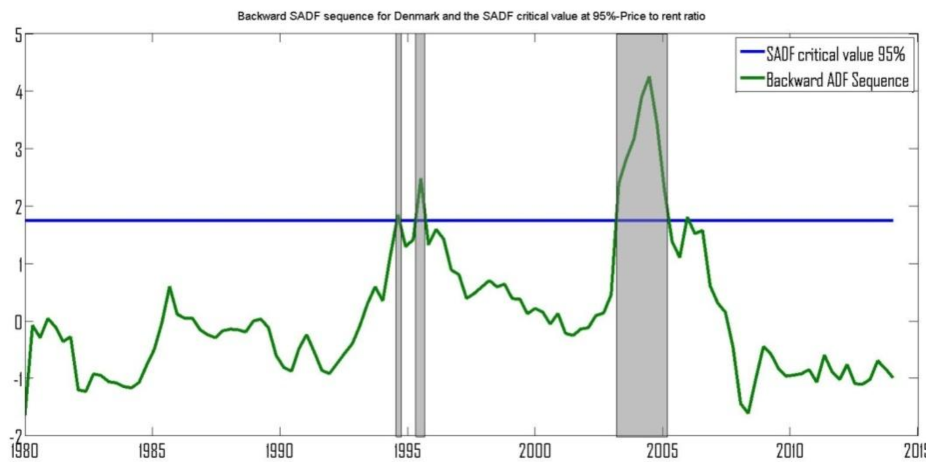
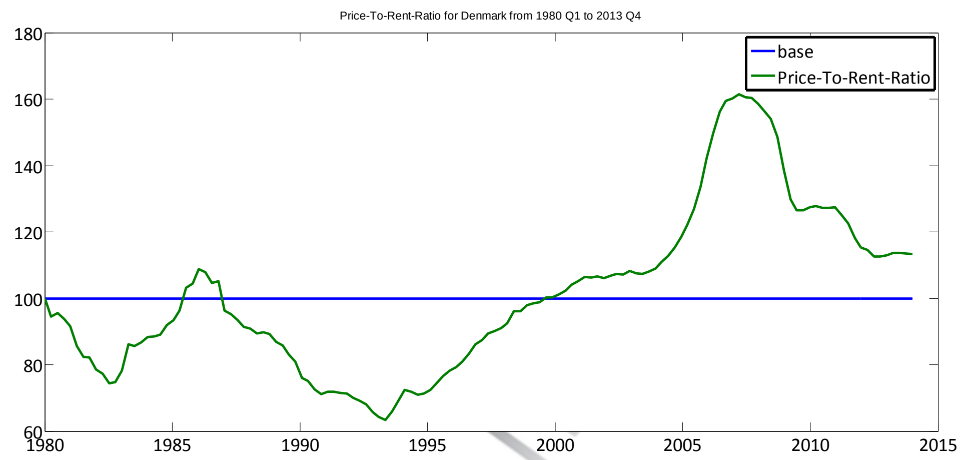


Figure 25 Denmark real house prices index with the 1971Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

Denmark despite some fluctuations shows an upward trend in general form 1971. Particularly in period from 1994 to 2007 the real estate prices experienced an expansionary phase before most countries and then featured a downward movement from the peak in 2007 to present. The graph of real house prices signals in total three explosive behaviors a faint one in 1994Q3 and in 1996Q1 and a more intense from 2003Q2 to 2005Q1.



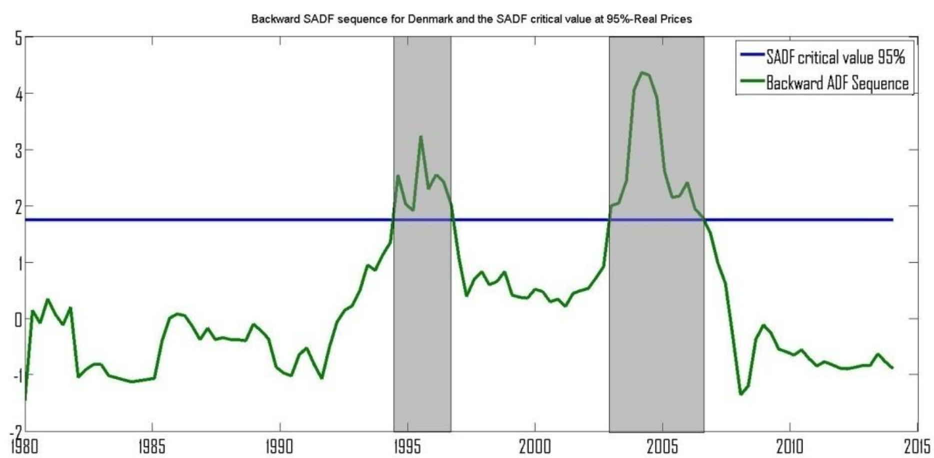
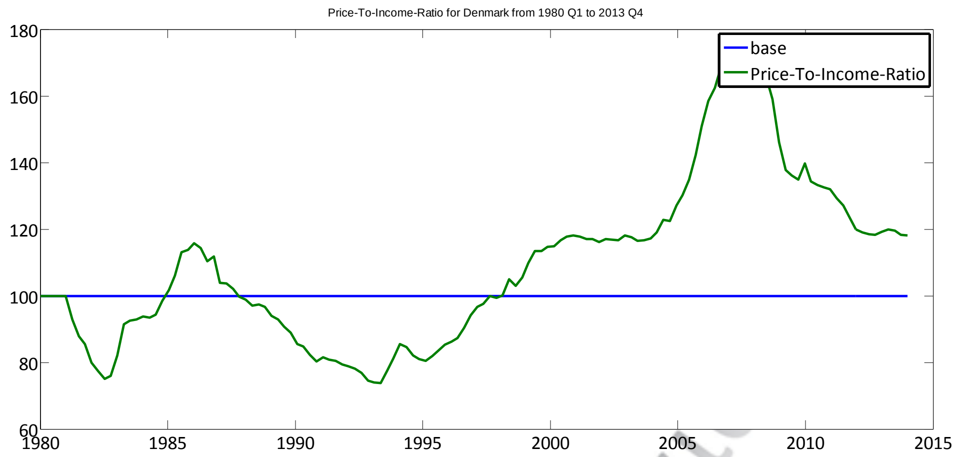


Figure 26 Denmark nominal house prices to rent index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The Figure 26 shows a dramatic rise from 1993 until 2007. The price-to-rent ratio shows explosive behavior from 1994Q2 to 1997Q2 and a bubble from 2003Q3 to 2006Q1 which almost coincides with the first dataset.



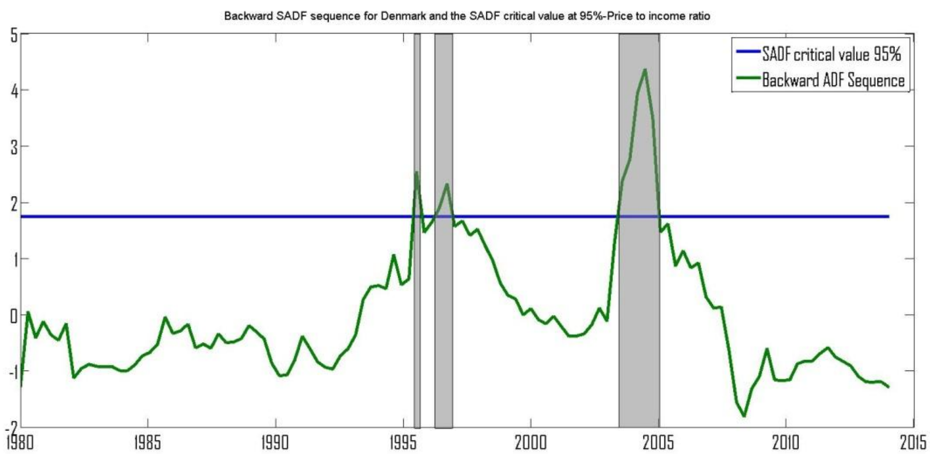


Figure 27 Denmark nominal house prices to income index with the 1980Q1=100 and BSADF sequence from 1980Q1 to 2013Q4 with the corresponding SADF critical value

Source: OECD and authors calculations

The price-to-income ratio seems to follow the same path as the price-to-rent ratio, meaning that income and rent move to the same direction. In addition, the Figure 27 of the nominal house price to income ratio dataset spots explosive behavior in 1995Q2, from 1996Q2 to 1997 and a bubble in the 2003Q3 to 2005.

Denmark and Spain have experienced a large house-price cycle in recent years. Each country experienced a large run-up in house price during 2000–2009 due to easy financial conditions and debt accumulation. These booms came to an end around the time around 2007 when the global financial crisis initiated. It is ascertained that this tool of bubble identification provide early warnings. Specifically for Spain which experienced the largest decline the graph warned that the real house prices of these countries would declined for Spain around 2005 to 2006 meaning one year earlier or more and for Denmark graph seems that the bubble collapsed around 2003 three years earlier from graph.

7. Comparison of the empirical results

Recently, many researchers used also the **Phillips, Shi and Yu** (2011) method in order to test and date the existence of bubble in many financial markets. For example, in stock market (e.g. (Martin T. Bohl 2013)) in gold market (e.g (Yanping Zhao 2015)), in budget deficits (e.g (Yoon 2012), in the health care sector of stock markets (e.g (Mei-Ping Chen 2015), in exchange rates (e.g (Timo Bettendorf 2013) and in the property market (e.g (Bong Han Kim and Hong-Ghi Min (2011)), (Engsted et. al (2015))).

Especially Table 3 summarizes the authors who identified bubbles in US and in EU property market using the **Phillips, Shi and Yu** (2011) methodology and the complementary information of their analysis. The most crucial decision for the application of the **Phillips, Shi and Yu** (2011) methodology is the definition of the size of the window as **Phillips, Shi and Yu** (2014a) said "Obviously, the critical values are sensitive to r_0 and this needs to be taken into account in empirical work". **Phillips, Shi and Yu** (2011) used approximately the 2% of their sample as the minimum size window and specifically they had 1680 observations and used a minimum windows size of 36 observations. If there was an analogy in 136 observation of this analysis it should be used 3 observations but according to the recommendation of **Phillips, Shi and Yu** (2014b) the window was initiated based on the formula 5.1. Another important matter is the insurance of the nation data to be representative as **Taipalus** (2006) said "Solely related to the price-indices we could list the following weaknesses: the underlying data comes from various sources and the statistics are compiled in various ways, the houses are heterogeneous assets and their qualities vary and in addition there are short-term fluctuations (seasonality etc.) that are not necessarily reflecting any long-term changes in house price trends and the differences in statistics between countries are large (non-harmonized national data, differences in coverage)".

Author	Data	Index used	Countries [i]	Window
This analysis	OECD from 1980Q1 -2013Q4	real house prices prices to rent ratio prices to income	US Germany France UK Italy Denmark Finland Spain	22
Pavlidis, et al. (2013)	Dallas Fed International House Price Database from 1975Q1 – 2013Q2	real house prices prices to rent ratio prices to income ratio	US Germany France UK Italy Denmark Finland Spain	36

[i] There are listed only countries which are in common with this analysis.

Chen and Funke (2013)	OECD 1987Q3 – 2012Q4	price-to-rent ratio	US Germany UK Spain	0.4*T[ii]
Engsted, Hviid and Pedersen (2015)	OECD 1970 -2013	price-rent ratio	US Germany France UK Italy Denmark Finland Spain	40

Table 3 Summary of similar researches applied the BSADF methodology for date stamping bubbles in US and some countries in EU

In comparison with the other authors this analysis obviously used the smallest window size. In addition the OECD database was used from all authors apart from **Pavlidis, et al.** (2013) who used only for US, UK and Spain the price-to-rent data from the OECD. In Figure 28 there is a comparison between the finding of this analysis and **Pavlidis, et al.** (2013) regarding the real house price index for the countries Spain, Finland, Denmark, Italy, UK, France, Germany and US.

[ii] For example in case of Germany the total observations (T) were 168 and the window size yielded 67.

For ease purposes in Figure 28, 29 and 30 there are included only bubbles detected after 1990 in order to compare the results during the recent financial crisis.

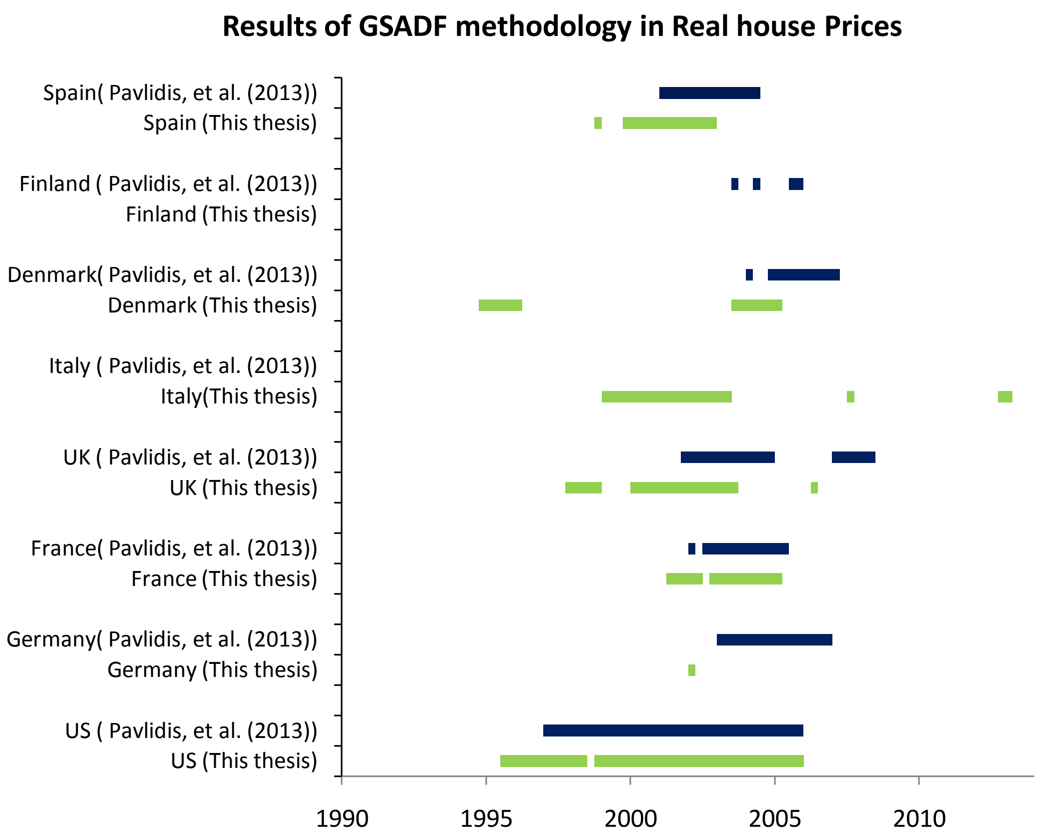


Figure 28 Comparison of this analysis and Pavlidis, et al. (2013) regarding the real house price index

Specifically in Spain, Denmark and UK the date stamping of the bubbles is close to this analysis with **Pavlidis, et al.** (2013) but in this analysis there are provided much earlier warnings of the bubble collapse. Moreover, in US and France the results are approximately the same while in Finland, Italy and Germany the results are very different. Particularly, in Finland and

Germany **Pavlidis, et al.** (2013) has found a bubble property whereas in this analysis there was no evidence of explosive behavior. In addition, in case of Italy there is happening exactly the opposite. This difference could be attributed to the largest window which is responsible for a decrease in critical values so the explosive behavior has more probabilities to be detected and appear with longer duration. Also this difference could also be explained with the different nature of the observations.

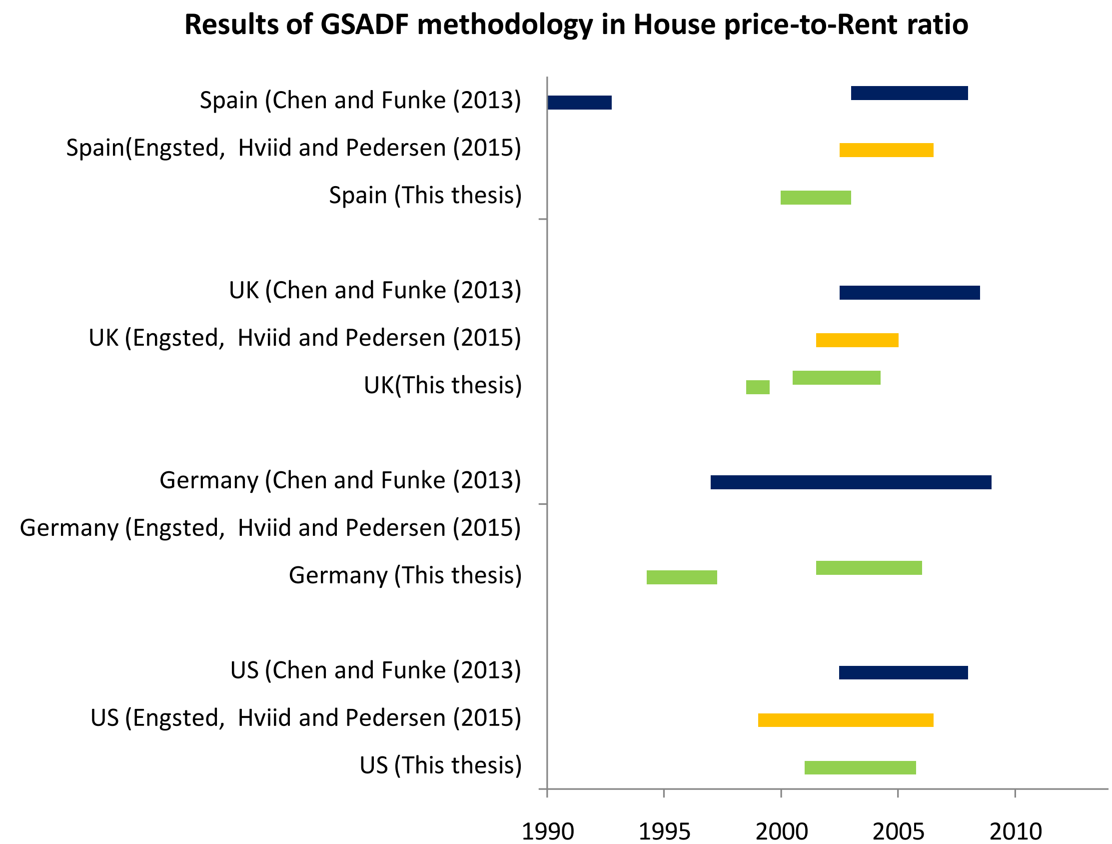


Figure 29 Comparison of this analysis, Engsted, Hviid and Pedersen (2015) and Chen and Funke (2013) regarding the nominal house price-to rent index

In Figure 29 there is a summary of the findings of the examination of the countries which were common and used data of the price-to-rent ratio from 1990 to 2014 in researches' of **this analysis**, **Engsted, Hviid and Pederse (2015)** and **Chen and Funke (2013)**. Although in this case the database used was the same there are important differences which are attributed to the significant difference of the size window which is not much more than the **Pavlidis, et al.**

(2013). A critical overview indicates the much earlier warning signs of this analysis on the contrary with other authors. The **Chen and Funke (2013)** who used the largest smallest window their findings seem to capture longer periods and delay the warning of the collapse. The **Engsted, Hviid and Pederse (2015)** who have almost the double smallest window than this analysis their results are more close to an early warning but there are some disagreements especially in the case of Germany.

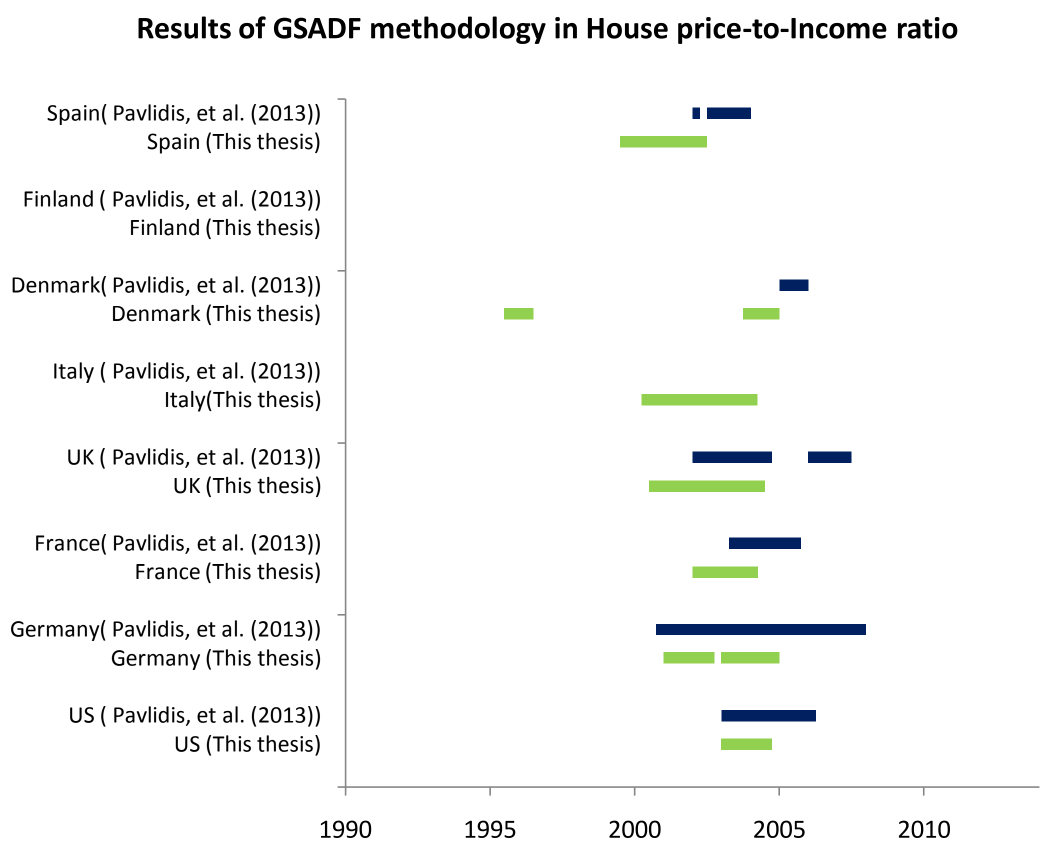


Figure 30 Comparison of this analysis and Pavlidis, et al. (2013) regarding the nominal house price-to-income index

Finally, in the Figure 30 there is a summary of the findings of the examination of the countries which were common between **this analysis** and **Pavlidis, et al.** (2013) and used data of the price-to-income ratio from 1990 to 2014. In this case there was used different database and but the results are not differ a lot. There is an agreement that in Finland data there was not any explosive behavior but in Italy the results are very different. In general this thesis in all cases provides earlier warning indicators at least one year.

8. Conclusion

House prices are important inputs to the complex analysis of macroeconomic and financial stability risks as the bursting of a house bubble firstly can hardly be identified, secondly encloses the risk of contagion, thirdly put the governors into crucial dilemmas fourthly costs a lot and finally has long lasting effects.

In this analysis it was conducted a thorough econometric analysis of bubbles in housing markets in the US and EU area, using quarterly OECD data for 8 countries from 1980 to 2014. It was applied the right-tailed unit root test procedure of **Phillips, Shi and Yu** (2011) which is a generalization of the test procedure of **Phillips, Wu and Yu** (2011) on the individual countries real house prices, price-rent ratio and nominal price-to-income ratio as it was observed the weakness of the **Phillips, Wu and Yu** (2011) methodology to identify explosive episodes.

The most crucial decision about this methodology was the definition of the minimum size window of the recursive rolling sample. It was empirically found that the more the minimum size window is increased the less the critical values will be so the captured explosiveness would be larger. Furthermore the synthesis of the real house prices, price-rent ratios nominal and price-to-income ratios is collected from national institutes with different measurements making the data be less representative and less comparable.

In this analysis results show that in period from mid 1995 to 2006 there was a strong rise in all of the three datasets for all countries which were included to the research apart from Germany and Finland. The BSADF methodology which is used for the date stamping technique of the bubble episodes reveals explosive behavior in almost all countries. In a comparison with other researches the results are in most cases approximately the same but this analysis presents much earlier warnings indicators of the bubble bursting. So, it is ascertained that this state of the art tool can provide early warnings indicators but the reliability of the exact dating is depending firstly on the database that will be used and secondly on the assumptions that will be made.

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10. Appendix

Countries	Source	SourceSeries
United States	Federal Housing Finance Agency (FHFA)	Purchase and all-transactions indices
Germany	Deutsche Bundesbank	Residential property prices in Germany
France	Institut National de la Statistique et des ÉtudesÉconomiques (INSEE)	Indicetrimestriel des prix des logementsanciens – France métropolitaine - Ensemble - Indice brut
Italy	Eurostat Residential Property Price Index for recent indicator and Nomisma for the past	Eurostat : Residential property prices, existing dwellings, whole country Nomisma : 13 Main Metropolitan Areas - Average current prices of used housing
United Kingdom	Department for Communities and Local Government	Mix-adjusted house price index
Denmark	StatBank	Price index for sales of property
Finland	Statistics Finland	Prices of dwellings
Spain	Banco de España	Precio medio del m2 de la vivienda libre (>2 años de antigüedad)

Table 4 Data used for the nominal house prices Source: OECD database