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Exuberance, Bubbles or Froth? Some Historical Results using Long Run House Price Data for Amsterdam, Norway and Paris

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Abstract

It has been argued that house prices may exhibit a period of bubbles and that they may also be either a cause or an effect of, for example, the Global Financial Crisis (GFC). In this paper, we test econometrically whether house price bubbles have historical precedents and also whether contagion from other financial crises are mirrored in these housing markets. We apply the generalized sup ADF (GSADF) test based procedure of Phillips, Shi, and Yu (2015a) to test for the evidence of exuberance or bubbles in historical housing price indices for the Herengracht index of Amsterdam (1649-2010), Norway (1819-2014) and Paris (1650-2012) based upon the right-tailed unit root null hypothesis with or without an intercept. We find, firstly, there is little evidence of exuberance in the real Herengracht index or of bubbles in the house price-rent ratio for Amsterdam. Secondly, our empirical results provide evidence of exuberance in Norwegian house prices where our identified episodes coincide with the major financial crisis in Norwegian history. Thirdly, no significant evidence of exuberance is found in the historical house price series of Paris under most model specifications.

Keywords

bubbles
generalized sup ADF test
exuberance
house prices
herengracht index
Amsterdam
Norway
Paris

JEL Classifications

G01, N2, N90, R30

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1 Introduction

The Global Financial Crisis (GFC) and its aftermath, the Great Recession, has popularized the idea that house prices can exhibit "bubbles" and although some economists continue to deny their existence, several central banks have decided to try and cool their hot domestic housing markets [1]. Perhaps the most famous deniers, Case and Shiller (2003), consider that the early 2000s were not in fact the beginning of a house price bubble in the US, but that income growth driven "fundamentals" could explain why houses were more affordable than they had been in 1995. Similarly, McCarthy and Peach (2004) and Himmelberg et al (2005) conclude that, based on data from 1980-2004, real estate prices could be explained by fundamentals alone. However, these studies typically involve visual 'inspection' of some house price measures without any (valid) econometric tests.

Identifying bubbles, or periods of aberrant, exuberant, price changes empirically, however, is a difficult and often controversial exercise, one made harder by the relatively short sample periods used by some recent authors see, Del Negro and Otrok (2007), Goodman and Thibodeau (2008), Shiller (2008), Wheaton and Nechayev (2008), Mayer (2011). It seems particularly hard when bubbles grow, but deflate slowly rather than bursting with prices converging, perhaps over decades and where identifying any or the most relevant fundamental, is problematic see, Ambrose et al (2013).

In terms of econometric testing, however, Peter Phillips and co-authors (Phillips and Yu (2011), Phillips, Wu, and Yu (2011) [2], Phillips, Shi, and Yu (2014), Phillips, Shi, and Yu (2015a, PSY), Phillips, Shi, and Yu (2015b)) have utilized right-tailed only unit root tests to "date-stamp" bubbles, even bubble episodes that might occur multiple times in a long time series. Their empirical examples include analysis of 150 years data for the S&P 500, the NASDAQ during the 1990s, and recently an investigation of Auckland, New Zealand; using quarterly house prices from 1993-2014, see Greenaway-McGrevy and Phillips (2016). Other authors have utilized the flexibility of the PSY approach see for example, (e.g., Chen et al (2015), Jiang et al (2015), Zhao et al (2015)). However, as discussed in Hu and Oxley (2016), several of these papers report spurious bubble episodes, when the reality is one only of collapse.

A crucial starting point for discussion and identification of bubbles relates to how they are defined. We follow the standard approach that defines price movements in relation to some 'fundamentals'. In terms of house prices this might be a price-to-rental cost ratio; a price-to-average income ratio etc. With a fundamental series and a house price series positive; negative; no bubble periods can be potentially identified. Without a fundamental series to compare the time path of (house)

[1] In 2014 the Reserve Bank of New Zealand introduced minimum deposit requirements to try and deflate what they saw as a bubbly Auckland housing market. The paper by Greenaway-McGrevy and Phillips (2016) supports this conclusion and that a similar, but more pervasive bubble occurred in New Zealand house prices in 2003.

[2] Harvey, Leybourne, Sollis, and Taylor (2015) investigate the non-stationary volatility effect on the reliability of the Phillips, Wu, and Yu (2011) test and propose wild bootstrap implementation of this test to overcome the spurious indications of explosive bubbles.

prices to, econometric tests including those of PSY can only identify periods of exuberant growth (or decline) in the house price series which may be a necessary property of a bubble but not sufficient (without a model of fundamentals). If the measured series is neither a bubble nor period of exuberance (or alternatively collapse in prices), then we refer to changes over time in the market as 'frothy'.

In this paper, we will utilize the new econometric approaches of PSY and variants thereof, to consider the extent to which house price bubbles or periods of exuberant behavior are simply recent behavior or whether history provides similar time series episodes. In particular, we will consider the time series properties and results of PSY-type tests applied to three long-term series; 355 years of the Herengracht, Amsterdam house price series (see, Eichholtz (1997), Ambrose et al (2013), and Eichholtz et al (2015)); house prices in four of the five main Norwegian cities (Oslo, Bergen, Trondheim and Kristiansand) between 1819-1989 (see Eitrheim and Erlandsen (2004)) and Friggit (2001)'s house price series for Paris, 1650-2012 [3]. These three series have the benefit of being (necessarily) historically long and have also been investigated by other authors (see Shiller (2007) and Loungani (2010)), although none using the time series approaches of PSY [4]. Furthermore, there is a clearly recorded historiography and sets of complementary data, which allow possible bubble/exuberant periods, identified by the time series approaches of PSY, to be scrutinized against contemporary events. We utilize this extant historiography to consider the extent to which events identified by the tests could likely have been driven by events of the time.

The remainder of the paper is organized as follows. Section 2 provides an overview of the data [5] and Section 3 gives a brief description of the GSADF and SADF tests of Phillips, Shi, and Yu (2015a) and Phillips, Wu, and Yu (2011). Particular attention is drawn on the 'with or without intercept' test results which is an important issue in its own right. Section 4 provides results for the three house price series and Section 5 concludes.

2 Data

This section describes three historical housing price indices and the time series plot of these indices is shown in Figure 1. We also construct the house price-rent ratio for Amsterdam in Figure 2.

[3] Recently, Blöndal (2015) investigated the possibility of speculative bubbles in the Stockholm housing market 1875-1935, using a newly created series and tests based upon the existence of common trends in a cointegrating regression framework. He concluded that there was no indication of a speculative bubble in the Stockholm housing market. His sample period is relatively short for our purposes, although it might be interesting to run the PSY approach over these data.

[4] Shiller (2006) suggested that there is no long-term uptrend in three real home prices including the Amsterdam, Norway and the US series.

[5] An excellent description of the data including sampling, coverage and sources can be found in Friggit (2008) and the references therein.

2.1 The Herengracht index (1649-2010) and the biennial Herengracht index (1628-1973)

The Herengracht index was sourced from Piet Eichholtz's website which reports both a nominal index (1649=100) for the period 1649-2010. We also obtain the biennial Herengracht index between 1628 and 1973 from Eichholtz (1997). These data represent an update on the biennial series (1628-1973) first presented and discussed extensively in Eichholtz (1997), updated to 2005 in Ambrose et al (2013) and Eichholtz et al (2015). Figure 1a and Figure 1b (below) provide the time series plots of the Herengracht index and biennial Herengracht index (both on a log scale)[6].

The series cover, on a biennial basis, 487 [7] properties located along the banks of the Herengracht, a canal in Amsterdam. In the Golden Age of this city, the 17th century, this area was the most fashionable place in the Netherlands. It was urbanized very early: by 1680 nearly all the lots along the canal had been developed. The index was created using a repeat sales method by comparing the successive sale price of buildings. 4252 transaction prices for the 1628-1973 period were collected, which means on average around 12.3 prices per year.

The only quality effect taken into account is the use of the buildings. Beginning in the 19th century, but especially in the 1920s and 1930s, many buildings along the Herengracht were changed into offices, which increased their value. Buildings used as offices have been excluded from the calculation. All other quality effects have not been filtered out, thus if for example central heating was installed between two successive transactions, the resulting effect of this amenity on the price is ignored.

2.1.1 House price-rent ratio for the Herengracht (1628-1850)

Ambrose et al (2013) have created an Amsterdam house price-rent ratio between 1650 and 2005, however, this ratio is not publicly available. Thus we construct the house price-rent ratio between 1628 and 1850 to assess the evidence of housing bubbles using data obtained from Eichholtz (1997) and Eichholtz et al (2012). The nominal biennial Herengracht index 1628 and 1850 is obtained from Eichholtz (1997) and is shown in Figure 2a. We utilise the temporal disaggregation method of Dagum and Cholette (2006) to disaggregate the nominal biennial Herengracht index series (1628-1850) to the annual Herengracht index series (1628-1850) and is displayed as Figure 2b. The rent index obtained from Eichholtz et al (2012) is shown in Figure 2c and we select the sub-period 1628 and 1850. A house price-rent ratio is therefore calculated and presented as Figure 2d.

[6] The real Herengracht index is deflated by the CPI from Van Zanden (2005).

[7] 487 presently, as opposed to 614 originally, this decrease stemming from the combination of lots to allow for the construction of bigger buildings.

2.2 House prices in Norway (1819-2014)

The house price indices for Norway are from Eitrheim and Erlandsen (2004) and can be downloaded from Norges Bank [8]. Figure 1c provides both aggregate nominal and real house price index [9] in Norway (1912=100, both in log scale) between 1819 and 2013 with 194 observations. The construction of this annual house price index, 1819-2014, is described in some detail in (Eitrheim and Erlandsen, 2004, p.357) and is calculated by a hedonic-weighted repeat sales (hybrid) approach based upon transaction prices in the property registers to 1985 and per m^2 from 1986 (based upon data from the Norwegian Association of Real Estate Agents). In particular, the indices are constructed on the basis of nominal transaction prices of real property, compiled from the archives of real property registers of the four cities (Eitrheim and Erlandsen, 2005, p.8). Only buildings located in the centre of the respective town are used and the types of buildings vary from rental apartment blocks to single family homes.

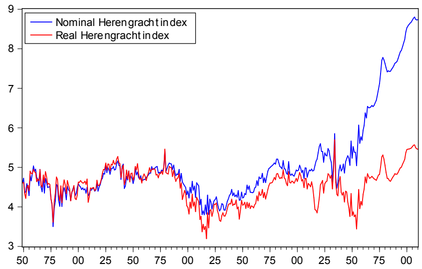
In addition to the national level series, data are available separately for four of the five main Norwegian cities, Oslo (1841-2014), Bergen (1819-2014), Trondheim (1897-2014) and Kristiansand (1867-2014). Due to data availability, the samples for these four cities cover different years in the 1800s. A weighted repeat sales method is used to construct the city house price indices, which are described in (Eitrheim and Erlandsen, 2005, p.15).

2.3 House prices in Paris (1200-2012)

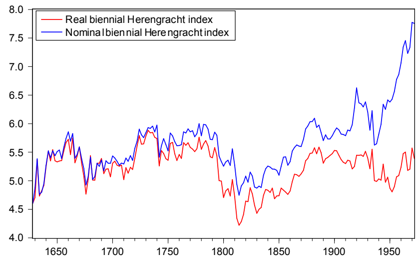
The house price index for Paris was constructed by Friggit (2008) using several different sources including d'Avenel (1894), Duon (1946), Friggit (2001) and covers the period 1200 to 2012 (2000=100). The time series plot of the real house price index is given as Figure 1d. The real series is deflated by a consumer price index from several sources. Friggit (2008) presents an extensive discussion of four related price indices for Paris and from this constructs his own Friggit (2001):

(i) d'Avenel (1894) who provides a series of average home prices (averaged over 25 years) for Paris, 1200-1800. No adjustments are made for house quality changes;
(ii) Duon (1943a,b) creates two variants of a repeat sales home price index for Paris. For the period 1790-1850 the calculations are based upon 10 year periods 1790-1850 and for 1840-1944 a yearly home price index; Notaries databases. This index applies to apartments sold by the unit and is based upon a record of transactions (both current and previous transactions for the unit are recorded). Quality changes are not recorded or recognised. Some 34,594 transaction pairs were used to construct the index for the period 1944-1999;
(iii) Notaires-INSEE index. For the years after 1999 an annualised value for quarterly Notaries-INSEE indices can be constructed based upon hedonic indices (see here Gouriéroux and Laferrère (2009));

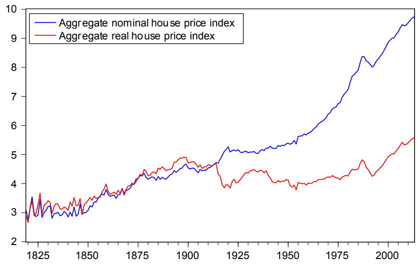
[8] Both house price index and CPI can be accessed from http://www.norges-bank.no/en/Statistics/Historical-monetary-statistics/.
[9] The real house price index is deflated by the CPI from Grytten (2004).



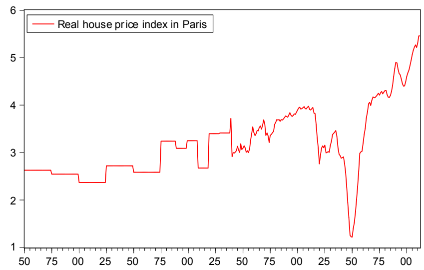
(a) Herengracht index in Amsterdam (1649-2010)



(b) Biennial Herengracht index (1628-1973)



(c) House price index in Norway (1819-2014)



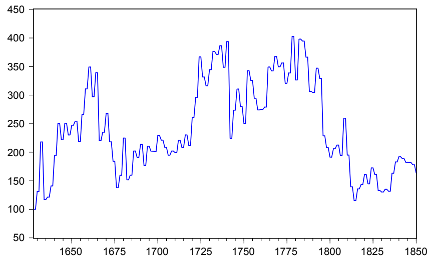
(d) House price index in Paris (1650-2012)

Fig. 1: (a) the nominal and real Herengracht index (1649=100, both in log scale) between 1649 and 2010; (b) the nominal and real biennial Herengracht index (1628=100, both in log scale) between 1628 and 1973; (c)the aggregate nominal and real house price index in Norway (1912=100, both in log scale) between 1819 and 2014; (d) the real house price index in Paris is between 1650 and 2012 (2000=100, in log scale).

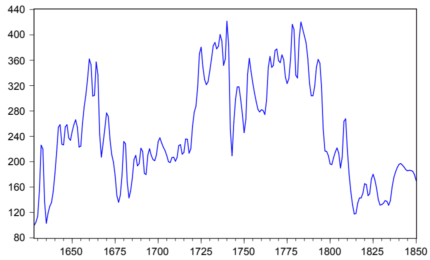
(iv) Based upon the properties of these indices, Friggit (2001, 2008) constructs a Paris house price 1840-2006 (updated to 2012) which has been adjusted for obsolescence prior to 1914 (see Friggit (2008) for details).

3 Method

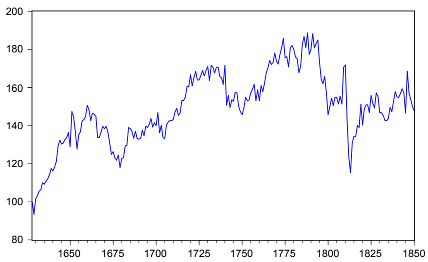
Phillips, Wu, and Yu (2011) develop a sup ADF (SADF) procedure that can test for evidence of price exuberance and date stamp its origination and collapse. Such a test procedure makes use of a right-tailed unit root and a sup test in a recursive way. One highlight of this new approach is the ability to capture explosive behavior and even the periodically collapsing bubbles of Evans (1991). The SADF test is recursively applied to the sample data and is implemented as follows. For each time series x_t, we apply the Augmented Dickey-Fuller (ADF) test for a unit root against the alternative of an explosive root (right-tailed). The following autoregressive



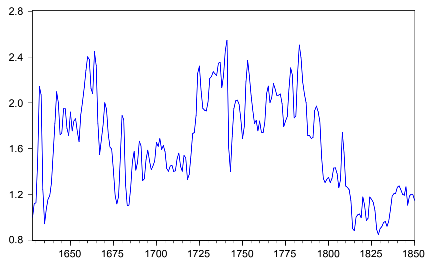
(a) Nominal biennial Herengracht index (1628-1850)



(b) Nominal Herengracht index (1628-1850)



(c) Nominal rent index (1628-1850)



(d) House price-rent ratio (1628-1850)

Fig. 2: (a) The nominal biennial Herengracht index (1628-1973, 1628=100) is obtained from Eichholtz (1997); (b) The nominal annual Herengracht index (1628-1973, 1628=100) is obtained using the temporal disaggregation method of Dagum and Cholette (2006); (c) The nominal rent index (1628-1850, 1628=100) is obtained from Eichholtz et al (2012); (d) A house price-rent ratio (1628-1850) is therefore calculated.

specification for x_t is estimated by least squares:

$$x_t = \mu_x + \delta x_{t-1} + \sum_{j=1}^{J} \phi_j \Delta x_{t-j} + \varepsilon_{x,t}, \qquad \varepsilon_{x,t} \sim \text{NID}(0, \sigma_x^2), \tag{1}$$

for some given value of the lag parameter J, where NID denotes independent and normally distributed. The null hypothesis of this test is $H_0 : \delta = 1$ and the alternative hypothesis is $H_1 : \delta > 1$. Equation (1) is estimated repeatedly using subsets of the sample data incremented by one additional observation at each pass in the forward recursive regression. Thus the SADF test is constructed by repeatedly estimating the ADF test. Let r_w be the window size of the regression. The window size r_w expands from r_0 to 1, where r_0 is the smallest sample window width fraction and 1 is the largest window fraction (the full sample). The starting point r_1 is fixed at 0, and the end point of each sample (r_2) equals r_w and changes from r_0 to 1. The ADF statistic for a sample that runs from 0 to r_2 is therefore denoted by $ADF_0^{r_2}$. The SADF statistic is defined as the sup value of the ADF statistic sequence:

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

Unlike the SADF test, the GSADF test is extended by using a more flexible window size. The end point r_2 varies from r_0 (the minimum window size) to 1. The start point r_1 is also allowed to vary from 0 to $r_2 - r_0$. The GSADF statistic is the largest ADF statistic over range of r_1 and r_2. The key difference between the SADF and GSADF is the window size of starting point r_1. The GSADF statistic is therefore defined as:

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

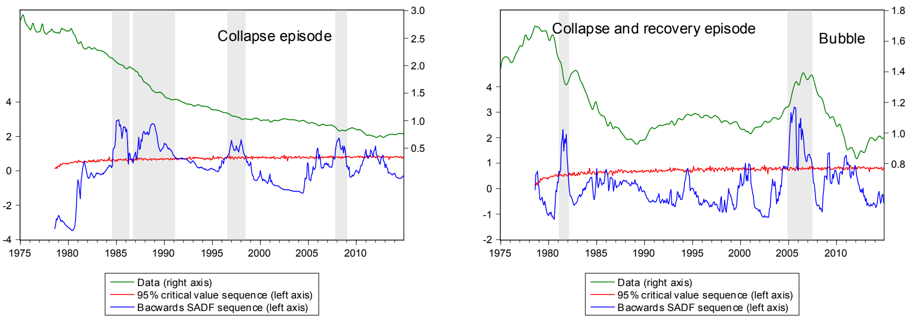
According to Phillips et al (2015a), the minimum window size r_0 needs to be large enough to allow initial estimation but it should not too large to miss the chance of detecting an early bubble period. We therefore follow Phillips et al (2015a) and let $r_0 = 0.01 + 1.8/\sqrt{T}$, where T is number of observation. A small fixed lag order approach is used in this study as suggested by Phillips, Shi, and Yu (2015a). Hence, the lag order is chosen at 0 and 3 for the following analysis. The finite critical values are obtained from Monte Carlo simulation with 2000 replications.

Both the SADF and the GSADF tests assess evidence for unit root behavior against mildly explosive alternatives for a time series x_t. If we reject the null hypothesis of a unit root, we are in favor of explosive behavior for the x_t. If the time series x_t involves its economic fundamentals[10], we may conclude that a finding of explosive behavior is the presence of *a bubble*[11]. On the other hand, if the time series x_t doesn't involve its economic fundamentals, we may conclude that a finding of explosive behavior is the presence of *exuberance*.

Many studies have followed PSY's suggestion to include an intercept in the right-tailed unit root test. As a result, many empirical papers have reported rejections of the null suggesting periods of rapid increase in for example prices or exchange rates associated with a growing bubble, when in fact the data identifies a 'collapse' or a 'collapse and recovery' phase and not a bubble. Visual inspection can usually resolve these cases, although it also seems that false (positive) bubbles also seem to be reported when an intercept is included. An example of 'collapse episode' and 'collapse and recovery episode' can be seen in Figure 3 below. The backward SADF statistic (blue line) and its 95% critical value (red line) for Figure 3a suggests a number of 'bubbles' as the test statistic exceeds the relevant critical value. However, the plot of the actual data (green line) shows that the data is continuously declining (a collapse period and not a series of bubbles). Figure 3b presents data and test results consistent that relate to a 'collapse and recovery' episode and a genuine 'bubble' or the presence of 'exuberance'. The plot of the actual data makes the classification of these different episodes clear and

[10] The time series x_t is commonly expressed as a ratio (e.g., house prices/ rents or income, stock prices/ dividends)

[11] A bubble is defined as a situation when a growth of the price is not supported by changes in its fundamentals (e.g., Stiglitz (1990)).



(a) Collapse episode

(b) Collapse and recovery episode and bubble/exuberance

Fig. 3: Examples of collapse episodes, collapse and recovery episodes and bubbles/exuberance.

highlight why the actual data and the test statistic (and relevant critical values) need to be presented on the same graph. Previous empirical studies have either ignored such cases or if they have mentioned them they have provided no explanation of the possible reason for the false test positives. Some empirical papers even obfuscate this issue by plotting only the backward SADF statistic with the 95% critical value sequences and provide no plot of the actual data series in the date-stamping strategy graph. In this paper, we use two different model specifications for the null hypothesis in the right-tailed unit root tests (a model without an intercept [12] as in Equation (2) and a model with an intercept in Equation (3)) to explore the evidence of bubbles and compare the results obtained from both formulations. We will demonstrate and compare the bubble detection results using the aforementioned model specifications. The model specification is explained as follows. In PWY of Phillips, Wu, and Yu (2011), the null hypothesis is:

$$H_{01} : y_t = y_{t+1} + \varepsilon_t, \qquad \varepsilon_{x,t} \sim \mathrm{NID}(0, \sigma^2). \tag{2}$$

The second specification for the null is obtained from Diba and Grossman (1988):

$$H_{02} : y_t = \alpha + y_{t+1} + \varepsilon_t, \qquad \text{where } \alpha \text{ is the constant.} \tag{3}$$

4 Results

In this section, we investigate the evidence of exuberant behaviour or bubbles (where relevant) in historical housing price indices for the Herengracht index of Amsterdam, Norway and Paris based upon the right-tailed unit root null hypothesis, where importantly we report results with or without an intercept term in the PSY test statistic calculation.

[12] When an intercept is excluded, the procedure detects only potential ‘bubbles’.

4.1 Herengracht index in Amsterdam

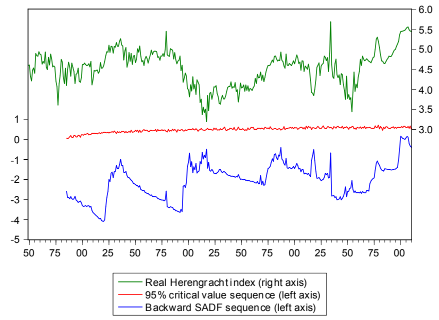
The date-stamping outcomes for the real Herengracht index in Amsterdam are provided as Figure 4. We firstly present results based on the lag order of 0 for the Herengracht index under the assumption 'with an intercept' and 'without an intercept' in Figure 4a and Figure 4b, respectively. According to these two figures, there is no evidence of exuberant behaviour in the real Herengracht index between 1649 and 2010.

Consider now results based on the lag order of 3 (in the PSY test) for the real Herengracht index under the both assumptions in Figure 4c and Figure 4d, respectively. Using the model specification 'with an intercept', the null hypothesis of no explosive behavior is not rejected at the 10% significance level. The test statistics is 1.5235 which is smaller than the 10% right-tail critical value of 2.5104. Figure 4c compares the backward SADF statistic sequence with the 95% SADF critical value from Monte Carlo simulation. As can be seen from Figure 4c, two episodes are identified: 1799-1803 (a 'collapse and recovery' episode) and 1812-1817 (a 'collapse' episode). Under the null hypothesis 'without an intercept term', the null hypothesis of no explosive behavior is not rejected at the 10% significance level as the test statistic is lower than the 10% critical value (e.g., 2.5868<3.4471) even if the presence of exuberance originated and collapsed during 1880-1889 is identified in Figure 4d. Under different formulations and the lag order selection in the null hypothesis, the above results suggest no evidence of exuberant behaviour in the real Herengracht index and thus Herengracht index on its own is not explosive.

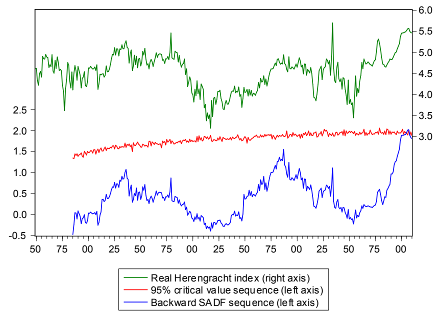
4.1.1 Biennial Herengracht index (1628-1973)

Empirical results for the real biennial Herengracht index can be found in Figure 5. Date-stamping outcomes based on the lag order of 0 for the real biennial Herengracht index under the assumption 'with an intercept' and 'without an intercept' are presented in Figure 5a and Figure 5b, respectively. Under the assumption 'with an intercept', the null hypothesis of no explosive behavior is not rejected at the 10% significance level as the test statistics (0.3134) is much smaller than the 10% right-tail critical value. As shown in Figure 5a, we observe no evidence of exuberance. Similarly, under the assumption 'without an intercept', the null hypothesis of no explosive behavior is not rejected at the 10% significance level (e.g., 2.4524<3.0932) although the presence of exuberance during 1876-1888 is detected in Figure 5b.

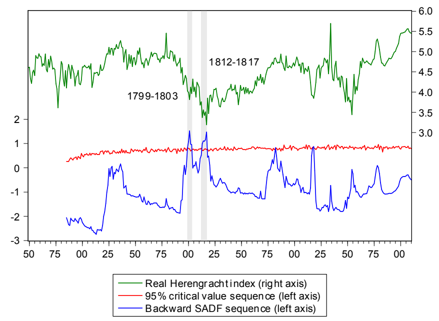
Date-stamping outcomes based on the lag order of 3 for the real biennial Herengracht index under the assumption 'with an intercept' and 'without an intercept' are presented in Figure 5c and Figure 5d, respectively. Under the assumption 'with an intercept', the test statistics is 1.5704. As indicated in Figure 5c, we observe three episodes in the real Herengracht index: 1800-1802 (a 'collapse' episode), 1812-1818 (a 'collapse and recovery' episode) and 1878-1884 ('exuberance'). On the other hand, under the assumption 'without an intercept', the test statistics is smaller than the 10% right-tail critical value (e.g., 2.7283<3.466). We detect the presence of exuberance between 1874 and 1888 in Figure 5d.



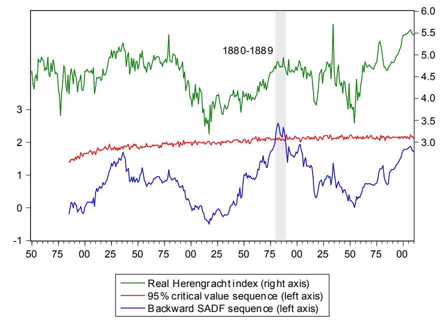
(a) real Herengracht index (1649-2010) with an intercept at the lag order of 0



(b) real Herengracht index (1649-2010) without an intercept at the lag order of 0



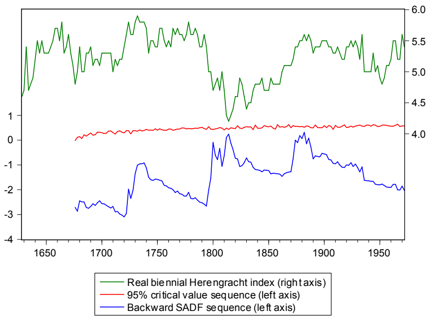
(c) real Herengracht index (1649-2010) with an intercept at the lag order of 3



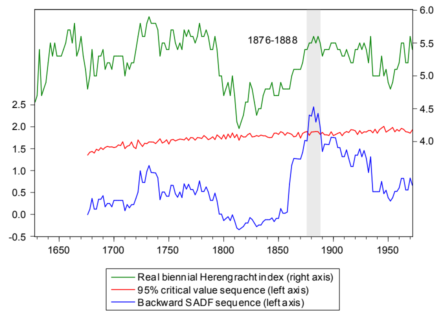
(d) real Herengracht index (1649-2010) without an intercept at the lag order of 3

Fig. 4: Date-stamping strategy for the real Herengracht index (1649=100, log scale) between 1649 and 2010 using the GSADF test under the assumption with/without an intercept at the lag order of 0 or 3.

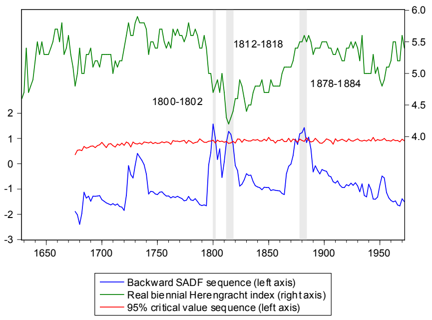
Although the null hypothesis of no explosive behavior is not rejected in two Amsterdam indices under various specifications of the null hypothesis, we find some episodes between mid-1870s or late 1870s and 1880s or early 1890s, which are clearly demonstrated in the real Herengracht index of Figure 4d (1880-1889) and the biennial Herengracht index of Figure 5b (1878-1890), Figure 5c (1878-1884), and Figure 5d (1874-1888). Comparing Figure 4c and Figure 5c shows that, under the assumption 'with an intercept' and a lag order of 3, we obtain similar date-stamping outcomes for these two indices in the early nineteenth century (e.g., the Herengracht index: 1799-1803, 1812-1817; and biennial Herengracht index: 1800-1802, 1812-1818).



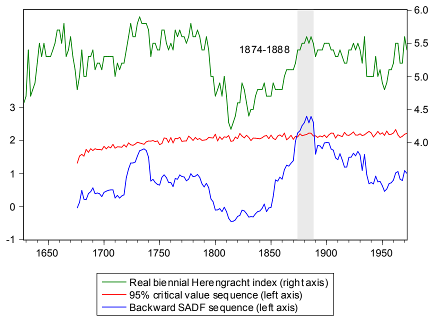
(a) real biennial Herengracht index (1628-1973) with an intercept at the lag order of 0



(b) real biennial Herengracht index (1628-1973) without an intercept at the lag order of 0



(c) real biennial Herengracht index (1628-1973) with an intercept at the lag order of 3



(d) real biennial Herengracht index (1628-1973) without an intercept at the lag order of 3

Fig. 5: Date-stamping strategy for the real biennial Herengracht index (1628=100, log scale) between 1628 and 1973 using the GSADF test under the assumption with/without an intercept at the lag order of 0 or 3.

4.1.2 House price-rent ratio in Herengracht (1628-1850)

We also test for evidence of housing bubbles in the Amsterdam house price-rent ratio during the period 1628-1850. Date-stamping outcomes obtained from the GSADF test for the Amsterdam house price-rent ratio (1628-1850) under the assumption 'with or without an intercept' at the lag order of 0 and 3 are presented in Figure 6. We observe a short-lived episode (1724-1725) in the price-rent ratio under the assumption 'with an intercept' at the lag order of 0 in Figure 6a. However, when the plot of the actual series (green line) is taken into account in Figure 6a, it is hard to believe that this short-lived episode is a 'genuine' bubble. Overall, as can be seen from Figure 6 under different assumptions in the unit root null hypothesis, we find no evidence of bubbles in the house price-rent ratio for Amsterdam. The historical house price-rent ratio (1628-1850) in Amsterdam is not explosive.

4.1.3 Discussion

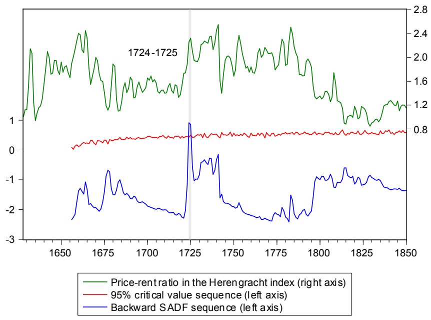
Eichholtz (1997) argues that the Tulipmania episode had a very limited effect on the Amsterdam housing market as in 1632, the real biennial Herengracht house price index was 212.7. However, the real biennial Herengracht house price index fell to 113.5, which was almost half its value in 1632. The Tulipmania bubble burst in 1637. However, at the same time, the real biennial Herengracht house price index started to recover reaching 136.8 in 1639. Eichholtz (1997) argues that a pest epidemic likely had more impact on the Amsterdam housing market as Amsterdam lost 14% of its population due to the pest in 1636 only.

There were four other famous bubbles in the eighteenth century: the Mississippi Bubble (1719-1720), the South Sea Bubble (1720), the Amsterdam Banking Crisis of 1763 and the Credit Crisis of 1772 (see Sheridan (1960), Garber (2001), Schnabel and Shin (2004), Kindleberger and Aliber (2011), Brunnermeier and Schnabel (2014)). Among these financial bubbles, the Mississippi Bubble and the closely related South Sea Bubble are the most well-known examples in the literature. The Amsterdam Banking Crisis of 1763 originated in Amsterdam and spread to Hamburg, Berlin, London. The Crisis of 1772 was more widespread as it spread to the Continent of Europe including Amsterdam. Most importantly, empirical results from Figure 4 and Figure 5 suggest these four crises do not have a great impact on real house prices in Amsterdam as we could not find significant evidence of exuberance in the two Herengracht series. Moreover, we find no evidence of housing bubbles for the Amsterdam house price-rent ratio (1628-1850) during the occurrences of these historical bubbles.

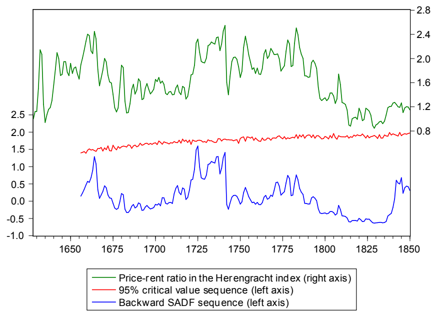
4.2 House price index in Norway (1819-2014)

Here, we investigate evidence of explosive behavior in the real Norwegian house price index between 1819 and 2014. Empirical results for the real Norwegian house price index are presented in Figure 7 under various specifications in the null hypothesis (e.g., with/without the intercept and the lag order choice). As previously, we firstly present results based on the lag order of 0 for two specifications. Considering an intercept in the null hypothesis, the test statistics is larger than the 5% right-tail critical value (i.e., 2.149>2.142), providing evidence of exuberance in the real Norwegian house price index. The corresponding date-stamping outcomes are shown in Figure 7a and two explosive episodes are identified (e.g., 1985-1988 and 2004-2014). Without including the intercept in the null, the test statistics is larger than the 10% right-tail critical value (i.e., 3.172>3.071), indicating some evidence of house price exuberance. As suggested in Figure 7b, we identify additional evidence of exuberance in the late nineteenth century (1874-1883 and 1885-1904) along with more recent evidence of exuberance during 1982-1989 and 2000-2014.

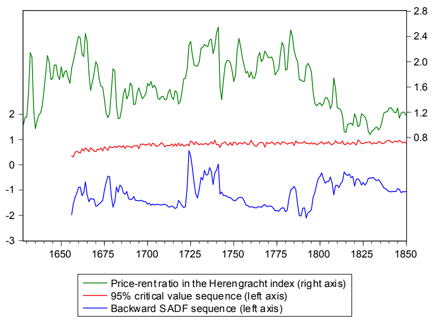
Results under the assumption of with/without an intercept at the lag order of 3 are presented in Figure 7c and Figure 7d, respectively. The null hypothesis of no explosive behavior is not rejected at the 10% significance level, suggesting no significant evidence of exuberance in Figure 7c. Even if the null hypothesis is not



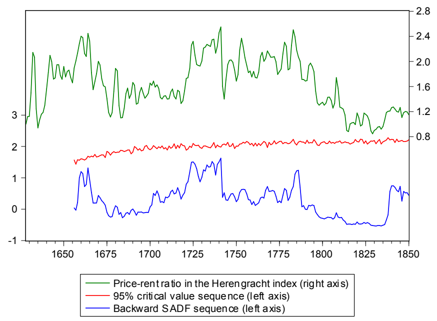
(a) House price-rent ratio (1628-1850) with an intercept at the lag order of 0



(b) House price-rent ratio (1628-1850) without an intercept at the lag order of 0



(c) House price-rent ratio (1628-1850) with an intercept at the lag order of 3



(d) House price-rent ratio (1628-1850) without an intercept at the lag order of 3

Fig. 6: Date-stamping outcomes obtained from the GSADF test for the house price-rent ratio in the Herengracht index (1628-1850) under the assumption with or without an intercept at the lag order of 0 and 3.

rejected, we are still able to spot three episodes from Figure 7c: 1875-1882, 1894-1900, and 1986-1989. On the other hand, without considering the intercept in the null hypothesis, the test statistic is greater than the 10% significance level (e.g., 3.599>3.425). As can be seen from Figure 7d, there are two explosive episodes (i.e., 1870-1917 and 1978-1990).

Overall, under various specifications in the null, our results seem to suggest some evidence of exuberance. Several periods of exuberance have been identified in Figure 7 and a summary of these episodes can be found in Table 1. Our identified episodes generally coincide or overlap with several major financial crises in Norway as discussed in Grytten and Hunnes (2010), who conclude in favour of nine most devastating financial crises in almost 200 years of Norwegian history (e.g., 1814-1839, 1847-1850, 1856-1861, 1875-1888, 1899-1905, 1920-1928, 1930-1933, 1987-1993, and 2007-2010). Therefore, our identified episodes are highlighted in bold

Table 1: Episodes identified from the real house price index in Norway (1819-2014), where ** and * indicate the 5% and 10% significance level. Episodes are highlighted in bold if they are overlapped with major financial crises in Norway as discussed in Grytten and Hunnes (2010).

Country/Model Specification	Test Stat	Episode(s)
Lag order=0		
Norway (with an intercept)	2.149**	**1985-1988, 2004-2014**
Norway (without an intercept)	3.172*	**1874-1883, 1885-1904, 1982-1989, 2000-2014**
Lag order=3		
Norway (with an intercept)	2.3836	**1875-1882, 1894-1900, 1986-1989**
Norway (without an intercept)	3.599*	**1870-1917, 1978-1990**

as shown in Table 1 where our empirically identified episodes coincide or overlap with these historical financial crises.

4.2.1 Episode during the 1870s-1900s

We find evidence of exuberance between 1870s and 1900s in the real Norwegian house price as shown in Figure 7b, Figure 7c, and Figure 7d. Norwegian economy grew strongly in the early 1870s and the late 1880s following the deep recessions in late 1870s and mid-1880s (Gerdrup, 2004). A spectacular real estate boom in Norway is caused by the increasing exports and economic development between late 1890s and early 1990s. Banks was able to get cheap capitals from the stock market prior to this crisis. The Norges Bank had relatively low reserves and had to raise the interest rate in 1898 due to the fall in exports. The failure of, a highly leveraged non-financial company, Chr. Christophersen led to the start of a crisis in 1899, which is linked to banks in Oslo and a real estate crash in several cities (Gerdrup, 2004; Brunnermeier and Schnabel, 2014). The crisis in 1899 was considered the first major banking crisis in Norway and triggered by a banking crisis and real estate crisis (Gerdrup, 2004).

4.2.2 Episode during the 1980s-1990s

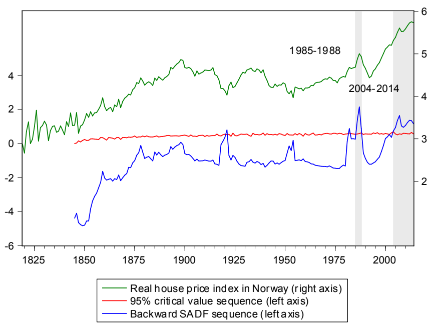
Evidence of house price exuberance in Norway is identified in Figure 7 under various specifications in the unit root null. Brunnermeier and Schnabel (2014) review 23 most important bubble episodes from the past 400 years including the Scandinavian crisis in Norway (1984-1992). The credit markets had been more regulated in both Norwegian and international markets since World War II (Grytten and Hunnes, 2010). The crisis between the 1980s and early 1990s had its roots in the structural imbalances that developed in the 1970s and 1980s, which stemmed from a heavily regulated financial system after World War II to the market-based system in the mid-1980s (Gerdrup, 2004). The Norwegian economy experienced accelerating growth from 1983. One of the important goals for Norwegian government was to keep a low interest rate to stimulate the economy. An incentive was created to invest in the domestic market. Norway deregulated its credit markets and a lending boom was created by foreign capital inflows as banks were allowed to borrow from abroad to fund their high lending growth (Gerdrup, 2004). The value of house prices soared prior to the crisis. In early 1986, a great challenge to the Norwegian economy was caused by the declining oil prices, higher wage demands, and speculative attacks on the Norwegian Krone. The Krone was devalued by around 10% in May 1986 and the failure of some small banks in 1987 revealed the first sign of a banking crisis and the crisis peaked in 1991 (Gerdrup, 2004). In particular, the second and fourth largest banks lost all their capital with a total market share of 24% in 1991 and the largest bank faced serious difficulties as well (Vale, 2004). Grytten and Hunnes (2010) summarise that the crisis in 1980-90s was the most severe financial crisis in Norway since the 1930s and the worst banking crisis since the 1920s.

4.2.3 Episode during the 2000s

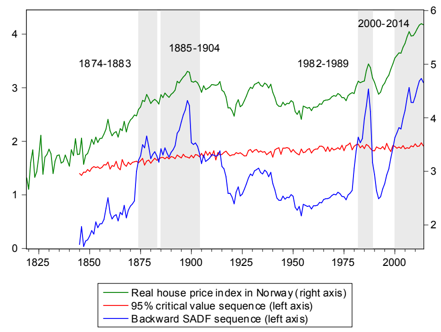
We observe evidence of exuberance in the 2000s when the lag order of 0 is considered in the null (i.e., Figure 7a, Figure 7b). It has been a rapid increase in house prices since 2000 in Norway. In a report from the International Monetary Fund (2012), house prices in Norway grew at an annual rate of 11% during the period 2004-07, which was much higher than the OECD average of 5.5%. The price-to-rent ratio shows price overvaluation as Norway has the highest price-to-rent ratio at around 70% above its historical average, the highest level of almost all OECD countries. Similarly, the price-to-income ratio also indicates the presence of overvaluation as it is 28% above its historical average. More importantly, this report suggests that the Norwegian house prices are overvalued by $15\% - 20\%$. Another report from International Monetary Fund (2013) suggests that house prices in Norway may be overvalued by 40% and both price-to-rent and price-to-income ratios still indicate the signs of overvaluation. The authorities have adopted tightening measure to cool down the housing market. Professor Robert Shiller had warned the existence of bubbles in Norway's housing market in 2013. Jurgilas and Lansing (2013) also conclude real house prices in Norway have risen by 30% since 2006. They also notice that the price-to-rent ratio for Norway from 1960 onwards reaches its highest level and the price-to-income ratio for Norway from 1980 onwards is higher than its previous peak. Moreover, the household leverage ratio (ratio of household debt to disposable income) remains historically high and around 210% above its level in 1980.

4.3 City-level house price index

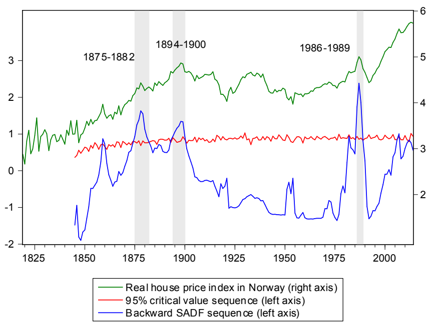
In this section, we consider analysis based on city-level house price indices using the PSY approach. Figure 8, Figure 9, Figure 10 and Figure 11 illustrate the date-stamping strategies for the real house price indices in Bergen, Kristiansand, Oslo, and Trondheim, respectively. As listed in Table 2, the null hypothesis of no explosive behavior for the house price index in Bergen is rejected either at the 10% significance level for choosing the lag order of 0 or at the 5% significance level



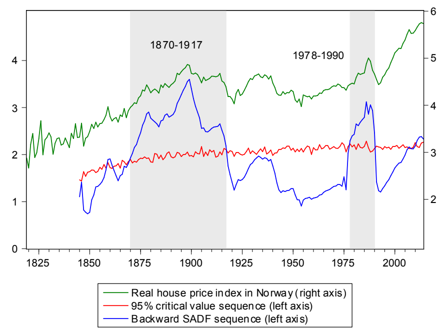
(a) Norway (1819-2014) with an intercept at the lag order of 0



(b) Norway (1819-2014) without an intercept at the lag order of 0



(c) Norway (1819-2014) with an intercept at the lag order of 3



(d) Norway (1819-2014) without an intercept at the lag order of 3

Fig. 7: Date-stamping strategy using the GSADF test for Norway under the assumption with/without an intercept at the lag order of 0 or 3.

for choosing the lag order of 3 in the null hypothesis. The presence of exuberance between the early or mid-2000s and 2014 is clearly demonstrated in Figure 8a, Figure 8b and Figure 8d, and this finding seems to be in line with the recent house price boom in Norway.

However, quite different results are obtained from Kristiansand. Table 2 suggests that the null hypothesis of no explosive behavior for Kristiansand can be rejected only for choosing the order of 0 in the null without the intercept and the lag order of 3 in the null with the intercept both at the 5% significance level. We observe exuberance in Figure 9b, Figure 9c and Figure 9d. A ‘collapse and recovery’ episode is identified from 1919 to 1922 in Figure 9c.

As shown in Table 3, we reject the null hypothesis of no exuberance in the real house price for Oslo if the intercept is removed from the null at the lag order of 0

Table 2: Episodes identified from the real house price index in Bergen and Kristiansand, where ***, ** and * indicate the 1%, 5%, and 10% significance level. Episodes are highlighted in bold if they are overlapped with major financial crises in Norway as discussed in Grytten and Hunnes (2010).

City/Model Specification	Data	Test Stat	Episode(s)
Lag order=0			
Bergen (with an intercept)	1819-2014	1.900*	**1986-1988**, 2002-2004
Bergen (without an intercept)	1819-2014	3.172*	**1986-1988, 2000-2014**
lag order=3			
Bergen (with an intercept)	1819-2014	3.101**	**1873-1880, 1892-1900**, **1983-1990, 2005-2008**
Bergen (without an intercept)	1819-2014	3.826**	**1870-1904**, 1907-1917, **1981-1990, 2005-2014**
Lag order=0			
Kristiansand (with an intercept)	1897-2014	0.342	
Kristiansand (without an intercept)	1897-2014	3.856**	**2006-2014**
lag order=3			
Kristiansand (with an intercept)	1897-2014	3.331**	**1919-1922, 2006-2014**
Kristiansand (without an intercept)	1897-2014	2.759	1982-1983, **2006-2014**

and the intercept is included in the null at the lag order of 3. We observe evidence of exuberance between the 1890s and early 1900s in Figure 10b, Figure 10c, and Figure 10d. We also find evidence of exuberance in the recent 2000s under most model specifications. We find significant evidence of exuberance for Trondheim in Table 3 as the test statistic is significant at the 1% level with a lag order of 0 and at the 5% level with a lag order of 3 only if under the assumption of excluding the intercept in the null. The corresponding date-stamping outcomes suggest the exuberance in the 2000s (e.g., Figure 11b and Figure 11d). An interesting finding from Figure 11a is that we spot a 'collapse' episode between 1918-1921. In addition, we find episodes during the 1980s in Figure 11b, Figure 11c and Figure 11d.

The majority of episodes identified from the city-level indices are consistent with those detected from the real aggregate house price index in Norway as displayed in Figure 7, the exceptions being 1918-1921 (Trondheim), and 1919-1922 (Kristiansand). According to Grytten and Hunnes (2010), the worst stock market crash in Norwegian history occurred between May 1918 and February 1923 along with the highest growth rate in Norwegian economy from 1919 to 1920. At that time, another banking crisis erupted in Norway (1920-1928). Our empirical results seem to suggest that the stock market and banking crises do not cause the explosiveness in the house prices at the national level based on Figure 7. Unlike the

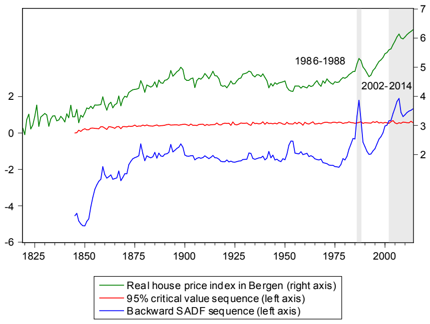
Table 3: Episodes identified from the real house price index in Oslo and Trondheim, where ***, ** and * indicate the 1%, 5%, and 10% significance level. Episodes are highlighted in bold if they are overlapped with major financial crises in Norway as discussed in Grytten and Hunnes (2010).

City/Model Specification	Data	Test Stat	Episode(s)
Lag order=0			
Oslo (with an intercept)	1841-2014	0.985	**2006-2008**, 2011-2014
Oslo (without an intercept)	1841-2014	3.660**	**1898-1899, 2005-2014**
lag order=3			
Oslo (with an intercept)	1841-2014	2.855*	**1896-1900**
Oslo (without an intercept)	1841-2014	2.908	**1893-1902**, 2012-2014
Lag order=0			
Trondheim (with an intercept)	1897-2014	1.521	**1918-1921, 2006-2008** 2012-2014
Trondheim (without an intercept)	1897-2014	6.377***	**1983-1989**, 2001-2014
lag order=3			
Trondheim (with an intercept)	1897-2014	1.973	1981-1984, **1986-1989**
Trondheim (without an intercept)	1897-2014	4.064**	**1985-1989, 2006-2014**

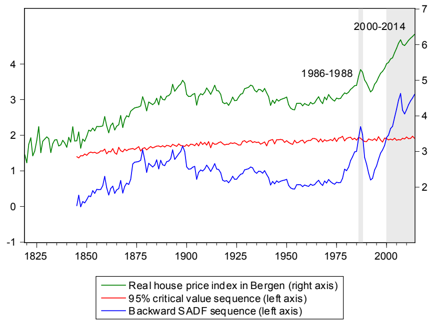
national level data, we find evidence of 'collapse' episodes in Figure 11a for Trondheim and 'collapse and recovery' episodes in Figure 9a for Kristiansand during the stock market and banking crises in the late 1910s and early 1920s. These two 'collapse' episodes are hardly bubbles and are likely caused by the stock market crash and banking crisis.

4.4 House price in Paris (1650-2012)

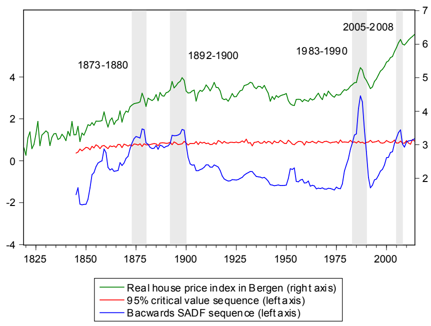
We carry out the analysis of the real house price index in Paris based on the sample period of 1650-2012 under various specifications in the null hypothesis. The date-stamping outcomes are shown in Figure 12. Allowing the intercept with a lag order of 0 in the null, the null hypothesis of no exuberance is rejected at the 1% level (4.5270>2.7015) and we find two 'collapse and recovery' episodes in Figure 12a (e.g., 1918-1922 and 1945-1953). Although the test statistic may suggest the rejection of the null hypothesis of no exuberance in the real house price index for Paris, however, these 'collapse' episodes are hardly believable bubbles as these episodes are detected when the real house price index is continuously declining. This example shows the rejection of the null hypothesis in the PSY could lead to false positive identification of 'genuine' exuberance/ bubbles if the plot of the



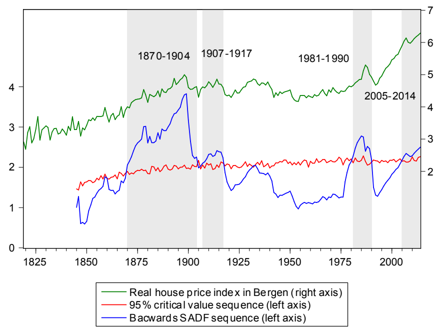
(a) Bergen (1819-2014) with an intercept at the lag order of 0



(b) Bergen (1819-2014) without an intercept at the lag order of 0



(c) Bergen(1819-2014) with an intercept at the lag order of 3



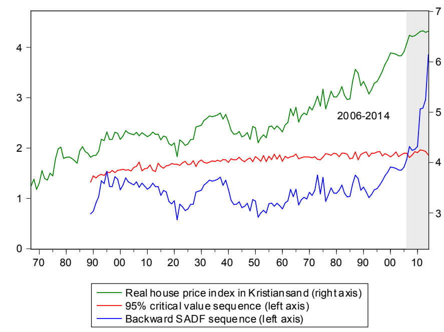
(d) Bergen (1819-2014) without an intercept at the lag order of 3

Fig. 8: Date-stamping strategy using the GSADF test for Bergen under the assumption with/without an intercept at the lag order of 0 or 3.

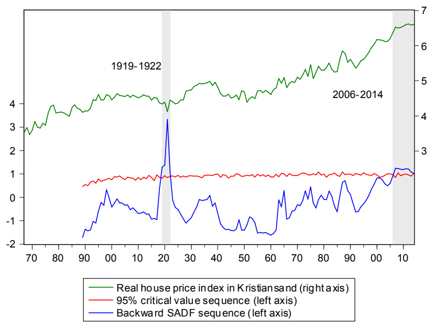
actual data series is taken into account. We may therefore conclude that there is no evidence of house price exuberance in Paris.

On the other hand, we obtain quite difficult results when the intercept term is excluded from the null. There is evidence of house price exuberance in the real house price series for Paris as the null is rejected at the 5% level (3.7572>3.5587). As suggested in Figure 12b, we can identify two 'exuberant' episodes: 1909-1915 and 1982-2012. When the lag order of 3 is considered in the null, we find little evidence of exuberance in the real house price series. The null of no exuberance cannot be rejected at the 10% level under the assumption with or without an intercept in the unit root, respectively. For example, we find a short-lived 'collapse' episode in Figure 12c between 1947 and 1948 and an episode in Figure 12d between 1907 and 1915. The latter episode identified in Figure 12d is almost in line with the one detected in Figure 12b in 1910s. In general, our results suggest no significant evidence of exuberance in the historical house price index for Paris

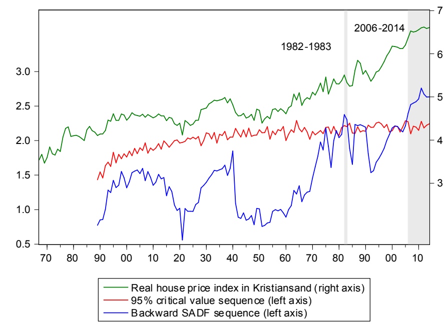
(a) Kristiansand (1867-2014) with an intercept at the lag order of 0



(b) Kristiansand (1867-2014) without an intercept at the lag order of 0



(c) Kristiansand (1867-2014) with an intercept at the lag order of 3

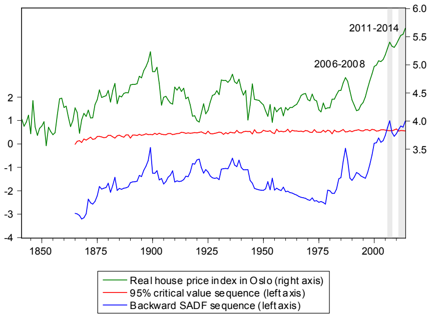


(d) Kristiansand (1867-2014) without an intercept at the lag order of 3

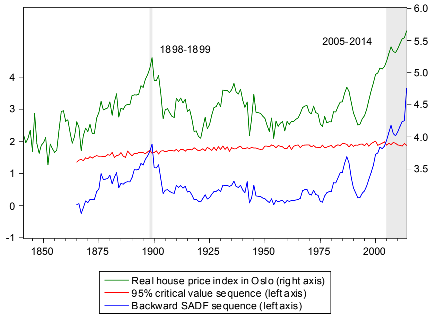
Fig. 9: Date-stamping strategy using the GSADF test for Kristiansand under the assumption with/without an intercept at the lag order of 0 or 3.

under most model specifications except that when the intercept with a lag order of 0 is considered in the null.

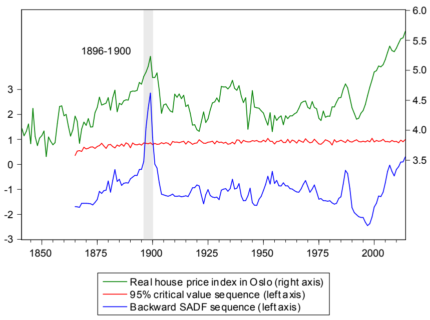
In order to shed insight into these experiences, we also explore whether some historical bubbles might have impacted on the real house price index in Paris. First, we could not find evidence of house price exuberance during the Mississippi Bubble (1719-1720). The same conclusions are drawn for the Crisis of 1763 and the Crisis of 1772. Second, the crisis in the French stock market in 1882 was the worst in French history in the nineteenth century and such a crisis led to a deep recession that lasted until the end of the decade (White, 2007). Our empirical results suggest that the crisis of 1882 doesn't cause any explosive behavior in the housing markets. It seems to suggest that these crises have no significant impact on the real house price in Paris. Third, according to White (2007), the Paris housing price bubbles started around 1884 and bust in 1900-1901. However, our empirical results suggest no evidence of house price exuberance during this period.



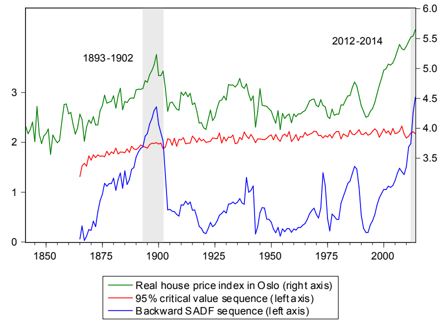
(a) Oslo (1841-2014) with an intercept at the lag order of 0



(b) Oslo (1841-2014) without an intercept at the lag order of 0



(c) Oslo (1841-2014) with an intercept at the lag order of 3



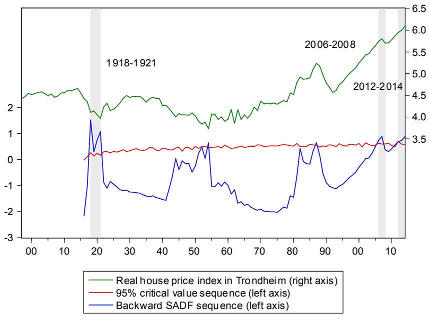
(d) Oslo (1841-2014) without an intercept at the lag order of 3

Fig. 10: Date-stamping strategy using the GSADF test for Oslo under the assumption with/without an intercept at the lag order of 0 or 3.

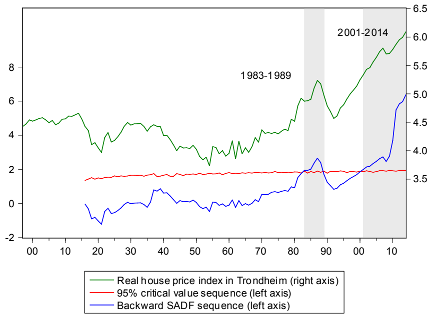
5 Conclusion

Recent debates relating to the role of sub-prime mortgage funded housing market booms in the US, has brought the concept of bubbles back into the public and academic arenas. Furthermore, the growing sophistication and integration of financial markets may have led to the rapid contagion of the original financial crisis spreading not only spatially but across different markets. In this paper, we have sought to test whether housing market bubbles (or periods of very rapid price rises-'exuberance') have historical precedents and furthermore, whether there is any evidence that bubbles or crisis in different financial markets (i.e., the Mississippi or South Sea bubbles spilled-over into local or national housing markets).

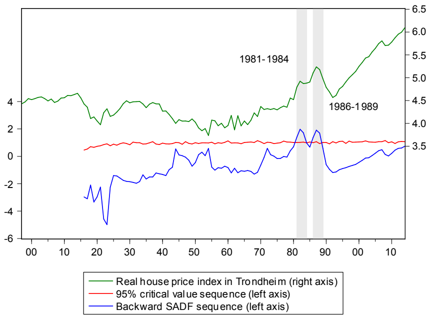
To consider these questions we tested for evidence of exuberance in three long-lasting house price indices, namely the Herengracht index of Amsterdam, Norwegian and Paris house price indices. In addition, we also investigate the presence of



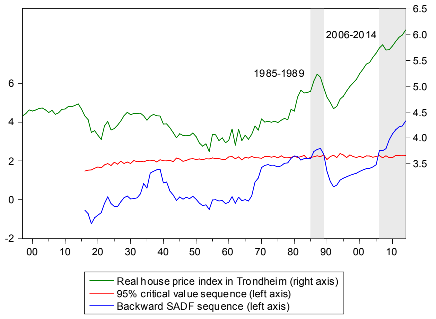
(a) Trondheim (1897-2014) with an intercept at the lag order of 0



(b) Trondheim (1897-2014) without an intercept at the lag order of 0



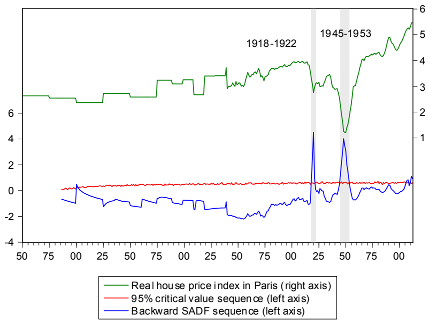
(c) Trondheim (1897-2014) with an intercept at the lag order of 3



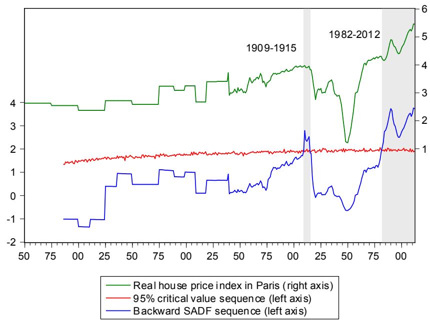
(d) Trondheim (1897-2014) without an intercept at the lag order of 3

Fig. 11: Date-stamping strategy using the GSADF test for Trondheim under the assumption with/without an intercept at the lag order of 0 or 3.

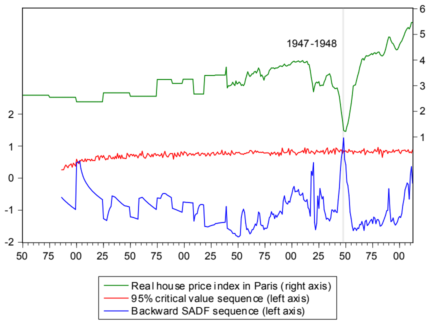
housing bubbles for the Amsterdam. Firstly, there is little evidence of exuberance in both the real Herengracht and biennial Herengracht indices. This finding indicates the real Herengracht index on its own is not explosive. More importantly, our results do not support the existence of housing bubbles in the Amsterdam price-rent ratio during 1628-1850 despite the occurrences of several (other) historical bubbles. Secondly, we find evidence of exuberance in the Norwegian house price index and these episodes either coincide or overlap with several major financial crises in Norway as discussed in Grytten and Hunnes (2010). Our empirical results also suggest that the house price episodes identified from four main cities (Oslo, Bergen, Trondheim and Kristiansand) are generally in line with those episodes obtained from the real house price index at the national level. Thirdly, the real house price index of Paris exhibits no significant evidence of exuberance under most model specifications. Moreover, several crises including the Mississippi Bubble, the Crisis of 1763 and the Crisis of (1772) have no significant impact on real house price index in Paris. Finally, our examples demonstrate that the rejec-



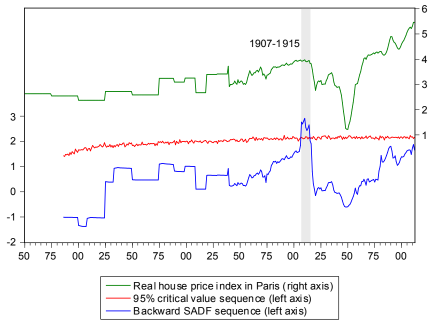
(a) Paris (1650-2012) with an intercept at the lag order of 0



(b) Paris (1650-2012) without an intercept at the lag order of 0



(c) Paris (1650-2012) with an intercept at the lag order of 3



(d) Paris (1650-2012) without an intercept at the lag order of 3

Fig. 12: Testing for explosive behaviour in Paris real house price index (2000=100, log scale) between 1650 and 2012 using the GSADF test under two different model specifications.

tion of the null hypothesis of no exuberance/ bubbles in the PSY could lead to false positive identification of 'genuine' exuberance or bubbles. There is a need to be careful when interpreting empirical results from these new time series-based methods of PSY, minimally checking that failed test date-stamping have both an empirical (a 'bubble' not a 'collapse and recovery' episode) and where possible, some historiographically sourced supporting information.

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