A Statistical Evaluation of Possible Bubbles in the Price Development in the German Housing Market

Thomas Mayer and Matthias Gehrke

Abstract Financial crises are often preceded by an asset market bubble or strong credit growth. To prevent further crises, it is essential to identify and combat excessive price and credit developments as early as possible. The momentum observed in the German housing market in recent years has led to concerns that a house price bubble already exists or still can emerge. However, a clear outcome is still missing. The present study analyses bubbles in the prices of owner-occupied flats in Germany by using the augmented Dickey-Fuller test and a generalized version of the sup augmented Dickey-Fuller test. A distinctive feature of the latter test is that it delivers a consistent date stamping strategy for the origination and termination of multiple bubbles. At first sight, there is evidence of so-called rational bubbles both in regional markets as well as in the overall German housing market. But most of them are linked to decreasing interest rates. Possibly, rational bubbles in seven German cities can be identified.

Thomas Mayer · Matthias Gehrke
FOM University of Applied Science
Leimkugelstraße 6, 45141 Essen, Germany
✉ mayertho90@googlemail.com
✉ matthias.gehrke@fom.de

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1 Introduction

The price development in Germany is currently discussed controversially in both media and empirical studies (e.g. BIS, 2016; Dombret, 2016; Deutsche Bundesbank, 2017; Empirica AG, 2017). As Tissot (2014) states a reasonable house price is a precondition of a stable economy as it has a great impact on the financial system as well as other parts of the economy. On the one hand, due to the rationing function, an overpriced housing market can lead to inefficient resource allocation and overcapacities as it was the case in Spain before the emergence of the global financial crisis (Dreger and Kholodilin, 2013). On the other hand, house prices are an important determinant of consumption. According to macroeconomic models and empirical studies, increased prices will lead to increased wealth and finally to increased consumption (Tissot, 2014). However, if there is a price bubble, the consumption may decrease disproportionately after the bursting of the bubble. Hence, according to Kivedal (2013) the negative consequences of decreased prices may be reinforced by a price bubble. An empirical study by Reinhart and Rogoff (2008) reveals that financial crises are often preceded by an asset market bubble or at least strong credit growth. Losses can easily spread to the whole economy if the asset price is driven by a high credit growth (Scherbina and Schlusche, 2012). This result was confirmed by the price development in the housing markets in industrial countries at the start of the 2000s (see Figure 4 in the appendix) and the emergence of the global financial crisis in 2007.

In contrast to the price development in other housing markets, German real house prices decreased until 2007, but have been increasing significantly, especially since 2009. In the light of the momentum in the German housing market and the potential consequences of unreasonably high prices, the German housing market must be closely monitored in order to detect price bubbles as early as possible. Although discussed controversially at various levels, the existence of a house price bubble could neither be clearly rejected nor clearly confirmed so far.

The present study aims at detecting house price bubbles on an aggregated level as well as in regional markets. The research of Kholodilin and Michelsen (2015) shows that, due to the regional segmentation of the housing market, it must be assumed that bubbles are visible in regional markets first. The data selected for the present study is in line with the data basis of other studies concerning the house price development in Germany. Regional and aggregated data are considered. Yearly average purchase prices and rents of newly built and second-hand apartments for 127 German cities from 1990 to 2015 are provided by bulwiengesa AG (a German consulting firm and analyst in the segment of real estates). In addition to that price indices for condominiums and residential rents on aggregated level (2003/Q1–2016/Q3) as well as for 7 cities (1991–2015) published by the Verband deutscher Pfandbriefbanken (vdp, Association of German Pfandbrief Banks) are used. To show the existence or non-existence of bubbles, tests for stationarity and explosive behaviour are used.

2 German Housing Market

The characteristics of the German housing market in 1990–2016 can be described by four key facts:

1. **Converse price development:**
   As indicated in Section 1, real house prices as well as rents are currently increasing after a long period of declining or stagnating prices and rents which can be traced back to the German reunification boom in the early 1990s (Michelsen and Weiß, 2009). This is in contrast to the price development in other industrial countries as illustrated in Table 1.

Table 1: Development of real house prices and rents in selected countries[a].

Country	Real House Prices		Real Rents	
	2000–2007	2008–2015	2000–2007	2008–2015
Germany	−12.8 %	12.6 %	−2.4 %	1.1 %
Ireland	64.0 %	−32.0 %	60.1 %	−22.8 %
Spain	106.6 %	−36.3 %	6.6 %	−2.4 %
United Kingdom	85.3 %	−1.5 %	9.0 %	4.0 %
Unites States	35.2 %	−1.8 %	6.7 %	3.2 %

[a] Data from OECD.

2. **Moderately increasing construction activity:**
   Following the reunification boom in the early 1990s, there has only been weak construction in Germany in the late 1990s. In 2010, construction activity began to rise. In comparison to other economies, the impact of

price movements on construction activity in Germany has been relatively moderate (Kholodilin et al, 2015).

3. **Stable mortgage loan market:**
First, the growth rates of new mortgage loans are more moderate than in Anglo-Saxon housing markets. At the end of 2016, the annual growth rate was 3.8 % (long-term average growth rate since the beginning of the 1980s of just under 5 %) (Deutsche Bundesbank, 2016). Second, due to the high share of long-term fixed interest rates, households are protected against an increase of interest rates in the short-term (Scherbina and Schlusche, 2012). In 2016, the share of mortgage loans with interest rates fixed for over 10 years was nearly 40 % (data from Deutsche Bundesbank). Third, according to the German bank's evaluation during the bank lending survey of Deutsche Bundesbank, the standards and preconditions for granting mortgage loans to households had been tightened since 2011 (Dombret, 2016).

4. **Low owner occupation rate:**
In the years 2003 to 2016 the owner occupation rate in Germany amounted to 53 % on average. It is lower than in other industrial countries (Spain: 79 %; United Kingdom: 69 %; Ireland: 75 %; The Netherlands: 67 %) and even lower than the average in the European Union (70 %) (data from Eurostat). Considering that, there is still growth potential in the German housing market.

In a nutshell, the German housing market is more conservative than others. At first sight, there is no risk to financial stability (Dombret, 2016).

3 Bubbles

Following Gilles and LeRoy (1992) and Gürkaynak (2008), every price system can be decomposed into two parts, namely a fundamental component and a bubble component. In the given context, the fundamental house price equals the sum of the present values of expected future rents. The bubble component equals the difference between the market value and the fundamental value.

Beside this simple explanation of a bubble component, there are different approaches to define the term *bubbles* as well as their emergence more in detail. But in fact, a generally valid definition is still missing (Brunnermeier and Oehmke, 2013). Rational and behavioural models are commonly accepted (Helbling, 2005).

The present paper is based on the concept of rational bubbles. Therefore, behavioural models are not discussed further. Speculation is the key factor in the concept of rational bubbles. If households are willing to pay a price exceeding the fundamental value just because they believe that the price will further increase, then a rational bubble exists (Stiglitz, 1990; Gürkaynak, 2008). Therefore, rational bubbles are also referred to as speculative bubbles (Gilles and LeRoy, 1992). The calculation of the house price in the context of rational models is illustrated in Equation (1).

$$P_t = \underbrace{\sum_{i=1}^{\infty} \left(\frac{1}{1+r}\right)^i E_t(d_{t+i})}_{P_t^f} + \underbrace{\lim_{T\to\infty} \left(\frac{1}{1+r}\right)^T E_t(P_T)}_{B_t}. \tag{1}$$

According to the rational models, the calculation of the asset price depends on its maturity. Real estates are assets with infinite maturity because there are no maturity constraints. As assets with finite maturity are not analysed in this paper, only the formula for assets with infinite maturity is depicted.

The house price P_t consists of a fundamental component P_t^f (sum of the present values of expected future rents d_t) and a bubble component B_t (discounted expected future selling price P_T). B_t grows at rate r_b which equals discount rate r (Scherbina, 2013). Consequently, the price is still rational, even despite the price bubble, as arbitrage is not possible (Wu, 1997). The growth rate r_b reasons the speculation of households as well as the assumption that the house price grows explosively in case of a price bubble (Phillips et al, 2011; Homm and Breitung, 2012). Due to the assumed growth rate, neither the value of the bubble component can be negative nor can the bubble emerge again after bursting (Diba and Grossman, 1988b).

4 Statistical Methods

Two statistical methods are used for the investigation of the price development in the German housing market: tests for stationarity and for explosive behaviour. The terms *stationarity* and *difference stationarity* are used simultaneously. In both tests, bubbles are assumed to be rational. The previously explained features of a price system and a rational bubble are modified respectively. We used R version 3.2.4 (R Core Team, 2017) to carry out the statistical analysis employing `Metrics` version 0.1.1 (Hamner and Frasco, 2017), `seasonal` version 1.4.0 (Sax, 2017), `tseries` version 0.10-34 (Trapletti and Hornik, 2017), and `urca` version 1.3-0 (Pfaff, 2008). The GSADF tests were carried out using EViews 9 using Rtadf (Caspi, 2016).

4.1 Testing for stationarity

The testing for stationarity is based on the concept of Diba and Grossman (1988a). There are two additional assumptions compared to the previously explained features. First, the fundamental component is defined to be the sum of the present values of expected future rents as described above plus an additional unobservable component. Second, the growth of a price bubble is not only determined by growth rate r_b but also by an additional random variable b_t. Against this background, the existence of a bubble can be rejected if house prices are stationary. The reason for this conclusion is b_t. Hence, in the case of a bubble the preconditions for stationarity are missing. However, non-stationarity does not prove the existence of a bubble due to the following two aspects. On the one hand, the result can be driven by the unobservable component. On the other hand, time series not only contain periods of increasing prices but of decreasing prices as well. The test does not distinguish between increasing or decreasing prices. So, if the time series is non-stationary, this result is not necessarily caused by increasing prices. It may theoretically be driven by a strong price decrease. So, this test can only reject the existence of a bubble.

To test for stationarity the Augmented Dickey-Fuller (ADF) test is used. The modification of the ADF test depends on the feature of the underlying time series (random walk, random walk with drift, or random walk with drift and deterministic trend). If this feature was not or at least wrongly considered, the ADF test leads to wrong results (Enders 2015, pp 206; McLeod et al 2012).

To receive correct results, a three-stage procedure based on the testing strategy proposed by Dolado et al (1990) is conducted. First, the model with drift and deterministic trend is used to test for stationarity. If the null hypothesis is rejected or if the deterministic trend is significant, there will be no need to continue. Otherwise, in a second or third step, the procedure will be applied to the model with drift or the model with neither drift nor deterministic trend, respectively (see Figure 5 in the appendix for more details). When the final result of the first round was non-stationarity, the whole procedure was repeated to test for difference stationarity.

4.2 Testing for explosive behaviour

Testing for explosive behaviour is based on the concepts of Phillips et al (2011) and Phillips et al (2012, 2015). It is assumed that the bubble component increases explosively, which means disproportionately, because of the bubble growth rate r_b. As this bubble component is part of the price system, the price will then increase explosively as well. But to detect the existence of a price bubble, the observable fundamental component must also be analysed. Only if the observable fundamental component is not increasing explosively at the same time, there is evidence of the presence of a price bubble. To facilitate the investigation, the ratio between market price and an observable fundamental component, in this context the price-to-rent ratio, is calculated. A house price bubble may then exist, if the price-to-rent ratio is increasing explosively.

Following Kivedal (2013), the price-to-rent ratio is additionally adjusted by the development of interest rates to eliminate price increases driven by the low interest rate environment and attractive credit conditions rather than speculation. To that end, the rents d_t are adjusted by yearly long-term interest rates according to German government bonds maturing in ten years r_t^{Gov10} as follows (interest rates from OECD):

$$d_t^{adj} = \frac{d_t}{1 + r_t^{Gov10}}. \tag{2}$$

To test for explosive behaviour, a right-tail variation of the standard ADF test is chosen. The right-tail variation refers to the alternative hypothesis of this ADF test. In contrast to a left-tail variation used for the testing for stationarity

($H_A : \delta < 0$ (stationarity)), the alternative hypothesis is of a mildly explosive process ($H_A : \delta > 0$). The test is called Generalized Sup ADF (GSADF) test. As illustrated in Figure 1, the test is divided into two parts. The first part (on the left) follows the idea of repeatedly running the right-tailed ADF test on a forward expanding sample sequence r_w (each sample sequence has a starting point r_1 and end point r_2, the smallest sample window is r_0). The test allows varying both the starting point and the end point within a feasible range. The null hypothesis of random walk can be rejected if the largest right-tailed ADF statistic exceeds the critical value. In that case, there would be evidence of the presence of a house price bubble. The second part (on the right) is conducive to deriving both the origination and termination date of the bubble. Unlike the first part, this test is running backward and the end point r_2 is fixed. The origination date is defined as the first point in time, when the backward sup ADF statistic exceeds the critical value. Accordingly, the termination date equals to the first point in time after the origination date, when the backward sup ADF statistic falls below the critical value (Phillips et al, 2012). A minimum period between both dates should be defined to avoid that strong but only short-term fluctuations are mistakenly highlighted as bubbles (Phillips et al, 2015). For the present paper, the period should be at least 2 years.

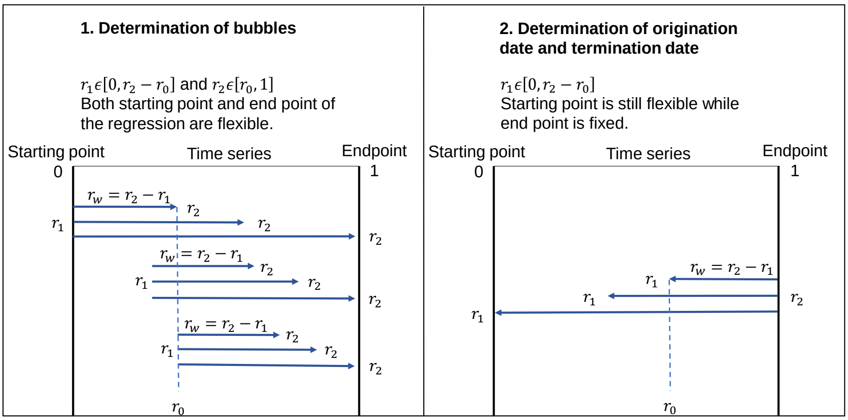

Figure 1: GSADF test procedure.

5 Structure of the Sample

Compared to other industrial countries, the availability of German house price data is restricted (Kholodilin and Michelsen, 2015). As already mentioned in the introduction, the present paper is based on regional and aggregated data provided by bulwiengesa AG and vdp.

The price data of *bulwiengesa AG* reflects the price development in the whole German housing market adequately because of their high market coverage. The analysed data set covers the yearly average purchase prices and rents of newly built and second-hand apartments for 127 German cities from 1990 to 2015. Considering the number of inhabitants in the respective cities, which was also provided by bulwiengesa AG, the aggregated price development for newly built and second-hand apartments for the whole of Germany is calculated. Not all data from bulwiengesa AG are publicly available.

In contrast to bulwiengesa AG, *vdp* provides the price data in form of indices. In the present paper, the nominal house price indices (price index for condominiums, price index for residential rents) on aggregated level (2003/Q1–2016/Q3) as well as for 7 cities (1991–2015) are used. Only the house price indices on an aggregated level are publicly available.

Real house prices, rents, and indices were calculated by adjusting the nominal values by the consumer price index (data from Statistisches Bundesamt). The need for seasonal adjustment was tested in R by X-13-ARIMA-SEATS from package `seasonal`. According to the Root Mean Squared Error Test and the Wilcoxon Signed Rank Test, there was no significant difference between the time series before and after the seasonal adjustment. Consequently, a seasonal adjustement of the quarterly data was not necessary.

6 Examples of GSADF Test Calculation for two Cities in Germany

The GSADF tests were carried out in EViews 9 using the add-in *Rtadf* (Caspi, 2016; EViews add-ins are a possibility to provide user-defined programs to other users and can be accessed via `http://www.eviews.com/Addins/addins.shtml`). The type of the GSADF test has to be selected as the add-in can be used for different kinds of right-tailed ADF tests. We used the *GSADF (PSY, 2015)* test according to Phillips et al (2015). Within the test specifications the initial window size r_0 which is the starting point for the repeatedly running right-tailed ADF test has to be defined. As proposed by Phillips et al (2015), the window size $r_0 = 9$ was derived from the sample size $T = 25$ as follows:

$$r_0 = 0.01 + 1.8 \cdot \sqrt{T}. \tag{3}$$

Additionally, the order of the lags has to be determined. This either can be set to a fixed value or to a variable one depending on some criteria like the BIC. As proposed by Phillips et al (2015), the order of the lags was set to zero.

The critical values were calculated by Monte Carlo simulation which is one of the methods the add-in provides. To use this method, the number of replications and the significance level for the series of critical values have to be selected. We set these parameters to 2000 (following Phillips et al, 2015) and 10 %. Additonally, the parameters c and η of the data generating process (a deterministic trend) for the null hypothesis have to be specified as well:

$$y_t = c \cdot \frac{t}{T^\eta} + \sum_{j=1}^{t} \epsilon_j + y_0. \tag{4}$$

Above Equation (4) is a transformation of the general Equation given in Phillips et al (2015) and reveals the deterministic drift $c \cdot \frac{t}{T^\eta}$. c is the constant drift factor and η is a coefficient which controls the magnitude of the drift. Phillips et al (2014) recommend to include a constant in the null hypothesis of the GSADF test to consider the slight drift in the price processes. Following Phillips et al (2015), we set $c = \eta = 1$.

Moreover, the user can decide whether to use the fixed sample size T or the changing regression window size r_w in the null model. According to Caspi (2016), the latter is more accurate but, especially with larger sample sizes, quite time consuming. Nevertheless, we selected r_w.

In Table 2 the adjusted (see Equation (2)) price-to-rent ratios in the market of second-hand appartments for two German cities are provided, one of category A, the other of category D. Bulwiengesa AG classifies all German cities in a range from A to D based on influence and reach on international, national, regional, or local markets. For further information refer to `https://www.riwis.de/online_test/en/info.php3?cityid=&info_topic=allg`.

Table 2: Prices-to-rent ratios (adjusted) of two German cities.

Year	A-City	D-City	Year	A-City	D-City	Year	A-City	D-City
1991	271.1	313.4	2001	282.0	272.6	2011	270.0	235.1
1992	282.8	274.7	2002	272.4	272.4	2012	290.0	230.7
1993	284.0	257.2	2003	270.6	260.2	2013	299.6	223.0
1994	289.4	291.7	2004	263.6	245.9	2014	315.5	226.1
1995	284.9	342.1	2005	251.6	244.3	2015	330.1	231.0
1996	303.4	329.5	2006	252.6	245.3			
1997	294.3	333.5	2007	247.5	233.6			
1998	291.3	313.9	2008	247.6	234.8			
1999	291.0	313.6	2009	258.0	238.2			
2000	290.5	305.4	2010	265.5	249.3			

The right tailed ADF test (part one of the test procedure) for the A-city is significant to the 5 %-level, whereas the test for the D-city does not show any significance (details see Table 3). Consequently, the null hypothesis of random walk can be rejected for the A-City and there is evidence of the existence of a house price bubble in this city.

Table 3: Results of the GSADF tests for two German cities – part 1: right tailed ADF test.

		A-City		**D-City**	
		t-statistic	p-value	t-statistic	p-value
Right tailed ADF test		2.305461	0.0210	0.010590	0.6695
Critical values	99 %-level	2.690009		2.741182	
	95 %-level	1.834232		1.840882	
	90 %-level	1.415521		1.415521	

In order to identify both the origination and termination date of the bubble, the backward sup ADF test (part two of the test procedure) has to be applied. The results are shown in Figure 2. The green line shows the price-to-rent ratio (right axis). The blue line represents the backward sup ADF test statistics and the red line represents the critical values at 10 % significance level (both on left axis).

The origination date is defined as the first point in time when the backward sup ADF statistic exceeds the critical value. Accordingly, the termination date equals to the first point in time after the origination date when the backward sup ADF statistic falls below the critical value. In case of the A-city, there is evidence of an ongoing house price bubble emerging in 2013. In addition to that, the backward sup ADF statistic exceeds the critical value in 2005 although the price-to-rent ratio decreases from 2004 to 2005. Phillips et al (2015) emphasize that the method may falsely identify strong price decreases as bubbles as well. Thus, in order to identify real price bubbles, the development of the underlying prices has to be considered, and 2005 is not classified as a price bubble. As expected, for the D-City the backward sup ADF statistics (blue line) are lower than the critical values (red line) at every point in time.

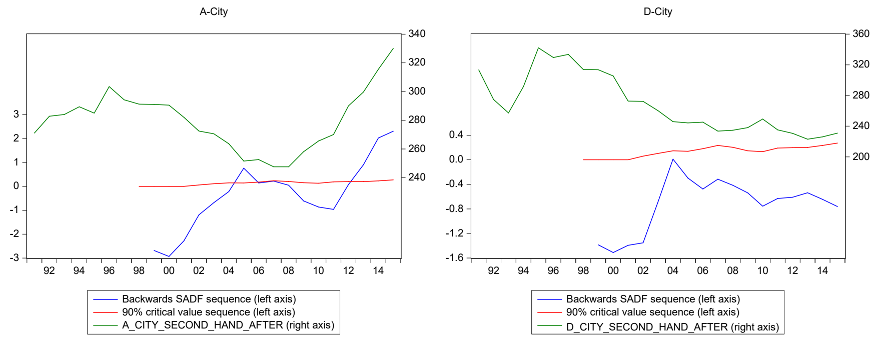

Figure 2: Results of GSADF tests for two German cities – part 2: backward sup ADF test. Left: A-City, showing a bubble, right: D-City: no evidence for a bubble.

7 Results and Discussion

The results of the statistical tests depending on the respective data basis are explained subsequently and summarized in Table 4. It needs to be emphasized that the GSADF test aims at detecting current bubbles. Current bubbles have emerged at a given point in the time series and did not burst until the end of the time series.

Table 4: Results of the ADF and GSADF tests.

Test	Aggregated level	Regional markets
	bulwiengesa data	
ADF test	Existence of a house price bubble cannot be rejected	No house price bubble in the following cases: Newly built apartments: 67 cities (52.8 % of all cities) Second-hand apartments: 100 cities (78.7 % of all cities)
GSADF test	**Before adjustment** Evidence of a house price bubble	**Before adjustment** Evidence of a house price bubble in 19 cities (11 x newly built apartments, 8 x second-hand apartments)
	After adjustment No house price bubble	**After adjustment** Evidence of a house price bubble in 7 cities (4 x newly built apartments, 3 x second-hand apartments)
	vdp data	
ADF test	No house price bubble	No house price bubble in 3 cities (42.9 % of all cities)
GSADF test	**Before adjustment** No house price bubble	**Before adjustment** No house price bubble
	After adjustment No house price bubble	**After adjustment** No house price bubble

7.1 ADF test

The **aggregated** data of bulwiengesa AG are not stationary. Hence, the existence of a price bubble cannot be rejected. However, the aggregated data of vdp are stationary. Thus, the results are ambiguous. At least, there is doubt that there is a price bubble in the entire German housing market.

Concerning the **regional** markets, the existence of a price bubble in the time series from bulwiengesa AG can be rejected for 67 cities in the segment of newly built apartments and for 100 cities in the segment of second-hand apartments. The regional data of vdp only reflects the prices in 7 cities. The existence of a price bubble can be rejected in 3 cases.

7.2 GSADF test

According to the price-to-rent ratios based on the **aggregated** data of bulwiengesa AG, there is explosive behaviour in the entire German housing market driven by the interest rate development. There is no evidence of a house price bubble in the adjusted price-to-rent ratios. Moreover, there is no explosive behaviour in the price-to-rent ratios based on aggregated data from vdp both before and after adjustment. Consequently, evidence of the existence of a Germany-wide house price bubble cannot be confirmed.

The investigation of **regional** price-to-rent ratios based on data from bulwiengesa AG reveals that there is evidence of a house price bubble in 7 cities (4 x in the segment of newly built apartments, 3 x in the segment of second-hand apartments). In 12 additional cases, explosive price increases are driven by the interest rates. Again, the data from vdp does not indicate a price bubble.

7.3 Discussion

Besides the fact that the ADF test can only reject the existence of price bubbles, there are further points of criticism showing that the results of the ADF test are not reliable. First, this test assumes that bubbles cannot emerge again after they have burst. Thus, it is inappropriate to deal with periodically collapsing bubbles (Evans, 1991). Second, as there is a high type II error, the power of left-tailed ADF tests is quite low (Enders, 2015, pp 235).Third, the characteristics of the underlying time series must be considered to prevent distorted results (Gujarati and Porter, 2009, pp 759).

The GSADF test seems to be appropriate to detect periodically collapsing bubbles. This is proved by the results of the GSADF test regarding the housing market in the U.S. As illustrated in Figure 3, the test can detect the house price bubble in the 2000s (emerging 1999, collapsing 2008). But, even this test cannot confirm the existence of a price bubble absolutely. Strong price increases can sometimes be reduced to factors influencing the fundamental component (e.g. interest rates). They must be considered by adjusting the fundamental component. This adjustment is necessary to detect explosive behaviour solely caused by speculation (Gürkaynak, 2008). Finally, strong price decreases are mistakenly highlighted as price bubbles (Phillips et al, 2015). The development of the price-to-rent ratio must be considered accordingly.

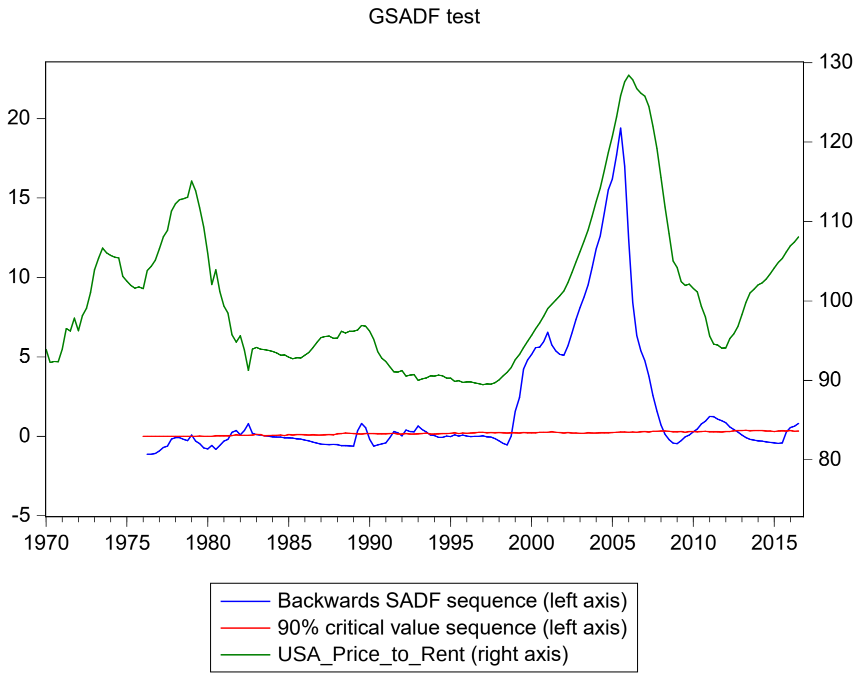

Figure 3: House price bubble in the U.S.

Against this background and against the description of the sample structure, the results of the GSADF test based on the data from bulwiengesa AG seem to reflect the situation on the German housing market on aggregated as well as regional level adequately.

8 Conclusion

The latest global financial crisis shows that price bubbles must be detected as early as possible. The situation on the German housing market differs from housing markets in other industrial countries. Especially since 2009, real house prices and rents have been increasing significantly after a long declining or stagnating period. The GSADF test used to test for explosive behaviour indicates the existence of a house price bubble in seven German cities at the end of 2015. The ADF test, however, turns out to be neither suitable for detecting price bubbles nor reliable in rejecting them. House prices and rents continued to increase in 2016. A clear prediction of the future development is not possible, especially due to the uncertain development of interest rates. Therefore, the German housing market must continue to be closely monitored.

Acknowledgements We should like to thank the reviewers for their valuable remarks.

Appendix

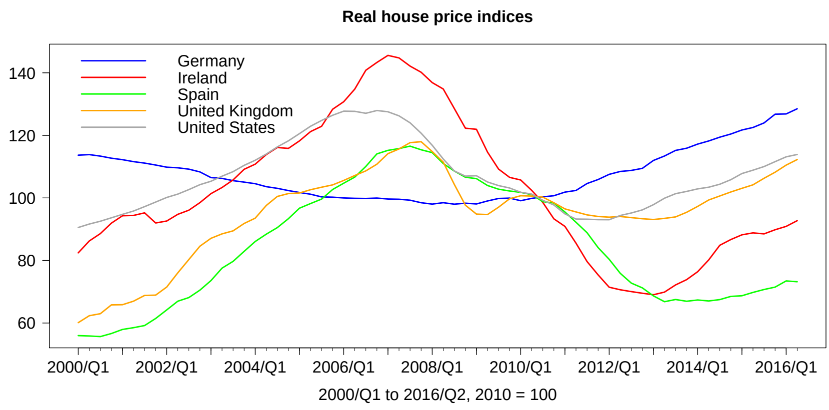

Figure 4: Price development in the housing markets in selected industrial countries (data from OECD).

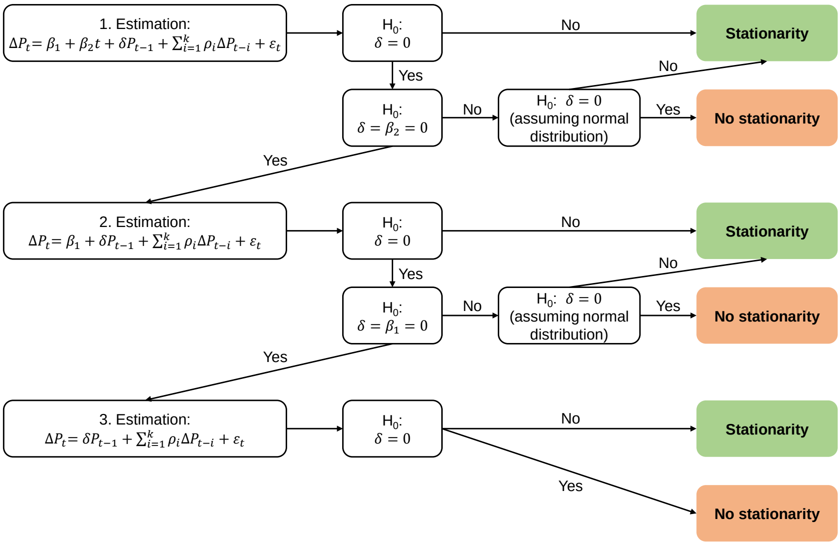

Figure 5: ADF test procedure.

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