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Speculative price bubbles in urban housing markets

Empirical evidence from Germany

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Abstract In the light of the unconventional monetary policies implemented by most large central banks around the world, there is an intense debate about the potential impact on the prices of capital assets. Particularly in Germany, skepticism about the sustainability of the current policy by the European Central Bank is wide spread and concerns about the emergence of a speculative price bubble in the housing market are increasing. The present study analyzes a comprehensive data set covering 127 large German cities from 1990 through 2013, using tests for speculative bubbles, both at a national and city level. Furthermore, we apply two new testing approaches: panel-data and principal components versions of explosive root tests. We find evidence for explosive price increases in many cities. However, it is only in select urban housing markets that prices decouple from their fundamental values. There is no evidence for speculative price movements nationally.

Keywords Housing prices · Speculative bubble · Explosive root · German cities

JEL Classification C21 · C23 · C53

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1 Introduction

After a protracted period of stagnation, German house prices began to grow at an accelerated pace in 2010 (see Fig. 1). Real house prices, which declined over the 2000–2008 period, started to climb steeply in the second half of 2010, followed with a substantial increase in construction activities. Having the lessons from the Great Recession in mind (Duca et al. 2010), there are concerns that the housing market dynamics are causing a speculative house price bubble in Germany. In 2013, the Deutsche Bundesbank (German Central Bank) reported an overvaluation of house prices in some metropolitan areas of up to 25% (Deutsche 2013; Kajuth et al. 2013. In response, the International Monetary Fund (IMF) called on the German government to enhance its macro-prudential toolkit in order to be prepared in the event of an overheated housing market, which the IMF identified as a potential threat to financial market stability (IMF 2014). In the light of the extremely expansionary monetary policy of the European Central Bank (ECB), the German minister of finance, Wolfgang Schäuble, said in July 2014 that he would take the warnings seriously and keep a close eye on future housing market developments.

In contrast, other discussants do not see the need for immediate intervention. They argue that, in international comparison, German house prices are relatively low and house price movements are modest against the background of Germany's sound macroeconomic fundamentals, a growing number of immigrants, and increasing rents (Haas et al. 2013; Henger et al. 2012). Moreover, it is argued that house price increases are concentrated in selected urban markets—particularly in the prosperous metropolitan areas like Berlin, Hamburg, and Munich—that are experiencing substantial economic and population growth (Dombret et al. 2013), while in more rural areas house prices remain unchanged at low levels. Finally, it is argued that a speculative house price bubble is always associated with a substantial increase in outstanding mortgage loans and excessive construction activity; both do not apply to real estate investment in Germany. Consequently, descriptive assessments of the housing market conclude that there are no indications of bubbles in German housing markets (Empirica 2014; IMF 2014).

However, there are good reasons to believe both stories behind the numbers. From a historical perspective, over the past 140 years, Jordà et al. (2014) point out that the ingredients (particularly loose monetary policy) for a substantial misalignment between house prices and economic fundamentals are present, which make the arguments by the Deutsche Bundesbank and the fears of the IMF appear valid. On the other hand, authors like Kofner (2014) emphasize the stability and the resilience of the German housing market to external shocks.

A key challenge in this context is that the real-time identification of a bubble is relatively complex and simply relying on a descriptive analysis of isolated indicators can be misleading. So far, there are three studies employing more advanced econometric techniques addressing a potential house price bubble in Germany. The most frequently cited work is that of Kajuth et al. (2013), who follow a "classical" approach by regressing house prices on market fundamentals. Using data for more than 400 regions over the 2004 through 2012 period, they capture the entire spatial variation of the German housing market. Kajuth et al. (2013) find that for most regions analyzed, house prices reflect the economic conditions quite well. However, in metropolitan areas, a substantial overvaluation of up to 25% is detected. In part, this is attributable to the fact that the time dimension of the data is rather short. The authors first estimate an "equilibrium" price for the 2004–2010 era and then compute the fundamental price for the period from 2010 onwards using the estimated coefficients. However, assuming that housing markets were in equilibrium in the period prior to 2010 is somehow counterintuitive. At least during the Great Recession (2007–2009) the pricing mechanism should have been disturbed substantially, which could lead to biased estimates of fundamental prices during the post-crisis period.

Another study by Chen and Funke (2013) analyzes aggregate house price data from 1987 through 2012. The authors apply a relatively new approach proposed by Phillips et al. (2011), which essentially is a unit root test for explosive behavior in time series. The authors conclude that, on the aggregate level, no signs of a speculative house price bubble can be detected. However, the major shortcoming of this study is the use of national level house prices. As pointed out by several authors, house price dynamics vary significantly across regions (Goodman and Thibodeau 2008; Hwang and Quigley 2006; Abranham and Hendershott 1996). Thus, signs of bubbles are hardly detectable in national data. For an early warning indicator, the use of regional data seems to be more appropriate.

The study by an de Meulen and Micheli (2013) picks up the spatial dimension of Germany's housing market. The authors analyze monthly data of metropolitan house prices from January 2008 through January 2013. Based on more powerful tests, as proposed by Homm and Breitung (2012), they conclude that explosive price dynamics can only be detected in selected regions and only for flats in apartment buildings. In summary, the authors conclude that signs of a speculative house price bubble are weak. Unfortunately, this study focuses on a very short period of time, a small number of cities, and selected market segments, which raises doubts about the relevance of their findings for the whole country.

Of the aforementioned approaches, the univariate tests are particularly suitable for a real-time analysis of price dynamics, as they do not require covariates that are regularly not available, at least on the subnational level. However, the use of these tests comes at the cost that we cannot explicitly disentangle the influence of market fundamentals, like income or population growth, but also the potential influence of dramatically decreasing interest rates and returns from alternative assets. However, we indirectly consider these factors, as we follow a multi-level testing strategy. We separately analyze house prices and rents in all market segments on a national and on a regional level. If prices were driven by increased demand, rents should reflect this adequately on a city level. If interest rates were the key driver of housing market development, then national and regional price series should follow a similar trend. We argue that speculation is a likely driver of house price dynamics in markets where national and regional, as well as rent and price, series do not show a common pattern, i.e., regional prices contain an explosive root, while rents and national prices do not. As we argue later on, this result is particularly robust for small and less liquid markets.

The contribution of this paper is manifold. First, this study is based on a very large panel comprising 127 German cities and covering the period from 1990 through 2013.

Using these data allows us to observe an entire housing market cycle and to account for heterogeneity across urban housing markets. Second, we distinguish between different housing market segments: we analyze the price dynamics of existing and newly built apartment houses separately. Furthermore, we distinguish between four types of housing markets—ranging from very large metropolitan areas to those in smaller, less liquid markets. Compared to previous studies, this clearly increases plausibility of the analysis. Third, we further develop existing tests for price bubbles: we construct a panel-data version of the Chow-type test for explosive roots. This allows us to exploit all time series and cross-sectional variation to construct a more powerful method that tests if there is a significant explosive root in at least one city. Moreover, we apply the Chow-type test to the first principal components of the individual city-specific prices/rents, which reflect a common trend in the house prices/rents across various cities. Fourth, we use a more precise definition of a bubble: we define price movements as bubbles when explosive growth of prices is not supported by explosive increases in rents. Therefore, to check for the existence of bubbles, we examine not only prices but also rents.

Our findings indicate that on the national level, strong price growth appears to be covered by fundamentals: for newly built apartments, prices increase explosively, which is covered by corresponding rent increases. The prices for second-hand apartments do not contain an explosive root. In contrast, we detect explosive price increases in many cities, particularly in the market for newly built homes. In some, rents do not cover these increases. To summarize, our results imply that the signs for a speculative bubble are weak.

The rest of the paper is organized as follows. In Sect. 2, we present stylized facts on the German housing market. Section 3 outlines our empirical strategy and presents the basic concepts and methods. Section 4 describes the data on house prices in German cities that are used in the study. Section 4.2 discusses the empirical setup of the study, while in Sect. 4.3 the tests for speculative bubbles are carried out and their results are discussed. Finally, Sect. 5 draws conclusions.

2 The German housing market: five stylized facts

It is often argued that speculation in a housing market goes along with increasing risk-taking behavior of agents that can be observed in several macroeconomic variables. Particularly, authors argue that in case of a house price bubble, housing starts and the volume of new credits to households would sharply increase (Anundsen et al. 2016); in addition, price-to-income and price-to-rent ratios are expected to rise. On the other hand, cap rates and risk premiums are expected to decline. Stylized facts on the development of these variables indicate that the German housing market on aggregate appears to be in a good condition.

Stylized fact 1: Long period of declining real house prices Unlike the markets in many other major economies, the German housing market did not experience a boom at the start of the 2000s. From 1996 to 2008, real house prices even declined (see Fig. 1). This, however, can be interpreted as a response to the reunification boom in the early

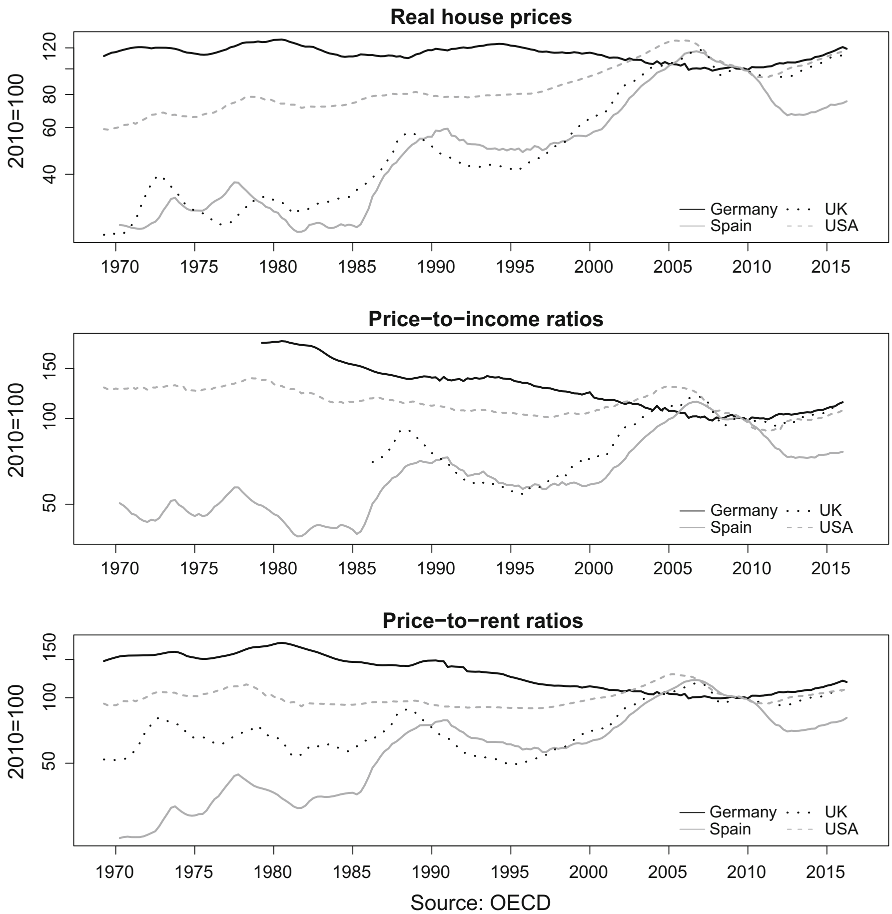

Fig. 1 Stylized facts on housing markets in major economies

1990s, when, especially in East Germany, price movements were not supported by economic fundamentals (Michelsen and Weiß 2010).

Stylized fact 2: Affordability above and risk taking below the level of the 1980s The moderate price development is also reflected in other indicators, like the price-to-rent and the price-to-income ratio, both of which were declining since the 1980s in Germany. Around 2010 these measures picked up again (see Fig. 1, middle and right panels). In most other countries, price-to-rent and price-to-income ratios were much more volatile. In historical comparison, the current level of these measures can still be rated as moderate in Germany. However, the recent increase in these ratios is quite strong, particularly that of the price-to-rent ratio, which indicates that investors are willing to take greater risks with real estate investment.

Stylized fact 3: Stable volume of new mortgage loans and high share of long-term fixed interest rates The third stylized fact shows that, in contrast to typical Anglo-

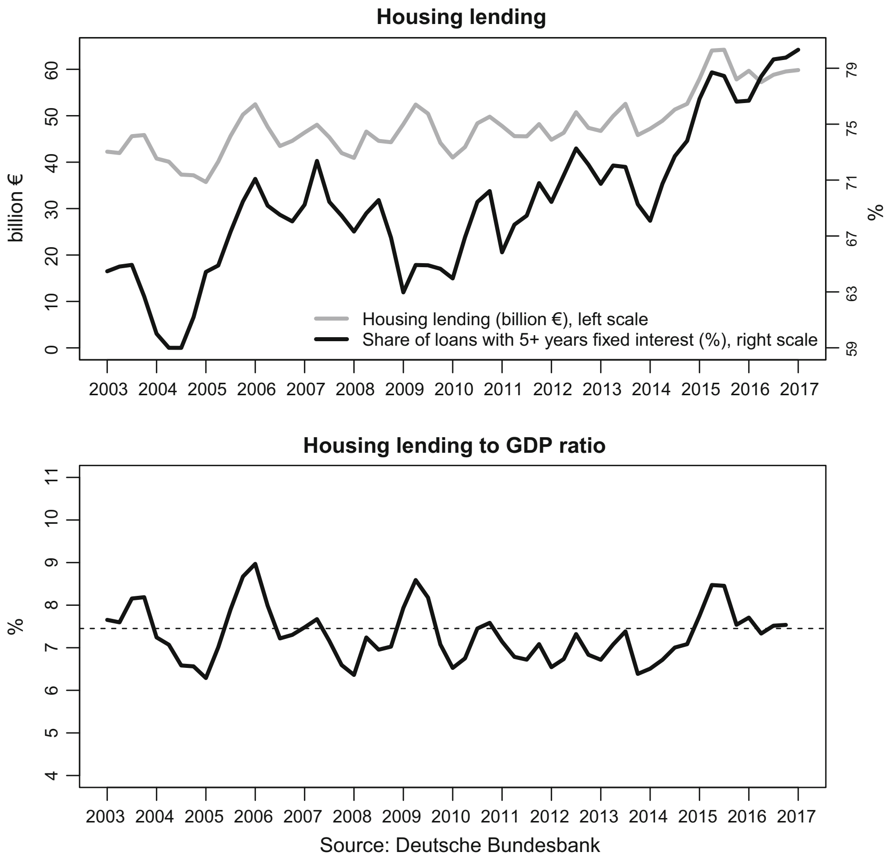

Fig. 2 Housing lending in Germany (new loans), 2003:q1-2016:q4

Saxon housing market developments, the current upswing of the German market is not associated with an increase in the volume of new credit to private households (see Fig. 2). Since 2011, new housing lending remained relatively stable around 16 billion euros per month. Moreover, the share of new contracts with long- and medium-term fixed interest rates is high and stable, as well.

Stylized fact 4: Declining cap rates and increasing risk premia Figure 3 shows the cap rates and implicit risk premia for newly built and second-hand apartments. [1] Compared to the first half of the 1990s—the period of the post-reunification boom—the cap rates have substantially increased for both market segments: newly built and second-hand apartments. Since 2009, the cap rates began to decline. However, as of 2013, they

[1] The ca rates are the initial yield of real estate investments. They are defined as the annual rental income divided by the per square meter price of the apartment. We calculated them based on the first principal components of the 127 German cities, as introduced in Sect. 4.2. The implicit risk premia are calculated as the spread between the cap rates and the yield of German 10-year treasury bonds.

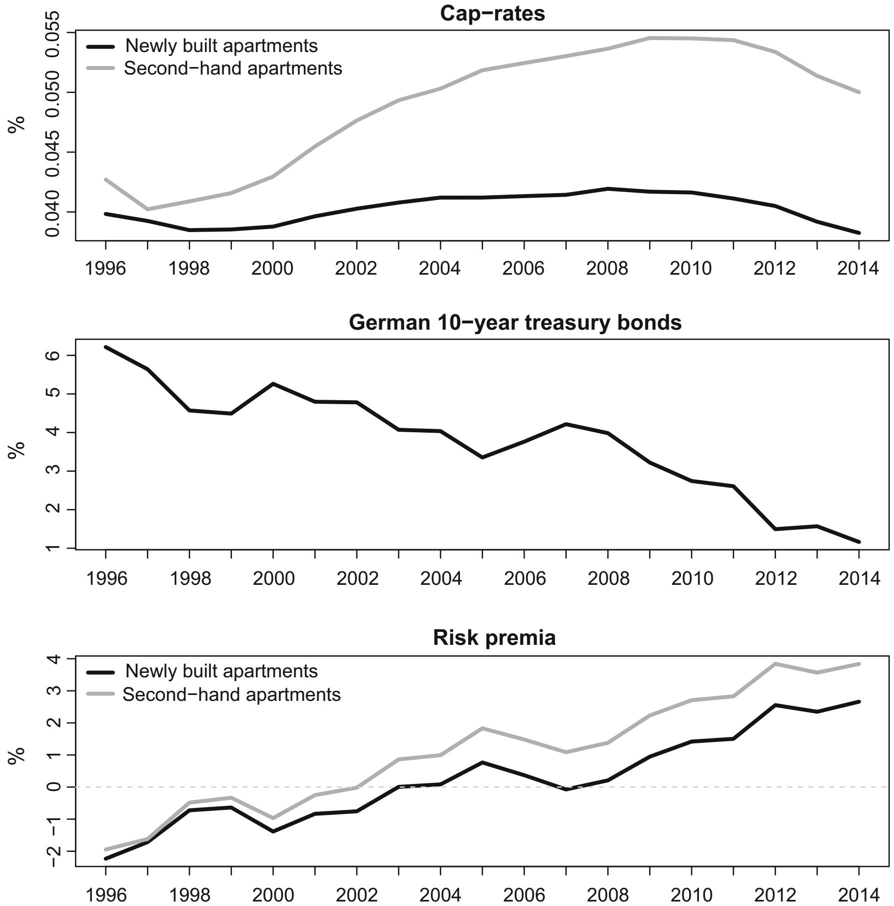

Fig. 3 Cap rates, yields of 10-year treasury bonds and implicit risk premia (all in %)

are still well above the levels observed in 1995. The opposite can be observed for the yields of the German ten-year treasury bonds (as a proxy for the risk-free interest rate). The yields declined from roughly 6% in 1996 to 1.5% in 2013. This has implications for the implicit risk premium of real estate investments: mostly driven by the decrease in the yields of the treasury bonds, implicit risk premia increased substantially over time and only dipped slightly downwards in 2013.

Overall, sound economic fundamentals seem to cover recent price increases on the national level. Nevertheless, these figures do not necessarily imply that recent house price movements are sustainable on the regional level.

3 A conceptional framework of bubbles in house prices

Economists are often blamed for ignoring the buildup of the speculative house price bubbles prior to the Great Recession and the subsequent harmful consequences for the world economy. There were plenty of signs of a misalignment between house prices and their fundamentals, like excessive lending to private households as well as sharply increasing prices and construction activity. Indeed, many studies published before 2007 found that house prices were not disconnected from their fundamentals (Himmelberg et al. 2005; Smith and Smith 2006; McCarthy and Peach 2004). In fairness, there were some studies warning about a potential house price bubble in major economies like the USA (Case and Shiller 2003; Belke and Wiedmann 2005; Fernández-Kranz and Hon 2006). Detecting a bubble ex ante, however, is not as straightforward as declaring past price movements to be unsustainable.

3.1 Theoretical concepts of price bubbles

There are several well-established theories that explain seemingly unsustainable developments by rational behavior of agents (Brunnermeier 2008; Brunnermeier and Oehmke 2012; Glaeser and Nathanson 2014). Brunnermeier and Oehmke (2012) provide a classification of the existing approaches to explaining the buildup of asset price bubbles. They distinguish between five types of theories.

The first explanation is the *rational bubbles* theory. It is argued that investors hold bubble assets since they expect the price of the asset to grow under the assumption that any investor in the future also expects asset price increases, even if the bubble may burst with a certain probability. Price increases then become self-fulfilling prophecies, which implies explosive growth of asset valuations (Blanchard and Watson 1982).

Second, *overlapping generations* models allow the existence of bubbles, because they can restore efficiency of an economy, which is inherently not Pareto optimal (Tirole 1985). The idea is that even fiat money—which has no intrinsic value—can have a positive price because it is a store of value. Storing value, and thus increasing the price of money, might be a rational option in situations of over-accumulation of private capital, i.e., when capital accumulation exceeds the "golden rule." Then, transferring capital to future generations and giving fiat money a positive price (which is then a bubble asset) can increase economic efficiency.

Third, the persistence of bubbles can be explained in the framework of the *informational frictions* theory. In this type of model, two sources of risk are introduced that encourage traders to invest in bubble assets. On the one hand, the fundamental risk arises from uncertainty of an unexpected jump of the fundamental value. In this case, investors who bet against a bubble lose money. On the other hand, risk-neutral traders, who are aware of the bubble, can still trade in order to benefit from speculative price increases, as long as they weigh the risk of a bursting bubble less than the chances of price increases; see Abreu and Brunnermeier (2003). In both cases, investors delay the bursting of the bubble and allow it to grow even larger.

Fourth, according to the *delegated investment* theory, most households delegate the management of their assets to the fund managers, who often are concerned only about short-run price movements (Shleifer and Vishny 1997) and may have incentives to buy overpriced assets (Allen and Gorton 1993).

Fifth, the theory of the *heterogeneous-beliefs bubbles* implies that investors, possibly due to psychological biases, have different beliefs about the future. These beliefs when combined—with short-sale constraints—can lead to overpricing when optimists push up prices, while pessimists are unable to counteract this (Miller 1977).

Regardless of the driving forces behind a bubble, house price bubbles can be defined as periods in which housing prices run well above their fundamental values, i.e., the development of rents. In addition, as pointed out by Brunnermeier and Oehmke (2012), asset values grow explosively during *speculative* bubble periods. While the notion "well above" is rather open to interpretation, an explosive house price growth can be formally tested using statistical methods.

3.2 Empirical approaches to detect speculative house price bubbles

There are three major approaches to empirically identify the existence of a speculative bubble in housing markets. The first approach detects the boom and bust periods in housing prices as deviations from some trend (e.g., moving average, Hodrick–Prescott trend, or as defined by the Harding and Pagan (2002) method). This literature is thoroughly discussed in Agnello and Schuknecht (2011). An earlier application of the approach to German data can be found in Dreger and Kholodilin (2013). The second approach identifies house price misalignments by comparing actual prices with a price that is estimated based on fundamental factors (Kajuth et al. 2013; Kholodilin and Ulbricht 2015).

Finally, the third approach relies upon statistical tests of the so-called explosive roots. Phillips et al. (2011) and Homm and Breitung (2012) develop empirical tests to identify unusually strong increases in asset prices. Caspi (2016) was one of the first to apply their approach by testing for speculative housing prices bubbles in Israel at national and regional levels between 1998 and 2013. The basic idea is to analyze the roots of an autoregressive process. If asset prices represent discounted expected incomes—in the housing context rental income—it is unlikely that prices grow at an exponential rate in the long run. Typically, this type of test is used to identify speculative price bubbles.

The empirical identification strategy of housing market bubbles in this context follows the ideas of the dynamic *Gordon growth model* (Gordon 1959). The original model was elaborated to describe the stock market. However, Campbell et al. (2009) suggest a housing market version. The underlying intuition is that house prices are fundamentally determined by future rents in the period of ownership and, moreover, by future asset price increases. Under the assumption of perfectly informed and rational agents, price increases are again solely determined by dividends earned in the period after the next sale.

In the real estate context, this implies that house prices are—in the long run—tied to the development of rents. Under the standard no arbitrage condition, the house price can thus be expressed as

$$P_t = \frac{E_t[P_{t+1} + R_{t+1}]}{1+i}, \tag{1}$$

where P is the real estate price, R denotes the rental income, t is the current time period, i the risk-free interest rate, and $E[\cdot]$ is the rational expectation, conditional on the information available (Homm and Breitung 2012). The fundamental price, P^{F}, can be determined by forward iteration of Eq. (1):

$$P_t^{\mathrm{F}} = \sum_{n=1}^{\infty} \frac{1}{(1+i)^n} E_t[R_{t+n}]. \tag{2}$$

However, there is a unique solution for Eq. (2) under the transversality condition

$$\lim_{k\to\infty} E_t\left[\frac{1}{(1+i)^k} P_{t+k}\right] = 0. \tag{3}$$

If the actual price process contains additional elements, like a bubble component B, the pricing equation becomes

$$P_t = \lim_{k\to\infty} E_t\left[\frac{1}{(1+i)^k}\cdot\left(\hat{P}_{t+k} + (1+i)^k B_t\right)\right] + P_t^{\mathrm{F}}. \tag{4}$$

In this case, there are infinitely many solutions. Today's house price can be decomposed in two elements—one covering the fundamental value, determined by future rental income and another that is related to potentially speculative motivations. In case of a bubble, any rational investors should expect the house price to increase at rate i. Because all rational investors expect other investors to pay a price $P_{t+1}^{\mathrm{F}} + B_{t+1}$, they are willing to pay $P_t^{\mathrm{F}} + B_t$ in period t.

The fundamental component in Eq. (4) cannot be observed. Hence, assumptions have to be made in order to characterize the time series properties of the fundamental price, P_t^{F}. One can impose a plausible assumption that housing rent, R_t, follows a random walk with drift:

$$R_t = \mu + R_{t-1} + u_t \tag{5}$$

where μ is the drift and u_t is a white noise process. Under this assumption the fundamental price can be expressed as

$$P_t^{\mathrm{F}} = \frac{1+i}{i^2}\mu + \frac{1}{i}R_t \tag{6}$$

where i is the risk-free rate (Homm and Breitung 2012).

As a result, if R_t follows a random walk with drift, so does the fundamental component of the housing price, P_t^{F}. This permits distinguishing the fundamental price from the speculative bubble that can be described as an explosive autoregressive process. Thus, a test procedure boils down to testing the null hypothesis of a random walk against the alternative of an explosive process. Among others, Caspi (2016), Kivedal (2013), as well as Clark and Coggin (2011) already implemented this idea in the housing context. In contrast to the Homm and Breitung (2012) and Phillips et al. (2011) tests, which are univariate procedures, the framework developed by Kivedal (2013) allows testing a theoretical model and, in particular, to consider interest rates as potential driver of house price dynamics.

4 Empirical setup

We follow the univariate approach proposed by Homm and Breitung (2012). We do so because we are particularly interested in the price dynamics on the regional level. Like Caspi (2016), we argue that in a real-time monitoring context of real estate bubbles, the regional level is the relevant dimension to examine. Housing is spatially fixed, and markets are regionally segmented. Thus, national time series are the least to reflect speculation in house prices. However, using regional time series comes at the cost that we cannot include market fundamentals directly, as these statistics are regularly published with a time lag of several years. This is particularly true for the determinants of demand and supply, like income, housing stock, and population. Other variables like interest rates are simply not available on the regional level. However, we indirectly consider demand and supply fundamentals, as we also analyze rents and test whether their development is in line with the surge of house prices. In contrast to Caspi (2016), we deal with prices and rents separately. We opted for this approach as being more appropriate in our context due to short sample time frame (see Sect. 4.2 for a detailed discussion).

Further, it can be expected that interest rates are the key driver of the recent price increases. However, it can be argued that the costs of borrowing money are spread quite evenly across the country (Reichert 1990). There should also be no differences in the returns of alternative investments, as stocks or bonds are traded on world markets and interest rates are determined by European monetary policy. *Ceteris paribus*, a global change in interest rates should enter investors' rationale (in terms of a lower internal discount rate) equally across markets. In this context, we follow Caspi (2016), who tests the real risk-free interest rate for explosiveness.

However, given the specific situation of very low interest rates, one can argue that price markups may also be driven by a change in investment motives: more explicitly, one can argue that different types of (international) investors enter the market, who are interested in investing in more liquid assets or are less informed about the specific investment opportunities. Therefore, they tend to invest in large metropolitan areas like Berlin, Hamburg, and Munich. This implies that the premium for liquidity and information changes, which might also serve as explanation for different house price dynamics (Krainer 2001). Particularly, this is a problem for the interpretation of our results in large and more liquid markets, where we cannot disentangle these effects. But, in turn, this allows for an even stronger interpretation of the results for smaller cities, where information is scarce and liquidity is lower.

Another intensively discussed aspect is the potential impact of option values on house price volatility.[2] It is consensus in the literature that real option values fluctuate and, thereby, increase the amplitude of the housing cycle. Clapp et al. (2013) added another important point to the debate: they demonstrate in a study on the Berlin housing market, that the option value is different in the various housing market seg-

[2] In a nutshell, the value of a real option describes investors willingness to pay to have the options to modify an existing building lot. In the land context, for example, undeveloped land contains a premium for the option to develop the site in the future, while this premium is lost in cases of already developed sites (for an overview, see Reuer and Tong (2007)).

ments. More specifically, they find that the option value is a function of the unrealized development potential. The authors present reasoning why house price fluctuations of detached homes might be different from dynamics in apartment buildings. In general, the amplifying effect of the option value on house prices appears to be less important in the rental (apartment) housing segment.

Consequently, we follow a multi-level test strategy: first, we concentrate on the apartment housing sector, to mitigate the potential bias of the option value. Second, we analyze whether an explosive behavior can be detected in national time series. If so, we evaluate the national series for rents and analyze if the dynamics of purchase prices were in line with that of market fundamentals. We replicate this procedure for four different market types, *A* to *D*, where *A* stands for the most important (hot) housing markets in Germany, while *D* markets are of local (cold) nature. In the final step, we analyze disaggregated data for 127 urban housing markets. In this context, we again argue that the likelihood of a speculative bubble is high if prices grew explosively, while rents did not. This result would be even strengthened for the case of explosive price dynamics in "cold" markets, while conclusions about the existence of a bubble are more ambiguous in large, more liquid markets.

4.1 House price data

The German data on house prices and rents, especially for individual cities, are quite poor (Hoffmann and Kurz 2002; Hoffmann and Lorenz 2006; Georgi and Barkow 2010). Typically, the data cover a short time period, cover a small number of locations, or reflect only advertised prices.

In the present analysis, we take advantage of a data set on prices and rents that is provided by real estate analysts of *BulwienGesa AG*. The company collected real estate data and constructing corresponding price indices for over 30 years, starting in the early 1970s.[3] A major shortcoming is that the time series are not grounded on micro-data of real transactions alone. Most information is collected from local experts, real estate brokers, advertisements, and real transactions. To some extent, the generation of these regional price time series lacks transparency. However, in absence of alternatives, these data are used by, among others, the Deutsche Bundesbank to examine the developments in the German real estate market. Furthermore, OECD utilizes the data to construct German-wide house price index for its international database.

The data set covers average prices and rents for 127 large German cities from 1990 through 2013. This makes it unique in terms of its geographical and temporal coverage, thus allowing us to tackle the main weaknesses of previous studies on the German housing market (see Sect. 1). In our analysis, we concentrate on the following four price series:

- average purchase price of newly built apartments;
- average purchase price of second-hand apartments;

[3] For more details, see Hampe and Wenzel (2011).

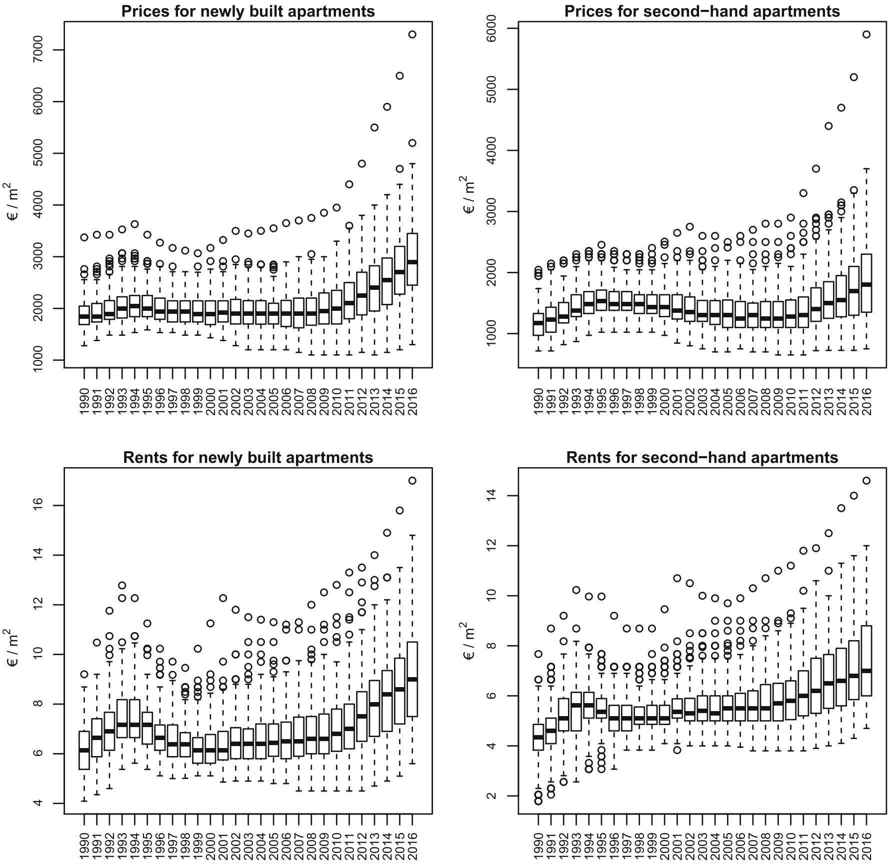

Fig. 4 Nominal house prices and rents in German cities, 1990–2016. *Note*: boxes denote the part of distribution between the 1st and the 3rd quartiles. Bold lines in the middle of boxes denote the median values. The lower (upper) whisker is defined as $Q_1 - 1.5 \times IQR$ ($Q_3 + 1.5 \times IQR$), where Q_1 is the first quartile, Q_3 is the third quartile, and $IQR = Q_3 - Q_1$ is the interquartile range. Finally, dots represent outliers

– average rent of newly built apartments; and
– average rent of second-hand apartments.

The dynamics of purchase prices and rents in all cities are depicted in box plots to characterize their distribution (Fig. 4). In both market segments, primary and secondary, prices increased strongly starting in 2010. To ensure that the tests applied indicate a bubble in the current upswing of house prices, we drop the observations from the early 1990s and start our analysis in 1996. Cities in the former GDR, in particular, experienced a boom in the years following reunification, which might bias our results.

Further, BulwienGesa data provide a rating of the locations in Germany, ranging from *A* to *D*, which became a standard classification for German real estate professionals. *A* stands for the most important German markets. Seven cities fall in category

Table 1 Characteristics of different market types

Variable	Market type			
	A	*B*	*C*	*D*
Population, million persons	1359.2	429.6	206.1	121.6
Population growth, %	2.4	1.5	1.6	0.5
Population density, persons/km^2	3027	1929	1473	1173
Number of cities	7	14	22	84
Growth of housing stock, %	1.8	1.7	3	1.7
Price for newly built housing growth, %	13.1	12	12.6	10.1
Price for second-hand housing growth, %	15.7	7.6	12.6	9.3
Rent for newly built housing growth, %	8.7	8.7	7.2	7.9
Rent for second-hand housing growth, %	7.7	5	6.9	7

A: Berlin, Cologne, Düsseldorf, Frankfurt, Hamburg, Munich, and Stuttgart. *A*—cities are characterized by international or at least national importance, high turnover of real estate transactions (annually $> 2.5\%$ of the market), and overall sound market conditions. According to BulwienGesa, 14 cities are rated *B*. *B*—markets are of national and regional importance and have an annual turnover of around 1.5% of the total market. *C*-rated markets (22 cities) are of regional importance and have less impact on national market development. Cities of category *D* (84) are predominantly local centers. Liquidity in *C* and *D* locations is significantly below *A* and *B* markets. The market types can be characterized by several key statistics reflecting demand and supply factors as well as evolution of prices and rents, see Table 1.

The cities in the four market types are clearly delineated by population. Indeed the *A*-rated cities are on average three times larger than the *B*-rated cities and more than ten times larger than their *D*-type counterparts. The *A*-rated cities are also characterized by the largest population growth: on average their population increases by 2.4% a year owing to the migration from the smaller cities and from abroad (Kholodilin 2017). This phenomenon has been observed since the beginning of the 2000s and was coined in Germany as "big cities renaissance," (Bundesinstitut für Bau- and Stadt- und Raumforschung 2011). The *A*-type cities offer much more employment and leisure opportunities, which make them so attractive. By contrast, the population growth in *D*-type cities is rather slow, at 0.5% a year. Despite large difference in population and, thus, demand growth, all the market types, with the exception of *C*-rated cities, have roughly the same growth of the housing stock (1.7–1.8% a year). This implies that the gap between housing supply and demand in the largest cities expands more quickly, thus driving housing prices and rents up. The difference is especially pronounced in case of the prices. The rental differential between different market types is less marked possibly due to the relatively strong rent controls in Germany.

4.2 Empirical tests

To test for explosive roots in the German house price and rent data, we apply the Chow-type unit root statistic. The test procedures are based on the time-varying AR(1) model

$$y_t = \rho_t y_{t-1} + u_t \tag{7}$$

where ρ_t is the time-varying autoregressive coefficient and u_t is a white noise process such that $E(u_t) = 0$, $E(u_t^2) = \sigma^2$, and $y_0 = c < \infty$. Notice that in order to simplify the exposition a possible constant in the autoregression is omitted. Therefore, before applying the test, the time series must be detrended by running an OLS regression on a constant and a linear time trend. In all tests carried out here, the test statistics are computed using the residuals of this regression instead of the original time series.

Under the null hypothesis y_t follows a random walk for all time periods:

$$H_0 : \rho_t = 1 \text{ for } t = 1, 2 \ldots, T \tag{8}$$

Under the alternative hypothesis the process starts as a random walk but changes to an explosive process at an unknown time $[\tau^* T]$:

$$\rho_t = \begin{cases} 1, \text{ for } t = 1, \ldots, [\tau^* T] \\ \rho^* > 1, \text{ for } t = [\tau^* T] + 1, \ldots, T \end{cases} \tag{9}$$

where $\tau^* \in (0, 1)$ and $[\tau^* T]$ denotes the greatest integer smaller than or equal to $\tau^* T$.

To test these hypotheses, we employ a Chow-type unit root statistic for a structural break that incorporates the information that y_t is a random walk for $t = 1, 2, \ldots, [\tau^* T]$ under both H_0 and H_1. Under the assumption that $\rho_t = 1$ for $t = 1, 2, \ldots, [\tau^* T]$ and $\rho_t - 1 = \delta > 0$ for $t = [\tau^* T] + 1, \ldots, T$, the model can be written as

$$\Delta y_t = \delta y_{t-1} \mathbb{I}_{\{t > [\tau T]\}} + u_t \tag{10}$$

where $\mathbb{I}_{\{.\}}$ is an indicator function that equals 1, when the condition in curly brackets is met, and equals 0, otherwise. Consequently, the null hypothesis is H_0: $\delta = 0$, which is tested against the alternative hypothesis H_1: $\delta > 0$. The regression t-statistic for this null hypothesis is defined as

$$DFC_\tau = \frac{\sum_{t=[\tau T]+1}^{T} \Delta y_t y_{t-1}}{\tilde{\sigma}_\tau \sqrt{\sum_{t=[\tau T]+1}^{T} y_t^2}} \tag{11}$$

where

$$\tilde{\sigma}_\tau = \frac{1}{T-2} \sum_{t=2}^{T} \left(\Delta y_t - \hat{\delta}_\tau y_{t-1} \mathbb{I}_{\{t > [\tau T]\}} \right)^2 \tag{12}$$

and $\hat{\delta}_\tau$ denotes the OLS estimator of δ in Eq. (10). The Chow-type Dickey–Fuller statistic to test for a change from I(1) to explosive in the interval $\tau \in [0, 1 - \tau_0]$ can be written as

$$\sup DFC(\tau_0) = \sup_{\tau \in [0, 1-\tau_0]} DFC_\tau \tag{13}$$

The test rejects the null hypothesis of random walk for large values of $\sup DFC(\tau_0)$.

Before analyzing the data on the city level, we extract the first principal components of the price and rent series and then test for explosive roots. The reason for this is twofold. Firstly, city-specific trends in rents and prices are heterogeneous and simply calculating the mean for all cities would potentially lead to biased results from outliers. The principal component should be smoother due to canceling out of these fluctuations. Secondly, the first principal component can be interpreted as a countrywide house price trend. Provided that a speculative bubble will be discovered, it can be treated as a house price bubble at the national level. The resulting factor loadings can be interpreted as contributions of each city to the national bubble. We replicate this procedure for each market type, as described in Sect. 4.1. This provides further insights for the existence of speculative bubbles.

Next, we develop a panel-data version of the Chow-type test for explosive roots. The panel data allow for exploiting the cross-sectional dimension, given a very short time dimension of our data. Here, we examine a null hypothesis of no explosive roots in any of the city-level housing markets. Finally, we investigate each price series on the city level separately. The rejection of the null is a minimum condition for the existence of a bubble in the German housing market.

Given the very short sample of house prices in German cities, we need to investigate the size and power of the test when applied to very short samples. In order to do this, we carry out simulations using a framework suggested by Homm and Breitung (2012). We generate an AR(1) process defined as in Eq. (7) with a time-varying autoregressive parameter defined in Eq. (9). Thus, this process models a single deterministic bubble that occurs after time $[\tau^* T]$.

Simulations were conducted for various values of ρ^*, τ^*, and T. We considered the following values of the autoregressive parameter $\rho^* \in [1.03, 1.05]$ and the time fraction $\tau^* \in [0.7, 0.8, 0.9]$ that most resemble the German case, given that the price increase started in 2010, that is, in 0.875-th fraction of the sample. Only one value of sample length was used, namely $T = 20$, which corresponds to a real-life situation where only 20 years of observations are available. The number of replications is 2000. We used the test statistic that turned out to be the best, according to Homm and Breitung (2012): the Chow-type unit root statistic for a structural break.[4]

Simulation results for Chow test are reported in Table 2. The empirical power of the test is very low. The break dates are imprecisely detected. The good news is a relatively low size of the test. Thus, if the test would reject the null hypothesis of no speculative bubble, its results would be considered as relatively robust.

It should be stressed that, unlike Caspi (2016) and other papers, we do not test for explosiveness in the price-to-rent ratios. Rather, we test price and rent series separately. The reason is that under the null hypothesis, both rents and prices are I(0) and cointegrated. This implies that under the null their ratio should be I(0). Thus, the application of Homm–Breitung test to the ratio potentially leads to an under-rejection of the null hypothesis. In our case, where the sample size is short, this would exacerbate the already low power of the test. However, testing rent and price series separately is only applicable in those cases where the null of a unit root is not rejected for the price–rent

[4] All the computations in this paper are carried out using the codes written by the authors in the statistical programming language **R** (R Core Team 2013). These codes are available upon request.

Table 2 Chow test: empirical size, power, and estimated break dates for $T = 20$

Autoregressive parameter, ρ^*	Break point, τ^*	Size and power	Break date	
			Mean	St. dev.
Size		0.059		
1.02	0.7	0.088	0.649	0.261
	0.8	0.076	0.656	0.262
	0.9	0.082	0.668	0.263
1.05	0.7	0.144	0.664	0.251
	0.8	0.129	0.680	0.246
	0.9	0.109	0.683	0.257

ratio. Augmented Dickey–Fuller (ADF) tests reveal that a unit root cannot be rejected for most of the cities analyzed: the test fails to reject the null for price-to-rent ratios of second-hand dwellings in 102 cities and price-to-rent ratios for newly built dwellings in 108 cities.[5]

To our knowledge, this paper is the first to apply a panel version of the Chow-type explosive root test. Its test statistic is computed as the mean of the city-specific Chow-type test statistics. The critical values for this test were obtained using bootstrap as follows:

1. Growth rates or differences of logarithms of the original price time series were computed: $\Delta y_{it} = y_{it} - y_{i,t-1}$.
2. The growth rates were collected in a vector $\Delta y_t = (\Delta y_{1t}, \Delta y_{2t}, \ldots, \Delta y_{Nt})$.
3. Out of this vector the values were drawn with replacement: Δy^*_{it}.
4. Simulated series were generated using the bootstrapped growth rates: $y^*_{it} = y_{i1} + \Delta y^*_{i2} + \cdots + \Delta y^*_{it}$. The number of simulations was set to 1000.
5. The Chow-type tests for explosive roots were carried out for each city and then the panel test statistic was computed as the mean of the city-specific test statistics: $\overline{\tau}^{DFC} = \frac{1}{N}\sum_{i=1}^{N} \tau_i^{DFC}$, where τ_i^{DFC} is the Chow-type test statistic for city i.
6. Based on the distribution of the mean test statistics, critical values were computed as 90th, 95th, and 99th percentiles.

4.3 Results

Following our test strategy, we examine the data on rents and prices on a national, on a market type, and on a city level. We distinguish between the market segments of newly built and second-hand markets, and we test for explosiveness in the risk-free interest rate.

[5] Test results are available on request.

Table 3 Chow-type test for principal components

Series	Test statistic	Bootstrapped critical values		
		10%	5%	1%
Price newly built apartments	4.87***	2.52	3.03	4.19
Price second-hand apartments	− 0.46	2.12	2.43	3.08
Rents newly built apartments	3.98**	2.83	3.27	4.03
Rents second-hand apartments	3.47	4.10	4.60	5.46

*, **, *** indicate significance at the 10, 5, 1% level, respectively

4.3.1 The national level

We first examine whether explosive roots can be detected in the first principal components of rents and price time series of all cities in our sample. The principal components can be interpreted as national trends.

Table 3 shows the Chow test statistics as well as the 1, 5, and 10% bootstrapped critical values for each of the 4 principal components. The bootstrapped critical values exceed simulated critical values at the 1 and 5% level of 2.6285 and 1.9327, respectively, presented in Table 4.3 in Homm and Breitung (2012). Thus, the former are more conservative than the latter. The null hypothesis can be rejected at the 1% level for prices of newly built apartments and at the 5% level for rents of newly built apartments. In our interpretation of the test, this implies that recent house prices increases are well covered by a corresponding development of market fundamentals, i.e., rents. We cannot reject the null for both series of second-hand apartments. On the national level, no signs of a bubble can be detected in this market segment.

4.3.2 Market types

We replicate the analysis of the first principal components for each of the four different market types (*A* through *D*-rated markets).

Figure 5 shows the first principal components[6] of the prices/rents of newly built and second-hand apartments by market segments. The first principal components reflect the current house price cycle quite reasonable. They follow a downward trend from 1996 to 2005. Since 2008, the principal components have grown, largely overcompensating for the preceding downward trend. Starting before 2000, the first principal components of the rents follow an upward trend, which has accelerated since 2010. However, for second-hand apartments, the increase slowed down a little in 2013.

Table 4 shows the test statistics and bootstrapped critical values for the market segment of newly built apartments. In line with the results on the national time series, the tests by market types indicate that all price series of the four market types contain

[6] The share of variance accounted for by the first principal component ranges from roughly 45 to 70% for newly built apartments and approximately one-third to two-thirds for second-hand apartments.

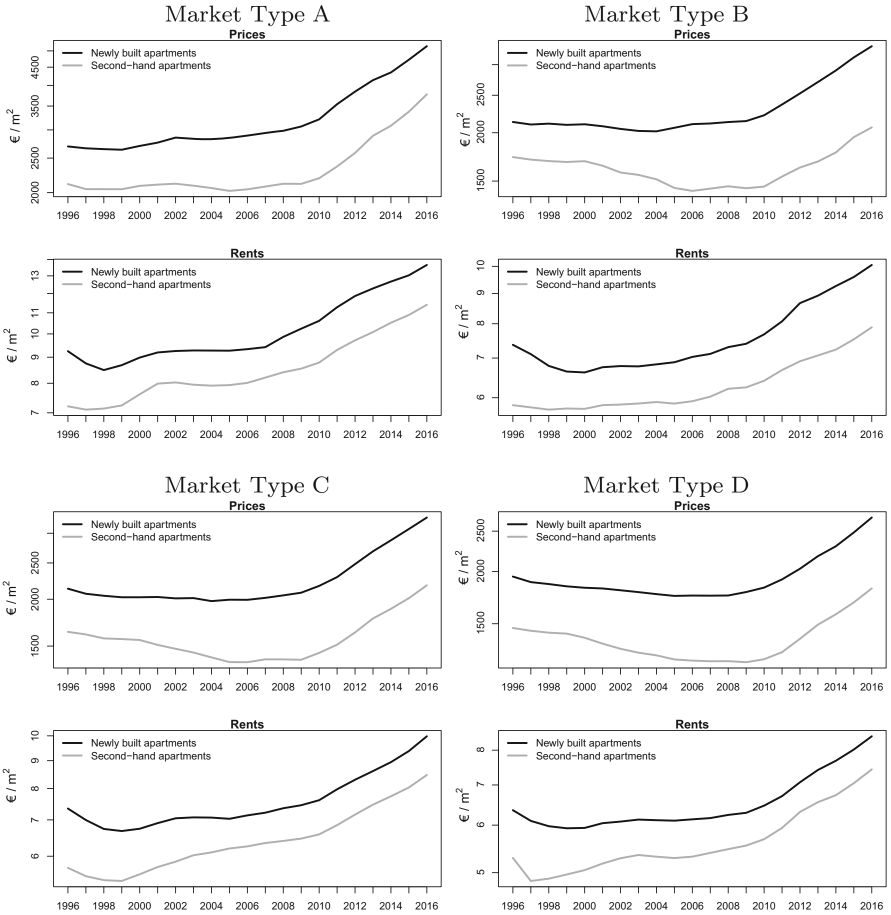

Fig. 5 Prices and rents of different market types in euros per square meter

explosive roots. However, as we also find these explosive roots in the rents data, we conclude that the post-2010 surge in house prices is well covered by fundamentals on this level of aggregation.

In Table 5, the results for the second-hand market are presented. In contrast to the findings on the national level, we find explosive roots in prices for second-hand apartments in A and C-markets. While the development in A markets is covered by a corresponding increase in rents, this is not the case in C-rated markets. In our interpretation, this indicates that prices have decoupled from fundamentals. On the other hand, we find an explosive root in the rent series for B-rated cities, while prices did not grow explosively. Here, there seems to be space for additional price increases. Overall, as on the national level, the more disaggregated results for different market types indicate that for most markets, price developments align quite well with fundamentals.

Table 4 Chow-type test for principal components of newly built apartments by market types

Market type	Series	Test statistic	Bootstrapped critical values		
			10%	5%	1%
A	Price	7.640***	3.423	3.898	4.853
	Rents	3.603*	3.420	3.889	4.872
B	Price	5.505***	2.744	3.175	4.089
	Rents	2.729*	2.701	3.129	3.960
C	Price	4.807***	2.643	3.120	4.189
	Rents	3.220*	2.999	3.494	4.523
D	Price	4.063***	2.382	2.823	3.924
	Rents	4.281***	2.694	3.091	3.915

*, **, *** indicate significance at the 10, 5, 1% level, respectively

Table 5 Chow-type test for principal components of second-hand apartments by market types

Market type	Series	Test statistic	Bootstrapped critical values		
			10%	5%	1%
A	Price	7.417***	2.801	3.333	4.628
	Rent	4.375**	3.867	4.270	5.272
B	Price	−0.444	1.868	2.200	2.981
	Rent	4.912***	3.408	3.818	4.757
C	Price	2.596**	1.977	2.319	3.015
	Rent	3.542	3.862	4.386	5.410
D	Price	−0.482	1.996	2.440	3.313
	Rent	2.116	3.776	4.322	5.278

*, **, *** indicate significance at the 10, 5, 1% level, respectively

4.3.3 The city level

In the third step, we examine the prices at the city level. We first test for explosive roots in each individual time series separately and then perform a panel version of the Chow-type test. In the case of newly built apartments, the null hypothesis can be rejected for 61 cities. This is also the case for second-hand dwellings in 19 cities. However, we also detect explosive roots in rents for newly built and second-hand apartments in several cities. For new dwellings, this is the case in 35 cities, while for second-hand apartments in 32 cities explosive price increases can be observed.

However, speculation is the likely driver of house price dynamics in only some of these markets. Figure 6 shows the geographical distribution of cities where explosive roots are found in prices, while no explosive roots can be detected in the corresponding rent series. Circles represent the segment of newly built apartments, while crosses stand for explosive roots in second-hand dwellings. There are no cities where both markets would be affected. Our results indicate that in about one-fourth of the sample (28

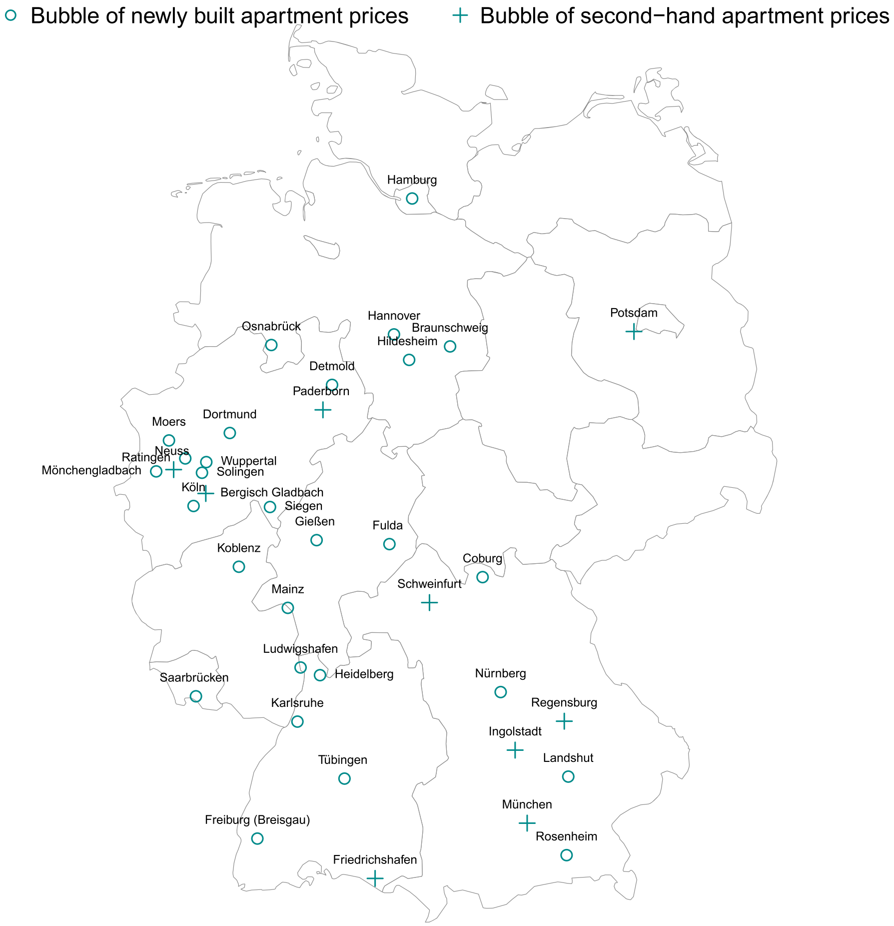

Fig. 6 Geographical distribution of bubbles

cities) prices of new apartments appear to be decoupled from demand fundamentals. Interestingly, this is the case in only two of the top locations in Germany, Hamburg, and Cologne, and four of the B-rated markets. Bubbles are mostly detected in small- to medium-sized cities, some of them having a prosperous university. In C and D markets, liquidity is much lower. In this case, we conclude that the likelihood of a speculative bubble is quite high, while we cannot draw such strong conclusion for A and B-rated markets. As outlined in Sect. 3, here we cannot distinguish between speculative motives and the potential effect of a higher liquidity premium.

Explosive roots, which are not reflected in rents, are contained in the prices of only nine cities. With the exception of Potsdam, the cities are spread relatively uniformly over West Germany. Only one city of the German top locations, Munich, is affected. The others are all C or even D-rated, which again suggests that in these locations speculative motives dominate investors' rationale. Overall, the signs for speculation in the second-hand market are weak (Table 6).

Table 6 Markets containing explosive roots in prices that are not covered by demand fundamentals

	Market type	Newly built apartments	Second-hand apartments
Liquid markets	*A*	2	1
	B	4	0
Less liquid markets	*C*	8	2
	D	14	6
Total		28	9

Table 7 Panel Chow-type test

Series	Test statistic	Bootstrapped critical values		
		10%	5%	1%
Prices for newly built apartments	2.64	1.92	1.95	2.02
Prices for second-hand apartments	1.00	1.81	1.85	1.89
Rents for newly built apartments	1.71	1.77	1.80	1.86
Rents for second-hand apartments	1.82	2.12	2.17	2.26

This is also confirmed by the panel Chow-type test. The results are presented in Table 7. The mean test statistic exceeds the 1% critical values in the case of newly built apartments. Thus, the null hypothesis of no city having a speculative bubble can be rejected in favor of the alternative that some cities have speculative bubbles in this market segment. For prices of second-hand apartments, rents of newly built and second-hand dwellings the null hypothesis cannot be rejected.

Overall, the results provide mixed evidence. Some results indicate the existence of speculative bubbles, while other tests reject speculation. On the national level, the recent surge of house prices appears to be covered by demand fundamentals. Largely, this applies also for the results on the market type level. The panel tests indicate that, in some cities, prices in newly built apartments might be driven by speculative motives. However, the null hypothesis of no city containing a speculative bubble cannot be rejected in second-hand markets. On the city level, we find explosive roots in house prices in about half of the sample. It is only in one-fourth of the cities analyzed that prices appear to be decoupled from demand. Here, we distinguish between liquid and less liquid markets. We argue that in less liquid markets, the likelihood of speculation is much higher than in liquid markets. In this context, we find that many of the detected explosive roots can be found in *C* and *D*-rated cities. We interpret this as first indication for speculative behavior of investors. The good news is that explosive roots are only detected in the segment of newly built apartments, which represents only a tiny share of the total market.

4.3.4 Interest rates

Following Caspi (2016), we also computed and tested a German real risk-free interest rate for explosiveness. This is calculated as a difference between the EONIA 1-year rate [7] and a measure of expected inflation. The latter was obtained based on the data of the monthly survey forecasts. For the period 1989–2010 (2010–2014) we use surveys of professional forecasters collected by Consensus Economics (Focus Economics).[8] Each monthly survey contains the forecasts of the inflation rate for the current year, $y^{i,\tau}_{t+k|t}$, and for the next year, $y^{i,\tau}_{t+k+12|t}$, where $k = 1, 2 \ldots, 11$ is the forecast horizon, and i, t, and τ indicate an individual forecaster, the year, and the month of year t when forecasts are issued, respectively. Thus, these are fixed-event forecasts. In order to recompute them into fixed-horizon forecasts serving as a measure of inflation expected within the next 12 months we use the following formula:

$$\Delta y^{i,\tau}_{t+12|t} = \frac{13-k}{12} y^{i,\tau}_{t+k|t} + \frac{k-1}{12} y^{i,\tau}_{t+k+12|t}, \tag{14}$$

Thus, the real risk-free interest rate is defined as:

$$i^{\mathrm{R}}_t = i_t - y^{i,\tau}_{t+12|t} \tag{15}$$

where i_t is the 1-year EONIA rate.

For the sake of robustness, four alternative rates were considered: (1) Yields, derived from the term structure of interest rates, on listed Federal securities with annual coupon payments / residual maturity of 10 years (10-year German Federal securities yields); (2) ECB's deposit facility rate; (3) ECB's marginal lending facility rate; and (4) ECB interest rates for main refinancing operations.[9] All these variables were price-adjusted using the same expected inflation indicator as for the risk-free rate. The real rates were then tested for explosive roots using the Chow-type test with bootstrapped critical values, see Table 8.

According to these tests, the null hypothesis of unit root cannot be rejected, even at a 10% significance level, for any of the rates, including the real risk-free rate. Thus, no evidence of explosive behavior can be found for these rates.

5 Conclusions

There is an intense debate about the surging house prices in Germany. Following the 2008 financial crisis, interest rates fell to historically low levels and alternative assets lost their attractiveness. Coupled with increased migration toward metropolitan regions, this led to strong house price increases in urban areas. However, there might be an unexplained, potentially speculative component, which could threaten not just financial stability, but also the entire economy.

[7] EONIA stands for the Euro OverNight Index Average, which is a weighted average of all overnight unsecured lending transactions in the interbank market in euros. It was used because, unlike the Bank of Israel, the European Central Bank does not have a 1-year interest rate.

[8] http://www.consensuseconomics.com/, http://www.focus-economics.com/.

[9] The time series cover the period between January 1999 and December 2015 and were taken from the Deutsche Bundesbank database .

Table 8 Explosive root tests for various real interest rates/yields

Variable	Test statistic	Critical values		
		10%	5%	1%
1-Year EONIA rate (real risk-free rate)	1.240	2.265	2.658	3.354
10-Year German Federal securities yields	1.247	2.284	2.667	3.351
ECB's deposit facility rate	0.940	2.350	2.753	3.466
ECB's marginal lending facility rate	1.709	2.597	3.003	3.748
ECB interest rates for main refinancing operations	1.437	2.524	2.870	3.623

This paper aims to propose a concept for the identification of potentially non-sustainable house price movements on a regional level. Therefore, we refined existing tests for speculative house price bubbles and applied them to data from 127 large German cities covering the 1996 through 2013 period. To test for the existence of bubbles, we performed a Chow-type unit root test for each city separately in a panel context and for the national trend represented by the first principal component. Based on this analysis, we draw the following conclusions.

First, at the national level, our results do not indicate the existence of a speculative bubble in apartment prices. While we detect explosive behavior in the first principal component of newly built apartment prices, these movements appear to be covered by rent development, which is also of an explosive nature. This result is also covered by macroeconomic variables. The volume of new housing loans is relatively stable, with price-to-rent and price-to-income ratios still below their historical averages. Moreover, risk premiums and cap rates are already declining, but still well above the level observed in the early 1990s.

Second, we find explosive roots in about half of the cities analyzed. More precisely, the prices of newly built apartments increase at an accelerated pace in 61 cities, while for second-hand apartments this is only the case in 19 cities. However, also rents increase explosively in 36 cities for newly built and in 31 cities for second-hand apartments.

Third, our results suggest that prices decouple from their demand fundamentals in some urban areas. In total there are 37 cities that are potentially affected by a speculative bubble, mostly in West Germany and mostly in the segment of newly built apartments. The robust panel explosive root test only confirms the existence of a bubble in prices for newly built apartments (in at least one German city).

Finally, speculation is likely to be an investment motive in small- to medium-sized markets. Potential bubbles are detected in 30 out of 37 C or D-rated cities.

While we find first evidence for speculative bubbles in selected urban markets, our results indicate that the overall German housing market still appears to be in a good condition. In the majority, only the small market segment of newly built apartments is affected by potentially speculative investment behavior. Indeed, the housing built in 2013 made up just 0.5% of the total housing stock. When accumulated over the period

2009–2013, the newly built housing makes up only 2.2% of the housing stock in 2013. In addition, due to the relatively small size of the segment, it can be characterized by a higher price and rent volatility. Moreover, in Germany the rents for new housing are free from rent controls. This to some extent may explain the explosive behavior of prices and rents for newly built housing.

Our results are largely in line with the assessment of most housing market analysts who find that the German housing market is quite stable. However, while most discussants argue that there is no need to worry at all, we conclude that decision makers are well advised to keep a close eye on the housing market and to track regional market developments. While it is true that, unlike in Spain or the USA, the boom in the German housing market is not credit driven on aggregate, this does not necessarily mean that housing lending on the regional level has not increased substantially. This might also apply to other regional level indicators.

However, the present study has two major limitations that should be subject to future research. First, as outlined in the description of the house price series analyzed, reliable transaction data for Germany are very hard to find. For the purpose of this analysis, we needed time series that cover a sufficiently long period and, moreover, a wide range of regions. To our knowledge, the only data meeting these criteria for Germany are that of BulwienGesa AG. This comes at the cost of transparency. BulwienGesa data strongly rely on experts' assessment of housing market developments rather than being based on real transactions. In absence of alternatives, these data are also used, for example, by the Deutsche Bundesbank. However, to further validate the findings of this study, it is desirable to replicate the analysis based on alternative information. Second, the results are restricted to the apartment housing segment. Nothing can be said about detached, mostly owner occupied, buildings. In this context, a deeper analysis is also desirable.

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