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# Assessing Housing Price Bubbles through an Affordability and Profitability Ratio Analysis. The case of Greek Residential Market

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**Abstract**

This research paper investigates housing price bubbles within the context of the residential real estate market in Greece, employing alternative analytical techniques and presenting novel econometric-based findings. The study concentrates on the temporal span from the first quarter of 1997 to the third quarter of 2022. Affordability and profitability indicators are employed to identify and evaluate episodes of either under- or overvaluation. Valuation is assessed by measuring the deviation of the price-to-rent ratio from its long-term average and trend, revealing an overvaluation of approximately 20% since the second quarter of 2019. Furthermore, the time-series properties of the dataset are subjected to rigorous econometric analysis, and specific housing-related hypotheses are empirically tested. Cointegration analysis yields varying implications for valuation depending on the chosen methodology and metric; nevertheless, the results collectively point to an overvaluation in terms of the price-to-income ratio. Moreover, among the four Right-Tailed Augmented Dickey-Fuller techniques employed, the Supremum Augmented Dickey-Fuller method identifies the presence of housing bubbles concerning the price-to-rent ratio. These bubbles are precisely dated using the Generalized Supremum Augmented Dickey-Fuller technique. The robustness of these findings is verified through the application of the Hodrick-Prescott Filter to real house prices. Remarkably, the most recent housing bubble episode, out of the four detected, persists until the final quarter of the sample period (2022Q3). This observation raises significant questions regarding its potential impact on the broader economy and necessitates a discussion on appropriate policy measures that should be considered.

**Keywords:** Housing price bubble, affordability and profitability ratio analysis, Right-tailed augmented Dicky-Fuller Statistics, Hodrick – Prescott Filter, Valuation, Greece

## 1. Introduction

The residential housing market's pivotal role in the economy is underscored by the significant dependence of banks' balance sheets on mortgage loans for property acquisitions, with the potential impact of house price shifts on loan collateral values. Additionally, any corrections in house prices are closely intertwined with consumption patterns, given that a substantial portion of households' income is allocated to housing expenses. For the majority of households, their principal residence constitutes their most significant asset, rendering household wealth highly reliant on house prices. Furthermore, dramatic shifts in house prices may discourage investments in the construction sector, introducing uncertainty and risk for potential investors.

The unprecedented decline in global house prices following the global financial crisis (GFC), triggered by the housing bubble in the United States, prompted extensive research into the determinants of house prices. Once the underlying fundamentals were established, the focus shifted to assessing whether real house prices exceeded their fundamental values, indicative of a housing bubble. The detection of housing bubbles gained increased significance following the dramatic decline in housing prices in countries affected by the GFC. Notably, the assessment of systemic risk by European authorities was elevated in response to the potential impact of house price reversals on financial stability.

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Within the European Union, Greece stands out with the highest percentage (37%) of income spent on housing by households without property ownership, reaching 40% for urban households, which is the highest among European countries. Over the period of this study from 1997 to 2022, house prices in Greece consistently rose for a decade (1997-2007), followed by a tapering in 2008 when the GFC hit Greece. Subsequently, Greece experienced uninterrupted decline in house prices until 2017, with prices even falling below their historical average in 2012. The cumulative drop in housing prices was approximately 60%, followed by a notable rebound of about 30%, bringing house prices back in line with their long-term average by 2022. For a comprehensive overview of house price evolution in Greece during this period, see Figure 1.

While some studies have explored the drivers of house price formation in Greece, the investigation of the presence of price bubbles in the Greek residential market has been notably absent in the literature. This study represents the inaugural attempt to employ econometric methods exclusively within the context of Greece to detect housing bubbles. It achieves this by examining house prices and fundamental housing-related ratios, specifically the price-to-income and price-to-rent ratios, in order to identify periods of overvaluation or potential bubble episodes over a sample period spanning more than two decades, concluding in 2022Q3.

Among the various definitions of housing bubbles, one general and simple characterization suggests that a bubble arises from homebuyers' unrealistic expectations regarding future house values. In essence, homebuyers believe they can resell their properties at higher prices in the future. Another simple yet more specific definition identifies housing bubbles as significant increases in housing prices followed by substantial declines. A common practice to assess the presence of a bubble involves comparing housing prices to incomes and rents, with deviations from long-run averages in the price-to-income and price-to-rent ratios potentially indicating a housing bubble. Additionally, scrutinizing the time series properties of these ratios through stationarity, integration, and cointegration tests can provide valuable insights into the presence of a housing bubble.

To investigate the presence of a housing bubble in the Greek residential market, this study employs econometric techniques consistent with previous empirical studies conducted in economies outside of Greece. Quarterly data on housing-related variables from 1997 to 2022 are analyzed to shed light on potential price bubbles. Multiple methods are employed, including comparing housing-related ratios (price-to-income, price-to-rent) to their long-run averages and trends, as well as examining the "user cost" of housing. Furthermore, the time series properties of these ratios are subjected to econometric analysis, forming hypotheses, and conducting tests for stationarity, integration, and cointegration to determine the existence of housing bubbles in the Greek market. To enhance the robustness of implications regarding overvaluation during the study period, alternative econometric procedures are employed. This includes the use of the commonly applied Augmented Dickey-Fuller and Johansen tests, as well as the application of right-tailed Dickey-Fuller techniques to detect and date-stamp housing bubbles in the Greek residential market. Finally, the Hodrick-Prescott Filter method is utilized for a robustness check.

The remainder of the study is organized as follows. Section 2 summarizes relevant methodological issues on the topic and the respective findings, through a brief presentation of selected empirical studies. In section 3preliminary evidence of house price bubbles in Greek residential market is discussed, on the basis of the development of the house prices and the fundamental housing-related ratios. The econometric procedures, adopted for the needs of the residential market's valuation and the date-stamping of the claimed bubbles, including the robustness check, are described in section 4 whereas the main findings are analyzed. A final section concludes the study.

## 2. Previous research on house price bubbles

As noted above, there are no previous econometric-based single-country studies focusing on bubbles in the Greek residential market. Nevertheless, in the multi-country context, the literature on the topic is quite rich. The recent study of Laura et al. (2023)shed light on the risks in European housing markets, including the Greek one. The authors used a cointegration approach, relating house prices to fundamentals. Utilizing data on price-to-income and price-to-rent ratio, the estimates indicated an overvaluation of housing markets across Europe in 2022, reaching 20% percent in most countries. Though overall interesting, the study does not further focus on the Greek residential market.

Assessing house prices by utilizing the historical averages of price-to-income or price-to-rent ratios is a common practice for policy makers, as well. See the analysis of Philiponnet and Turrini (2017) at the European Commission and Igan and Loungani (2012) at the International Monetary Fund.

Greek property market is included in the sample of markets analyzed in the Financial Stability Review of the European Central Bank for the year 2015 (ECB, 2015). The findings of the model-based valuation metric employed, are indicative of the deviation of the property values from their long-term average, implying hence the presence of a bubble.

In this vein, the respective 2011 Financial Stability Review (ECB, 2011) examined whether fundamentals could fully explain house price levels in selected European countries (not including Greece), focusing on the evolution of the price-to-rent ratio. Based on the hypothesis that the return on a housing investment is equal to the returns on alternative investment opportunities bearing the same risk, a simplified static dividend discount model were developed in the toolbox of the above Review. The findings regarding the reported ranges for the year 2010 showed an average overvaluation between around 10% and 30%. As far as Greece is concerned, the bubble hypothesis has been also examined by Engsted et al. (2016)in an econometric analysis of bubbles in the housing markets of 18 countries - members of the Organization for Economic Cooperation and Development (OECD), for the period from 1970 to 2013. The researchers found evidence of explosiveness, supporting, thus, the bubble hypothesis in many housing markets, including Greece (Q32011 - Q32013).

In an earlier study, Gomez-Gonzalez et al. (2018) dealt with the spread of housing bubbles among 20 OECD economies during the period 1970 - 2015. The authors utilized the Augmented Dickey Fuller(ADF) unit root test for the multiple recursive regression while they further used the Generalized Supremum ADF (GSADF) to detect the origin of bubble(s). According to their findings, one bubble had origin in the US housing bubble preceding the subprime crisis whereas, as far as Greece is concerned, bubbles encountered during the late 1990s and early 2000s.The methodology of the recursive right-tailed unit root tests, adopted by most recent studies for the detection of price bubbles, have been proposed by Phillips et al.(2015). Similarly, Vogiazas and Alexiou (2017) detected price bubbles in the housing markets of seven OECD countries, during the period 2002 – 2015and they further examined the relation of property prices with the business cycle while Pavlidis et al. (2016) proposed a novel extension of the above methodology in order to exploit the large cross-sectional dimension of the dataset they utilized. Focusing on the markets of US, UK and Spain, the authors tried to connect housing exuberance to the 2008 GFC through a ratio analysis with the use of an extended form of the GSADF method. Their findings were indicative of the presence of house price bubbles in the early 2000s that eventually collapsed around 2006, preceding thus the 2008 GFC. Further, the authors argued that housing exuberance prior to the GFC could be characterized as an international phenomenon.

In the single-country context, Asal (2019) studied house price bubbles in Sweden, through an asset-pricing approach. The author initially employed affordability and profitability indicators such as price-to-income ratio, price-to-rent ratio, and the user cost as well, to detect the presence of bubbles during the period 1990 – 2016 and furthermore to date-stamp them. The findings of the univariate right-tailed unit root test procedure employed, supplemented by cointegration techniques, indicated price bubbles since 2004. Further, the robustness of the findings were checked by the procedures of the right - tailed ADF Statistics and, additionally, by use of the Hodrick-Prescott filter. In a similar vein, the housing-related above-mentioned ratios were examined in the 2016 country report for Sweden (European Commission Report, 2016). The findings of the analysis undertaken on the basis of a fundamental model for the period 2008-2015, indicated overvaluation in Swedish residential market.

The presence of house price bubbles in the Ukrainian residential market was investigated more recently, by Shmygel (2022). With the help of the ratio analysis, the author tried to identify a possible over-or undervaluation of house prices in Ukraine during the period 2004 – 2021. Further, a regression analysis was performed for different cities and by running a pooled OLS regression. The results of both approaches provided evidence indicative of price bubble for the period that coincides in time with the GFC. Hejlova et al. (2017) underlined the benefits of employing different approaches to assess over- or undervaluation residential prices. Examining potential price misalignments in the Czech Republic for the period 2000 – 2014, they adopted four approaches. The two first based on a general supply and demand, and on an accelerator model, respectively. The third approach was based on the economic sense of home ownership and the last one on affordability of housing. The aggregated results indicated a slight undervaluation in Czech Republic since the mid-2009 while the authors argued that high correlation among different approaches strongly indicates price misalignment.

Warisse (2017) dealt with the trends in property prices in Belgium, adopting a statistical approach to determine the extent to which recorded market prices deviated from the equilibrium price in either direction for the period 1973 – 2016. The findings, based on the ratio (price-to-rent , price-to-income) analysis pointed to high levels of overvaluation in Belgium in 2016. Further, the author developed an econometric approach aiming at estimating an equilibrium price which can be used as a benchmark for measuring any deviations in market prices. Once the fundamental determinants were estimated, the model- based approach indicated overvaluation in first half of the 1980s, in the early 2000s, and during period 2012 - 2015.

Coskun et al. (2020) valuated Turkish residential market by utilizing monthly data of the house price index. The authors based their analysis on the time series' properties, for the period 2010-2014. Alternative stationarity tests were carried out, namely ADF, Phillips and Perron (PP), and Ng-Perron (NP), while cointegration was checked by the use of the bound test. According to the authors' findings, the Turkish house market was overvalued during the period under examination while the results did not differ when least squares methods were performed. The literature on the topic, regarding U.S., is quite rich. Among others, Hu and Oxley (2018b) used the GSADF method to detect price bubbles on a state level, in terms of price-to-income ratio, providing evidence indicative of the presence of house price bubble in the 1980s and in the 2000s, with the most recent bubble being greater compared to that of the 1980s. Shi (2017) came to the same conclusion, regarding the periods of overvaluation in the US, by employing a vector autoregressive (VAR) model for the period 1978 - 2015.

Regarding house price detection in US markets with the use of the right-tailed ADF statistics, a different methodological approach was offered by Escobari and Jafarinejad (2016);to test for bubbles, either single or multiple ones, in the U.S. residential market, three real estate investment trusts, namely, Equity index, Mortgage index, and Hybrid index were used. The utilization of monthly data for the period 1980 - 2013 provided evidence supportive for the presence of speculative bubbles in the above indices. In an earlier study, McCathy and Peach (2004) pointed out the need for additional evidence to solidify any claim of housing bubble based on the observed increasing rates of house prices. The author argued that this need is met by the two widely used measures, namely, price-to-income and price-to-rent ratio while his analysis, focusing on the period 1977 – 2003, did not strongly indicate house price bubble(s).

The GASDF and the SADF statistics were also performed by researchers dealing with the Chinese economy. Huang and Shen (2017) examined the housing market of Hong Kong for the 2009 - 2015 period. They used monthly data to find out the presence of bubble(s)and to further identify the cause of the bubble whereas their findings showed the presence of a bubble caused by supply and demand factors as well. Lastly, Liu et al. (2016) proposed an analysis of the Chinese economy, in respect to house price bubbles, by splitting the sample of the 70 – in total - cities of China into three sub-samples, by size. Using monthly data covering the period 2006 – 2013, the findings of those study showed the presence of bubbles in various cities. That said, the motivation to undertake this study is to shed light on the presence of bubble(s) in the housing market of Greece during sample period of over two decades, given that there is not any study carried out to have clearly addressed this issue.

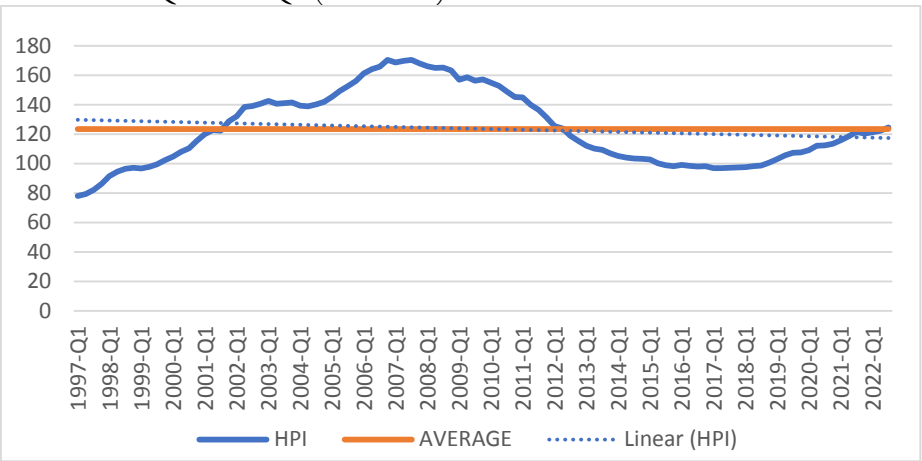
## 3. Evidence from the development of the Greek house price-related ratios

### 3.1 House prices and their long-run average and trend

A quite simple and still rarely used approach of price bubbles, drawn from physics, focuses on the rate of growth in prices. Lind (2009) and Mayer (2011)have defined a housing bubble as dramatic increases in prices followed by rapid decreases in prices. Another approach is offered by Zhou & Sornette (2006) who have defined a housing bubble as a situation in which housing prices increase faster than exponentially. However, this approach raises questions regarding how fast and by how much housing prices must increase and decrease to constitute a bubble. Nevertheless, to get a general view of the overall trend of house prices in Greece, the development of real house prices in Greece is shown in Figure 1.

As one can see in Figure 1, there was a boost in house prices in the period from 1997 to 2007. In 2002Q1 house prices overpassed their historical average and kept on rising until 2007Q1 when prices started to fall. The correction observed in the rest of the year 2007 was not strong enough to reverse the downturn in house prices which lasted for about a decade. After a drop below their average in 2012Q2,house prices kept on falling until Q12016, strongly resisting then to a further decline during the period 2016Q2 – 2018Q2. Lastly, house prices started to increase since 2018Q3, to finally reach, in 2021Q2, their long-term average. As far as recent price levels are concerned, the slight deviation of house prices from their long-run overage in 2022Q3 (about 0.08%, above)does not provide evidence supportive of overvaluation in the Greek housing market, implying that they are probably driven by their fundamentals.

**Figure 1.** Real Greek house prices vs their long-run average and trend, 1997Q1 - 2022Q3 (2015=100)




Source: OECD, author's compilation
Note: HPI = House Price Index, AVERAGE = Long-term average of HPI, (HPI) = Trend of HPI

On the other hand, assessing the development of house prices for the period 2004 – 2007Q2, and taking into consideration the sharp slope of the inclining curve and the fact that prices exceeded their average by almost50%,one can argue - on the grounds of the theoretical context discussed above (Lind, 2009; Mayer, 2011) – thatGreek housing market was overvalued at about 40 per cent, in terms of deviation of the historic price (regarding the sample period). The price bubble seems to have burst in the end of 2006, leading to a decade of continuous decline in house prices in Greece by 42%, cumulatively.

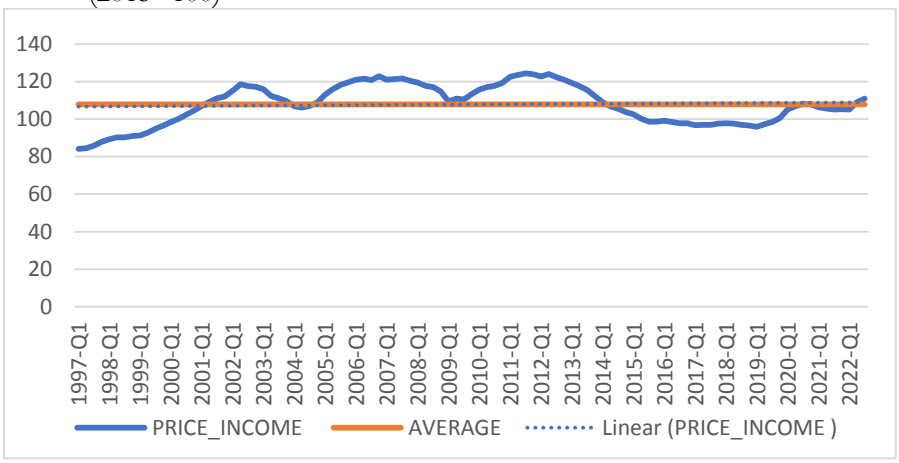
### 3.2 Price-to-income ratio

Respectively with the price analysis discussed above, a bubble is typically identified if the current price-to-income ratio is much greater than the historical average or/and trend. Concerning the Greek housing market, Figure 2 illustrates the evolution of the price-to-income ratio in comparison to its long-term average and trend. It reveals three consecutive periods during which the price-to-income ratio exceeded both its long-term average and trend, followed by a subsequent period during which the ratio fell below its average and trend. To provide further details, the first peak in the ratio occurred in 2002Q2, reaching a level 10% higher than its average. Subsequently, the next two peaks, observed in 2006Q2 and 2012Q4, were slightly higher than the first one, registering increases of 13% and 15%, respectively.

When evaluating the duration of the periods during which the price-to-income ratio remained above its long-term average and trend, along with the relatively modest deviations exhibited by the ratio from these benchmarks, it is difficult to assert the presence of overvaluation within the timeframe of 2001 to 2014.Notably, in 2014Q2, the ratio fell below its historical average and reached its lowest point in 2018Q4, with a deviation of 10% from its average and trend. Subsequently, the levels below the average persisted until 2020Q4. However, for the remainder of the sample period, the price-to-income ratio aligned closely with its long-term average. The minimal deviation, standing at 2.8% as of 2022Q3, further suggests that house prices are adequately valued when assessed using the price-to-income ratio as a metric.

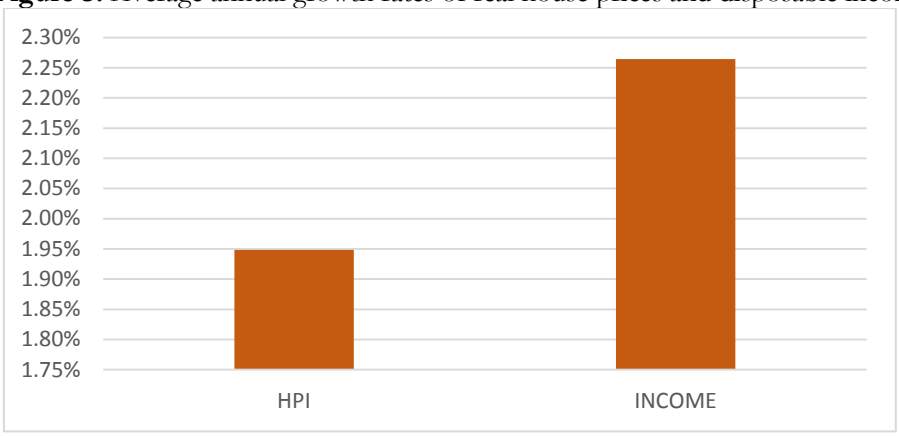
Note that a decrease in the price-to-income ratio might imply that the growth of income exceeds that of the real house prices(McCarthy & Peach, 2004). This might be the case for the prolonged decline observed in the period 2012 – 2017, given the annual average respective growth rates for the whole period under examination ,as depicted in Figure 3. As seen in Figure 3, overall, for the whole period under examination, the average annual growth rate of disposable income during the period 1997 - 2022 is about 1.60%, being outpaced by the growth rate of real house prices, which grew, on average, by 1.95% per year, during the above period.

**Figure 2.** Price-to-Income vs its long-run average and trend, 1997Q1 –2022Q3 (2015=100)




Source: OECD, author's compilation
Note: PRICE_INCOME= Price-to-income ratio, AVERAGE = Long-term average of PRICE_INCOME,(PRICE_INCOME) = Trend of PRICE_INCOME

**Figure 3.** Average annual growth rates of real house prices and disposable income, 1997-2022




Source: OECD, author's compilation
Note: HPI = House Price Index, INCOME = Real Disposable Income

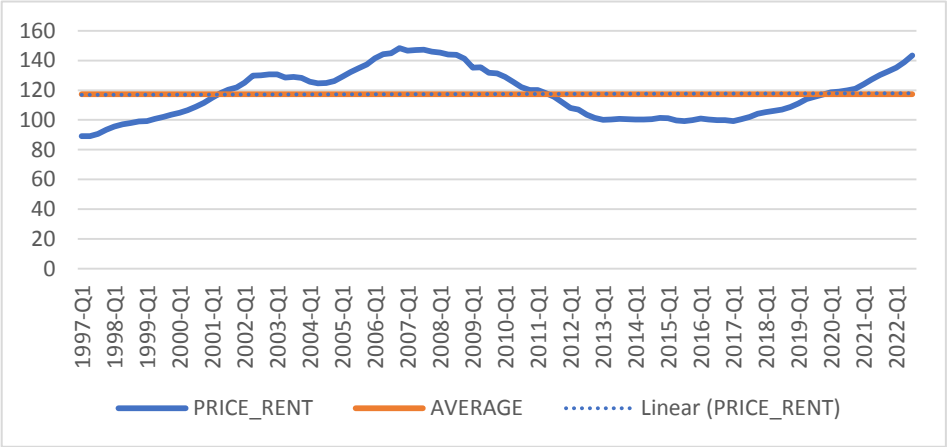
### 3.3. Price-to-rent ratio

Figure 4 depicts the development of the price-to-rent ratio in comparison to its long-run average and trend.

As seen, the price-to-trend ratio exhibited an upward trend which lasted, with the exception of a slight correction (2004-2006), until the end of 2006. In 2006Q4 the ratio reached its peak, exhibiting a 26% deviationfromits average. After 2006, the ratio started to decrease, falling in 2011Q2 even below its log-run average and trend while exhibiting its higher deviation from the two above measures (about 8%) in 2016Q3. After a cumulative decrease of 33%, in the end of 2016 the price-to-income ratio started to increase, to finally exceed its long-run average and trend in the end of 2019.

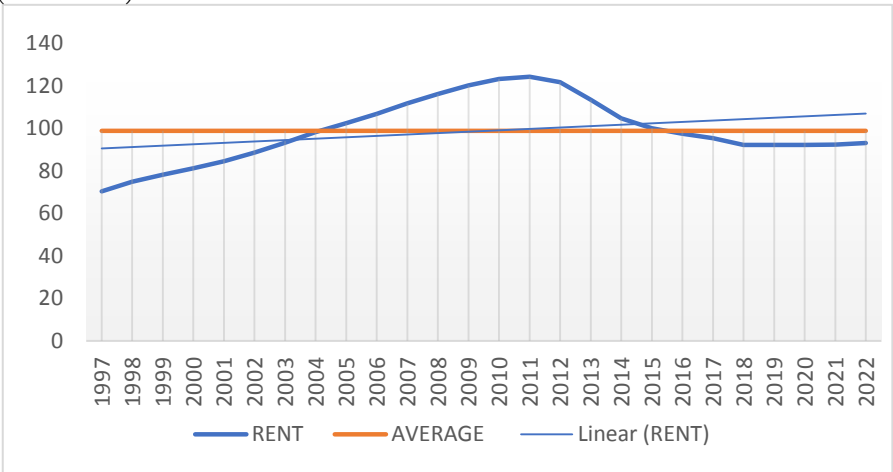
Examining the trajectory of the price-to-rent ratio from 2020Q1 onwards, it becomes evident that the Greek housing market experienced overvaluation to the extent of 22%, as indicated by the deviation of the ratio from its historical average. This finding underscores the influence of rental rates on the formation of house prices.Figure 5 provides insight into the evolution of rental prices. Notably, rental rates displayed an unbroken upward trend from 1997 to 2011, followed by a sharp decline between 2012 and 2015. This decline was subsequently moderated during the period from 2015 to 2018 and eventually stabilized at a level below their long-term average for the remainder of the sample period, spanning from 2018 to 2022.

**Figure 4.**Price-to-Rent vs its long-run average and trend, 1997Q1 – 2022Q3 (2015=100)




Source: OECD, author's compilation
Note: PRICE_RENT = Price-to-rent ratio, AVERAGE = Long term average of PRICE_RENT, (PRICE_RENT) = Trend of PRICE_RENT

**Figure 5.** Real Greek rents' prices vs their long run average and trend, 1997-2022 (2015 =100)




Source: OECD, author's compilation
Note: RENT = Real Greek rents' prices, AVERAGE = Long term average of RENT, (RENT) = Trend of RENT

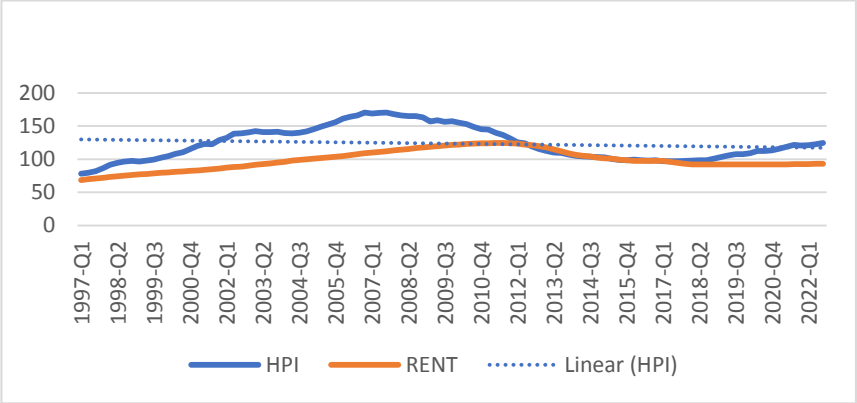
Lastly, Figure 6 shows the evolution of rents as compared to the respective evolution of house prices. As seen, during the 2012 - 2017 period, the level of the two measures converge, both slightly decreasing. However, since 2017Q2 rents did not follow the upward trend of house prices with the latter exceeding their trend in 2022Q3.

### 3.4. The "user cost" of owner-occupied housing

When analyzing house prices, it is imperative to consider the annual cost of ownership, commonly referred to as the user cost of owner-occupied housing. In a market experiencing a bubble, one would anticipate the user cost to escalate at a faster rate than rental prices. This phenomenon could result in imputed rent-to-actual-rent ratios reaching unjustifiable levels, as highlighted by Himmelberg et al. in 2005.It is worth noting that various researchers, including Maher Asal (2019), have developed and calculated the user cost using complex equations. These equations typically encompass factors such as the risk-free interest rate, property tax rates, effective tax rates on income eligible for tax deductibility, nominal mortgage interest rates, maintenance and other carrying costs, depreciation, expected capital gains, and risk premiums. These components collectively contribute to a comprehensive understanding of the user cost, allowing for a more accurate assessment of the housing market's dynamics.

On the above basis, user cost is tightly connected to price-to-rent ratio, given that the equilibrium price-to-rent ratio should equal the inverse of the user cost while declining user costs would increase the price-to-rent ratio.

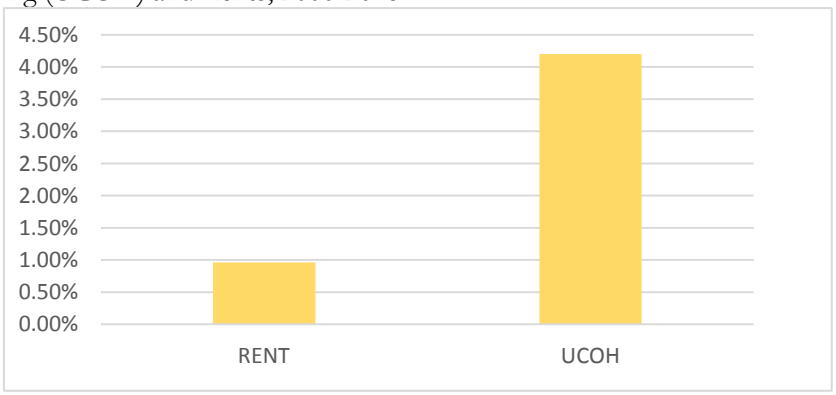
**Figure 6.**Real rent prices vs real house prices, 1997Q1 - 2022Q3, (2015=100)




Source: OECD, author's compilation, Note: HPI = House Price Index, RENT = Real Greek rents' prices,(HPI) = Trend of HPI

Figure 7 shows the average annual growth rate of the user cost of owner-occupied housing compared to the respective rate of rents, for the period 2000 – 2018[2]. As is clearly shown, the user cost increased faster than rents. Specifically, the increase of the user cost is about four times that of rents. On the grounds of previous empirical studies (Himmelberg et all, 2005; Maher Asal, 2019), such finding might imply a raise of the imputed rent-to-actual-rent to unjustifiable levels, implying, in turn, a house price bubble**.** Note that, though interesting, the above statement is just an indication and should be treated cautiously given that the user cost-relevant hypothesis is not econometrically tested in this study.

**Figure 7.**Average annual growth rates of User Cost of Owner – Occupying Housing (UCOH) and Rents, 2000-2018




Source: European Commission, author's compilation, Note: RENT = Real Greek rents' prices,UCOH = User Cost of Owner-Occupying Housing

## 4. Econometric Analysis

### 4.1. Data description

For the needs of the econometric proceduresperformedin the study hereafter, quarterly data on real house prices or else the House Price Index (HPI), Price-to-income ratio (PRICE_INCOME), Price-to-rent (PRICE_RENT) and real disposable income (INCOME) are utilized, in logs. Data for all variables are taken from the OECD Statistics database while summary statistics are presented in Table 1.

[2]The data on UCOH are obtained from the Housing Taxation Database of the European Commission (Joint Research Centre – The European Commission's in house science service, 2019). Data are only available for the period 2000 – 2018.

**Table 1.** Summary Statistics

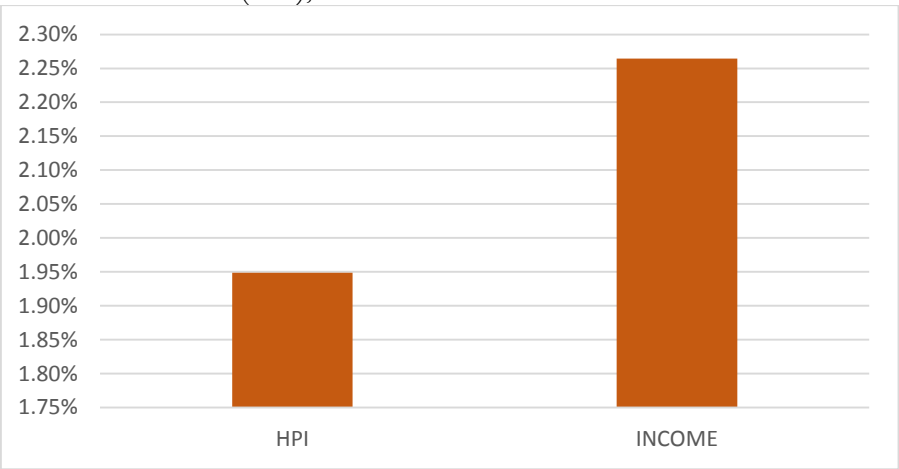
| Variable | Obs. | Mean | Std. Dev. | Skewness | Kurtosis | Min | Max |
|---|---|---|---|---|---|---|---|
| logHPI | 103 | 2.083 | 0.088 | 0.084 | 1.928 | 1.892 | 2.231 |
| logPRICE_INCOME | 103 | 2.030 | 0.043 | -0.417 | 2.293 | 1.924 | 2.094 |
| LogPRICE_RENT | 103 | 2.065 | 0.060 | 0.069 | 1.792 | 1.949 | 2.171 |
| logRENT | 103 | 1.989 | 0.066 | -0.209 | 2.391 | 1.836 | 2.094 |
| logINCOME | 103 | 4.294 | 0.070 | -0.782 | 2.827 | 4.139 | 4.389 |

### 4.2. Stationarity and Cointegration Analysis

### 4.1.Price-to-income Ratio

The relationship between real disposable income and house prices has been examined in prior research (e.g., Andrews, 2010; Geng, 2018), and it is posited that real disposable income serves as a driver of house prices. In the context of the period under examination, it is noteworthy that disposable income in Greece exhibited a faster average growth rate compared to house prices. Figure 8 provides a visual representation of the respective average annual growth rates. Specifically, real disposable income experienced an average annual growth rate of 2.25% over the period spanning from 1997 to 2022. In contrast, the average growth rate for real house prices during the same timeframe was slightly lower at 1.95%. This observation suggests that, on average, real disposable income outpaced the growth of real house prices, indicating the potential influence of income levels on the dynamics of the Greek housing market.

**Figure 8.**Average annual growth rates of Real Disposable Income and Real House Prices(HPI), 1997-2022




On grounds of the study of Yiu et al. (2013),who employed unit root tests to assess the presence of house price bubble, the hypothesis of whether there is a long-run stationary relationship in the price-to-income ratio, is econometrically tested. Practically, a failure to reject a unit root is considered evidence of a bubble. Given the above, the hypothesis to be tested is formed as below.

*Ho: There is a Unit Root (Series Price-to-income is Non – Stationary)*
*If Prob value is ≤ 5%, reject Ho.*

Stationarity of the data is tested by employing the Dickey Fuller (1981) technique while results are listed in Table 2.

The findings regarding the price-to-income ratio are mixed and differ depending on the level accounting for the rejection of the null hypothesis. Specifically, the null hypothesis can be rejected at levels, though at a 10% significance level. If that was the case, the null hypothesis could be rejected (at levels) and there would be, thus, no evidence for bubble. Nevertheless, as a rule of thumb, the null hypothesis can be rejected if the probability is equal or less 5%. Taking this rule into consideration, the null hypothesis cannot be rejected at levels (including intercept as well as intercept plus trend), indicating evidence of house price bubble.

On the contrary, the hypothesis can be rejected at first differences (including intercept as well as intercept plus trend), thus not indicating evidence of house price bubble.

**Table 2.** Unit Root Test for Price-to-income, Real House Prices, and Real Disposable Income
Augmented Dickey Fuller test statistic

| | Level | | | | 1st Difference | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Intercept | | Intercept + Trend | | Intercept | | Intercept + Trend | | |
| Variables | t-statistics | Prob | t-statistics | Prob | t-statistics | Prob. | t-statistics | Prob | Order of integration |
| PRICE_INCOME | -2.68 | 0.08 | -2.67 | 0.24 | -4.68 | 0.00 | -4.76 | 0.00 | I(1) |
| HPI | -2.59 | 0.108 | -2.35 | 0.39 | -2.28 | 0.18 | -2.90 | 0.18 | I(2) |
| INCOME | -1.94 | 0.30 | -3.23 | 0.10 | -2.73 | 0.08 | -2.64 | 0.26 | I(2) |

**Notes:** Augmented Dicky-Fuller test including intercept as well as constant plus trend; Lag length was chosen automatically based on Swartz criterion; All variables are expressed in logs. Number of observations is 99.

Econometric techniques can be applied to assess whether real house prices and real disposable income are nonstationary but cointegrated. The presence of cointegration between these two variables is significant as it suggests a long-term equilibrium relationship, potentially indicating the absence of explosive rational bubbles in asset prices,as argued by Gallin (2006).

Regarding the first assumption stated above (stationarity), the results of the unit root test are reported in Table 2. As is shown by the respective probability values, both series, namely the real house prices and the real disposable income, are non-stationary. Nevertheless, to argue against the presence of a bubble during the period 1997 – 2022 in Greek housing market, the second assumption (cointegration of both series) has to be tested, as well[3]. Two alternative statistics offered the Johansen Cointegration Test, namely the trace test and the maximum eigenvalue test, are employed to test the following null hypothesis (Ho) while the results of the test are reported in Table 3.

*Ho: There is No Cointegration (No long-run relationship between real house prices and real disposable income)*
*If Prob value is ≤ 5%, reject Ho.*

The probabilities (Prob.) reported above, which do not provide sufficient evidence to reject the null hypothesis of no cointegration, suggest that there is no strong support for the absence of a bubble in the Greek housing market concerning real disposable income. Therefore, it is implied that there may indeed be indications of house price bubbles in Greece during the period under examination. In other words, it can be argued that disposable income alone may not be the sole fundamental driver of housing prices in Greece. Other factors and dynamics may have played a role in influencing house prices, potentially including speculative or irrational behavior in the housing market.

**Price-to-rent Ratio**

Following the analysis regarding the price-to-income ratio, examining the stationarity of the price-to-rent ratio and further the cointegration of the series of real prices and rents, could provide valuable evidence regarding the potential presence of house price bubble in Greek housing market during the period under examination.

Stationarity of the data is tested by employing the Dickey Fuller (1981) technique while results, concerning the following null hypothesis (Ho), are listed in Table 4.

*Ho: There is a Unit Root (Series is Non – Stationary)*
*If Prob value is ≤ 5%, reject Ho.*

Regarding the price-to-rent ratio, according to the values of the probabilities reported above, the null hypothesis cannot be rejected at levels, thus not providing evidence indicative of house price bubble.

Further, given that the price level is non-stationary, there would be indications of bubble if the rent level is stationary. Series of rents in Greek housing market, as shown in the Table 4, is non-stationary thus not providing evidence on the presence of a bubble.

[3]Both series are of same order of integration, allowing thus to test for co-integration.

**Table 3.** Johansen cointegration test between real house prices and real disposable income

| Trend assumption: Linear deterministic trend (restricted) | | | | |
|---|---|---|---|---|
| Lags interval (in first differences): 1 to 1 | | | | |
| *Unrestricted Cointegration Rank Test (Trace)*[1] | | | | |
| Hypothesized No. of CE(s) | Eigenvalue | Trace Statistic | 0.05Critical Value | Prob.[2] |
| None | 0.423 | 17.025 | 25.87211 | 0.4130 |
| At most 1 | 0.172 | 4.3546 | 12.51798 | 0.6904 |
| | | | | |
| *Unrestricted Cointegration Rank Test (Maximum Eigenvalue)*[3] | | | | |
| Hypothesized No. of CE(s) | Eigenvalue | Trace Statistic | 0.05Critical Value | Prob.[2] |
| None | 0.423578 | 12.67107 | 19.38704 | 0.3553 |
| At most 1 | 0.172490 | 4.354682 | 12.51798 | 0.6904 |

**Notes:**
[1] Tests the hypothesis that there are at most r cointegrating vectors (Johansen, 1991)
[2]MacKinnon et al (1999)*p*-values.
[3]Tests the hypothesis that there are at most r + 1 cointegrating vectors (Johansen, 1991)

**Table 4.** Unit Root Test for Price-to-rent, Real House Prices, and Rents - Augmented Dickey Fuller test statistic

| | **Level** | | | | **1st Difference** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Constant | | Constant + Trend | | Constant | | Constant + Trend | | |
| | | | | | | | | | |
| Variables | t-statistics | Prob | t-statistics | Prob. | t-statistics | Prob. | t-statistics | Prob. | Order of integration |
| PRICE_RENT | -1.70 | 0.42 | -1.67 | 0.75 | -2.55 | 0.10 | -2.47 | 0.33 | I(2) |
| HPI | -2.59 | 0.10 | -2.35 | 0.39 | -2.28 | 0.18 | -2.90 | 0.18 | I(2) |
| RENT | -1.99 | 0.28 | -1.86 | 0.66 | -1.94 | 0.31 | -1.98 | 0.60 | I(2) |

**Notes:** Augmented Dicky-Fuller test including intercept as well as constant plus trend; Lag length was chosen automatically based on Swartz criterion;All variables are expressed in logs. Number of observations is 99.

An alternative way to examine house price bubbles through the evolution of the rent level is to test whether the series of house prices and rents are both integrated at first differences but are not cointegrated (Maher, 2019). If both conditions hold, one could argue there is a house price bubble. In the case of Greek housing market, both series (house prices, rents) are integrated at second differences so there is no need to further test for cointegration (given that the first condition does not hold).

### 4.2.1 Right-tailed Dickey Fuller Statistics: subperiod analysis

The implications drawn from the analysis of time series properties of the variables under examination indeed vary depending on the specific hypotheses tested and the analytical approaches used. It is important to acknowledge that the findings, when considered collectively, do not provide strong overall support for the presence of a housing price bubble in Greece during the period studied (1997-2022).However, it is worth noting that preliminary evidence has been obtained, which may serve as a foundation for further subperiod analysis. Such an approach can offer more nuanced insights into the dynamics of the Greek housing market. In this section, right-tailed Dickey Fuller Statistics (RTDFS) are employed, aiming, initially at detecting any differences in the so far findings in respect to real house prices, price-to-income, and price-to-rents, as well, and further and more importantly at detecting specific periods of overvaluation in Greek housing market. Note that the employment of the RTDFS, as developed by Phillips et al (2015), allows for testing and, furthermore, date-stamping bubbles.

The standard (right-tailed version of) ADF and the rolling ADF (RADF) are performed to test the null hypothesis of a unit root in the above three series of interest while the alternative hypothesis would be the presence of a bubble. Furthermore, the sub ADF (SADF)and the generalized ADF (GSADF) methods are employed to date-stamp any bubbles. The main different of the last two methods is that the alternative hypothesis in the SADF procedure is the presence of a single periodically collapsing bubble whereas GSADF method tests for multiple periodically collapsing bubbles.

The hypotheses to be tested, concerning real house prices and the two fundamental ratios under examination, are stated in Table 5. Econometric results of all four methods employed, are also presented in Table 5. Note that the whole econometric analysis for the needs of the study was executed by the use of the package E-Views 10 while the RADF and GSAFF tests were performed by following the procedure proposed by Caspi (2017). In total, twelve hypotheses were tested; the four techniques were applied to each of the variables (HPI, PRICE, INCOME_INCOME, PRICE_RENT), separately.

As can be seen in Table 5,the null hypothesis can be rejected in the RADF, SADF, and GSAD tests, regarding all three variables of interest (except for the case of HPI in SADF test), given that the values of the Dickey-Fuller (DF) statistics exceed the respective critical values. For example, in the case of the relevant to the price-to-income hypothesis, the values of interest indicate a bubble at the 1 per cent significance level(because 2.35 > 2.74).

**Table 5.** Right-tailed Augmented Dickey - Fuller Tests

| | **ADF** | | **RADF** | | **SADF** | | **GSADF** | |
|---|---|---|---|---|---|---|---|---|
| | t-Stat. | Prob.[1] | t-Stat. | Prob.[1] | t-Stat. | Prob.[1] | t-Stat. | Prob.[1] |
| ***Null hypothesis: log real House Prices has a unit root*** | | | | | | | | |
| | -2.82 | 0.95 | 2.98 | 0.00* | 0.01 | 0.48 | 3.71 | 0.00* |
| Test critical values[2]: | | | | | | | | |
| 99% level | 0.52 | | 0.74 | | 1.92 | | 2.80 | |
| 95% level | -0.08 | | 0.04 | | 1.30 | | 2.07 | |
| 90% level | -0.40 | | -0.32 | | 1.02 | | 1.73 | |
| ***Null hypothesis: log Price to Income Ratio has a unit root*** | | | | | | | | |
| | -2.65 | 0.92 | 2.35 | 0.01** | 2.71 | 0.00* | 2.71 | 0.01** |
| Test critical values[2]: | | | | | | | | |
| 99% level | 0.52 | | 0.74 | | 1.92 | | 2.80 | |
| 95% level | -0.08 | | 0.04 | | 1.30 | | 2.07 | |
| 90% level | -0.40 | | -0.32 | | 1.02 | | 1.73 | |
| ***Null hypothesis: log Price to Rent Ratio has a unit root*** | | | | | | | | |
| | -1.19 | 0.322 | 3.20 | 0.00* | 2.58 | 0.00* | 5.93 | 0.00* |
| Test critical values[2]: | | | | | | | | |
| 99% level | 0.52 | | 0.74 | | 1.92 | | 2.80 | |
| 95% level | -0.08 | | 0.04 | | 1.30 | | 2.07 | |
| 90% level | -0.40 | | -0.32 | | 1.02 | | 1.73 | |

**Notes:**
[1]Right-tailed test
[2] Critical values are based on a Monte Carlo simulation (run with E-Views)
* and ** indicate significance at 1 and 5% level, respectively

The acceptance of the alternative hypothesis, in all eight hypotheses, provided strong evidence for the presence of housing bubble in Greece, during the period under examination. Further, the exact periods of overvaluation of the housing market are detected though the GASF test and depicted in Figures 9 – 11. The green line in each graph (Fig. 9 – 11) depicts the series of the three alternative measures of the housing market, namely house prices, price-to-income ratio, and price-to-rent ratio. The blue line depicts the ADF statistic sequence and the red line the corresponding 95 per cent critical values.

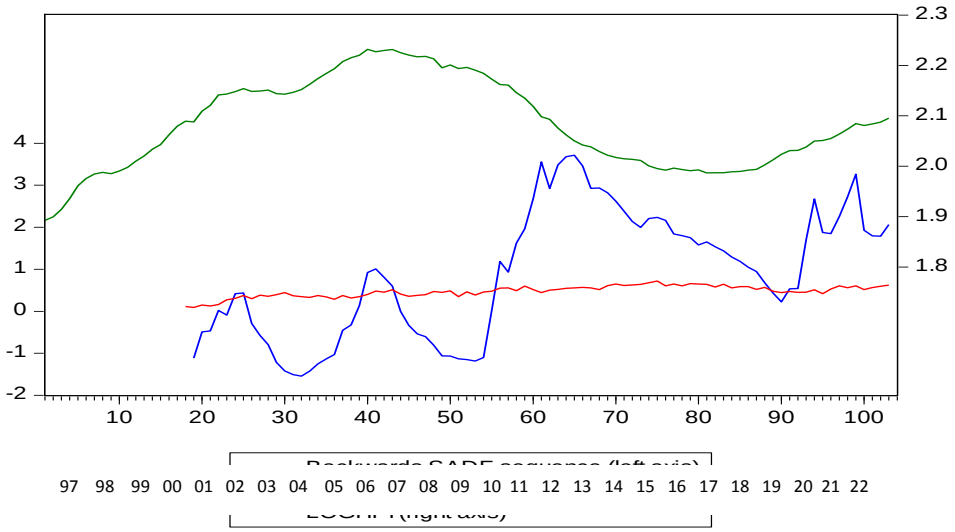
Figure 9 depicts the valuation of Greek housing market by using real house prices. On the basis of the above discussion over the GASDF procedure, the lines of the diagram show that prices have been overvalued since (2010Q3) despite the fall in house prices that had already started in (2007Q3) and lasted until (2015Q3). In (2013Q2) overvaluation started to de-escalate until (2018Q4). After a short period during which house prices seem to have been driven by their fundamentals (2018Q4 – 2019Q3), a second period of overvaluation began in (2019Q4).

The implied bubble still existed in the last year of the sample period (2022Q3) having, though, half the extent of the respective bubble period. As far as the bubble periods are concerned, there seems to have been one more period of overvaluation during the period (2006Q3 - 2007Q4), however being short and mild. Lastly, during the periods 2003Q1 - 2006Q3 and 2007Q3 – 2010Q3 Greek housing marker was undervalued, as indicated by the position of the line of the ADF statistic sequence compared to the respective line of the 95 per cent critical values.

Regarding the rest two alternative approaches of house price valuation, Figure 10indicates three periods of overvaluation, in terms of the price-to-income ratio, with the most recent bubble originating in (2020Q1) and lasting until (2021Q1). The preceding bubble period, dated from (2014Q3) to (2017Q4), is characterized by the smooth deceleration of the overvaluation (see the rate of de-escalation, depicted by the line of SAD sequence, from 2015Q4). Overviewing the whole sample period, it is worth noticing that there has been a quite long period of undervaluation, as well, for the period (2002Q4 – 2014Q3) right before the first bubble period. Despite the stop in undervaluation in (2004Q4), leading to an aggregate reduction by 80% for the whole period from (2004Q4-2006Q4), house prices in Greece continued to be undervalued until 2014Q3.

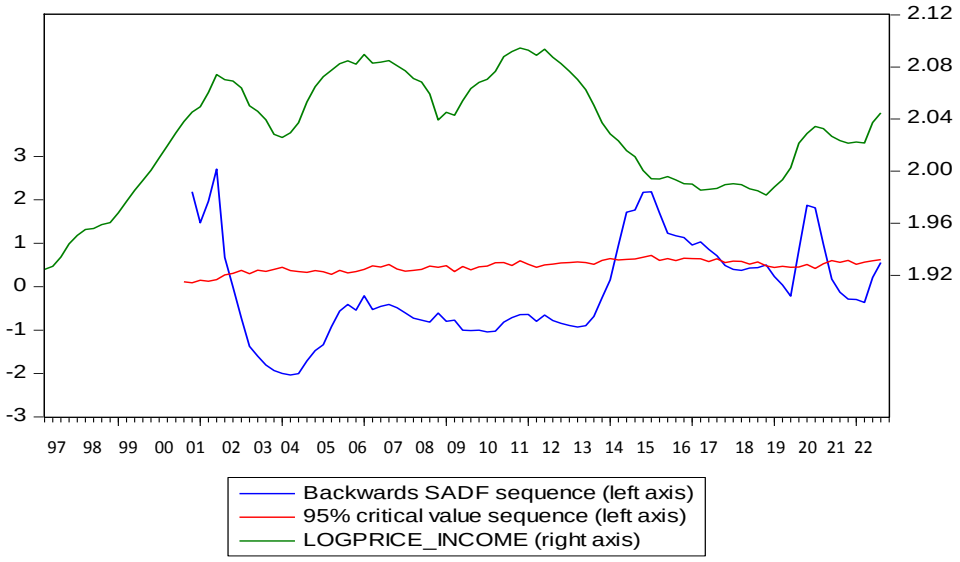
More importantly, as far as the recent developments in the Greek residential market are concerned, the focus need to be on the sharp acceleration of the SADF sequency line since 2022Q1, almost crossing(the SADF line) the respective line of the critical values. On the grounds of the price-to-income ratio assessment, the above findings imply that Greek housing market may very soon enter, onceagain, a period of overvaluation.

**Figure 9.**GSADF Test for House Price Bubbles (in terms of real house price)




Source: Author's estimation.

**Figure 10.**GSADF test for House Price Bubbles (in terms of the price-to-income ratio)

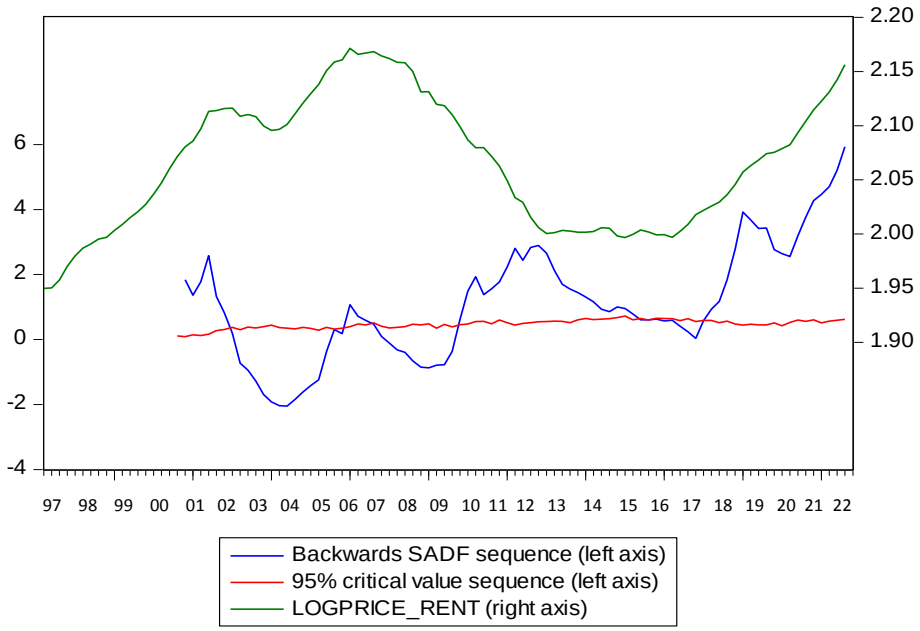



Source: Author's estimation.

In the case of the price-to-rent ratio (Fig. 11) four bubble periods are defined, with the latest originating in (2018Q1) and lasting until 2022Q3, after a short period of a correction effort (2019Q2 – 2020Q4). Since (2020Q4) overvaluation is sharply accelerating while, more interestingly, the degree of overvaluation in 2022Q3 was more than twice the degree of the previous bubble period which lasted from 2010Q2 – 2016Q1 (peak level in 2012Q4), indicating that the ongoing bubble period, as measured by the price-to-rent ratio, might be even sharper and quite extensive. The two first episodes of price bubble took place in the periods 2001Q3 – 2003Q1 and 2006Q2 - 2007Q3 while, as in the cases of real house prices and price-to-income ratio, in the case of price-to-rent ratio there were periods of undervaluation as well. Among the three, in total, periods, the most extended was the 2003Q2 - 2006Q1 period, as seen in figure 11.

That said, the current situation in Greek residential market could be described as overvalued, no matter the measure used. To be precise, based on the findings regarding the most recent disposable data, residential market in Greece is overvalued in terms of real prices and of rents while being potentially overvalued, when the price-to-income ratio is taken into consideration. Lastly, episodes of house price bubble during the sample period (1997 – 2022) are date-stamped and listed, by measure, in Table 5.

**Figure 11.**GSADF test for House Price Bubbles (in terms of the price-to-rent ratio)




Source: Author's estimation.

**Table 5.** Episodes of house price bubble in Greek residential market (1997 – 2022)

| Measure | Real House Prices | Price-to-income | Price-to-rent |
|---|---|---|---|
| Period | 2006Q3 - 2007Q4 | 2001Q2 - 2002Q4 | 2001Q3 – 2003Q1 |
| | 2010Q3 - 2018Q4 | 2014Q3 - 2017Q4 | 2006Q2 - 2007Q3 |
| | 2019Q4 - 2022Q3 | 2020Q1 - 2021Q1 | 2010Q2 - 2016Q1 |
| | | | 2018Q1 - 2022Q3 |

Source: Author's estimations.

### 4.2.2. Robustness Check (Applying the Hodrick – Prescott filter on real house prices)

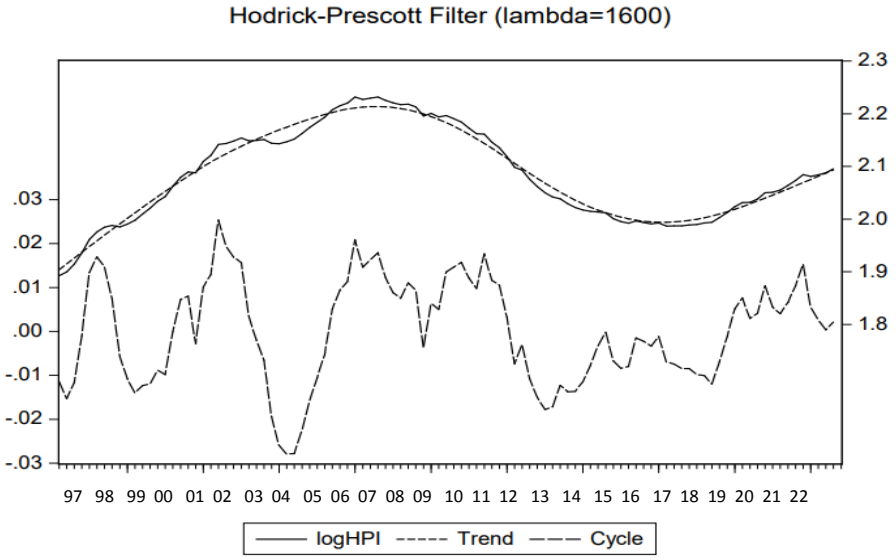
Lastly, additional evidence on the presence of house price bubble in the housing market of Greece is given by the use of the Hodrick – Prescott filter (Hodrick & Prescott, 1997).[4] The method has been previously applied to test for house price bubbles, by Asal (2019), among others. Figure 12 depicts the real house prices (continuous line) in Greece for the period 1997 – 2022,

[4]The HP filter is a smoothing procedure that is widely employed in macroeconomics to find a smooth estimate of the long-term trend component of a series. See Asal (2019) for a brief overview of the relevant to the trend component calculations.

Along with their long-run trend (upper dashed line) whereas the percentage difference between the actual real house prices and the Hodrick – Prescott filter on real house prices equals the cyclical component, shown in the figure by the lower dashed line. Note that the above-mentioned difference is claimed to indicate overvaluation or even undervaluation in a given housing market.

On the basis of the above discussion, figure 12 confirms that there have been periods during which real house prices in Greece were overvalued. Especially concerning the ending period of the sample, since (2021Q2) Greek residential market seems to have entered, once again, a bubble. It remains to be seen whether the slight correction implied by the co-movement of the line of real house prices and the respective one depicting the cyclical component, continued to an extent capable of limiting overvaluation.

**Figure 12.** Testing for overvaluation by applying the Hodrick – Prescott Filter On Greek real house prices (1997 – 2022)




Source: Author's estimation

Note: A value of l = 1600 is used (common practice for a quarterly time series)

## 5. Conclusions

The investigation of factors driving house prices in Greece has been a recurring theme in the relevant literature, with empirical studies typically focusing on fundamental factors within the realms of demand and supply. These studies seek to quantify the influence of each fundamental factor on the formation of house prices. However, the primary motivation behind this particular study is to illuminate periods during which house prices in Greece were propelled by homebuyers' unrealistic expectations about the future value of their properties, rather than being primarily driven by the underlying fundamentals.In essence, the study's core objective is to identify, detect, and precisely date-stamp instances of housing bubbles in Greece over the past twenty-five years. By doing so, it seeks to distinguish between periods of genuine price growth driven by economic fundamentals and periods characterized by speculative or irrational behavior in the housing market. This nuanced analysis aims to contribute to a deeper understanding of the dynamics within the Greek housing market and the potential impact of speculative forces on house prices. Given that there has been a significant gap in research addressing the issue of housing price bubbles in Greece over the last twenty-five years, this study represents a pioneering and novel endeavor within the context of Greece. By undertaking this research and applying various approaches and econometric techniques to identify and analyze housing price bubbles, this study work not only fills a critical void but also adds valuable insights to the field of housing market analysis in Greece.

Initially, the development of real house prices and the price related ratios, namely the price-to-income and the price-to-rent ratio, is illustrated to get a clear overall picture regarding the period 1997Q1 – 2022Q3. The deviation of the above measures from their long-term average and trend might imply the presence of a housing bubble. On the basis of the above, there seems to have been a long period (2001 – 2012) of overvaluation, reaching at a level of almost 40%, as is shown by the deviation of real house prices from their long-run overage. However, as far as the most recent developments in Greek housing market are concerned, the slight deviation of house prices from their long-run overage in 2022Q3 (about 0.08%, above) does not provide strong evidence supportive of overvaluation.

Regarding the rest two measures, the negligible deviation (2.8% as far as 2022Q3 is concerned) of the price-to-income ratio from the average and trend, indicates that house prices are correctly valued, in terms of price-to-income ratio whereas there have been three subperiods of overvaluation during the period 2001 – 2014. On the contrary, when rents are taken into consideration, the implications differ; since 2019Q2 Greek market exhibits price-to-rent levels over their long-run average, indicating hence an overvaluation of about 20%.

Building upon the theoretical foundation provided by the relevant literature on the time series properties of house price-related data (Holly et al., 2010; You et al., 2013), specific hypotheses concerning real house prices in Greece, as well as the two key ratios of interest, were formulated and rigorously tested. The outcomes vary depending on the chosen measure for evaluating the housing market. When considering real disposable income, the results of the stationarity test do not suggest the presence of a house price bubble. However, upon conducting further cointegration tests, as proposed by the relevant literature (e.g., Gallin, 2006), indications of house price bubbles emerge. This implies that disposable income alone may not have been the sole driving force behind housing prices in Greece during the examined period. Further, this analysis was replicated with a focus on the price-to-rent ratio, but it did not yield evidence indicative of housing price bubbles.

In light of the preliminary indications mentioned above, a more comprehensive analysis was conducted to shed further light on the implications of housing bubbles in the Greek residential market. The right-tailed Dickey-Fuller statistics were employed, and the bubble-detection procedure proposed by Phillips et al. (2015) was followed. Three hypotheses, each corresponding to one housing market valuation measure, were rigorously tested using both the RADF method and the respective SADF. Remarkably, the acceptance of the alternative hypothesis in all cases, at both the 1% and 5% significance levels, provides robust evidence supporting the existence of a housing bubble in Greece. What's even more intriguing, following the methodology outlined by Caspi (2016) and leveraging the E-Views add-ins provided by Caspi, the bubble episodes were date-stamped using GSADF. According to the results, there was one distinct bubble episode during the examined period when assessing real house prices and the price-to-income ratio. However, when considering valuation based on the price-to-rent ratio, a total of four bubble episodes were identified.

An important discovery from the above analysis is that the most recent bubbles identified (beginning in 2019Q4 for real house prices and in 2018Q1 for the price-to-rent ratio) persisted until 2022Q3. To further validate these findings and ensure their robustness, the Hodrick-Prescott Filter method, as suggested by Asal (2019), was also employed. The analysis, focusing on the percentage difference between actual real house prices and the Hodrick-Prescott filter on real house prices in the Greek residential market, offers confirming evidence of overvaluation.

The implications of the identified bubble episodes, whether historical or ongoing, give rise to concerns regarding the future of the housing market in Greece. Assuming that house prices must eventually return to their fundamental values, the absence of adequate corrective measures by policymakers could result in a scenario where a home buyer continues to willingly purchase at a price higher than its actual value, thereby fueling the price bubble.

The aim of the study was to shed light on house price developments in Greece during the period 1997Q1 – 2022Q3, by providing novel evidence on the presence of housing bubbles. Taking into consideration the findings and the implications discussed, the study contributes to the single-country context literature on housing bubbles in respect to the multi-method approach of the topic and furthermore to the period examined, concerning Greek housing market.

Regarding the caveats of this study, it's essential to bear in mind that, while widely used, the two housing-related ratios do not encompass all the components of the total housing cost. The inclusion of the user cost calculation could offer an additional metric to supplement the analysis, alongside the price-to-income and price-to-rent ratios. Consequently, investigating the fundamental drivers of housing prices in Greece becomes particularly interesting, especially concerning the relationship between real house prices and their long-term fundamentals during periods identified as bubble episodes in this study. Therefore, this study presents a promising avenue for further research. Lastly, considering the implications for policymakers, this study could serve as a valuable resource when policymakers in Greece contemplate the timely implementation of precautionary measures related to the residential market, with the aim of preventing or mitigating the impacts of a housing bubble on the broader economy.

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