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Research Article

Time Series Analysis for Detecting Real Estate Bubbles A Case Study of East Marmara

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Abstract – A bubble occurs when the value of assets significantly exceeds their intrinsic worth. Detecting bubbles is crucial for policymakers and regulators to mitigate financial crises. This study utilizes a time-series analysis approach to detect real estate bubbles in the East Marmara region, encompassing Kocaeli, Sakarya, Bolu, Düzce and Yalova. Residential Property Price Index (RPPI) dataset (2017=100), covering the duration from January 2013 to January 2024, was acquired from the Central Bank of the Republic of Turkey's Electronic Data Distribution System (TCMB-EVDS). Using the Augmented Dickey-Fuller (ADF), Supremum ADF (SADF), Generalized SADF (GSADF), and Rolling ADF (RADF) tests. The SADF test returned a t-statistic of 32.80130 ($p < 0.0001$), indicating strong evidence of bubble-like behavior, while the GSADF test confirms the occurrence of multiple speculative bubbles with similar statistical significance. The RADF test provided insights into real-time bubble progression, detecting a peak in speculative activity in 2022 when the ADF statistic (5.743343, $p < 0.0001$) crossed critical thresholds. Across all tests, the results indicate that real estate prices in the East Marmara region showed an explosive growth during 2021 and 2022 years, followed by a correction phase at the end of 2022. These patterns coincide with a steep increase in the Residential Property Price Index (RPPI), highlighting the political and economic influences in the region in recent years. These results offer valuable insights for policymakers and market participants in detecting and managing speculative behavior in real estate markets and making changes to minimize financial instability.

Keywords –Time Series Analysis, Bubble Detection, Real Estate, Augmented Dickey-Fuller, GSADF.

I. INTRODUCTION

Real estate has long been important and major to human society, presenting both security and wealth across different cultural and historical backgrounds. In general, real estate consists of any property or land, including structures such as homes, industrial spaces and commercial buildings [1]. Real estate represents more than just physical structures; it reflects the achievements and desires of People and communities. In addition to its primary role in providing shelter, real estate works as a key part for long-term investment, wealth generation and the transfer of assets between generations [2]. Real estate encompasses a wide range of property categories, each fulfilling distinct roles within the market. Residential properties provide living spaces and can also serve as investment assets. Commercial real estate consists of properties that are made for business purposes, such as offices, restaurants, retail

centers, and fitness facilities, while industrial real estate emphasizes manufacturing plants, logistics hubs, and distribution centers. Additionally, land comprises undeveloped parcels, vacant lots, and agricultural areas like farms, orchards, and ranches. Investment strategies in real estate are equally diverse, including acquiring rental properties for steady income, participating in Real Estate Investment Trusts (REITs) for diversified exposure, or engaging in property flipping by refurbishing and reselling undervalued properties for profit [1].

In recent years, Turkey has become a significant player in the global real estate market, driven by factors such as demographic changes and foreign investment. Turkey's real estate market has become an important investment potential for both households and investors. Turkey's strategic location at the intersection of Asia, Europe, and the Middle East further encourages its attractiveness and appeal as a center for investment and trade. However, the Turkish real estate market faces some challenges, such as inflationary pressures, rising construction costs, and currency fluctuations, all of these challenges influence property prices. These factors can occasionally result in overvaluation and the creation of real estate price bubbles, threatening the stability of the market [3].

When the assets value increases beyond their original worth, this is called a bubble, in order to avoid financial crises bubbles must be detected by financial regulators and policymakers. When the price of real estate increases due to speculation, oversupply, and inadequate supply, it can lead to a property price bubble. This may lead to a situation where property prices eventually peak and become unaffordable, which could cause a sharp decline in value and possibly contribute to a downturn in the economy [4].

There are many reasons to use bubble detection; it can help to manage the risk by helping the investors, policymakers, and financial institutions to identify any potential risks in asset markets to take into account the suitable risk management measures to prevent any losses, it can help Investors modify their investment strategies to protect against market downturns, also policymakers and central banks use it to sustain financial stability and prevent systemic risks [2].

In 2015, Phillips, Shi, and Yu (PSY) developed a real-time bubble detecting test. The PSY approach is a real-time detection approach that imitate the way a trader would actually inspect her bubble-timing data, the method is based on the idea that speculative bubbles are characterized by explosive dynamics, which means that the asset price can changes and increases rapidly then suddenly collapse and it uses statistical tests to detect when the dynamics of an assets price change from just being a random walk to be explosive behavior [5].

Time series analysis refers to the approach of analyzing a collected series of data points over specific periods of time. This approach is used to determine patterns, trends, and the relationships within the data, which helps to discover the underlying dynamics, make predictions, and inform decision-making processes. Time series analysis discovers applications in different sectors, including economics, finance, engineering, and environmental science. Time series data which consists of sequence observations recorded at either regular or irregular periods over time. Time series analysis involves several components; trend refers to the general direction where the data moves over time, which can be increasing, decreasing or stable. Seasonality demonstrates the patterns that repeat at a certain time, typically due to seasonal reasons. Cyclical patterns are determined by variations that do not follow a fixed period of time but appear and happen from economic or other external factors. Lastly, irregularity demonstrates random fluctuations or unpredictable events that cause variations from the expected pattern, which may or may not be random [6].

In recent years, there has been a lot of interest in investigating and detecting real estate market bubbles, especially in the context of Turkey's evolving real estate market. As we can see in [4] study that conducted an in-depth analysis into real estate price bubbles in Istanbul, Ankara, and Izmir, analyzing data collected between duration extending from April 2010 to October 2022, the study applied the

Generalized Supremum Augmented Dickey-Fuller (GSADF) approach which is a robust statistical approach that aims to determine the variations from essential market values. The results showed significant price fluctuations which is evidence of speculative or non-fundamental factors influencing the real estate market. While another study [7] analyzed the existence of real estate price bubbles in Turkey generally and its major metropolitan cities, specifically Istanbul, Ankara, and Izmir, using the Supremum Augmented Dickey-Fuller (SADF) and Generalized Supremum Augmented Dickey-Fuller (GSADF) test approaches. The analysis covers the period that starts from January 2010 to October 2022 and is based on data acquired from the Central Bank of the Republic of Turkey's Electronic Data Distribution System and the results showed substantial evidence of real estate price bubbles.

II. MATERIALS AND METHOD

This study conducts a time-series analysis approach to detect real estate bubbles in the East Marmara region, that covers Kocaeli, Sakarya, Bolu, Düzce and Yalova. Residential Property Price Index (RPPI) (2017=100) dataset, covering the duration from January 2013 to January 2024, was acquired from the Central Bank of the Republic of Turkey's Electronic Data Distribution System (TCMB-EVDS).

The analysis was conducted using the following tests Augmented Dickey-Fuller (ADF), Supremum ADF (SADF), Generalized Sup ADF (GSADF), and Recursive ADF (RADF) tests. ADF test is a commonly used statistical test to assess whether a time series is stationary or includes a unit root, which would indicate non-stationarity. Time series models depend mainly on stationarity; because non-stationary data can develop inaccurate results in forecasting and hypothesis testing. The main purpose and goal of the ADF test is to checks time series has a unit root in autoregressive models, its methodology can be expressed as follows:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta y_{t-i} + \epsilon_t \quad (1)$$

Where Δy_t represents the first differences of the time series, α is a constant, βt represents a deterministic trend, y_{t-1} is the lagged value of the series, $\delta_i$are the coefficients for the lagged differences and ϵ_t express the error term. ADF test checks if γ=0, if that is true then the time series has a unit root and is considered as non-stationary, recording to this the hypotheses of the ADF test can be considered as follows:

The Null Hypothesis (H_0): When γ=0 the time series is considered to have a unit root, indicating non-stationary.

The Alternative Hypothesis (H_1): When γ<0 the time series is considered to be stationary.

The ADF test statistic is calculated and compared against the critical values from the Dickey-Fuller distribution, if the test statistic is less than the critical value, then the null hypothesis rejected, indicating that the series is stationary and if the test statistic is equal or more than the critical value it fails to reject the null hypothesis which will indicates a non-stationarity.

The SADF test focuses on identifying a single period of time series explosive behavior. It performs multiple ADF tests over expanding sample windows, where each test's starting point remains fixed, but the endpoint progresses through the data. The equation can be expressed as follows:

$$SADF = supADF_{r_0}^{r_1} \quad (2)$$

Where r_0 is the initial window size and $r_1$is the expanding endpoint. SADF test is limited in detecting only one bubble episode in a given time series. Meanwhile GSADF test generalizes the SADF test by allow both the start (r_0) and end (r_1) points of the sample window to change. This recursive approach detects multiple periods of explosiveness. GSADF test can be expressed as follows:

$$GSADF(r_0) = sup_{r2\in[r0,1]r1\in[0,r2-r0]}\ ADF_{r_1}^{r_2} \quad (3)$$

Where (r_1) and (r_2) represent multiple combinations of start and end points for the window.

The RADF test conducts a rolling window approach to monitor bubbles in real time; it computes ADF statistics over fixed-sized subsamples that roll forward in the time series. This makes it ideal for ongoing monitoring and early detection of bubble formation.

III. RESULTS

The Augmented Dickey-Fuller (ADF) test applied on the East Marmara region's real estate price index reveals strong evidence of explosive price behavior, indicating the existence of a speculative bubble within the dataset that spans from January 2013 to January 2024. The calculated ADF test statistic of 10.26792 is significantly higher than the critical values generated through Monte Carlo simulations as shown in Table 1 thereby decisively rejecting the null hypothesis of a unit root. The associated p-value of 0.0000 further supports the statistical significance of the result, indicating that the price index does not follow a random walk and exhibits patterns consistent with explosive behavior. These findings highlight unsustainable growth in real estate prices in the East Marmara region during the sample period, reflecting the presence of market exuberance or speculative dynamics. The test used a fixed lag length of 0 and a window size of 13 observations, with a total of 133 observations included in the sample.

Table 1. Augmented Dickey-Fuller (ADF) test results for explosive behavior in East Marmara real estate prices (2013–2024)

		t-Statistic	**Prob.***
ADF		10.26792	0.000
Test critical values:**	99% level	-0.445266	
	95% level	-0.883050	
	90% level	-1.219931	

*Right-tailed test

**Critical values are based on a Monte Carlo simulation (run with EVIews)

Table 2. Rolling Augmented Dickey-Fuller (RADF) test results for bubble detection in East Marmara real estate prices (2013–2024)

		t-Statistic	**Prob.***
max RADF		5.743343	0.000
Test critical values:**	99% level	0.038648	
	95% level	-0.664593	
	90% level	-1.009452	

*Right-tailed test

**Critical values are based on a Monte Carlo simulation (run with EVIews)

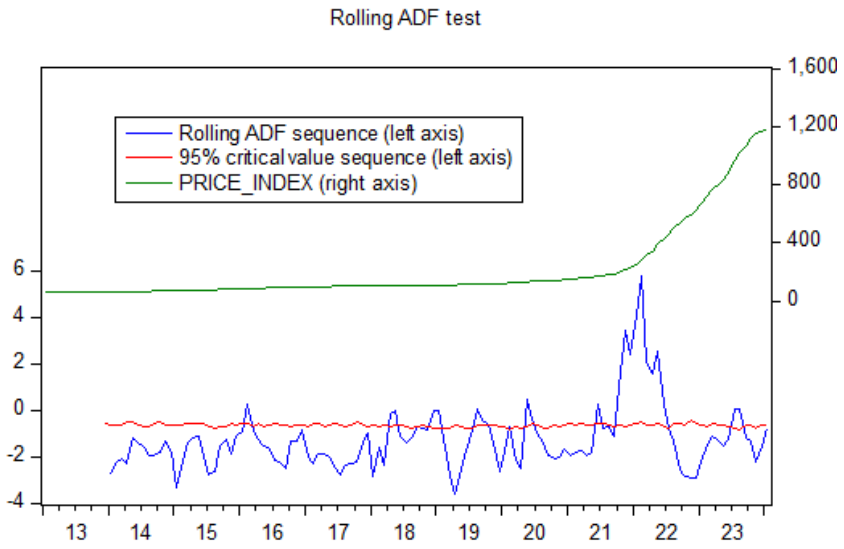

Figure 1. Rolling ADF sequence test graph for East Marmara real estate prices (2013–2024)

The RADF test results statistic is 5.743343, which significantly exceeds the critical values generated through Monte Carlo simulations at all confidence levels as shown in Table 2 with a p-value of 0.0000, the result strongly rejects the null hypothesis that the price index follows a unit root process, providing clear evidence of explosive dynamics in the real estate market. The test was performed using a fixed lag length of 0 and a window size of 13 observations, with 133 total observations in the sample. As shown in Figure 1 that indicates the RADF test graph which includes the blue line represents the rolling ADF test statistics over time, capturing the existence of potential explosive behavior in the series; the red line corresponds to the 95% critical value threshold. When the blue line exceeds the red line, it indicates statistical evidence of a bubble and the green line represents the price index (on the right axis), showing the trend in real estate prices during the analyzed period. Based on the rolling ADF test results, a speculative bubble was detected in the East Marmara real estate market starting in 2022. The bubble formation is evident as the rolling ADF statistic (blue line) surpasses the 95% critical value (red line), corresponding with a significant increase in the price index. This finding suggests potential overvaluation and heightened market instability during that period.

When conducting SADF the test statistic is 32.80130, which is well above the critical values generated through Monte Carlo simulations as shown in Table 3 that clearly rejects the null hypothesis of a unit root and indicating that the series exhibits explosive, bubble-like behavior. The p-value of 0.0000 further confirms the statistical significance of the result, providing strong evidence against the null hypothesis. The analysis was conducted using a fixed lag length of 0 and a window size of 13, with 133 total observations in the sample. As demonstrated in Figure 2 that indicates the SADF test graph which compress of blue line represents the forward ADF sequence (SADF statistics) calculated over expanding subsamples, capturing the likelihood of explosive behavior in the series, red line denotes the 95% critical value threshold, if the blue line exceeds the red line, it indicates statistical evidence of a bubble and green line is the price index (on the right axis), showing the trend in real estate prices during the analyzed period. The SADF test results indicate the detection of a speculative bubble in the East Marmara real estate market starting in 2022, as evidenced by the forward ADF sequence surpassing the 95% critical value. This coincides with a steep rise in the price index, confirming overvaluation during this period.

Table 3. Supremum Augmented Dickey-Fuller (SADF) test results for explosive behavior in East Marmara real estate prices (2013–2024)

		t-Statistic	Prob.*
SADF		32.8013	0.000
Test critical values**:	99% level	1.156041	
	95% level	0.582983	
	90% level	0.344366	

*Right-tailed test

**Critical values are based on a Monte Carlo simulation (run with EVIews)

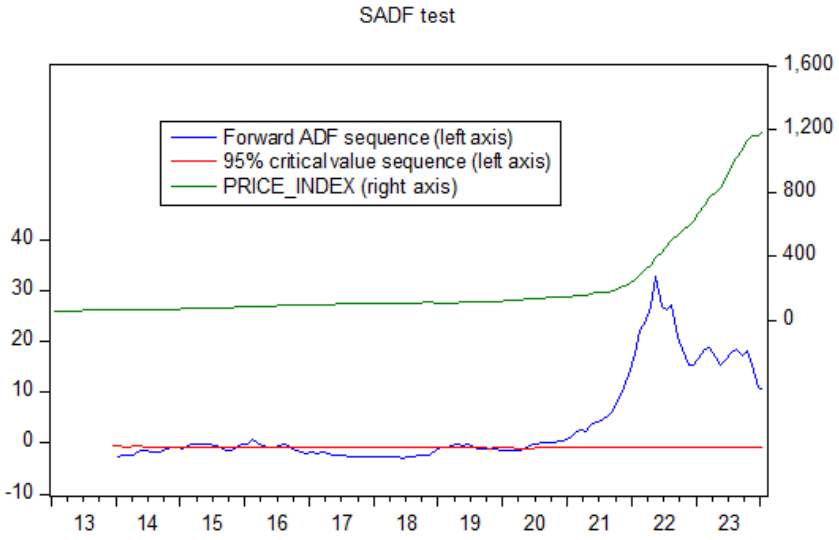

Figure 2. Forward SADF sequence test graph for East Marmara real estate prices (2013–2024)

The GSADF test statistic is 32.80130, which is substantially higher than the critical values generated through Monte Carlo simulations as shown in Table 3 indicating the rejection of the null hypothesis that the series has a unit root. The p-value of 0.0000 confirms the statistical significance of this result, strongly suggesting that the price index does not follow a random walk and instead exhibits explosive dynamics, characteristic of a market bubble. This test was conducted using a fixed lag length of 0 and a window size of 22 observations, with a total of 133 observations included in the analysis. As displayed in Figure 3 that indicates the GSADF test graph, which consists of a blue line representing the backward SADF sequence (GSADF test statistics), calculated to identify explosive behavior across different subsample intervals; the red line is the 95% critical value threshold. When the blue line surpasses the red line, it signals the detection of speculative bubbles and the green line shows the price index (on the right axis), representing the trend of real estate prices during the period of analysis. The GSADF test reveals the presence of a speculative bubble in the East Marmara real estate market, beginning in 2022 and coinciding with a significant rise in the price index. The bubble detection is evident as the GSADF statistics (blue line) exceed the 95% critical value (red line). The decline in test statistics in 2023 suggests some market correction, although elevated price levels persist. This test confirms the episodic and localized nature of the bubble, offering valuable insights into market dynamics during this period.

Table 4.Generalized Supremum Augmented Dickey-Fuller (GSADF) test results for bubble detection in East Marmara real estate prices (2013–2024)

		t-Statistic	Prob.*
GSADF		32.8013	0.000
Test critical values**:	99% level	2.136557	
	95% level	1.524341	
	90% level	1.263721	

*Right-tailed test

**Critical values are based on a Monte Carlo simulation (run with EVIews)

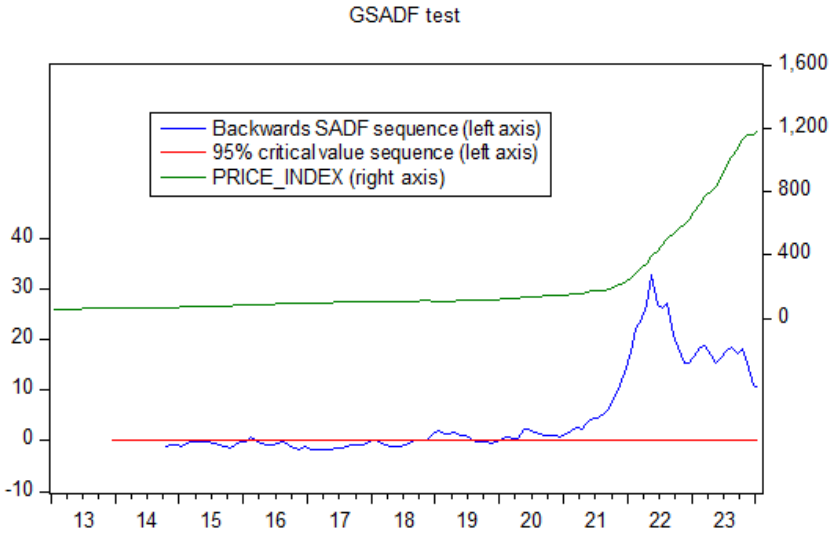

Figure 3. Generalized Supremum Augmented Dickey-Fuller (GSADF) test graph for East Marmara real estate prices (2013–2024)

As shown in the SADF, Rolling ADF and GSADF graphs, the high growth in the price index during the 2021 and 2022 years stands out clearly. The graphs show that the backward-looking SADF sequence stayed above critical values for extended periods, indicating market exuberance the rolling ADF on the other hand, captured shorter-term fluctuations, highlighting the market's repeated nature.

The SADF test returned a t-statistic of 32.80130 ($p < 0.0001$), indicating strong evidence of bubble-like behavior, while the GSADF test confirms the occurrence of multiple speculative bubbles with similar statistical significance. The RADF test provided insights into real-time bubble progression, detecting a peak in speculative activity in 2022 when the ADF statistic (5.743343, $p < 0.0001$) crossed critical thresholds. These patterns coincide with a steep increase in the Residential Property Price Index (RPPI), highlighting the political and economic influences in the region in recent years

The detected bubbles in East Marmara appear to be a significant stream of investment and civilization in the region, cities such as Kocaeli and Sakarya experienced rapid price growth, ultimately caused by increased industrial activity and population migration and these factors indicate that the real estate market in East Marmara is sensitive to macroeconomic factors and regional developments.

IV. DISCUSSION

The results of the applied statistical tests showed significant evidence of speculative bubbles in the East Marmara real estate market between 2013 and 2024, particularly during 2021–2022. The SADF, GSADF, and RADF tests consistently identified explosive price behaviors, with t-statistics far exceeding critical values at the 99% confidence level. These results align with the prospect that real estate markets, affected by some of economic and social dynamics or factors, are affected by periods where speculative growth is extreme. The GSADF test demonstrated effectiveness in identifying multiple bubble occurrences, identifying the repeated nature of speculative behavior in time series. The Rolling ADF test further demonstrated the changing progression of these bubbles, which emphasizes the cyclical stages of formation and correction.

The identified timing of bubbles corresponds with broader macroeconomic trends, which includes a period of high inflation, low-interest rates, and a high demand for real estate in Turkey. These factors and trends commonly helped speculative investment and inappropriate price increases in the East Marmara region. However, the market correction following 2022 implies that external impacts or policy

adjustments, such as stricter lending criteria or rising interest rates may have reduced the speculative behavior in real estate prices. This emphasizes the importance and significance of market monitoring and timely actions in order to minimize risks associated with price fluctuation and financial instability.

V. CONCLUSION

This study offers strong evidence of speculative bubbles in the East Marmara real estate market over the time. The implementation of SADF test that returned with t-statistic of 32.80130 ($p < 0.0001$) which indicates a strong evidence of bubble-like behavior, while GSADF test affirms the occurrence of multiple speculative bubbles with similar statistical significance, and RADF statistical tests emphasized the appearance of real-time bubble progression, especially during 2022, when the ADF statistic (5.743343, $p < 0.0001$) crossed critical values. These patterns coincide with a high increase in the Residential Property Price Index (RPPI), highlighting the political and economic influences in the region in recent years. These results highlight the importance of performing advanced bubble detection methods to identify and assess the speculative dynamics in real estate markets.

The results have important implications for market participants and policymakers to adopt proactive strategies and procedures to manage market exuberance, such as macroprudential regulations, whereas market participants must be careful in speculative environments. Future research should investigate the underlying reasons for these bubbles and assess the effectiveness of regulatory measures and rules in preventing similar behaviors. By realizing and understanding the changes or dynamics of speculative bubbles, stakeholders can better manage and control risks and enhance the stability of the real estate market.

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