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RESEARCH ARTICLE

Did the February 6-7 Türkiye Earthquake Trigger a Housing Market Bubble? Empirical Insights from Right-tailed Unit-root Tests

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ABSTRACT

This study primarily aims to assess whether the destructive earthquakes of February 6-7, 2023 triggered a potential nationwide housing market bubble. Spanning the period from January 2010 to September 2024, the analysis employs Generalised Supremum Augmented Dickey-Fuller and Backward Supremum Augmented Dickey-Fuller methods to identify bubble formations. The findings reveal significant bubble periods, including January to August 2015, November 2015 to November 2016, May 2018 to January 2019, May to June 2019, and February to December 2023. The latest bubble formation occurred immediately after the earthquake, highlighting a strong link between the disaster and housing market dynamics. While the earthquake's impact—through abrupt housing stock loss, large-scale displacement, and intensified demand for secure housing—was undeniably a crucial trigger for this bubble, other macroeconomic factors, such as inflationary pressures, low interest rates, and the perception of housing as a lucrative investment, also played a reinforcing role. The Türkiye experience enhances the understanding of speculative cycles in seismic regions, demonstrating how non-economic shocks such as earthquakes can rapidly boost demand and strain housing supply, amplifying speculative behaviour. This bubble, which peaked in May 2023 and gradually deflated, completely dissipated by December 2023. This development can be associated with the policies implemented by economic authorities, including interest rate hikes, restrictive credit measures, as well as the normalisation of conditions across the country following the earthquake. This highlights the need for proactive monitoring and intervention by economic authorities through appropriate economic policies and regulations to address supply-demand imbalances and mitigate the risks of future housing bubbles, particularly in response to external shocks. Furthermore, in response to the study's findings on earthquake-triggered bubbles, policymakers should prioritise initiatives aimed at strengthening building infrastructure and implementing urban transformation strategies.

Keywords: Speculative bubbles; Housing market dynamics; Earthquake and housing market; February 2023 Türkiye earthquakes; Right-tailed unit-root tests
JEL Clasification: R31, G12, C22

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1. Introduction

Türkiye is frequently exposed to earthquakes because of its location in a geologically active region. Earthquakes occur because of sudden movements in the Earth's crust and often lead to significant damage and loss of life. Throughout history, Türkiye has witnessed many major earthquakes, causing both material and spiritual losses. However, the earthquakes that occurred on February 6-7, 2023, are recorded as one of the most devastating disasters in the country's recent history. These earthquakes, with epicentres in the Pazarcık and Elbistan districts of Kahramanmaraş, were recorded as two separate shocks measuring 7.7 and 7.6 magnitudes, respectively. The earthquakes occurred on the fault line known as the Eastern Anatolian Fault Zone or the Dead Sea Fault Zone. These tremors caused extensive destruction along a roughly 550-kilometer line from Hatay to Kahramanmaraş, Adıyaman, Malatya, and Elazığ. The region experienced a significant human tragedy, with more than 50,000 lives lost and substantial material damage in 11 provinces. The total population of the 11 affected provinces accounted for 16.43% of Türkiye's population, constituting approximately 9.8% of the country's 2022 GDP. This devastating disaster, impacting such a vast area, has deeply affected both the region and the country as a whole, leading to various socio-economic consequences.

Table 1: Some Statistical Data on the Effects of the 6-7 February Earthquakes

Province	Pop.*	GDP%	Tot. Hous.*	Destroyed or Damaged	Moderate Damaged	Slight Damage	Displaced Pop.	Deaths
Adana	2.274 (2,67)	2,00	973 (2,42)	2.952 (0,30)	11.768 (1,21)	71.072 (7,31)	52.779 (2,32)	454 (0,02)
Adıyaman	635 (0,74)	0,30	217 (0,54)	56.256 (25,96)	18.715 (1,92)	72.729 (7,48)	307.204 (48,37)	8.387 (1,32)
Diyarbakır	1.804 (2,12)	0,90	563 (1,40)	8.602 (1,53)	11.209 (1,15)	113.223 (11,64)	98.913 (5,48)	414 (0,02)
Elazığ	591 (0,69)	0,50	292 (0,73)	10.156 (3,47)	15.220 (1,56)	31.151 (3,20)	28.090 (4,75)	5 (0,00)
Gaziantep	2.154 (2,53)	2,00	894 (2,22)	29.155 (3,26)	20.251 (2,08)	236.497 (24,32)	252.317 (11,71)	3.897 (0,18)
Hatay	1.686 (1,98)	1,40	847 (2,11)	215.255 (25,40)	25.957 (2,67)	189.317 (19,47)	774.483 (45,93)	23.065 (1,37)

Kahramanmaraş	1.177 (1,38)	0,90	481 (1,20)	99.326 (20,63)	17.887 (1,84)	161.137 (16,57)	489.149 (41,54)	12.622 (1,07)
Kilis	147 (0,17)	0,10	75 (0,19)	2.514 (3,35)	1.303 (0,13)	27.969 (2,88)	13.750 (9,30)	74 (0,05)
Malatya	812 (0,95)	0,50	346 (0,86)	71.519 (20,70)	12.801 (1,32)	107.765 (11,08)	320.100 (39,39)	1.393 (0,17)
Osmaniye	559 (0,66)	0,40	243 (0,61)	16.111 (6,62)	4.122 (0,42)	69.466 (7,14)	69.442 (12,41)	993 (0,18)
Şanlıurfa	2.170 (2,54)	0,80	718 (1,79)	6.163 (0,86)	6.041 (0,62)	199.401 (20,50)	58.895 (2,71)	340 (0,02)
Toplam	14.01 (16,43)	9,80	5.649 (14,05)	518.009 (9,17)	145.274 (14,94)	1.279.727 (3,18)	2.465.122 (17,59)	51.644 (0,37)
Türkiye	85.279 (100)	100,00	40.200 (100)	(1,29)	(0,36)	(3,18)	(2,89)	(0,06)

Notes: Values in parentheses indicate the proportion of the respective data in Türkiye's total. For example, the values in the "Population" column represent the population of the province, while the values in parentheses represent the proportion of the province's population in Türkiye's total population. Similarly, other values in the table indicate the respective data's proportions in Türkiye's total. *Values are in thousands.
Source: TUIK (2022), Presidency of the Republic of Türkiye (2023), Sağıroğlu, Ünsal and Özenci (2023), Wikipedia (2023).

One of the effects of earthquake disasters in the country is the general increase in earthquake fear, which has been felt not only in earthquake-prone areas but also nationwide. This has resulted in many people feeling unsafe in their homes, particularly in regions with high earthquake risks. As a result, many individuals have turned to lower-rise buildings or preferably detached houses. This trend has heightened people's demand for safer housing and caused significant changes in the housing sector.

In particular, the major destruction in the earthquake zone have led to a significant decrease in the housing stock. Before the earthquake, the housing stock in the region was approximately 5 million 649 thousand units, which accounts for approximately 14% of the country's total housing stock, as shown in Table 1. The number of completely destroyed or heavily damaged buildings was recorded as 518 thousand, which is approximately 9.17% of the region's housing stock and 1.29% of the country's total housing stock. Additionally, the number of moderately and slightly damaged houses in the region has also significantly increased. On average, the total number of moderately and slightly damaged houses is approximately 1 million 425 thousand, representing 25.22% of the region's total housing stock and 3.54% of the country's total housing stock. Taking into account the total number of destroyed, heavily damaged, moderately damaged, and slightly damaged buildings, the affected housing units in the region will be approximately 1 million 943 thousand, accounting for 34.39% of the region's total housing stock and 4.832% of the country's total housing stock. These data indicate that the major earthquake disaster in the region has had a significantly adverse effect on the housing stock and has also affected the country's total housing stock. Consequently, there is a high risk of a significant imbalance between supply and demand in the housing market. As it will take time to rebuild the damaged or destroyed buildings, there may be a significant decrease in the housing supply during this process. This situation could disrupt the balance between housing supply and demand and lead to significant changes in the market. Therefore, it is inevitable that the decrease in housing stock due to the earthquake will seriously disrupt the supply-demand balance in the housing market and lead to some market-disturbing effects. In particular, the occurrence of major destruction in the earthquake zone could render the housing supply unable to meet demand, leading to price increases or uncertainties in the housing market. Furthermore, the decrease in housing supply could also affect new housing projects and investments. The economic dimension of these changes in the housing market is also crucial. In particular, the housing shortage in the region after the earthquake directly impacts the construction sector. While there is a significant demand for rebuilding destroyed or heavily damaged buildings, there may also be increases in factors such as materials and labour during this process. This situation could lead to increases in construction costs and, consequently, affect housing prices.

However, the effects of the earthquake are not limited to the residents of the region; people outside the region, especially those living in high-risk earthquake areas, have also deeply felt the fear of earthquakes. This fear has led many individuals to tend to move to safer areas. Additionally, there has been significant migration from the earthquake zone to other regions; as seen in Table 1, approximately 2 million 465 thousand people have had to move to other areas from the region. While some displaced individuals may have done so temporarily, it is highly likely that some of them have permanently settled in the places they moved to. This situation will increase the demand for housing in the target regions from a different perspective. Consequently, due to the deep-seated fear of earthquakes even among those living outside the earthquake zone, the increased demand for secure housing in other regions, as well as the migration from the earthquake zone to other regions, can lead to serious disruptions in the housing supply and demand structure in other regions. The increase in housing demand in migration-receiving areas can adversely affect the housing supply-demand balance, and this situation can lead to imbalances in supply and demand even in regions where there are no earthquakes in Türkiye. This situation can lead to increased uncertainties and price fluctuations in the housing market nationwide. Therefore, we can say that a regional earthquake poses a significant risk of imbalance in supply and demand in both the regional and national housing markets.

Natural disasters like earthquakes can have significant effects on the housing market. The following earthquakes, there can be a substantial decrease in housing stock, changes in the demands of displaced individuals, and overall market uncertainties. This situation can increase the risk of a housing bubble as significant changes in the demand and supply balance can occur. Especially in high earthquake-risk areas like Türkiye, the impacts of earthquakes on the housing market can be even greater. While rebuilding destroyed or heavily damaged buildings takes time, the housing demand from displaced populations can unexpectedly surge. This can lead to sudden and uncertain changes in housing prices and the supply-demand balance. In this context, evaluating the potential formation of a housing bubble in the aftermath of earthquakes is crucial. A balance should be struck between the dynamics of the housing sector and the effects of earthquakes, and economic risks should be minimised. Additionally, identifying and addressing imbalances in the housing market is vital for maintaining overall economic stability. Therefore, careful analyses should be conducted to prevent the formation of a housing bubble or minimise its effects, and appropriate policies should be implemented.

Speculative bubbles are typically characterised by rapid price increases driven by investor behaviour, often fuelled by optimism and the anticipation of future price appreciation, rather than by fundamental values. According to Minsky (1992)who implied that the economy can be best understood by assuming that it is constantly an equilibrium-seeking and sustaining system. The theoretical argument of the FIH emerges from the characterization of the economy as a capitalist economy with extensive capital assets and a sophisticated financial system. In spite of the complexity of financial relations, the key determinant of system behavior remains the level of profits: the FIH incorporates a view in which aggregate demand determines profits. Hence, aggregate profits equal aggregate investment plus the government deficit. The FIH, therefore, considers the impact of debt on system behavior and also includes the manner in which debt is validated. Minsky identifies hedge, speculative, and Ponzi finance as distinct income-debt relations for economic units. He asserts that if hedge financing dominates, then the economy may well be an equilibrium-seeking and containing system: conversely, the greater the weight of speculative and Ponzi finance, the greater the likelihood that the economy is a \"deviation-amplifying\" system. Thus, the FIH suggests that over periods of prolonged prosperity, capitalist economies tend to move from a financial structure dominated by hedge finance (stable's Financial Instability Hypothesis, credit expansion and excessive borrowing can lead to speculative bubbles, emphasising the crucial role of debt and credit cycles in driving asset price volatility. This theory emphasises the role of debt and credit cycles in driving asset price bubbles. Theoretical models suggest that such bubbles arise from a combination of psychological factors, market inefficiencies, and external shocks, which can distort the rational pricing mechanisms typically observed in efficient markets. By also considering the valuable insights in Scherbina (2013)'s study analysing theoretical approaches to speculative bubbles, theoretical approaches to speculative bubbles can be summarised as follows:

1. Psychological Factors:

- Herding Behaviour: Investors tend to follow the crowd, buying assets when prices are rising and selling when prices are falling.
- Overconfidence: Investors may overestimate their ability to predict future price movements, leading to excessive risk-taking.
- Anchoring Bias: Investors may anchor their expectations on past price levels, leading to overvaluation.

2. Market Inefficiencies:

- Short-Sale Constraints: Restrictions on short-selling can limit the downward pressure on prices, allowing bubbles to persist.
- Information Asymmetries: Unequal access to information can lead to mispricing and speculative behaviour.
- Market Frictions: Transaction costs, liquidity constraints, and regulatory barriers can hinder efficient price discovery.

3. External Shocks:

- Monetary Policy: Low-interest rates can stimulate borrowing and investment, fuelling asset price inflation.
- Fiscal Policy: Government spending and tax cuts can increase aggregate demand, leading to higher asset prices.
- Global Economic Conditions: International factors such as global economic growth and financial market volatility can influence domestic housing markets.

4. Theoretical Models:

- Rational Bubble Models: These models assume that investors rationally expect future price increases, even though fundamentals do not justify them.
- Behavioural Finance Models: These models incorporate psychological factors, such as overconfidence and herding behaviour, to explain irrational exuberance and price bubbles.
- Fundamental Value Models: These models focus on the relationship between asset prices and underlying economic fundamentals, such as income and interest rates. Deviations from fundamental values can lead to speculative bubbles.

The formation of housing market bubbles can pose a serious risk to economic and financial stability. Particularly, rapid and continuous increases in housing prices attract speculators and challenge market confidence. Examples like the Mortgage Crisis in the United States have demonstrated that housing market bubbles can lead to collapses. This situation can transform the housing sector from being just a tool for economic growth into an area where financial risks intensify. Similar dynamics shape Türkiye's housing market as well. Factors such as demographic changes, urban transformation projects, low interest rates, income increases, and investment/ speculation demand are significant elements affecting housing demand. These factors can lay the groundwork for imbalances and potential housing market bubbles. In this sense, by understanding the theoretical underpinnings of speculative bubbles, policymakers and regulators can develop effective strategies to mitigate their negative consequences and promote financial stability.

In this context, it is important to examine the potential effects of major earthquake disasters on Türkiye's housing market and analyse the economic dimensions of these effects. This pioneering study aims to contribute significantly to the literature by investigating the impact of earthquakes on the housing market, covering the data period from January 2010 to September 2024, encompassing both pre- and post-earthquake periods. Therefore, the primary goal of this research is to assess whether the most devastating earthquake in recent history, which occurred on February 6-7, 2023, triggered a potential housing market bubble nationwide. The study will delve into whether the risks emerging after the earthquake have heightened housing market imbalances and potentially led to a bubble formation. Consequently, the study will primarily focus on evaluating the risks and effects associated with a potential housing bubble, representing the distinct impact of the earthquake. Throughout the study, the GSADF method was used to analyse potential housing market bubble formations. This method is effective in determining the existence or absence of bubbles. Additionally, the BSADF method has been used to identify the periods during which bubble formations occurred. This method is useful in determining the start and end periods of the bubble formations. The use of these methods has allowed for a more detailed analysis of the potential housing market bubble formations and the timeframes in which these formations occurred.

The subsequent sections will start with a comprehensive literature review focusing on housing market bubbles. Following that, the Data and Methodology section will detail the data sources, variables, and the application of the GSADF and BSADF methods in analysing potential housing market bubbles. The Empirical

Results section presents the findings regarding the existence of housing bubbles before and after the earthquake, along with their economic impacts. Finally, the Conclusion and Discussion section will synthesise the findings, discuss their implications, and suggest policy recommendations for mitigating the risks associated with housing market bubbles triggered by major earthquake disasters.

2. Literature Review

The 2008 Mortgage Crisis served as a pivotal point that sparked increased interest in analysing housing market bubbles across different regions. Researchers have used various econometric methods to explore the presence and impact of housing bubbles in different economic contexts. Empirical studies focusing on housing market bubbles in countries outside Türkiye have played a significant role in understanding the dynamics of these bubbles and their economic implications. For instance, studies conducted by Balcilar, Katzke and Gupta (2018), Phillips and Yu (2011), Kishor and Morley (2015), Mikhed and Zemčík (2009), and Shi (2017) in the United States have identified multiple periods of housing bubbles, notably during the late 1800s, mid-1950s, and mid-2000s. Similarly, research by Chan, Woon and Ali (2016) in Asia-Pacific countries, excluding Japan and Thailand, highlighted housing bubble occurrences before and after significant economic crises such as the 2000s dot-com bubble and the 2008 global financial crisis. Studies focusing on other regions such as Brazil (de Oliveira & Almeida, 2014), China (Hui & Gu, 2009; Liu et al., 2016), Hong Kong (Yiu, Yu, & Jin, 2013), Ireland (Gallagher, Bond, & Ramsey, 2015), Sweden (Asal, 2019), Kenya (Kiarie Njoroge, Aduda, & Mugo, 2018), and many others have also documented the presence of housing bubbles during specific economic periods or events. Additionally, studies utilising panel data from multiple countries have provided insights into synchronised housing bubble behaviours across different regions (Gomez-Gonzalez et al., 2017; Pavlidis et al., 2013). These studies have contributed significantly to the literature by highlighting the interconnectedness of housing market dynamics on a global scale.

The literature on the housing bubble phenomenon in Türkiye encompasses several studies that analyse different aspects of this issue. In this context, Coskun et al. (2020) employed various statistical methods to analyse housing bubble formation in Türkiye during different time frames, concluding that while there were instances of overvaluation, an actual bubble did not form. Abioğlu (2020) examined bubble formation in multiple cities in Türkiye and identified significant bubble formations, particularly in areas excluding Bursa and İzmir, from 2007:06 to 2018:01. In addition, other studies have investigated housing bubbles in Türkiye using various methodologies and analysing different time periods. For example, Bakır Yiğitbaş (2018) discusses the increase in housing prices compared to economic indicators post-2010, indicating potential artificial stimuli in the housing demand. Zeren and Ergüzel (2015) analyse Istanbul, İzmir, and Ankara from January 2010 to June 2014, finding no long-term bubbles but short-term price increases. Karakoyun and Yıldırım (2017) focused on demand-side factors in the real estate sector, showing the significant explanatory power of real interest rates in the long term. Coskun and Jadevicius (2017) assessed Istanbul, İzmir, and Ankara's housing markets from January 2010 to December 2014, finding no support for the existence of a bubble. Berk, Biçen and Seyidova (2017) suggest unsustainable high prices in certain regions. Dogan and Afsar (2018) investigated bubble formations without conclusive evidence. Mandacı and Çağlı (2018) identified bubbles in certain regions from January 2010 to April 2017. Cağlı (2019) explores explosive behaviours in housing prices from January 2010 to December 2017. Using data from January 2010 to August 2019, Gökçe and Güler (2020) identified evidence of housing market bubbles in Ankara. Similarly, Güler and Gökçe (2020) detected bubbles across Turkey during the periods of November 2014 to November 2016 and April 2018 to January 2019. Their study also highlighted the presence of bubbles in Istanbul during March 2013 to December 2013, April 2014 to December 2016, and January 2018 to August 2019, as well as in Antalya from August 2018 to November 2018. Akkuş (2021) confirmed the bubble presence from January 2010 to June 2020. Ayan and Eken (2021) found in their study conducted in the 2007 to 2019 data period that balloon formations in Istanbul's housing market neighbourhoods varied regionally and temporally, with some districts showing disappearing balloons towards the end of 2019 in the first analysis using monthly data, while the second analysis using three-month data suggested more widespread and persistent balloon formations. Kartal (2022) identified housing bubbles in Türkiye from January 2010 to July 2021, revealing 4 bubble periods for Türkiye overall (February 2013 to December 2013, June 2014 to July 2017, February 2018 to October 2019, and June 2020 to August 2020), and emphasised the need for continuous regulatory oversight due to associated macroeconomic risks. Akkaya (2024) identified two speculative housing bubbles (2014-2018 and June 2019-June 2022) in Türkiye from January 2013 to June 2022. Yalçın Kayacan (2022) study examined the presence of housing bubbles in Türkiye and its 26 sub-provinces/regions, including major cities, from January 2010 to March 2022, revealing the presence of inflated bubbles and emphasising the need for continuous regulatory control in both housing and financial markets associated with housing.

Considering the empirical methods used in these studies, it can be seen that housing bubble detection studies employ various econometric methods to identify potential bubble formations in the housing market. In this regard, some of the econometric methods used by researchers are such as Generalised Supremum Augmented Dickey-Fuller (GSADF) developed by Phillips, Shi and Yu (2015) (Akkaya, 2024; Kartal, 2022; Yalçın Kayacan, 2022; Coskun et al., 2020; Abioğlu, 2020; Zeren and Ergüzel, 2015), Backwards Supremum Augmented Dickey Fuller (BSADF) developed by Phillips, Shi and Yu (2015) (Kartal, 2022; Yalçın Kayacan, 2022; Abioğlu, 2020; Zeren and Ergüzel, 2015), Supremum Augmented Dickey-Fuller (SADF) developed by Phillips, Wu and Yu (2011) (Zeren and Ergüzel, 2015), statistical models like Ordinary Least Squares (OLS)/ Fully Modified Ordinary Least Squares (FMOLS)/AutoRegressive Integrated Moving Average (ARIMA)/Kalman filters (Coskun et al., 2020), Blanchard-Quah SVAR (Structural Vector Autoregressive) model (Karakoyun and Yıldırım, 2017), and Logit models (Akkuş, 2021), LSTM (Long Short-Term Memory) automatic encoder model (Ayan and Eken, 2021).

The general assessment of the literature on housing market bubbles in Türkiye reveals that most studies focus on the post-2010 period and primarily use statistical tests such as GSADF, BSADF, and SADF. These studies predominantly cover Türkiye as a whole or specific major cities, often providing some evidence of the existence of housing bubbles. However, considering that many of these studies concentrate on older data periods and typically analyse pre-earthquake periods, changes in the housing market post-earthquake and potential bubble formations are not evaluated. In this regard, this study's focus on the post-earthquake period and its use of the most recent data sets for analysis are expected to make it a significant contribution as the first study to investigate the relationship between earthquakes and housing bubbles, filling a gap in the literature. In this context, the results of this study could deepen our understanding of the dynamics of the housing market in Türkiye and establish a stronger foundation for future policy decisions.

3. Data and Methodology

In this study, we investigated the presence of housing bubbles and their formation periods using econometric methods. Our data period spans from January 2010 to September 2024, specifically chosen to cover the period before and after the significant earthquake on February 6-7. We determine whether the earthquake impacted triggering a housing bubble in Türkiye. The Housing Price Index data were obtained from the Central Bank of the Republic of Türkiye (TCMB). Subsequently, we adjusted the Housing Price Index to real terms using the Producer Price Index (PPI) data. This process ensured the accurate representation of the housing market trends and dynamics in our analysis. We employ the Generalised Supremum Augmented Dickey-Fuller (GSADF) method to examine the existence of housing bubbles. Additionally, we use the Backwards Supremum Augmented Dickey Fuller (BSADF) method to accurately identify the periods of bubble formation. By focusing on this particular data period, we aim to contribute to the understanding of how external events such as earthquakes may influence housing market dynamics and potential bubble formations.

In this study, we employed the Generalised Supremum Augmented Dickey Fuller (GSADF) test developed by Phillips, Shi and Yu (2015), which is an extension of the Supremum Augmented Dickey Fuller (SADF) test developed by Phillips, Wu and Yu (2011). The SADF test proposed by Phillips, Wu and Yu (2011) uses recursive regression and right-tailed unit root tests to examine explosive behaviours (i.e., bubbles) in stock prices in the U.S. Nasdaq stock exchange. Unlike left-tailed unit root tests, such tests generally focus on the alternative hypothesis (rather than the unit root hypothesis) due to their interest in possible deviations from fundamentals and the presence of market irrationalities or mispricing (Phillips, Shi, & Yu, 2015: 1047). The SADF test (Equation 1) begins with the least squares estimation of Eq. (1) (Phillips, Wu and Yu, 2011, p. 206).

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

Here, j represents the lag value, and NID denotes the normal distribution. The null hypothesis of the unit root H_0:δ= 1, with the right-tailed alternative hypothesis H_1:δ > 1. The SADF test relies on repeated predictions of the ADF model over an expanding sample series and obtains the test as the sup value corresponding to the ADF test series (Phillips et al., 2011, p. 207).

$$ADF_r \Rightarrow \frac{\int_0^r \tilde{w} dw}{\left(\int_0^r \tilde{w}^2\right)^{1/2}}, \text{ and; } \sup_{r\in[r_0,1]} ADF_r \Rightarrow \sup_{r\in[r_0,1]} \frac{\int_0^r \tilde{w} dw}{\left(\int_0^r \tilde{w}^2\right)^{1/2}} \tag{2}$$

The PWY test uses an expanding sample sequence with a window size that increases from r0 to 1. It relies on repeated ADF model estimations and calculates the sup value of the ADF statistic sequence. The starting point of the sample sequence is fixed at 0, and the endpoint varies from r0 to 1. The PWY test statistic, denoted as SADF(r0), is obtained as the supADF value from the forward recursive regression (Phillips et al., 2015, p. 1048):

$$SADF_{(r_0)} = \sup_{r_2\in[r_0,1]} ADF_0^{r_2} \tag{3}$$

Following this, Phillips, Shi and Yu (2015) introduced the Generalised Supremum Augmented Dickey Fuller (GSADF) test and Backwards Supremum

Augmented Dickey Fuller (BSADF) dating algorithm to detect multiple bubbles, building upon the SADF test by Phillips, Wu and Yu (2011). The GSADF test expands the coverage significantly by recursively applying ADF test regressions on the data sub-samples based on equation 4.

$$\Delta y_t = \hat{a}_{r_1,r_2} + \hat{\beta}_{r_1,r_2} y_{t-1} + \sum_{i=1}^{k} \hat{\psi}^{i}_{r_1,r_2} \Delta y_{t-i} + \hat{\varepsilon}_t \tag{4}$$

The GSADF test expands on the concept of recursively applying ADF test regressions on data sub-samples (Equation 4). However, unlike the SADF test, the GSADF test uses much broader sub-samples in the recursion. This allows for varying the endpoint of the regression r2 from r0 (the minimum window width) to 1, and also permits the starting point r1 in Equation (4) to vary within a feasible range, specifically from 0 to r2 - r0. The GSADF statistic is defined as the largest ADF statistic obtained through this double recursion across all feasible ranges of r1 and r2, denoted as GSADF (r0).

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} \left\{ \frac{\frac{1}{2} r_w \left[W(r_2)^2 - W(r_1)^2 - r_w \right] - \int_{r_1}^{r_2} W(r) dr \left[W(r_2) - W(r_1) \right]}{r_w^{1/2} \left\{ r_w \int_{r_1}^{r_2} W(r)^2 dr - \left[\int_{r_1}^{r_2} W(r) dr \right]^2 \right\}^{1/2}} \right\} \tag{5}$$

Additionally, the GSADF statistic is simply defined as follows in Equation (6) Phillips, Shi and Yu, 2015, p. 1049):

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} ADF_{r_1}^{r_2} \tag{6}$$

The Generalised Supremum Augmented Dickey Fuller (GSADF) statistic proposed by Phillips, Shi and Yu (2015) allows for the detection of multiple bubbles, unlike the Supremum Augmented Dickey Fuller (SADF) statistic proposed by Phillips, Wu and Yu (2011), due to its allowance for the window size to vary from 0 to r2 - r0, providing a significant advantage in this regard (Phillips, Shi and Yu, 2015, p. 1048).

Following the GSADF test statistic, Phillips, Shi and Yu (2015) proposed the Backwards Supremum Augmented Dickey Fuller (BSADF) series for determining the start and end dates of bubble formations. This procedure uses a flexible window similar to the one mentioned earlier. Specifically, the backward SADF test conducts a sup ADF test on a backward expanding sample sequence, where each sample's endpoint is fixed at r2 (the sample fraction corresponding to the window's endpoint), while the starting point varies from 0 to r2 - r0 (the sample fraction corresponding to the window's origin). The backward SADF statistic is then defined as the sup value of the ADF statistic sequence over this interval, represented as (Phillips, Shi and Yu , 2015, p. 1051):

$$BSADF_{r2}\left(r_0\right) = \sup_{r_2 \in [0, r_2 - r_0]} \left\{ ADF_{r_1}^{r_2} \right\} \quad (7)$$

Consequently, this approach offers greater flexibility in detecting multiple bubbles. PWY (Phillips, Wu and Yu, 2011) proposed comparing ADF_{r2} with the (right-tail) critical values of the standard ADF statistic to identify explosiveness at observation T_{r2}. The point at which the backward SADF sequence first intersects the critical value indicates the onset of bubble formation, the points where the BSADF sequence is above the critical value indicate the region where the bubble is located, and the last point where the BSADF sequence is above the critical value indicates the end of bubble formation. In this context, the BSADF curve can be considered as a representation of "the fair price curve" in the market. This curve serves as a tool for detecting overvaluations within the housing market, illustrating how closely market prices align with their fundamental values. Fair pricing is crucial for understanding the relationship between the true values of assets and their market prices. If the BSADF curve remains below a certain threshold, it may signal excessive overvaluation or the formation of a bubble. Therefore, the BSADF curve can be used as a reference point for determining fair pricing. However, it is essential to assess whether this curve accurately reflects fair prices by considering market conditions, economic indicators, and other relevant factors.

4. Empirical Findings

During the data period from January 2010 to September 2024, an analysis was conducted to identify potential housing bubbles in Türkiye's real estate market. Initially, the Generalised Supremum Augmented Dickey-Fuller (GSADF) test was applied to examine the presence of housing bubble formations. The results indicated the existence of housing bubble formations throughout the data period, highlighting significant trends in the Türkiye housing market. Following the identification of multiple bubble formations, the Backward Supremum Augmented Dickey-Fuller (BSADF) test was used to pinpoint the specific periods of bubble formation. This involved generating the Backward SADF series and critical values, which are presented in Table 1. The combination of the GSADF and BSADF test results offers comprehensive insights into the dynamics of housing bubbles in Türkiye, shedding light on the occurrence and duration of the bubble formation periods.

Table 1: Bubble Formation Periods in the Türkiye Housing Market: Results of the GSADF and BSADF Analysis

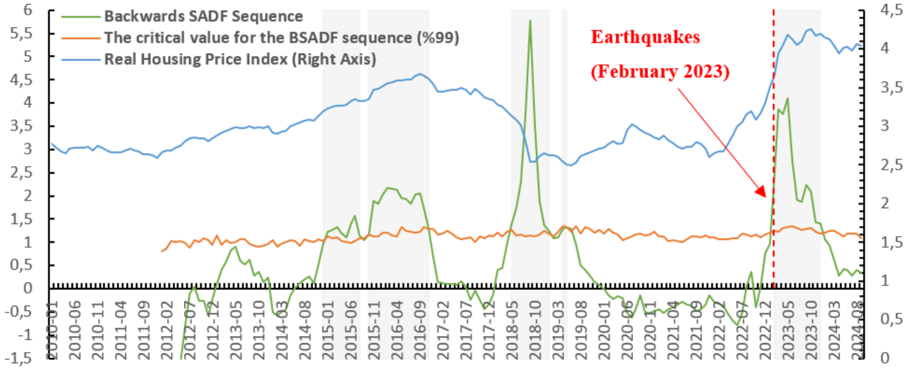
GSADF Statistics	Bubble Period	
5.770***	First Bubble Period	January 2015-August 2015
	Second Bubble Period	November 2015-November 2016
	Third Bubble Period	May 2018-January 2019
	Fourth Bubble Period	May 2019-June 2019
	Fifth Bubble Period	February 2023-December 2023

Note: ***, **, and * indicate the presence of housing bubble formations at the significance levels of 1%, 5%, and 10%, respectively, in the right-tailed tests. The critical values for the GSADF statistic are 1.754, 2.077, and 2.596, respectively. These critical values were obtained through 2000 repeated Monte Carlo simulations with a minimum estimation window size of 24 months for 177 observations. According to the BSADF results, the housing bubble formation periods are indicated at the 1% significance level.

The housing bubble formations observed in Türkiye from January 2010 to September 2024 exhibit considerable diversity. When examining the periods of bubble formation, the first four bubble periods are generally associated with economic cycles. For instance, intense housing demand supported by factors such as economic growth and low-interest rates characterises the first bubble period from January 2015 to August 2015. Similarly, the second bubble period from November 2015 to November 2016 can be linked to an increase in housing loans and high investor interest. The third and fourth bubble periods are typically associated with liquidity increases in the market and rapid rises in housing prices. In this direction, potential triggers for bubble formation include low-interest rates, liquidity abundance, rising housing demand, speculative investments, and government policies encouraging the housing sector. In particular, low-interest rates and expansive monetary policies may have contributed to increased housing loans and investor interest, thus supporting the formation of the bubble.

The most intriguing period among the obtained results is the latest housing bubble formation period, which emerged immediately after the earthquake. This period deserves special attention due to several critical factors and warrants a thorough evaluation due to its significant implications. In this context, it is obvious that Türkiye implemented negative interest rate policies despite the increasing interest rates globally, from before the earthquake disaster until the period when the transition to orthodox policies took place after the elections. There is a strong possibility that this will pave the way for a bubble in the housing market, as has been the case in other periods. However, the fact that this period coincides with the largest earthquake disaster in Türkiye's history cannot be overlooked; it is of paramount importance. It is undeniable that the earthquake's correlation with housing bubble formation is not coincidental, especially considering the sudden breach of the critical value in the BSADF series immediately after the earthquake. Initially, in January 2023, the BSADF test statistic was below the critical threshold for bubble formation, at 0.968 compared to a critical value of 1.208. However, in February 2023—the month of the earthquake—the test statistic surged to 2.492, surpassing the critical value of 1.244, marking the beginning of a pronounced housing bubble. This dramatic spike underscores the earthquake's impact on the housing market, fuelling an acute imbalance in supply and demand that spurred rapid price escalation. The BSADF series continued its upward climb, peaking at 4.100 in May 2023, well above the 1.33 critical threshold. This apex indicated the bubble's maximum intensity, reflecting a highly speculative phase marked by accelerated buying and rising prices, particularly in the earthquake-affected regions and beyond. Yet, from June 2023 onwards, the BSADF values declined steadily, suggesting the onset of the bubble's deflationary phase as the market began to adjust. By December 2023, the bubble had fully dissipated, indicating a normalisation of housing prices. This cycle—from rapid inflation to eventual deflation—illustrates the housing market's sensitivity to exogenous shocks, regulatory changes, evolving investor sentiments, and the complex interplay of supply-demand factors following significant natural disasters.

Figure 1: Periods of Housing Bubble Formation According to the Backward SADF Test Results



It may be suggested that the February 2023 earthquake, which impacted approximately 13 million people, caused severe disruptions in Türkiye's housing market, resulting in a housing bubble with significant price inflation. The disaster not only led to a drastic reduction in the housing stock in the affected regions but also spurred a wave of internal migration as people sought safer living conditions in other areas of the country. This movement intensified demand in relatively unaffected regions, creating a heightened demand for housing that outpaced the available supply. Additionally, in cities with higher seismic risks, even those unaffected by the recent earthquake, many residents experienced renewed apprehension about potential future earthquakes. This led to an increased demand for newly constructed or structurally sound buildings, further straining housing availability. The combination of reduced housing supply in impacted areas, increased migration, and heightened caution towards earthquake-resilient housing ignited a surge in prices across the market, reinforcing the bubble formation beyond what the BSADF test alone indicated. The econometric analysis thus illustrates how the intersection of reduced supply, elevated demand in safe zones, and psychological responses to seismic risk collectively drove the post-earthquake housing bubble—a phenomenon that underscores the profound and far-reaching impact of natural disasters on market dynamics. This study does not claim that the last bubble formation was solely caused by the earthquake. In other words, the recent housing bubble cannot be attributed solely to the earthquake. However, it is clear that the seismic event was a key factor in igniting the market's speculative frenzy. Apart from the earthquake disaster experienced during this period, there were other crucial factors that triggered the formation of this bubble in the housing market. In this respect, the following points outline the potential reasons behind the recent housing market bubble formation:

1. Direct earthquake-related factors:

- Sudden decrease in building stock: The seismic event rendered a substantial number of buildings unusable (either collapsed or severely damaged), creating a surge in the demand for housing in an area inhabited by 13 million people. This scarcity aligns with **fundamental value models**, where the supply-demand imbalance drives prices up beyond intrinsic values, setting the groundwork for speculative behaviour.
- Displacement of population: The displacement of people from earthquake-affected areas to various parts of Türkiye has led to increased mobility, contributing to the diffusion of the housing bubble across the country. **Rational bubble models** may interpret this as a response to perceived future price increases in previously stable regions, where displaced populations have increased demand.
- Increased demand for safe housing in historically seismic regions: Even in areas not directly affected by the earthquake but historically prone to seismic activity, residents' heightened concerns about safety have fuelled demand for secure housing, contributing to bubble formation. Fear-driven demand in other seismic zones illustrates **psychological factors** in speculative bubbles, particularly **herding behaviour** and **overvaluation due to anchoring bias**, as households seek safety and are willing to pay premiums for secure housing.

2. Market conditions unrelated to the earthquake but influenced by it indirectly:

- Inflationary effects: The anticipation of ongoing inflationary trends in Türkiye, coupled with increased housing demand, led to pricing based more on the future value of properties than their current worth. Inflationary trends and price adjustments based on anticipated future values rather than current valuations reflect **overconfidence and speculative exuberance** within **behavioural finance models**, as buyers may overvalue properties with expectations of continued appreciation.
- Rise in foreign currency and foreign demand for housing: The surge in the exchange rate made domestic properties more affordable for foreigners, prompting sellers to adjust prices accordingly. This is consistent with **asymmetric information theories**, where non-local buyers with different valuation strategies influence market prices, potentially creating distortions that heighten bubble formation.
- Housing as an investment vehicle: The perception of housing as a lucrative investment akin to stocks or foreign exchange, driving an increase in demand. The perception of real estate as an investment commodity, akin to that of stocks, reveals a **speculative shift in asset perception**. Investors, betting on continuous price increases, align with **rational expectation models** that predict speculative buying when assets are considered detached from fundamental values.
- Asymmetric information and moral hazard in the market: The heightened demand for housing led to opportunistic behaviour, with sellers taking advantage of buyers' situations to demand higher prices, especially from earthquake victims needing new housing either in the affected area or in different regions. This behaviour is consistent with **the moral hazard and market asymmetry models**, where price inflation persists due to unequal bargaining power and limited alternatives for urgent buyers.

3. Financial Market Dynamics and Credit Accessibility

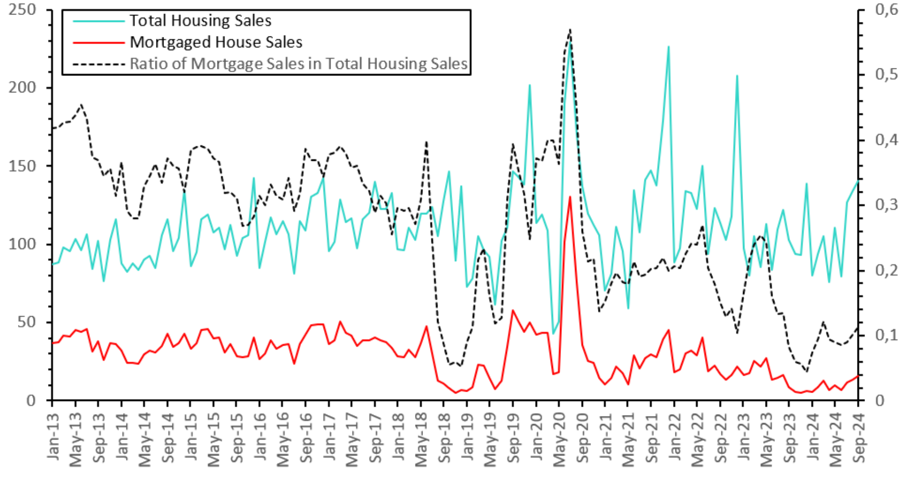
- Ease of credit and borrowing conditions: Low interest rates may have substantially broadened access to housing credit, facilitating borrowing at favourable rates. Particularly before the shift back to orthodox policies after the election, these low rates potentially enabled a larger segment of the population to obtain mortgage financing, thereby stimulating housing demand. In line with **Minsky's Financial Instability Hypothesis**, expanding credit access and debt cycles are likely to encourage asset price bubbles, suggesting that easier borrowing conditions could have contributed to speculative price inflation.

- Investor speculation due to low-interest rates or anticipated rate changes: Market actors may have anticipated that the continuation of significantly negative real interest rates was unsustainable, foreseeing eventual rate increases that would tighten credit conditions. This expectation may have spurred speculative demand, with investors seeking to leverage favourable credit terms before rates increased. Consequently, speculative housing demand during the low-rate period may have contributed to asset bubbles as buyers aimed to capitalise on prospective price appreciation. This aligns with **rational bubble models**, where market participants' expectations of future price gains foster speculative demand, thus potentially inflating housing prices ahead of anticipated credit tightening.
- Impact of emergency public housing initiatives in earthquake-affected regions: In response to the urgent housing needs of the 13 million people affected by the earthquake, extensive government-led construction projects were initiated in the impacted areas, effectively transforming these regions into large-scale construction zones. This rapid expansion of public housing construction likely placed upward pressure on the demand for building materials, labour, and land. Such large-scale state intervention, combined with heightened private sector activity, may have influenced housing market dynamics nationwide by driving up costs and amplifying the housing bubble. This is consistent with **market frictions and supply chain effects**, where public intervention in housing markets intensifies resource constraints and contributes to speculative pricing in related markets.

The trajectory of the BSADF series during this period is particularly noteworthy, with the test statistic used to detect the bubble peaking in May 2023 and then displaying a steady downward trend after that. This shift signals the beginning of a deflationary phase in the housing bubble, which ultimately dissipated by December 2023. The primary question here is why the BSADF series saw a downward break. The simplest explanation for this situation can be expressed as the elimination or alleviation of the issues explained above as possible causes of bubble formation. First, several factors may explain this, including the population gradually overcoming the initial shock of the earthquake, a reduction in migration from earthquake-affected areas to other regions, and the return of temporary migrants to the impacted zones.

Afterwards, most importantly, the policies implemented by the economic authorities, particularly the Central Bank's post-election monetary tightening, have had a profound impact on the housing market. As part of efforts to control inflation, interest rates were raised, which directly increased borrowing costs and, consequently, housing expenses. Additionally, credit access was restricted under these contractionary policies, making it more difficult for individuals to obtain mortgage financing. This led to a notable reduction in mortgage-driven demand, evident in the declining share of mortgage sales within total housing sales, as illustrated in Figure 2. This decrease in mortgage sales, which aligned with the downward movement of the housing bubble's trajectory, is a significant market reaction, highlighting a strong correlation between these restrictive financial conditions and the reduced demand in the housing sector. By December 2023, when the bubble had fully dissipated, the share of mortgage sales had dropped to approximately 4.36% (in April 2023, the month before the curve broke down, this rate was at its peak in recent months at 25.42%), the lowest level within the data period analysed. This decline in mortgage sales is not merely coincidental; it aligns closely with the downward trend in the BSADF series, indicating that the reduced demand for mortgage-driven housing played a critical role in the deflation of the bubble. Furthermore, as interest rates rose, investor preferences began to shift towards less risky options, such as savings, further curbing investment-driven demand for housing.

Figure 2: Ratio of Mortgage Sales in Total Housing Sales



In summary, two main factors underpin the deflation of the housing bubble. First, the gradual fading of the psychological and physical impacts of the earthquake and the normalisation of market conditions; and second, the Central Bank's contractionary monetary policy, which includes higher interest rates and restricted credit access to counter inflationary pressures. Together, these factors have dampened both investment and mortgage-based demand, stabilising housing prices and contributing to the bubble's decline.

5. Conclusion and Evaluation

Speculative bubble formation refers to the pricing of an asset significantly higher than its intrinsic value. This phenomenon is crucial in financial markets as it can trigger macroeconomic crises, as seen in the case of the Mortgage Crisis in the United States, which escalated into one of the most significant financial crises globally. Additionally, it can disrupt income distribution, significantly impacting societal welfare. As widely observed, there has been a steep increase in housing prices in Türkiye recently. Are these increases based on real fundamentals, or are they entirely a "bubble"? This contentious issue can be identified using econometric methods.

The earthquake disasters that struck Türkiye on February 6-7, 2023 have had profound and far-reaching effects on various aspects of the country, including its housing market. This paper aimed to investigate the impact of these earthquakes on the housing market, specifically focusing on the potential formation of a housing bubble. The data period from January 2010 to September 2024 was analysed using the Generalised Supremum Augmented Dickey-Fuller (GSADF) and Backward Supremum Augmented Dickey-Fuller (BSADF) methods to identify housing bubble formations and their durations. The empirical findings offer substantial insights into the speculative dynamics of Türkiye's housing market, revealing several distinct periods of bubble formation. Notable instances include from January 2015 to August 2015, from November 2015 to November 2016, from May 2018 to January 2019, from May 2019 to June 2019, and from February 2023 to December 2023, each reflecting phases of rapid price escalation influenced by macroeconomic factors and shifts in market conditions. However, the most significant period detected through the GSADF and BSADF tests is the housing bubble triggered by the February 2023 earthquakes, which caused a sharp increase in housing prices and a severe disruption in the supply-demand equilibrium. Unlike prior bubbles that evolved over time, this bubble emerged abruptly in response to the catastrophic natural disaster.

These findings underscore the profound impact of sudden supply shocks and population displacement on market dynamics, particularly in high-risk seismic regions. The earthquake-induced housing bubble in Türkiye offers a unique case study that broadens our understanding of speculative dynamics in housing markets, particularly in regions prone to seismic activity. Unlike typical housing bubbles, which often arise gradually due to extended periods of economic exuberance or policy shifts, this bubble emerged abruptly following a catastrophic natural event. This divergence underscores the significant impact of sudden supply shocks and population displacement on market prices, illustrating how external, non-economic shocks can trigger speculative cycles under conditions of heightened demand and limited supply. The findings reveal that, in high-risk seismic areas globally, housing markets may be highly vulnerable to similar speculative pressures in the aftermath of natural disasters. As such, this study emphasises the critical need for policymakers in these regions to implement adaptive regulatory measures that can mitigate the inflationary effects of crisis-driven demand, stabilise housing availability, and enhance resilience against future market disruptions.

Several factors contributed to the post-earthquake housing bubble, including the sudden decrease in building stock, displacement of populations, increased demand for safe housing, inflationary effects, rise in foreign demand, perception of housing as an investment, and market asymmetries. These factors, coupled with regulatory measures and monetary policies, influenced the severity and duration of the housing bubble. The findings of this study illustrate how the earthquake-induced bubble diverges from traditional speculative bubbles, aligning closely with Minsky's Financial Instability Hypothesis and models that emphasise market inefficiencies and psychological factors. Specifically, the sudden supply shock caused by the earthquake created conditions ripe for speculative behaviour, theories on asset bubbles driven by herding behaviour, overconfidence, and anchoring bias. The combination of low interest rates, heightened demand for safe housing, and increased investor activity demonstrates the interplay between external shocks and existing market dynamics, illustrating a situation where speculative pricing extended beyond intrinsic values. This context reinforces the relevance of behavioural finance models, which account for psychological drivers and market frictions that can intensify bubble formation in times of crisis.

The downward break in the BSADF series, which can also be considered as "the fair price curve" in the housing market, after June 2023 can be attributed to various factors, including the population's adaptation to the earthquake's aftermath, reduced migration, government policies, increased interest rates, and restricted credit availability. This downward shift continued until December 2023, when the series dropped below the critical threshold, indicating the bubble's complete deflation. These factors collectively played a crucial role in mitigating the housing bubble's impact, leading it into a full deflationary phase.

In conclusion, the empirical analysis confirms that the February 2023 earthquakes triggered a housing bubble in Türkiye's housing market. The findings underscore the importance of considering external shocks, such as natural disasters, in assessing housing market dynamics and risks. Another point to be emphasised based on the recent bubble formation is that the central bank's post-election interest rate hikes played a pivotal role in curbing this bubble, as reflected in the declining share of mortgage-based sales within total housing sales. As interest rates increased, borrowing costs rose, which reduced the affordability of mortgages, leading to a marked decrease in mortgage-driven demand. This shift aligned with the housing market's deflationary trend, where mortgage sales as a share of total sales dropped significantly, reaching their lowest level at the point when the bubble had completely dissipated by December 2023. This correlation between restrictive monetary policy, declining mortgage sales, and the deflation of the housing bubble emphasises the impact and necessity of timely policy interventions in stabilising speculative markets. These findings highlight the importance for economic authorities to maintain an active role in monitoring and intervening in the housing market as needed, especially in response to external shocks, to address supply-demand imbalances, and to mitigate the risks associated with future housing bubbles. Moving forward, policymakers and stakeholders need to continue monitoring the housing market closely, implement prudent regulatory measures, and address supply-demand imbalances to maintain market stability and mitigate the risks associated with housing bubbles.

In this sense, this study contributes valuable insights to the literature on housing market bubbles, emphasising the need for comprehensive analyses that integrate external shocks and economic factors. Further research can explore long-term trends, policy implications, and risk management strategies in the context of post-disaster housing markets, providing a robust foundation for informed decision-making and sustainable market development.

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