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Speculative Bubbles in Regional Wheat Markets: Evidence from Türkiye

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ABSTRACT
Despite its strategic role in the wheat trade, Türkiye's wheat markets remain vulnerable to volatile price movements and speculative behavior. While significant progress has been made in the global literature on detecting speculative bubbles in agricultural commodities, there is a clear empirical gap in applying advanced econometric bubble detection methods to the wheat sector in Türkiye. This study aims to address this issue by offering region-specific insights into the speculative dynamics that influence wheat prices in major production centers in Türkiye. We applied the Supremum Augmented Dickey-Fuller (SADF) and Generalized Supremum Augmented Dickey-Fuller (GSADF) tests to monthly wheat price data from Ankara, Edirne, and Konya provinces to detect speculative price bubbles. After identifying bubble periods, we used probit and logit models to explore potential drivers, including the producer price index (UFE), input price index (IPI), real effective exchange rate (R), and the marketed quantity of wheat (LNQ). The empirical results revealed multiple statistically significant bubble episodes in Ankara and Edirne between 2020 and 2022. In contrast, Konya exhibited fewer, shorter-lived bubbles concentrated in 2023–2024. GSADF results confirmed that price exuberance was neither uniformly distributed nor persistent across provinces. Regression analyses showed that the UFE and IPI significantly increased the probability of bubble formation in Ankara and Konya. Meanwhile, R had a stabilizing effect in Ankara and Edirne. These results imply regional differences in speculative price behavior within Türkiye's wheat market. The results highlight the importance of incorporating localized market structures and macroeconomic indicators into national agricultural price stabilization policies. Methodologically, this study contributes by integrating recursive right-tailed unit root tests with nonlinear probability models to better understand speculative forces in commodity markets. As a policy recommendation, the licensed warehousing system should be revised to enable physical and/or online transactions through regionally authorized procurement centers. Real-time monitoring and analysis of wheat exchange prices would allow timely intervention when price bubble signals emerge.

Keywords: Effect Speculative bubbles, Price volatility, GSADF test, Regional price dynamics

1. Introduction

Wheat is crucial for agriculture, feeding livestock, and people's diets. It is important economically and culturally, and it is a significant source of calories. Wheat can be grown in many places, is highly nutritious, and has a balanced amino acid profile. Wheat is easy to store, transport, and process (Kılıç & Giray 2021). Recently, the volatility of agricultural commodity prices, particularly wheat, has received more attention because of its critical role in global food security, trade, and rural livelihoods. Wheat is a staple food for much of the world's population, so any disruption in its price structure can lead to socioeconomic instability.

Wheat is the most widely produced grain in Türkiye and is primarily used to make bread, which makes it an important crop. It is one of the country's strategic products and plays a key role in food security (Yılmaz & Tomar 2022). According to FAO's Cereal Supply and Demand Brief, global wheat production is forecasted to reach 796 million tons in 2025, marking a modest increase of nearly 1 percent from the previous year (FAO 2024). However, the sector faces ongoing challenges, including price volatility, high input costs, and climate-related risks. Robust production systems and strategic planning are necessary to ensure the sector's resilience and growth in the face of these challenges. Research on Turkish wheat markets (Urak et al. 2022) indicates that speculative behavior significantly influences price movements. Although Türkiye is a major wheat producer in the Mediterranean region, it faces price instability due to import dependence, weather volatility, and exchange rate fluctuations. Government interventions often fail to stabilize prices. The elasticity level of demand can further amplify the effects of supply changes. Especially in cases where demand exhibits relatively low-price elasticity, such as in agricultural products, volatile movements in market supply can lead to significant fluctuations in the equilibrium price without causing substantial changes in the equilibrium quantity (Şengül 2023).

Price bubbles have been associated with various factors, including economic conditions, interest rates, and inflation levels. (Khan et al. 2022). The identification and comprehension of speculative bubbles within the wheat market are imperative for ensuring price stability, safeguarding farmers' incomes, and formulating efficacious food security policies.

In literature research, Etienne et al. (2014) applied explosive root tests to U.S. grain futures (2004-13). They found bubbles were rare (~2% of the time), short-lived, and mostly downward, challenging views that financial speculation drives positive bubbles. Similarly, Adämmer & Bohl (2022) detected speculative bubbles in cereals (but found wheat less bubble-prone than maize), using MTAR methods. The Master's Hypothesis posits that commodity index funds fueled the 2007-08 price spikes. Yet EMBO Reports (2011) note mixed evidence: while some find speculative capital contributed up to 15% to food price increases, find no significant harmful bubble formation. Studies using GARCH/GJR-GARCH methods (e.g., MDPI 2022) suggest speculation sometimes dampens volatility in wheat markets, though short-term effects vary. Demir & Ersoy (2019) employed ARMA-GARCH on Turkish wheat between 2010 and 2018, finding speculation contributed marginally to volatility, overshadowed by weather/climate shocks. Structural factors-biofuels, currency, oil prices, and inventories- consistently emerge as major drivers of wheat price spikes. Lagi et al. (2011) modeled food crises, attributing both price peaks and trends to speculation and ethanol conversion. Kaya & Uslu (2021) compared Turkish and global wheat prices, finding Türkiye more sensitive to global oil price changes and EUR/TRY dynamics than domestic speculative positions. European analysts (MDPI 2021) note leadership in price discovery has shifted from the U.S. to the EU (MATIF), stressing that seasonality and market structure matter for speculation. Aksoy & Can (2022) combined CONGARCH with seasonal indices on Turkish and Mediterranean wheat, concluding that Mediterranean markets are more prone to price pressure from physical shocks (e.g., droughts) than from financial speculation.
Despite the existence of substantial evidence, there are still significant gaps in the integration of speculative price dynamics with bubble detection, specifically for Türkiye's wheat within a unified framework. Existing Turkish studies frequently concentrate on proximate markets, such as meat, or employ specialized models devoid of cross-market bubble dynamics. The objective of this paper is to address this knowledge gap by employing a consistent bubble-testing methodology (Phillips et al. 2015) and structural volatility modeling to analyze Turkish wheat prices over the past decade. The study will compare domestic behavior with global trends. The term speculative bubbles are used to describe significant deviations of market prices from their intrinsic values. These deviations are driven by investor behavior rather than supply and demand fundamentals. In the context of commodity markets, the formation of bubbles has the potential to distort production incentives, impede the efficacy of policy measures, and intensify food insecurity.

Given the increasing integration of Türkiye's wheat market with global financial dynamics, a deeper understanding of speculative behavior is necessary. This study contributes to the literature by applying advanced bubble detection techniques to identify non-fundamental price movements. The primary objective of this study is to investigate the current situation, frequency, and determinants of speculative bubbles in the Turkish wheat market using recent price data and econometric techniques such as the Generalized Supremum Augmented Dickey-Fuller (GSADF) test.

2. Material and Methods

In this study, the Supremum Augmented Dickey-Fuller (SADF) test developed by Phillips and Yu (2011) and the Generalized Supremum Augmented Dickey-Fuller (GSADF) test proposed by Phillips et al. (2015) were applied to detect potential bubble formations in wheat prices. Following the identification of bubble periods, probit and logit regression models were employed to examine the underlying factors associated with the emergence of these speculative bubbles by modeling the probability of bubble occurrence as a function of selected economic and market-related variables.

2.1. Data and model

This study investigates the presence of speculative bubbles in regional wheat prices in Türkiye, focusing on three key provinces: Ankara, Edirne, and Konya. These provinces were selected due to their economic relevance in wheat production and trade, as well as the availability of consistent price data. For each province, monthly nominal producer prices for wheat were used to construct separate time series. The analysis period spans from January 2018 to December 2024 for Ankara, January 2018 to December 2023 for Edirne, and January 2022 to November 2024 for Konya, depending on the availability of complete monthly observations in each case. The price data used for detecting speculative bubbles were originally obtained at a daily frequency. However, due to the presence of gaps and missing observations in the daily series, a direct application of bubble detection tests could lead to biased or unreliable results. To address this issue and ensure the robustness of the analysis, the daily prices were aggregated into monthly averages, resulting in a smoothed time series suitable for econometric testing.

Subsequently, for each province, a binary bubble variable was constructed based on the GSADF test results. In this coding scheme, months identified as bubble periods were assigned a value of 1, while non-bubble months were coded as 0. Accordingly, three separate dummy variables were created: Bubble_A for Ankara, Bubble_E for Edirne, and Bubble_K for Konya. To investigate the potential determinants of speculative bubbles, several explanatory variables related to the wheat market were incorporated into the analysis. These include the Producer Price Index for wheat (UFE), the Agricultural Input Price Index (IPI), the real effective exchange rate (R) based on the domestic producer price index, and the quantity of wheat marketed (Q). Given that the wheat quantity is originally expressed in kilograms, it was transformed using the natural logarithm to ensure scale

compatibility with the other variables and to allow for more interpretable coefficients in the probit and logit models. All variables were obtained from the official database of the Turkish Statistical Institute (TURKSTAT 2025).

Table 1- Definitions of The Variables

Variable	*Definition*	*Source*
Bubble_A	Shows the bubble periods for Ankara	Constructed by the authors based on monthly wheat prices.
Bubble_E	Shows the bubble periods for Edirne	Constructed by the authors based on monthly wheat prices.
Bubble_K	Shows the bubble periods for Konya	Constructed by the authors based on monthly wheat prices.
P	Wheat prices averaged every month from daily observations	TÜİK (2025)
UFE	Producer price index for wheat	TÜİK (2025)
IPI	Agricultural input price index	TÜİK (2025)
R	Real effective exchange rate based on the domestic producer price index	TÜİK (2025)
LNQ	Natural logarithm of wheat quantity	TÜİK (2025)

To identify the determinants of speculative bubbles in regional wheat markets, three separate models were estimated for Ankara, Edirne, and Konya using both probit and logit methods. In each model, the dependent variable is the corresponding bubble indicator (Bubble_A, Bubble_E, or Bubble_K), while the explanatory variables include UFE, IPI, R, and Q. The selection of these explanatory variables was guided by insights from previous empirical studies (Li et al. 2017; Dastagiri & Bhavigna, 2019; Wang et al. 2022; Fang et al. 2023) in the literature. The structure of the models is presented as follows:

Model 1: $Bubble_A_t = \beta_0 + \beta_1 UFE_t + \beta_2 IPI_t + \beta_3 R_t + \beta_4 LNQ_t + \varepsilon_t$

Model 2: $Bubble_E_t = a_0 + a_1 UFE_t + a_2 IPI_t + a_3 R_t + a_4 LNQ_t + \mu_t$

Model 3: $Bubble_K_t = \gamma_0 + \gamma_1 UFE_t + \gamma_2 IPI_t + \gamma_3 R_t + \gamma_4 LNQ_t + \delta_t$

In Models 1–3, the parameters β_0, a_0, and $\gamma_0$are the intercept terms, while β_1-β_4, a_1-a_4, and γ_1-γ_4 represent the slope coefficients associated with the explanatory variables in Models 1, 2, and 3, respectively. The terms ε_t, μ_t, and δ_t denote the error terms for Models 1, 2, and 3, respectively.

2.2. Methods

2.2.1. SADF and GASDF Test

A bubble is a process characterized by a sharp and sustained increase in the price of an asset or a group of assets. During this process, the initial rise in prices leads to the expectation that similar increases will continue in the future. These expectations attract speculators to the market who seek to make profits not through the use of the asset, but through its trade (Kindleberger, 2008; Li et al. 2017). On the other hand, bubbles are also defined as self-fulfilling prophecies of market participants who act based on the belief that prices will continue to rise in the future (Flood & Hodrick 1990; Li et al. 2017). In summary, the common view is that bubbles are typically associated with periods of rapid price increases followed by sharp declines (Li et al. 2017).

In commodity markets, it is frequently observed that prices deviate from fundamental market dynamics (Zhang et al. 2019). In some cases, such deviations may lay the groundwork for the formation of bubbles. Two main approaches in the literature are widely accepted as explanations for this phenomenon (Chen et al. 2023). The first is the speculative bubbles theory introduced by Tirole (1982; 1985), which is considered one possible cause of such deviations. The second is the concept of investor over-optimism or market exuberance developed by Shiller et al. (1984). In addition to these, Gürkaynak (2008) proposed an alternative commodity pricing model that holds under the assumption of no arbitrage and is also valid in futures markets. According to a study conducted by Zhang et al. (2019), wheat prices in the provinces of Ankara, Edirne, and Konya in Türkiye can be expressed using the bubble model in Equation 1.

$$P_t = P_t^f + b_t \quad (1)$$

In Equation (1), P_t^f represents the fundamental price of the wheat market, while b_t denotes the bubble component. Accordingly, the observed price P_t is decomposed into the fundamental price P_t^f and the bubble component btb_tbt through a log-linear estimation. Based on Equation (1), if there is no bubble effect in the market, the fundamental component P_t^f fully determines the price. However, when a bubble effect occurs, wheat product prices are affected by this bubble component. In such cases, the price of agricultural products exceeds its fundamental value, and this situation can be explained by Equation (1). The empirical identification of bubbles has emerged as a significant challenge in literature. Econometric methods employed in this context are often subject to sample selection bias, and particularly, conventional unit root or cointegration tests are typically capable of

detecting only a single bubble episode. These methods are inadequate in identifying bubbles that appear sporadically and collapse rapidly. For instance, detecting early warning signals of a potential future bubble in stock markets can be delayed, as this process requires identifying the start and end dates of the bubble. At the core of this issue lies the inability of standard unit root tests to capture structural shifts involving transitions from an I(0) process to an I(1) process and then back to I(0). This limitation further complicates bubble detection through cointegration-based approaches, as these tests are affected by distributional constraints such as skewness and kurtosis (Evans 1991; Liaqat et al. 2019). Within this framework, Phillips and Yu (2011) developed the Supremum Augmented Dickey–Fuller (SADF) test to identify the presence of speculative bubbles. The SADF test relies on the repeated application of the right-tailed ADF test across forward-expanding sample windows. The SADF test statistic is based on the maximum (supremum) value obtained from the sequence of ADF statistics. In the implementation over the fractional interval [0,1], the SADF test fixes the starting point of the test window and varies the endpoint from the minimum window size to the full sample (Huang & Wang 2024). The main objective of the SADF approach is to detect mildly explosive price behavior in the available data by recursively applying the right-tailed ADF unit root test. Unlike traditional left-tailed stationarity tests, the SADF test focuses on the detection of bubble dynamics through its right-tailed structure (Liaqat et al. 2019). Accordingly, the mathematical formulation of the SADF test is presented in Equation (2).

$$SADF(r_0) = r_2 \in [r_0, 1] sup\{ADF_0^{r_2}\} \quad (2)$$

In Equation (2) is defined as follows: r_0 denotes the minimum window size, r_2 represents the end point of the expanding subsample window, $ADF_0^{r_2}$ is the augmented Dickey-Fuller statistic computed over the interval, and sup selects the maximum statistic across all admissible windows.

Phillips and Yu (2011) state that the SADF test has a distinctive strength, as it can capture transitions over time between a unit root process and a mildly explosive one, or vice versa. This right-tailed test demonstrates greater sensitivity in detecting deviations from stationarity compared to traditional left-tailed unit root tests. However, bubbles often appear temporarily and dissipate during specific periods (Liaqat et al. 2019). The SADF test statistic is capable of identifying such periodically collapsing bubbles and can estimate the dates of their emergence and collapse. Nevertheless, Phillips et al. (2012) noted that the SADF test may be insufficient in detecting multiple bubble episodes occurring within the same sample period. Econometric applications of the SADF test have remained largely limited to studies focused on financial markets (Phillips et al. 2011; Phillips & Yu 2011; Areal et al. 2016).

To overcome the limitations of the SADF test, Phillips et al. (2015) developed the GSADF test method and proposed a repeated backward regression approach to more precisely determine the start and end dates of bubble episodes. Unlike the SADF test, the GSADF approach does not proceed from a fixed starting point. Instead, it allows the beginning and end points to vary through a flexible window structure, which expands the range of the analyzed sample (Huang & Wang 2024). Phillips et al. (2015) suggested that the SADF test can serve as a supportive tool for dating bubble periods historically. The ADF analytical method is based on the sequential application of right-tailed ADF tests and offers a broader and more adaptable sampling framework for data structuring (Nusair 2012; Liaqat et al. 2019). Compared to the SADF test, the GSADF test incorporates a larger number of subsamples and, due to its recursive structure, enables a more comprehensive use of the sample space. The GSADF method not only allows the starting point of the regression to vary but also permits the endpoint to range from the minimum window size up to 1. The GSADF test is compatible with the presence of multiple bubble episodes occurring simultaneously within a given period (Pavlidis et al. 2016; Liaqat et al. 2019). This test is defined by selecting the maximum ADF statistic calculated over all possible combinations of starting and ending intervals (Liaqat et al. 2019). Accordingly, the mathematical representation of the GSADF test is presented in Equation (3).

$$GSADF(r_0) = r_2 \in [r_0, 1], r_1 \in [r_2 - r_1] sup\{ADF_0^{r_2}\} \quad (3)$$

Phillips et al. (2015) stated that the GSADF rolling window test enhances the SADF test by allowing the analysis of volatile market behaviors observed during different bubble periods as the sample size increases. They also emphasized that the GSADF test has a low risk of producing false results, even in relatively uncertain sample structures. This advantage stems from the test's ability to include a greater number of subsamples and offer a high degree of flexibility in its window structure. As with the SADF test, the null hypothesis is rejected at the beginning and end points of a bubble in the GSADF framework (Liaqat et al. 2019). To improve the date-stamping strategy of the right-tailed recursive ADF test used in the SADF procedure, Phillips et al. (2015) proposed a double-recursive testing approach known as the backward supremum ADF (BSADF) test. In this method, $BSADF_{r_2}(r_0)$ fixes the endpoint of the sample at r_2, while the starting point r_1 varies within the interval from 0 to r_2-r_0. The statistic $BSADF_{r_2}(r_0)$ represents the supremum value in a series of ADF tests. Similar to the study by Phillips et al. (2011), the feasible range of r_2 must also recursively span from r_0 to 1. Within this new identification strategy, the potential explosiveness of a bubble at the observation point r_2 is assessed based on the value of $BSADF_{r_2}(r_0)$. The estimated bubble origin date, r_s, is the first time that the $BSADF_{r_2}(r_0)$ statistic exceeds the critical value. The bubble's end date, r_e, is calculated as the first observation after r_s where the $BSADF_{r_2}(r_0)$ statistic falls below the critical threshold again (Huang & Wang, 2024). According to the GSADF test, the dating of bubble periods is formulated as shown in Equations (4) and (5).

$$r_s = r_2 \in [r_0, 1] inf\left\{r_2 : BSADF_{r_2}(r_0) > cv_{r_2}^{\beta_1}\right\} \quad (4)$$

$$r_e = r_2 \in [r_s, 1] inf\left\{r_2 : BSADF_{r_2}(r_0) < cv_{r_2}^{\beta_1}\right\} \quad (5)$$

In Equations (4) and (5), $cv_{r_2}^{\beta_1}$ denotes the 100(1− β_1)% critical value of the SADF statistic derived from the observed data. The GSADF procedure conducts the backward sup ADF test repeatedly for each $r_2 \in [r_0, 1]$, drawing conclusions based on the supremum value from the sequence of BSADF statistics $BSADF_{r_2}(r_0)_{r_2 \in [r_0,1]}$. As a result, the GSADF test statistic yields a constant value when applied to a specific full sample and fixed r_0. Conversely, $BSADF_{r_2}(r_0)$ behaves as a continuous function that changes with varying r_2 (Huang & Wang, 2024). The formal mathematical definition of the GSADF test is presented in Equation (6).

$$GSADF\ (r_0) = r_2 \in [r_0, 1]\ sup\left\{BSADF_{r_2}(r_0)\right\} \quad (6)$$

In Equation (6) $BSADF_{r_2}(r_0)$is the backward supremum ADF statistic computed for a fixed end point r_2 and for all possible starting points within the interval, given the minimum window size r_2.

The BSADF test provides more detailed information and greater flexibility in detecting bubbles within a sample compared to the approach proposed by Phillips et al. (2011). This advanced method enables the identification of multiple bubbles by considering the highest ADF statistics that may arise within various observation intervals. The maximum test statistic can correspond to any subsample within the overall dataset. Moreover, the new date-stamping strategy based on the BSADF test can be applied in real time to detect bubbles ex ante, whereas the GSADF test is used for ex post analysis of bubble behavior based on historical data (Phillips et al. 2015; Huang & Wang 2024).

2.2.2. Logit and probit models

The logit regression model does not require several key assumptions that are commonly associated with classical linear regression analysis. For example, assumptions such as a continuous and linear dependent variable, normally distributed independent variables, normally distributed error terms, and independence of error terms are not required in the logit framework. However, when the dependent variable is categorical or binary (e.g. 0–1), logit or probit regression methods are more appropriate and yield more reliable results than linear regression (Long & Freese 2006; Güneri & Durmuş 2020).

As one of the generalized linear models, the logit model is widely used to explain the probability of an event when the dependent variable takes one of two possible values. Rather than modelling the probability directly, the model assumes a linear relationship between the explanatory variables and the logarithm of the odds of the event occurring. Therefore, especially in cases where the assumptions of normality and continuity are not satisfied, the logit model provides an effective tool for analyzing binary classification and decision-making processes. In practical applications, the coefficients are typically interpreted through odds ratios or marginal effects, while the sign of the coefficients indicates whether the associated explanatory variable increases or decreases the probability of the event (Güneri & Durmuş 2020).

One of the most commonly used approaches for modelling binary outcome variables is the linear probability model. However, its main limitation is that the predicted probabilities may fall outside the theoretical [0, 1] interval. The probit model was developed to overcome this issue and ensure that the predicted probabilities always remain within the valid 0–1 range. The probit model is used when the dependent variable is binary and estimates the probability of an event occurring as a function of a set of explanatory variables (Güneri & Durmuş 2020). In line with this, since the bubble periods in our study are coded as 1 when a bubble is present and 0 otherwise, logit and probit models are employed as the estimation methods.

3. Results and Discussion

Before presenting the results of the bubble tests, descriptive statistics for the variables used in the analysis were examined. The results are reported in Table 2.

Table 2- Descriptive Statistics

Variable	*Observation*	*Mean*	*Standard Deviation*	*Minimum*	*Maximum*	*Date*
			Ankara			
Bubble_A	84	0.2619	0.4423	0	1	2018M1-2024M12
P	84	4.4728	3.4185	0.9959	12.4383	2018M1-2024M12
UFE	84	3.9282	3.1572	0.91177	10.17	2018M1-2024M12
IPI	84	2.725	3.0283	-0.63	14.38	2018M1-2024M12
R	84	83.3668	7.5972	66.99	97.14	2018M1-2024M12
LNQ	84	9.5855	0.0978	9.3809	9.9106	2018M1-2024M12
			Edirne			
Bubble_E	72	0.2361	0.4277	0	1	2018M1-2023M12
P	72	3.2576	2.3952	0.9336	8.5568	2018M1-2023M12
UFE	72	3.0479	2.4695	0.9118	7.9003	2018M1-2023M12
IPI	72	2.7815	3.1883	-.063	14.38	2018M1-2023M12
R	72	81.623	6.6941	66.99	96.07	2018M1-2023M12
LNQ	72	9.7225	0.01313	9.6594	9.7707	2018M1-2023M12
			Konya			
Bubble_K	35	0.2286	0.4260	0	1	2022M1-2024M11
P	35	7.8614	1.7005	4.3255	11.4287	2022M1-2024M11
UFE	35	7.175	1.8008	3.0166	10.11	2022M1-2024M11
IPI	35	3.6491	3.4545	-0.22	13.25	2022M1-2024M11
R	35	89.2485	6.5013	72.01	97.14	2022M1-2024M11
LNQ	35	10.1205	0.0343	10.0644	10.1963	2022M1-2024M11

Table 2 summarizes the descriptive statistics of the variables for Ankara, Edirne, and Konya. The period covered varies by province, with data spanning from 2018M1 to 2024M12 for Ankara, from 2018M1 to 2023M12 for Edirne, and from 2022M1 to 2024M11 for Konya. The variable Bubble_A shows a higher average occurrence compared to Bubble_E and Bubble_K, suggesting that speculative patterns in wheat prices may have been more common in Ankara during the sample period. The values of P are notably higher in Konya relative to the other provinces, while Edirne has the lowest average. Fluctuations in P appear to be most pronounced in Ankara. The variable UFE is also the highest in Konya, pointing to relatively stronger upward movements in producer prices during the observed period. In contrast, UFE levels in Edirne and Ankara are comparatively lower. Regarding IPI, the averages are relatively similar across provinces, though Konya again records slightly higher values. Variation in IPI is more apparent in Konya, indicating greater input price dynamics. The values of R show that Konya consistently holds higher levels than Ankara and Edirne. This could reflect broader macroeconomic differences among the provinces during the study period. Finally, LNQ is highest in Konya, followed by Edirne and Ankara. The low variation in LNQ across provinces suggests relative stability in production volumes, particularly in Edirne and Konya. These initial findings point to distinct spatial patterns in price levels, input costs, and broader market conditions, which may contribute to the observed differences in bubble formation frequency across the provinces.

Table 3- Bubble Test Results for the Wheat Markets

Test	*Statistic*	*RTMC 90*	*RTMC 95*	*RTMC 99*	*Tab 90*	*Tab 95*	*Tab 99*
Ankara Wheat							
SADF	3.4629	2.1181	2.5394	3.3921	0.9548	1.2693	1.8764
GSADF	5.8769	3.4349	3.8851	4.9039	1.6597	1.9630	2.7092
Edirne Wheat							
SADF	4.5862	2.1263	2.5181	3.5428	0.9225	1.2484	1.861
GSADF	5.8902	3.4959	4.0808	5.3269	1.6425	1.9643	2.5940
Konya Wheat							
SADF	0.0959	1.1285	1.5568	2.3625	0.8175	1.1324	1.8615
GSADF	2.0255	2.8189	3.3894	4.9260	1.4142	1.8294	2.6224

Notes: The test reported in the table includes SADF as proposed by Phillips et al. (2011), and GSADF developed by Phillips et al. (2015). The right-tail Monte Carlo (RTMC) critical values at the 90^{th}, 95^{th}, and 99^{th} percentiles were computed using the wild bootstrap method with 2000 replications. Additionally, the right-tail tabulated critical values (Tab) corresponding to the 90%, 95%, and 99% confidence levels were obtained from Vasilopoulos et al. (2020).

Table 3 presents the results of the SADF and GSADF tests applied to identify potential speculative bubbles in wheat prices for Ankara, Edirne, and Konya. The test statistics are evaluated against both right-tail Monte Carlo and tabulated critical values at the 90%, 95%, and 99% confidence levels. In Ankara, both SADF and GSADF statistics exceed all RTMC and tabulated critical values. This provides strong statistical evidence for the existence of at least one explosive episode in the wheat market during the period examined. The magnitude of the GSADF statistic, in particular, suggests the presence of recurring speculative dynamics. Similarly, Edirne shows consistent signs of speculative behavior in wheat prices. Both SADF and GSADF test statistics surpass all corresponding RTMC and tabulated thresholds, indicating that the market experienced multiple bubble episodes. The results for Edirne are comparable in strength to those observed for Ankara. In contrast, the test results for Konya

do not support the existence of speculative bubbles. The SADF statistic remains well below all critical values, and the GSADF statistic, while exceeding the lowest tabulated threshold, does not reach the levels required to confirm explosiveness at conventional significance levels. The results in Table 3 imply that wheat price dynamics in Konya are relatively more stable and do not show any statistically significant signs of excitement during the sample period.

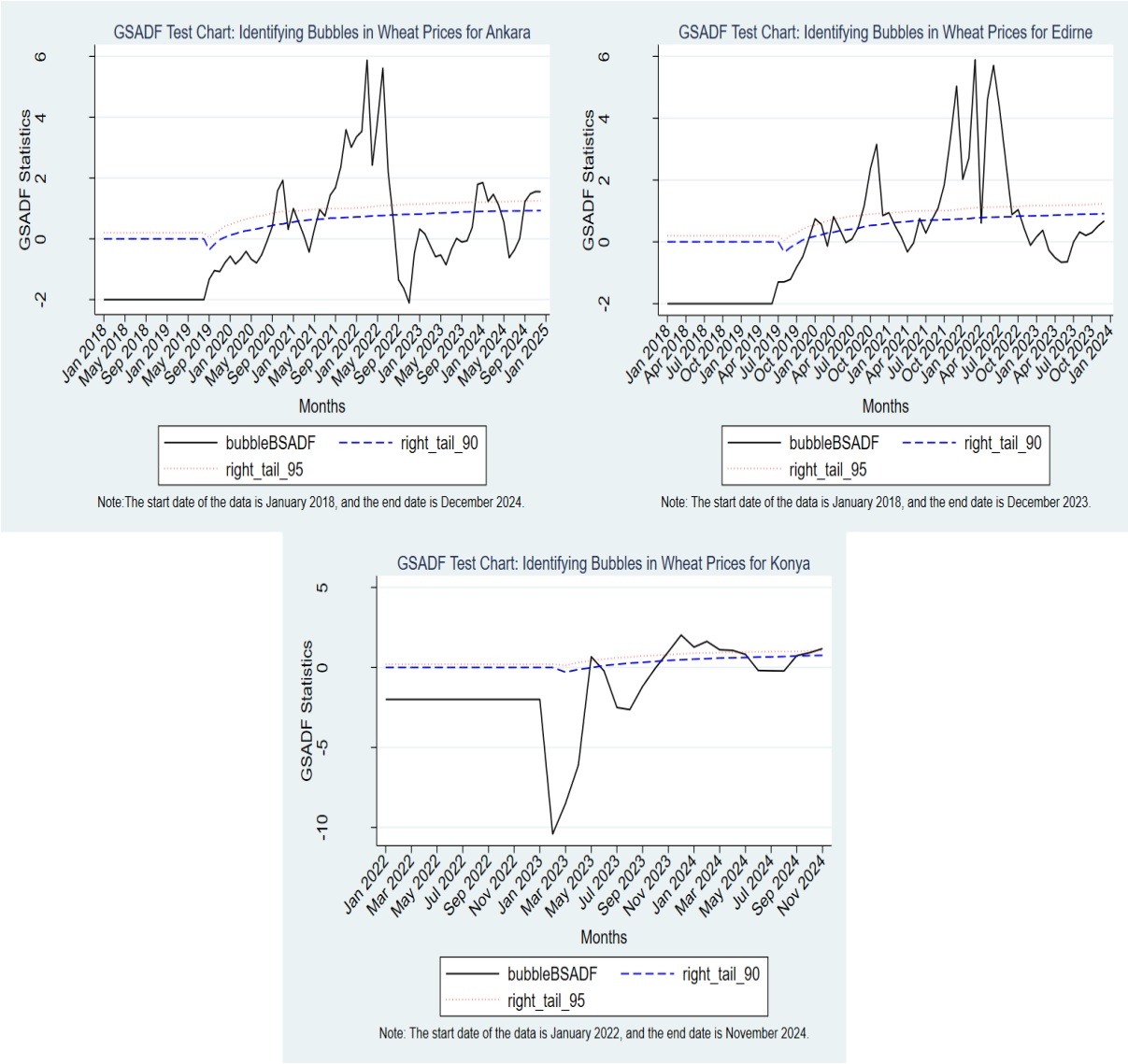


Figure 1- Identification of Speculative Bubbles in Wheat Markets Using GSADF Test Statistics

According to the GSADF test charts presented in Figure 1, all three wheat markets-Ankara, Edirne, and Konya-exhibit speculative price behavior in specific months. In Ankara, the BSADF statistic first exceeds the 95% critical value in July 2020, and this upward movement continues with pronounced peaks between October 2021 and October 2022. The statistic remains above the 95% threshold during several intervals, particularly in March 2022, May 2022, and August 2022, pointing to distinct bubble episodes. After some fluctuation, the series stabilizes but hovers near the critical threshold through 2023 and 2024, suggesting persistent but moderate exuberance. In Edirne, explosive behavior emerges slightly earlier. The BSADF statistic surpasses the 95% critical value around June 2020, with marked spikes in March 2022, May 2022, and July 2022. These peaks confirm strong bubble dynamics during this period. However, from early 2023 onward, the values gradually decline and remain below the critical line, indicating a dissipation of speculative pressure by late 2023. In Konya, the GSADF statistic displays a relatively milder profile. The curve remains below the critical lines for most months. Yet, signs of speculative pressure appear in June 2023 and persist through September 2023, where the statistic approaches or slightly surpasses the 90% and 95% thresholds. Despite these movements, no strong or sustained bubble formation is evident compared to the other two markets. Overall, Figure 1 provides a visual representation of the monthly dynamics of speculative bubbles in wheat prices across the three provinces. The most persistent and intense signals are found in Ankara and Edirne between mid-2020 and late-2022, while Konya presents only short-lived and modest signs of price exuberance. The start and end months of the balloon periods identified for Ankara, Edirne, and Konya are provided in more detail in Tables 4, 5, and 6, respectively.

Table 4- Bubble Periods Identified in Ankara Wheat Prices According to GSADF Test Results

BSADF Statistic	*95% Critical Value*	*Start of Bubble Period*	*End of Bubble Period*
1.584428	0.877081	2020M10	-
1.924713	0.895342	-	2020M11
0.996217	0.913126	2021M1	2021M1
1.434229	0.993013	2021M8	-
1.685401	0.993272	-	-
2.358236	0.993272	-	-
3.586770	1.000095	-	-
3.008737	1.002316	-	-
3.356605	1.010768	-	-
3.532215	1.015024	-	-
5.876885	1.041933	-	-
2.422078	1.052182	-	-
3.897999	1.082619	-	-
5.613957	1.091896	-	-
2.210288	1.097106	-	2022M7
1.790882	1.201201	2023M12	-
1.851250	1.201201	-	-
1.229295	1.208205	-	-
1.463048	1.208721	-	2024M3
1.477370	1.247690	2024M10	-
1.554784	1.247690	-	-
1.549254	1.249361	-	2024M12

According to the GSADF test results presented in Table 4, multiple bubble episodes were identified in the Ankara wheat price series over the observed period. The first short-term bubble was detected in October 2020, ending the following month in November 2020. Another brief bubble occurred in January 2021, where both the start and end points coincide. From August 2021 onwards, a longer-lasting and more pronounced bubble phase emerged, extending across multiple months until July 2022, indicating persistent speculative dynamics in the wheat market. Following a brief pause, a new bubble episode was observed to begin in December 2023, with intermittent fluctuations continuing through March 2024 and another peak starting in October 2024, ultimately ending in December 2024.

Table 5- Bubble Periods Identified in Edirne Wheat Prices According to GSADF Test Results

BSADF Statistic	*95% Critical Value*	*Start of Bubble Period*	*End of Bubble Period*
0.7446153	0.5379566	2020M1	2020M1
0.8137388	0.7354707	2020M4	2020M4
1.1865280	0.8770807	2020M9	-
2.3739370	0.8953420	-	-
3.1512580	0.9154347	-	2020M11
0.9433241	0.9342992	2021M1	2021M1
1.0986630	1.0107680	2021M9	-
1.8497470	1.0107680	-	-
3.3526910	1.0150240	-	-
5.0325330	1.0408190	-	-
2.0248010	1.0630260	-	-
2.7119660	1.0827500	-	-
5.8901810	1.0981730	-	2022M3
4.5862150	1.1209480	2022M5	-
5.7079580	1.1209480	-	-
4.2835920	1.1324580	-	-
2.5786540	1.1324580	-	2022M8

In the case of Edirne wheat prices, the GSADF test results displayed in Table 5 reveal a series of distinct bubble episodes over the 2020–2022 period. The first short-lived bubbles occurred in January 2020 and April 2020, both beginning and ending within the same month. A new bubble episode began in September 2020 and extended through November 2020, reflecting a more sustained period of explosive price behavior. Another brief bubble was observed in January 2021, with identical start and end dates. Starting in September 2021, a more extended and intense bubble phase emerged, continuing with elevated BSADF values across the subsequent months. This speculative episode culminated in March 2022, when a bubble endpoint was recorded. Following a short pause, another significant bubble emerged starting in May 2022, with high BSADF statistics persisting through the summer months. This episode ultimately ended in August 2022, marking a clear bubble cycle. Overall, Edirne wheat prices experienced multiple and, in some cases, overlapping bubble phases, particularly concentrated around the periods of late 2020 and mid-2021 to mid-2022.

Table 6- Bubble Periods Identified in Konya Wheat Prices According to GSADF Test Results

BSADF Statistic	*95% Critical Value*	*Start of Bubble Period*	*End of Bubble Period*
0.669796	0.4164603	2023M5	2023M5
0.9786183	0.8030518	2023M11	-
2.025466	0.8431655	-	-
1.268781	0.8948513	-	-
1.627855	0.9075217	-	-
1.103230	0.9217272	-	-
1.066836	0.9422768	-	2024M4
1.174933	1.0632790	2024M11	2024M11

The GSADF test results presented in Table 6 indicate the emergence of several short-term and extended bubble episodes in Konya wheat prices during 2023 and 2024. The first bubble episode was observed in May 2023, with both its beginning and end occurring in the same month, suggesting a brief but significant speculative spike. A more persistent bubble phase began in November 2023 and continued across several months, as evidenced by the absence of an end date, with elevated BSADF values recorded consistently through early 2024. This sustained bubble phase ultimately concluded in April 2024, marking the end of a multi-month speculative episode. Finally, a distinct and short-lived bubble was detected in November 2024, where both the start and end occurred within the same month, similar to the episode in May 2023.

A comparison of the GSADF test results for Ankara, Edirne, and Konya wheat prices reveals both shared patterns and distinct regional dynamics in bubble formation. All three regions experienced multiple bubble episodes; however, the timing, duration, and intensity of these episodes varied considerably. Ankara and Edirne exhibited bubble activity beginning earlier, with Ankara's bubbles first emerging in late 2020, followed by a prolonged phase from August 2021 to July 2022. Edirne similarly showed early and frequent bubble occurrences between 2020 and mid-2022, including a sustained speculative episode between September 2021 and March 2022, and a subsequent cycle from May to August 2022. In contrast, Konya's bubble activity was confined to a later period, with all episodes occurring during 2023 and 2024. While Konya experienced short-lived and discrete bubbles in May and November 2023, a more extended phase was observed from late 2023 to April 2024. A commonality among all three regions is the presence of brief but statistically significant spikes, particularly those beginning and ending within the same month. However, whereas Ankara and Edirne showed evidence of overlapping or sequential bubble phases over longer durations, Konya's speculative episodes were more temporally isolated. After identifying the bubble periods for wheat prices in Ankara, Edirne, and Konya, a binary bubble variable was created for each province. Bubble periods were coded as 1, and non-bubble periods were coded as 0. Before estimating the models, a correlation analysis and Variance Inflation Factor (VIF) diagnosis were performed to assess the presence of multicollinearity among the explanatory variables. These preliminary tests ensure that the model characteristics are not affected by unnecessary information or inflated standard errors. The results of these diagnostic analyses are presented in Table 7.

Table 7- Correlation Matrix and VIF Statistics

Ankara	**UFE**	**IPI**	**R**	**LNQ**	**VIF**
UFE	1.0000				4.29
IPI	0.1189	1.0000			2.02
R	0.7674	-0.3566	1.0000		4.87
LNQ	-0.0010	0.2144	-0.1456	1.0000	1.06
Edirne	**UFE**	**IPI**	**R**	**LNQ**	
UFE	1.0000				3.06
IPI	0.2237	1.0000			2.16
R	0.6296	-0.3969	1.0000		3.77
LNQ	-0.1374	0.1161	-0.3500	1.0000	1.18
Konya	**UFE**	**IPI**	**R**	**LNQ**	
UFE	1.0000				2.48
IPI	-0.5854	1.0000			3.59
R	0.7153	-0.8481	1.0000		4.92
LNQ	0.3036	0.0357	0.0159	1.0000	1.22

Table 7 presents the pairwise correlation coefficients and the corresponding VIF values for the explanatory variables used in the probit and logit models for Ankara, Edirne, and Konya. Notable differences are observed across the three provinces in terms of the direction and strength of correlations, as well as the degree of multicollinearity. In Ankara, the correlation between R and UFE is relatively strong and positive, indicating a potential linear association between these two variables. However, all VIF values remain below the commonly accepted threshold of 5. The highest VIF is observed for the exchange rate variable, suggesting the presence of multicollinearity, though still within acceptable limits. In Edirne, the correlation structure appears more balanced and moderate. While R and UFE show a positive correlation, a negative relationship is observed between R and IPI. All VIF values range comfortably below 5, between 1.18 and 3.77, indicating a low to moderate level of multicollinearity and a stable model environment for estimation. In Konya, the correlation between IPI and R is notably strong and negative, while

R also shows a relatively high positive correlation with UFE. This pattern points to a pronounced linear relationship among the variables. Although the VIF value for R reaches 4.92, it remains below the critical threshold of 5 and does not pose a serious concern in terms of multicollinearity. Following the confirmation that multicollinearity does not indicate a serious issue, the models were estimated using both logit and probit methods, and the results are presented in Table 8.

Table 8- Probit and Logit Analysis Results

	Probit		***Logit***	
Dependent Variable: Bubble_A	***Coefficient***	***Probability***	***Coefficient***	***Probability***
UFE	0.3024***	0.004	0.5339***	0.009
IPI	0.1843**	0.015	0.3144**	0.025
R	-0.1028**	0.016	-0.1778**	0.021
LNQ	-0.9018	0.629	-1.1591	0.730
Dependent Variable: Bubble_E				
UFE	0.0409	0.767	0.0679	0.799
IPI	0.1717**	0.024	0.2855**	0.036
R	-0.1031**	0.045	-0.1774**	0.049
LNQ	41.7278*	0.064	71.9555**	0.045
Dependent Variable: Bubble_K				
UFE	0.8218***	0.009	1.4257**	0.027
IPI	-0.1114	0.504	-0.1979	0.556
R	-0.1209	0.194	-0.2075	0.239
LNQ	-21.4924**	0.026	-35.9963*	0.055

Note: ****, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.*

Table 8 presents the estimation results of probit and logit models for identifying the determinants of bubble formation in wheat prices across Ankara, Edirne, and Konya. The dependent variable is a binary indicator representing the presence of a price bubble in each province. For Ankara, the results show that both UFE and IPI have a statistically significant and positive effect on the probability of bubble formation at the 1% and 5% levels, respectively, in both the probit and logit models. Conversely, R is negatively associated with bubble probability, also significant at the 5% level. The variable LNQ does not exhibit a significant effect in either model. In Edirne, IPI and R are again found to be significant predictors of bubble episodes. IPI positively influences the likelihood of bubble formation, while R has a negative effect. These results are consistent across both models at the 5% significance level. Notably, LNQ becomes significant in Edirne, showing a strong positive effect at the 10% level in the probit model and at the 5% level in the logit model, suggesting that rising wheat quantity may be associated with speculative behavior in this region. In Konya, the coefficient on UFE is positive and statistically significant at the 1% level in the probit model and at the 5% level in the logit model, indicating a strong link between producer prices and bubble formation. LNQ displays a negative and statistically significant effect at the 5% and 10% levels in the probit and logit models, respectively. However, IPI and R are not statistically significant in this region, suggesting limited explanatory power for these variables in Konya's case. Overall, the results highlight regional heterogeneity in the drivers of speculative price dynamics in wheat markets. While producer and input prices play a consistent role in Ankara and Konya, Edirne displays stronger sensitivity to quantity-related dynamics. The exchange rate shows a stabilizing effect in Ankara and Edirne, but appears less influential in Konya.

4. Conclusions

The objective of this study was to examine the occurrence of speculative bubble formations in the regional wheat markets of Türkiye, with a particular focus on Ankara, Edirne, and Konya provinces. To this end, advanced econometric tools were employed, including the GSADF test and nonlinear probability models. The impetus for this research stemmed from a critical lacuna in the extant literature: despite Türkiye's strategic position in wheat production, there is a paucity of empirical studies that have rigorously analyzed the formation, frequency, and determinants of speculative bubbles at the regional level.

Empirical evidence has demonstrated that speculative price behavior exhibits non-uniformity across geographical regions. A multitude of statistically significant bubble episodes were witnessed in Ankara and Edirne between 2020 and 2022, while Konya exhibited comparatively shorter and less intense periods of exuberance, primarily occurring between 2023 and 2024. Regression analyses were conducted to identify the key regional drivers. The results indicated that the producer price index and the input price index exhibited a significant increase in bubble probabilities in Ankara and Konya. Conversely, the real effective exchange rate demonstrated a stabilizing effect in Ankara and Edirne. The findings of this study are noteworthy in that they reveal a curious association between the marketed quantity of wheat and the formation of bubbles in Edirne. However, this association is not replicated in Konya, where a negative relationship is observed.

These findings offer several critical takeaways. First, speculative bubbles in wheat prices are regionally heterogeneous in Türkiye, shaped by a complex interplay of market fundamentals and macroeconomic factors. Secondly, policies aimed at stabilizing agricultural markets must be adapted to account for regional dynamics, as opposed to presuming uniform national

behavior. Thirdly, the integration of recursive bubble detection methods with probit and logit modeling provides a robust framework for identifying and explaining price exuberance in commodity markets.

The findings indicate that the likelihood of wheat price bubbles cannot be explained by a uniform dynamic across regions. Instead, costs, exchange rates, price momentum, and supply conditions interact with regional market structures to shape bubble risk through different channels. As discussed in the theoretical framework, the increase in the wheat producer price index and the agricultural input price index (especially in Ankara and Konya) raises the possibility of a bubble is consistent with cost pass-through and expectation formation mechanisms. While rising producer prices may strengthen market actors' expectations of future price increases, encouraging delayed sales and stockpiling behavior, increases in input costs may weaken the supply response and increase cost-driven price pressure, feeding the perception of higher prices. The fact that the domestic PPI-based real effective exchange rate (in Ankara and Edirne) had a stabilizing effect indicates that exchange rate conditions can limit domestic price volatility through import substitution costs, export parity, and arbitrage incentives. The fact that the relationship between the amount of wheat traded and the formation of a bubble is observed in Edirne but not repeated in Konya can also be explained by regional differences. The increase in the quantity marketed in Edirne may reflect not only an expansion in supply but also an increase in transaction volume (and, indirectly, speculative participation) due to trade intensity, market integration, and buyer-seller composition. Furthermore, during periods of rapid price increases, producers may release stocks into the market, leading to a simultaneous appearance of quantity and bubbles. In contrast, in a market such as Konya, where the scale of production is large and supply is relatively deeper, an increase in the quantity traded may mean that supply enters the market along with the harvest, thereby reducing price pressure and playing a dampening (negative) role in bubble risk. Therefore, the results indicate that, considering regional market structure and behavioral responses, it is necessary to interpret the effects of variables on the likelihood of bubbles comparatively and causally, and that the findings are consistent with expectations, stock behavior, cost shocks, and market integration channels within this framework. In terms of policy recommendations, revising the licensed warehousing framework to operate via regionally authorized purchasing centers, with both physical and digital transaction channels, would facilitate timely policy intervention based on real-time detection of speculative price bubbles in wheat markets.

In sum, this paper makes a significant methodological and empirical contribution to the understanding of speculative behavior in the realm of agricultural economics. Future research should expand on this regional approach by exploring potential spillovers from global wheat markets and incorporating climate variables to better assess systemic risk in food security.

Author Declarations

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