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When will food price bubbles burst? A review

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Abstract: This paper examines whether there are multiple explosive bubble episodes in international food market by employing the Generalised Supremum Augmented Dickey-Fuller (GSADF) test. This method is particularly suitable for practical application of time series and provides an innovative consistent date-stamping strategy for the origination and termination of bubble episodes. Our results show that there are four explosive bubble episodes mostly accompanied by huge price volatilities during 1990–2017, which is largely in line with the asset pricing model (Gürkaynak 2008). The exuberance and collapse of bubble episodes can be explained by imbalance between supply and demand, depreciation of U.S. dollar, financial crisis and speculation. Our findings also provide supporting evidence for the Masters hypothesis that tremendous buying pressure from index investments contributes to substantial bubble episodes. The authorities should accurately identify bubble episode and monitor its evolving process, which is propitious to achieve the effective stabilisation of global food system. Particularly, restrictions on excessive speculative trading should be arranged under extreme market situations in order to forestall the explosion of multiple food bubbles.

Keywords: Generalised Supremum Augmented Dickey–Fuller (GSADF), food price, multiple bubbles, speculation

This paper examines the existence of bubble episodes in international food commodity price and identifies the origin and collapse of multiple bubbles. As essential consumption goods or core inputs to the production process, food grains are considered of great importance in commodity markets (Brooks et al. 2015). Over the last decade, international food prices have experienced drastic swings, generally characterised by drastic upward and downward trends (Mcphail et al. 2014). Currently, from a hedging and speculation perspective, food commodities are increasingly perceived as profitable alternative assets and are extensively included in investment strategies, triggering concerns about bubble-type patterns and global food security. Excessive fluctuation and bubbles in food prices not only lead to huge shocks in regional markets but also destabilise the global economy and have significant welfare effects among market participants (Bekkers et al. 2017). Furthermore, high and volatile prices amplify the incidence of poverty and spark political unrest, especially in countries where food commodities constitute a major share of household budgets (Sanders and Irwin 2010; Algieri 2014). Consequently, food price bubbles and drastic volatility have become a critical global concern in public policy debates (Bekkers et al. 2017).

Since dramatic food price volatility has a significant effect on the overall economic situation, it is vital to identify the main drivers of the value of commodities and reasons behind price bubbles. From a theoretical perspective, the supply-and-demand conditions primarily contribute to price volatility, influencing the fundamental value of food commodities (Brooks et al. 2015). In consideration of the low-elasticity property of food supply and demand, small shocks can cause sharp spikes and dramatic fluctuations (Brooks et al. 2015). Negative supply shocks, which imply price upsurges, are driven by political unrest, adverse weather conditions and an increase in input costs of transportation and fertilisers (Hochman et al. 2014). From the demand view, new potential sources of price dynamics, including the enormous demand growth in emerging countries like China as a result of higher per capita income, contribute

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to additional volatility in food system over the past decade (Algieri et al. 2017). Meanwhile, Lehecka (2014) argues that growing demand driven by biofuel policies and enhanced links with the energy industry has been a contributing factor to the excessive fluctuation of food price. Multiple bubbles may come into existence if food prices are deviated from the fundamentals (Irwin and Sanders 2012).

As food commodity is increasingly considered as an investable asset class, the significant role of speculation has been highlighted in facilitating price deviation from fundamentals and intensifying explosive bubble movements. Substantial speculative components motivated by noise traders with unpredictable trading patterns can potentially promote the explosiveness of bubbles in international food price. Tang and Xiong (2012) confirm that excess speculative behaviors with the expectation of subsequent capital gains are prone to be disruptive forces to push food prices away from fundamentals and induce explosive bubble movements. More recently, with the accelerating process of financialisation, commodity index traders (CITs) – a new type of participant in food market – strongly incline to utilize innovative long-only commodity index funds to capture risk premiums and reduce portfolio risk. Irwin and Sanders (2012) state the Masters hypothesis[1] that the unprecedented buying pressure from CITs enhances the potential of explosiveness of massive bubbles in food prices. According to Irwin and Sanders (2011), excessive price surges induced by speculation may facilitate the over-production of food and trigger the misallocation of productive resources, which imposes enormous efficiency losses on grain markets. Meanwhile, once food bubbles burst, price maladjustment exposes market participants to severe welfare losses, weakening public confidence in the global food system (Gardebroek and Hernandez 2013). Consequently, the potential for bubbles to affect real allocation of economy makes their detection extremely important for policymakers and academics.

This paper contributes to present literature by utilising methods of Supremum Augmented Dickey–Fuller (SADF) and Generalised SADF (GSADF) (Phillips et al. 2011, 2013) to detect the possible presence of multiple bubble episodes in the international food price. Since the conventional techniques are demonstrated to have limited ability to detect bubble episodes that collapse periodically, the empirical validity of the methods is being questioned. Compared to the other recursive procedures, the SADF and GSADF tests perform satisfactorily in capturing any explosive behaviours across the overall sample. First, the method extends the sample sequence to a more flexible range, ensuring sufficient observations to achieve estimation efficiency (Phillips et al. 2011, 2013). Second, this technique can explore non-stationary behaviours of series against mild explosive alternatives, which is more effective to real-timely detect bubbles. Third, we could employ the tests to data at any frequency. A further contribution of the paper is to deliver an innovative, consistent date-stamping strategy. This test is not simply *ex post* detecting method but the anticipative date-stamping algorithm that is conducive for regulatory agencies to monitor market behaviours with the assistance of early warning diagnostic tests. Our findings show that there exist four bubble episodes across the overall sample, which is basically in line with the asset pricing model (Gürkaynak 2008). The authorities should actively monitor the bubble evolving process in order to alleviate the negative influence of multiple bubbles and achieve the effective operation of the global food system.

ASSET PRICING MODEL

The theoretical framework for the identification of multiple bubble episodes originates from the asset pricing model proposed by Lucas (1978). Following Gürkaynak (2008), the fundamental price of food derives from the following standard non-arbitrage condition:

$$P_t = \left(1 + r_f\right)^{-1} E_t\left(\delta_{t+1} + U_{t+1}\right) \tag{1}$$

where P_t and E_t indicate food price and expectation over the period t, r_f represents the free-risk rate, δ_{t+1} and U_{t+1} represent the returns and invisible components over the period of $t + 1$. This equation can be iterated forward to reveal its solution:

$$P_t^f = \sum_{i=0}^{\infty}\left(\frac{1}{1+r_f}\right)^i E_t\left(\delta_{t+i} + U_{t+i}\right), \text{ for } i = 0,1,2 \ \dots \ n \tag{2}$$

[1]Masters (2008) testifies that unprecedented buying pressures from CITs deviate commodity prices from fundamental values and cause explosive bubbles. Irwin and Sanders (2012) apply the term “Masters hypothesis” as a shorthand label for the argument.

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where P_t^f represents the fundamental price of food, δ_{t+1} represents the returns over the period of $t + 1$.

$$B_t = \left(1 + r_f\right)^{-1} E_t\left(B_{t+1}\right) \tag{3}$$

where B_t indicates bubble component of food price. Equation 3 represents any sequence of random variables satisfying the homogeneous expectation equation. The general solution to Equation 1 is expressed as follows:

$$P_t = P_t^f + B_t \tag{4}$$

Equation 4 decomposes food prices into two components: the market fundamental component, P_t^f, and another is generally described as bubble component, B_t. According to Piesse and Thirtle (2009), bubbles are generally defined as economic cycles with a characteristic of sharp expansion followed by sudden contraction. When identifying $B_t = 0$, it indicates the inexistence of bubble episodes. Otherwise, B_t with non-zero value denotes that multiple bubbles will not terminate until its explosion because of the expectation. Periods of bubble episodes are often associated with adverse welfare implications for various agents in the economy (Irwin and Sanders 2011). Obtaining accurate recognitions and forecasts of bubble episodes is crucial for policymakers to conduct precautionary policies and for market participants to alleviate negative influence.

METHODOLOGY

As proved by Evans (1991), conventional tests are invalid to explore multiple bubble episodes if cyclical collapsing behaviours exist in time series. The conventional stationarity test is based on standard Augmented Dickey-Fuller (ADF) and Phillips-Perron tests. Given that:

$$\Delta p_t = \alpha + \beta p_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta p_{t-i} + \varepsilon_i, \;\; \varepsilon_i \sim NID\left(0, \sigma^2\right) \tag{5}$$

where p_{t-1} is the logarithmic food price, α denotes drift component, β corresponds to the log-run nexus, γ_i represents the error correction dynamic, ε_i is random error term, σ is standard deviation, and k represents the lag number determined by the significance test in empirical applications. *NID* denotes independent and normal distribution. The null hypothesis $\beta = 1$ indicates that p_{t-1} is a unit root process (Δp_t is stationary). The alternative hypothesis $\beta > 1$ implies that p_{t-1} is explosive (Δp_t is not stationary). Nevertheless, the techniques have discriminatory power due to the sensitivity to changes occurring when the process experiences changes from a unit root to mild explosive root or vice versus. In order to overcome the drawback, Phillips and Yu (2011) recommend utilizing the supreme of recursively determined ADF *T*-statistics.

The SADF test estimates the ADF model repeatedly on a forward expanding sample sequence. The window size r_w ranges from r_0 to 1. The starting point r_1 is fixed at 0, thus the ending point r_2 is equal to r_i, ranging from r_0 to r_1. The ADF statistic running from 0 to r_2 can be expressed by $ADF_0^{r_2}$. The SADF statistic can be defined as:

$$\mathrm{SADF}\left(r_0\right) = \sup_{r_2 \in \left(r_0, 1\right)} \left\{ ADF_{r_2} \right\} \tag{6}$$

As indicated by Phillips et al. (2013), the SADF test would lose effectiveness if multiple explosive bubbles are included during the overall sample. Toconquer the drawback and deal with multiple episodes of exuberance and collapse, the GSADF test utilises flexible window width (Phillips et al. 2013). Apart from changing the ending points r_2 from r_0 to 1, the GSADF test allows the starting points r_1 to vary over a feasible range from 0 to $r_2 - r_0$. According to Phillips et al. (2013), GSADF statistic can be defined as the largest ADF statistic within its range from r_1 to r_2, and it is denoted by GSADF(r_0).

$$\mathrm{GSADF}\left(r_0\right) = \sup_{r_2 \in \left(r_0, 1\right), r_1 \in \left(0, r_2 - r_0\right)} \left\{ ADF_{r_1}^{r_2} \right\} \tag{7}$$

When the regression model contains an intercept and the null hypothesis is a random walk, the limit distribution of GSADF test statistic is as in Equation 8 below.

In Equation 8, $r_w = r_2 - r_1$ and W is a standard Wiener process. Suppose that n_1, n_2 ... n_N are equally spaced in a finite interval. At each point, a Gaussian

$$\sup_{r_2 \in \left(r_0, 1\right),\, r_1 \in \left(0,\, r_2 - r_0\right)} \left\{ \frac{(1/2) r_w \left[W\left(r_2\right)^2 - W\left(r_1\right)^2 - r_w \right] - \int_{r_1}^{r_2} W(r) dr \left[W\left(r_2\right) - W\left(r_1\right) \right]}{r_w^{1/2} \left\{ r_w \int_{r_1}^{r_2} W(r)^2 dr - \left[\int_{r_1}^{r_2} W(r) dr \right]^2 \right\}^{1/2}} \right\} \tag{8}$$

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random variable with mean zero and variance $1/N$ can be generated. We acquire the asymptotic critical values through numerical simulations, and adopt the bootstrap technique to compute the finite sample distributions. Furthermore, this technique delivers an innovative, consistent date-stamping strategy.

DATA

To investigate the existence of multiple bubbles in international food price, we utilise the food price index (FFPI) covering the period from January 1990 to August 2017. The dataset is obtained from the Food and Agricultural Organization (FAO 2018), which has been available to the public since January 1990. FFPI is considered a major indicator of monthly variation in the international price of a food basket composed of cereal, oilseed, dairy, meat and sugar. Accordingly, FFPI contributes to the reflection of global food supply and demand conditions. Within the selected sample period, explosive behaviours in multiple bubble episodes can be explored because the dataset covers biofuel development, speculative events and crises, with global food market experiencing extremely high levels of fluctuations.

As shown in Figure 1, FFPI has soared since the early 2000s. Specifically, FFPI rose sharply from 85.1 in 2002 to a record high level of 225.8 in June 2008 and increased by nearly 170%, leading to the food riots around the world. During the global financial crisis, FFPI subsequently plummeted by over 40% at the end of 2008 as the global economy entered into recession. With the re-emergence of the precipitous rising trend, the price skyrocketed again to a record level in February 2011. Given such furious fluctuations, it is considered that FFPI might contain multiple collapsing bubble episodes.

EMPIRICAL RESULTS

We utilise the SADF and GSADF tests to explore multiple episodes of explosive bubbles in the global food market. Table 1 registers the SADF and GSADF statistics and critical values of the corresponding sample. The statistics of both tests are 7.303 and 9.707, exceeding the respective 1% right-tail critical values. Based on these results, the null hypothesis of H_0: $r = 1$ can be rejected at 1% significance level, providing evidence for the occurrence of multiple explosive behaviours in international food price.

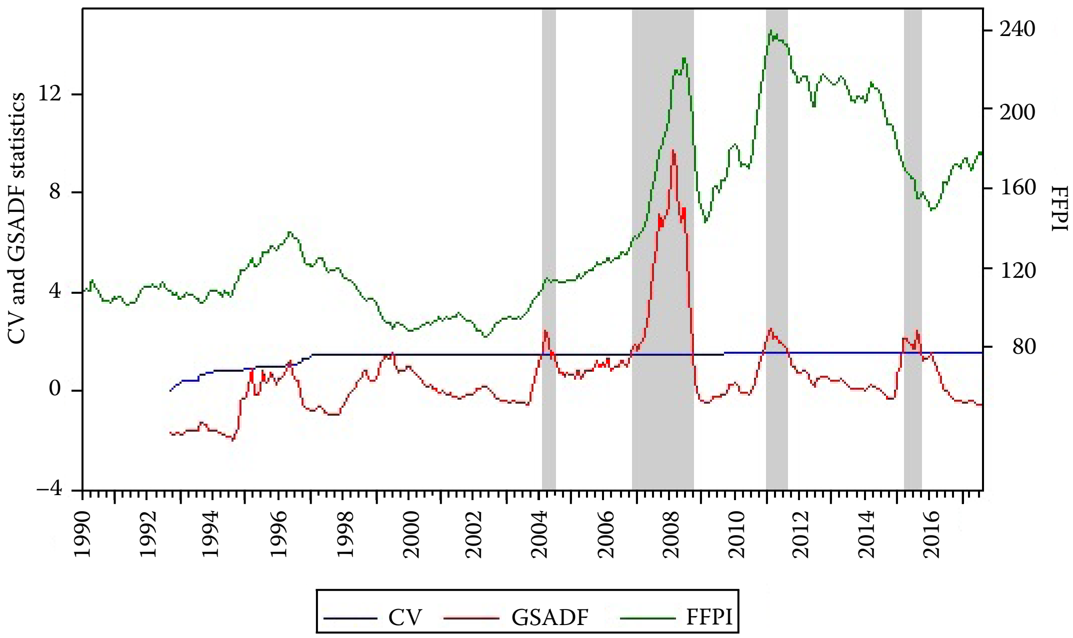

Figure 1. Generalised Supremum Augmented Dickey–Fuller (GSADF) test of food price index (FFPI)

the shadows are sub-periods with bubbles; CV – 95% critical values

Source: authors' elaboration based on FAO (2018)

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Table 1. Results of Supremum Augmented Dickey–Fuller (SADF) and Generalised SADF (GADF) tests

	SADF	GSADF
Food price	7.303***	9.707***
Critical value (%)		
90	1.019	1.985
95	1.329	2.348
99	2.096	2.512

critical values for both tests are obtained from Monte Carlo simulations with 10 000 replications; *** denotes significance at 1% level

Source: authors' elaboration based on FAO (2018)

Utilising the GSADF test, we graph the estimate of FFPI in Figure 1. The upper curve represents FFPI. The middle curve represents the 95% critical values. The bottom curve is GSADF statistics. In consideration of the origination and termination of bubble episodes, four food price bubbles are detected across the overall sample.

The first bubble occurs in February 2004 and quickly collapses in June. In pace with strong economic development in developing countries since the early 2000s, including China and India, the rapidly rising per capita income has triggered huge demand growth for food commodities, contributing to the sharp increase in FFPI. In 2004, the annual growth rates of GDP for East Asia and the Pacific region that make up a large proportion of world population, have exceeded 8%, promoting the enormous growth of demand in the international food market (Piesse and Thirtle 2009). Moreover, consumers in emerging economies not only increase per capita consumption of food but also improve the diversity of dietary patterns by including more meat and dairy products, amplifying demand growth of food commodities and driving FFPI up (Mcphail et al. 2014). Nevertheless, supply constraint limits production response from keeping abreast of worldwide food demand. In general, the imbalance between supply and demand for food facilitates the surge of FFPI during this phase. China and India have gradually promoted food self-sufficiency to match grain production with increased demand, leading to the bubble burst.

The second bubble originates in November 2006 and bursts in September 2008. This can prove to be the longest bubble period, which lasts nearly two years. In response to the continuously growing petroleum price since 2006, the global demand for biofuel has been significantly facilitated, contributing to the price spike for bioenergy feedstocks. Subsequently, the Energy Independence and Security Act of 2007 is signed into law, requiring a further increase in biofuel use. The policy instruments of biofuel subsidies and mandates have strengthened the worldwide demand for maize, sugarcane, and oilseeds, which are directly used in bio-energy production (Tadesse et al. 2014). The enormous demand growth for biofuels can also trigger a chain reaction and lower production for other grains via substitution in supply, pushing up the overall price level in the global food market (Gardebroek and Hernandez 2013). In response to sharply rising international food price, over thirty exporting countries successively implemented export bans and restrictions during the period of 2007–2008 to protect domestic grain supplies (Gardebroek and Hernandez 2013). The resulting excess hoarding exacerbates the global stress over tight supplies, contributing to the explosive price growth and amplifying volatility in the international food market. Under such background, the depreciation of dollar adds further impetus to reach the peak in FFPI. In 2007, the United States dollar (U.S. dollar) depreciates nearly 10% against most major currencies, motivating investors to flee dollar assets. The sustained depreciation trend makes investments in commodities more attractive, inducing large flows of capital into the food market and fuelling bubble-type pattern (Piesse and Thirtle 2009).

Furthermore, food commodity futures provide popular investment vehicles for market participants who aim to diversify portfolio risk, optimize asset allocation, and capture risk premiums, triggering huge inflows of funds (Lehecka 2014). During the period of 2007–2008, index investments in cereal and meat increase nearly five-fold, which may distort price signals and induce speculative bubbles. When the global financial crisis and recession subsequently erupt, food prices dropped sharply due to the negative expectation of investors for the future economy, contributing to the bubble burst (Algieri et al. 2017).

The third bubble is found in December 2010, which lasts nearly 9 months. In February 2011, FFPI exceeds the peak reached in 2008 and skyrockets to a record high level in nearly 20 years according to FAO (2018). The international food price surges due to the outbreak of weather anomalies and natural disasters (Tadesse et al. 2014). Since 2010, the drastic droughts in Russia and Ukraine as well as floods in Canada and Australia substantially reduce global

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export supplies and further promote the massive price spike. Drought in southern China results in serious grain shortage, forcing China to turn to large-scale import. Furthermore, the second round of quantitative easing policies in November 2010 contributes to further depreciation of U.S. dollar. The interest rate is maintained at an exceptionally low level, pushing the capital flight out of U.S. (Algieri 2014). As an attractive hedge against the declining dollar, long-only commodity index investments extremely facilitate the rapid rising participation of investors in the food market (Algieri et al. 2017). The unprecedented buying pressure from CITs is conducive to fostering speculative bubbles through a number of mechanisms (Sanders and Irwin 2017). First, liquidity is not sufficient to absorb the large order flow of index funds, leading to temporary price deviation from fundamentals. Second, CITs may create noise-trader risk, making arbitrage against their positions difficult and price shocks possible. Third, other traders may confound index fund on the long side with valuable private information and revise demands upward, pushing up commodity prices. International food prices have since dropped followed by the subsequent collapse of bubbles, mainly affected by favourable weather situations and slowing demand due to the aggravating expectation of global economic recession engendered by the European sovereign debt crisis (Bekkers et al. 2017).

The last bubble is observed in March 2015 and collapses in September 2015. The bubble episode is mainly attributed to an imbalance between supply and demand as well as the appreciation of U.S. dollar. Along with the increasing investment in production and improvement of efficiency, the global supply of grains has grown substantially during the past few years, significantly advancing situation that output exceeds demand. Meanwhile, Argentina cancels the export ban on most grains in 2005, which enhances the competitiveness of exports and further stimulates the massive increase of supply in the international food market. From the demand view, the global economy presents a sustained slowdown while emerging economies such as China step into a period of adjustment and escalation of the economic structure, causing a shrinking demand for food. Furthermore, the substantial sustained appreciation of dollar contributes to temporary price deviation from fundamentals, intensifying the explosive bubble movements (Algieri et al. 2017). The recent expectations of rising United States (U.S.) interest rates, combined with the continuously strengthening supervision of commodity markets by Europe and U.S., have also propelled capital outflows from stable commodities, fostering the explosiveness of bubble.

In general, the four explosive bubbles detected in the international food market are largely consistent with the asset pricing model that there are fundamental and bubble components within the price formation process. The imbalance between supply and demand, the value of U.S. dollar, economic crisis, and speculation, play a significant role in explaining multiple bubbles during explosive episodes. Considering the basic commonality that commodities tend to track major macro-economic development, growing demand triggered by economic growth in emerging economies aggravates food bubble component (Piesse and Thirtle 2009). However, bubble-type pattern collapses when the more standard level of supply-and-demand resume (Tadesse et al. 2014). Temporary volatility due to regional adverse weather is demonstrated to have no long-run impact on food prices. Policy supporting biofuel production may foster transitory bubbles but not long-term fluctuations of food prices since decentralised freely operating markets can moderate the shock sustainability and restore prices to the equilibrium trend (Mueller et al. 2011). Turning to the financial conduit, the global recessionary effect induced by economic crisis exerts an extremely strong effect on the sharp price decline and the bubble burst, confirming the intensifying links between financial and commodity markets and exposing the food system to potential contagion risks. According to Adämmer and Bohl (2015), speculation component is considered as a vital driver to a longer term bubble. Moreover, the depreciation of U.S. dollars and massive speculative behaviours with the expectation of higher prices in the future provide strong incentives for causing excess price surge and fostering bubbles.

Based on the empirical results, it is crucial for policymakers to understand the reasons behind explosive bubble episodes and adopt appropriate precautionary strategies to prevent extensive and negative consequences. To mitigate food price spikes and volatilities, flexible biofuel policies which response actively to global grain supply-and-demand situations should be designed. Moreover, authorities should prevent excessive speculative behaviours through the formulation of trading restrictions and the supervision of long-only positions in index investments under extreme situations, which is propitious to mitigate

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massive fluctuations in the international grain market and prevent food crises.

CONCLUSION

This paper applies the GSADF test (Phillips et al. 2013) to detect the initiation and termination of multiple explosive bubble episodes in international food price from 1990 to 2017. Compared with previous approaches, the method is valid for application to detect possible bubble episodes at any data frequency and does not depend upon the subjective judgement of deviation from fundamental values. Our findings show that there are four explosive bubbles in the sample period, which is largely in line with the asset pricing model (Gürkaynak 2008) that there are fundamental and bubble components within the price formation process. In general, we find that food bubble episodes generally occur over periods of price volatility, due to demand growth in emerging economies, biofuel development and adverse weather conditions as well as non-fundamental factors including the value of U.S. dollar, economic crisis, and speculation. The results also provide supporting evidence for the Masters hypothesis that the unprecedented buying pressure from CITs enhances the explosiveness of massive bubbles in commodity prices. Identifying the initiation and termination of bubble episodes occurring over the last decades immensely contribute to identifying the vital drivers of food bubble episodes. Considering the extensive and negative consequences of explosive bubbles, authorities should design flexible biofuel policies which response actively to global grain supply-and-demand situations to reduce the volatility of food markets. Moreover, policymakers should frame restrictions on excessive speculative trading and supervise long-only positions in index investment under extreme market situations to prevent massive price fluctuations and forestall the explosion of multiple bubbles.

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