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Journal of Applied Economics

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*Suggested Citation:* Huang, Huilian; Xiong, Tao (2020) : Price bubbles and market integration in global sugar futures markets, Journal of Applied Economics, ISSN 1667-6726, Taylor & Francis, Abingdon, Vol. 23, Iss. 1, pp. 1-20, https://doi.org/10.1080/15140326.2019.1693202

This Version is available at: https://hdl.handle.net/10419/314077

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Journal of Applied Economics

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/recs20

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To cite this article: Huilian Huang & Tao Xiong (2020) Price bubbles and market integration in global sugar futures markets, Journal of Applied Economics, 23:1, 1-20, DOI: 10.1080/15140326.2019.1693202

To link to this article: https://doi.org/10.1080/15140326.2019.1693202

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Published online: 25 Dec 2019.

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#### ARTICLE

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# Price bubbles and market integration in global sugar futures markets

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#### ABSTRACT

We use a Supremum Augmented Dickey-Fuller test to detect price bubbles in the world's most important sugar futures markets (ZCE, NYBOT, and LIFFE) from 2006 to 2017. Results show 19 bubbles with characteristics similar in quantity, duration, and price variation. We explore whether sugar futures prices in ZCE, NYBOT, and LIFFE are integrative in a full sample with an improved hybrid method of directed acyclic graphs and structural vector autoregression. Based on the bubble test, we examine market integration in the sugar futures markets during explosive and unexplosive episodes. We find the impact of price bubbles on market integration and explore the cause of price bubbles in a macro-economic environment. Empirical results show futures markets are more integrative when price bubbles occur. We find sugar futures price bubbles reflect supply and demand imbalance, market participants are extremely sensitive, and market information exchanges frequently during the bubble period.

#### **ARTICLE HISTORY**

Received 20 March 2019 Accepted 11 November 2019

#### **KEYWORDS**

Sugar futures; market integration; price bubbles; Supremum Augmented Dickey–Fuller test (SADF or PWY)

### 1. Introduction

China is the world's largest sugar importer with annual imports of more than two million tons. Using 2010 as a cut-off point, before its import volume had increased significantly, China's import dependence was less than 10%. By 2014, China's sugar import dependence was as high as 26% to 27%.<sup>1</sup> As for long-term price trends, China's sugar price is not out of line with the overall international market trend due to a low-tariff free-trade policy and China's limited sugar planting area. However, we cannot ignore the connection between China and the international market.

International sugar spot prices have been exceptionally volatile over the past several years, reaching a high of \$ 0.3257/lb. on 3 February 2011 (daily spot price in nominal dollars) and a low of \$ 0.1119/lb. on 25 August 2015, which definitely amplifies the price risks that sugar industry practitioners face. Meanwhile, the price of sugar in China has also undergone tremendous fluctuations even though sugar prices in China are somewhat independent due to domestic supply, regulation, and other factors (Reddy, 2011). Sugar futures provide farmers and traders with an important defense or "hedge" against

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price risks. Sugar contracts not only are the benchmark for international sugar trading but also serve as the price basis for the major exporting countries.<sup>2</sup>

Zhengzhou Commodity Exchange (ZCE) in China, the New York Board of Trade (NYBOT) in the US, and London International Financial Futures Exchange (LIFFE) in UK are the most dominant participants in the global sugar futures markets. China is one of the world's largest sugar producers and importers, the US is the world center for sugar pricing, and the European Union is the world's largest sugar beet producing region – accounting for about 60% of the total production in the world.<sup>3</sup> These sugar futures markets provide appropriate chances for hedgers to participate in hedging, price discovery, and speculation (Ulusoy & Onbirler, 2017). China's entry into the World Trade Organization in 2001 further integrated the sugar markets of China, the United States, and the European Union. Their sugar futures prices present a common trend, as some evidence indicates that bi-directional lead relations and long-run equilibrium relationships exist (Jiang, Su, Todorova, & Roca, 2016; Xu, Tong, Wang, & Chen, 2017), possibly due to market integration among these sugar futures markets.

Market integration, based on the law of one price, states that two assets with identical payoffs should not be priced differently. In other words, integrated markets should assign the same positive price to assets in different markets (Valdes, Von Cramon-Taubadel, & Engler, 2016). We can define integration as assets in different currencies or countries displaying the same risk-adjusted expected returns, contrary to segmentation. It is worth mentioning that co-integration is different than integration, and a co-integration test is not informative in respect to market integration (Laframboise, De, & Faubert, 2005). Obviously, market integration plays a very important role for national economies, as prices in different markets will be more connected and tend to remain stable during difficult economic times (Valdes et al., 2016). Therefore, we can consider integration an effective defense instrument that results in each country's resources exchanging more quickly and efficiently, which means more capital, goods, and an in-flow of investment that creates more jobs. Thus, market integration is widely seen as a development opportunity for national economies. Warell (2006) finds evidence of global market integration in cooking and steam coal markets, demonstrates the stable long-run co-integrating relationship between the respective price series in different world regions, and concludes that co-integration testing has become a common way of investigating the law of one price. Co-integration often provides an appealing way to represent long-run equilibrium relationships implied by economic theory, and Lence and Falk (2005) use the model to study the relationship between market integration and statistical co-integration.

Food commodity prices fluctuate acutely, irregularly trending upward or downward and frequently experiencing several large spikes. At the same time, prices are often overvalued compared to economic fundamentals, which means price bubbles occur (Etienne, Irwin, & Garcia, 2014). Obviously, prices change more dramatically and traders are more sensitive to the market during a price bubble. Thus, we can assume that market integration relationships may change correspondingly when a price bubble occurs. We should be able to confirm this assumption with our study. Specifically, the purpose of this article is to investigate whether price bubbles influence market integration in the global sugar futures markets.

<sup>&</sup>lt;sup>2</sup>http://www.ynsugar.com/.

<sup>&</sup>lt;sup>3</sup>www.ynsugar.com/Article/TYWX/201,303/38,597.html.

The body of our article consists of two main parts. First, we test the daily prices of sugar futures contracts traded in ZCE, NYBOT, and LIFFE from 2006 to 2017 with the recently proposed Supremum Augmented Dickey–Fuller test (SADF or PWY) (Phillips, Wu, & Yu, 2011). We then analyze the characteristics of price bubbles in these three sugar markets according to the bubble results. The test outcome covers quantity, duration, price variation, and other aspects of price bubbles. Second, we explore whether sugar future prices in ZCE, NYBOT, and LIFFE are integrative in the full sample using an improved hybrid method of directed acyclic graphs (DAG) and structural vector autoregression (SVAR). More importantly, based on the bubble test, we also examine the market integration in these three sugar futures markets during explosive and unexplosive episodes using the hybrid DAG/SVAR method. By comparing the results of market integration.

In summary, this article contributes to the literature in two ways. First, as there is little literature focusing on the price bubbles of sugar futures markets, we test and analyze the characteristics of price bubbles in the world's three most important sugar futures markets. And then we analyze the integration relationship in these sugar futures markets. Second, we explore, for the first time, the impact of price bubbles on market integration, we find that sugar futures prices in these markets exhibit a close and unbalanced intrinsic relationship through price transmission. During the bubble periods, the original integration relationship in these three markets changes, and more importantly, sugar prices in these three markets are more integrative at this time.

We organize the remainder of the paper as follows. Section 2 presents a literature review. Section 3 introduces the methodologies on SADF, DAG, and SVAR. Section 4 presents the data set and preliminary analysis. Section 5 presents major empirical results – the key point of the study. Section 6 concludes.

#### 2. Literature review

In recent years, market integration has attracted more and more attention, as many scholars have come to realize its significance, especially in agricultural commodities markets. Miljkovic (2009) considers that, due to import bans, Canadian and U.S. livestock prices can be either integrated or separated from 1996 to 2004, and that high trade dependency of prices would cause fragility and prices would be more vulnerable to exogenous shocks that reduce trade flows. Ge, Wang, and Ahn (2010) test the integration relationship of China's cotton market with the international market, especially the United States, and find that a long-run integration relationship exists, and that price hostilities are similar. Furthermore, they assess for the first time the impact of a market-oriented exchange rate system on cotton futures prices. Yang, Zhang, and Leatham (2011) focus on the three major wheat markets from 1996 to 2002, and examine futures prices and volatility transmissions among these three markets and exporting regions. They point out that U.S. wheat prices influence Canadian wheat prices; however, the EU is highly self-dependent, but exerts some effects on Canadian wheat prices. Valdes et al. (2016) explore the nine possible determinants of regional stock market integration, focusing on the agribusiness-sector-relevant regional trade blocs around the world, and show that most variables help capital flow among these stock markets and promote market integration. Chen and Saghaian (2016) investigate market integration and asymmetric price transmission by testing the monthly export rice prices from Thailand, Vietnam, and the United States with the Johansen test, and then estimate the threshold vector error correction model (VECM). Their results suggest that the world rice-export markets are integrated. They also briefly discuss government policies.

Price bubbles are typically associated with boom-bust situations where rapid price declines follow explosive price patterns. Price bubbles arise in unstable markets and are associated with rapid price increases and unstable dynamics. As discussed in rational price bubble literature, we can use continuous unusual price movements to evaluate whether a bubble component drives markets (Li, Li, & Chavas, 2016).

There are several articles about price bubbles in agricultural futures markets - some focus on the inspection process and feature an analysis of futures price bubbles, while others study the causes of agricultural futures price bubbles. Gilbert (2010) examines the possible price impact of speculative bubbles and index-based investment activity on commodity futures prices in crude oil, three nonferrous metals, and three agricultural commodities from 2006 to 2008. He also examines the effects of index-based investment on the same markets and finds strong evidence that index-based investment did contribute to the rises in oil and metals prices, but he finds weaker evidence for similar effects on grains prices. Areal, Balcombe, and Rapsomanikis (2013) raise two important questions: (a) whether price bubbles found in food commodities are of speculative origin; and, (b) whether some commodities are more prone to suffer price bubbles than others are. Areal et al. (2013) conclude that cereals, (e.g., wheat and rice), staple crops, and vegetable oils (e.g., soybean and rapeseed oils) have shown bubble behavior. Therefore, we should pay close attention to price evolution. Etienne et al. (2014) find that all 12 agricultural markets experience multiple periods of price explosiveness. Though they receive far less attention, negative bubbles significantly contribute to price behavior, accounting for more than one-third of explosive episodes. Etienne et al. (2014) detect and date-stamp explosive episodes (bubbles) in corn, soybean, and wheat futures markets. They find that speculation has little or a negative effect on price explosiveness, and that positive bubbles are more likely to occur in the presence of low inventories, strong exports, a weak U.S. dollar, and booming economic growth, whereas negative bubbles are more likely to occur with large inventories, weak exports, and stagnant economic growth. Li et al. (2016) detect price bubbles in the Chicago Board of Trade (CBOT) and Chinese agricultural futures markets (wheat, corn, and soybean) from 2005 to 2014. They attribute the difference in price behavior to differences in market intelligence and China's agricultural trade policies and domestic government policies. Li et al. (2016) also discuss challenges to the sustainability of the stable price trajectory in China's markets.

Additionally, Alexakis, Bagnarosa, and Dowling (2017) conduct unusual, but interesting, research and conclude that there are three multivariate dynamic possibilities in feed and hog markets. Bubbles in feed futures priced in lean hog with a log is a fundamental view of their work. An alternative expectation is that these markets are contemporaneously related and bubbles should also occur contemporaneously (Irwin & Sanders, 2011). A third possibility is that there would be temporary breaks in co-integration during bubble periods – namely, there would be no bubble in hog pricing caused by bubbles in underlying feeds (Irwin & Sanders, 2012). However, they simply analyze an integration relationship by comparing the bubble characteristics of hog, corn, and soybean commodity markets.

In conclusion, a number of studies shed light on the relationship of different markets and price transmissions and the drivers of market integration. Some literature suggests that integration relationships could be more of a feature of pricing in recent years. However, these works ignore the influence of price bubbles on market integration – only one article makes a preliminary attempt to analyze an integration relationship when bubbles hit its components (Alexakis et al., 2017).

#### 3. Methodologies

#### 3.1. Supremum Augmented Dickey–Fuller test

Diba and Grossman (1988) first propose the traditional unit root and co-integration -based tests to detect bubbles. However, the traditional method fails to detect the existence of bubbles when they are periodically collapsing. Phillips et al. (2011) develop a new testing procedure, SADF. Motivated by Diba and Grossman (1988), SADF can detect and date-stamp exact bubble origination and collapse dates accurately, which overcomes the weaknesses of previous methods. SADF has become the standard method to test bubbles. Phillips, Shi, and Yu (2015) improve the SADF and develop the Generalized Supremum Augmented Dickey-Fuller test (GSADF or PSY), which finds explosive episodes embedded in price processes and does not need very strict assumptions. In addition, GSADF embeds a recursive approach, which can obtain the ADF statistics repeatedly and cover more sub-episodes of the entire sample period, which solves the issue of collapsing bubbles to some extent. More importantly, the GSADF test not only detects the presence of bubbles but also date-stamps the bubble episodes, which provides more information about the price bubbles. After that, plenty of literature concentrates on price bubbles with the SADF and the GSADF (Areal et al., 2013; Etienne et al., 2014; Etienne, Irwin, & Garcia, 2015; Li et al., 2016).

In this article, we adopt SADF to test the price bubbles in three sugar futures markets (ZCE, NYBOT, and LIFFE).

There is a random walk process with an asymptotically negligible drift:

$$\mathbf{y}_{t} = \mathbf{d}T^{-\eta} + \theta \mathbf{y}_{t-1} + \mathbf{e}_{t}, \quad \mathbf{e}_{t} \stackrel{\text{iid}}{\sim} N(0, \sigma^{2}), \quad \theta = 1$$
(1)

where *d* is a constant;  $\eta$  is a localizing coefficient that controls the magnitude of the drift; *T* is the sample size; and,  $e_t$  is the error term.

We base the SADF on the following reduced form empirical equation:

$$y_t = \mu + \delta y_{t-1} + \sum_{i=1}^p \phi_i \Delta y_{t-i} + \varepsilon_t$$
(2)

where  $y_t$  is the variable in question (the price of sugar in this study);  $\eta$  is an intercept; and, p is the maximum number of lags.

Our assumption is that the null hypothesis is of a unit root and the alternative is of a mildly explosive autoregressive coefficient.

$$H_0: \delta = 1$$

$$H_1: \delta > 1 \tag{3}$$

When using a sample interval of [0, 1] and denoting  $r_1$  and  $r_2$  as the starting and ending fraction of the sample,  $r_w = r_2 - r_1$  is the window size (the user sets the initial size of this window). We set the window to constitute approximately 2% of the whole sample.

According to Caspi (2017), the starting point of the estimation  $r_1$  and the endpoint of the estimation  $r_2$  are set. The first observation in the sample is  $r_1,r_1 = 0$ , and the initial window size is  $r_w = r_2$ . We then recursively estimate the regression while incrementing the window size,  $r_2 \in [r_0, 1]$ , one observation at a time. Therefore, the corresponding standard ADF statistic,  $ADF_{r_2}$ , is

$$SADF(r_0) = \sup_{r_2 \in [r_0, 1]} \{ADF_{r_2}\}$$
(4)

We will reject the null hypothesis in SADF, when SADF statistics are greater than  $ADF_{r_2}$ , and accept the alternative hypothesis; that is, we accept there is a weak explosive process.

#### 3.2. Structural vector autoregression and directed acyclic graphs

In the last several decades, economists have developed many approaches to measure market integration. Typical applications rely on time series methods (Thompson, Sul, & Bohl, 2002), vector autoregression of prices (Ravallion, 1986), and Granger-causality tests (Miljkovic & Paul, 2001). A stream of research explores new methods for testing market integration. For example, Ji and Fan (2014) construct a minimal spanning tree based on the graph theory; and, Fackler and Tastan (2008) propose three new approaches defined directly in terms of a well-known spatial price determination model and developed econometric methodology. We use an improved hybrid method based on SVAR, in which DAGs are used to sort out causal flows of price information, to investigate market integration during explosive and unexplosive episodes.

Vector autoregression (VAR) was first developed by Sims (1980) to explore the relationship between economic variables. Let  $P_t$  denote a vector that includes *m* non-stationary prices. According to Park, Mjelde, and Bessler (2008), the data generating process of  $P_t$  can be appropriately modeled in a VECM as

$$\Delta P_{t} = \mu + \Pi P_{t-1} + \sum_{i=1}^{k-1} \Gamma_{i} \Delta P_{t-i} + \Psi Z_{i} + e_{i} (t = 1, \dots, T), e_{i} \sim Niid(0, \sum)$$
(5)

where  $\Delta P_t = P_t - P_{t-1}$ ,  $\Delta$  is the difference operator;  $\mu$  is a vector of constant terms;  $\Pi$  is a matrix of coefficients relating lagged levels of prices to current changes in prices;  $\Gamma_i$  is a matrix of short-run coefficients relating lagged period *i* price changes to current changes in prices;  $Z_i$  is a vector of exogenous variables; and,  $\Psi$  is a coefficients matrix associated with the exogenous variables.

Bessler, Yang, and Wongcharupan (2003) developed the SVAR based on the VAR. To provide a structural for SVAR, we model a matrix, *A*, representing the non-orthogonal innovations:

$$e_t = A^{-1} \varepsilon_t \tag{6}$$

where  $\varepsilon_t$  is the orthogonal of other sources of variation; and, the orthogonal variation causes  $e_t$ . Following the SVAR, the DAGs will summarize the contemporaneous causal flow of the innovations.

The basic principles of DAGs are as follows. There are three series (X, Y, Z), but we remove the edge between X and Y not conditional on Z; thus, we can then direct the triple X - Z - Y as  $X \to Z \leftarrow Y$ . We condition on variable Z to remove the edge between X and Y – the PC algorithm would leave the triple undirected as X - Z - Y. The latter is due to conditioning on Z to remove the line between X and Y being consistent with any one of the following three causal pictures:  $X \to Z \to Y$ ,  $X \leftarrow Z \to Y$  and  $X \leftarrow Z \leftarrow Y$ . Our article only gives a brief introduction to this method, please refer to Spirtes, Glymour, and Scheines (1993) for more details.

#### 4. Data descriptions

Following previous literature (Etienne et al., 2015; Li et al., 2016), we use the respective daily close price from 6 January 2006 to 14 September 2017 as the price series for our analysis based on both data compatibility and availability<sup>4,5</sup> Thus, our data set starts when China's sugar futures started public trading, which is convenient for making a comparison of the price bubbles. The sugar futures come from ZCE, NYBOT, and LIFFE, which are the most dominant participants in the global sugar futures markets. The original sugar price sequences for the bubble test contain 2,837, 2,794, and 2,831 observations from ZCE, NYBOT, and LIFFE, respectively. Specially, following previous literature (Alexakis et al., 2017; Etienne et al., 2015), no logs are used in our document.

ZCE quotes sugar futures prices Chinese Yuan, which we convert to US dollars based on the exchange rate for consistency with NYBOT and LIFFE prices. We use dollars per ton as the unit for these prices series; and therefore, we process sugar futures prices in NYBOT and LIFFE in the same way. We convert ZCE and NYBOT prices according to the formula, 2204.622 *pound*= 1 *ton*. Taking into account the holidays, we remove timeinconsistent data for every variable. By doing so, the sample size is 2,467 for each futures price series.

Table 1 provides the basic descriptive statistics for key variables appearing in our model. Clearly, there is a big difference when examining the minimum and maximum of these contracts. The mean and standard deviation show that all contracts exhibit high fluctuation. In general, the sugar commodity futures prices illustrate a high fluctuation pattern with irregularity. Figure 1 plots the sugar prices in these three markets. We find a very clear and consistent trend, which implies an integration relationship among these three important sugar futures markets.

<sup>&</sup>lt;sup>4</sup>The datasets are available from the Wind Financial Terminal.

<sup>&</sup>lt;sup>5</sup>Following Fung, Leung, and Xu (2003), to address the synchronous trading problem, when we analyze the effects of the Chinese market on U.S. and U.K. traded sugar futures, we use same-day futures prices. That is, the Chinese market on day t closes before the U.S. and U.K. markets on day t, so it can affect the U.S. and U.K. markets on the same day. Both U.S. and U.K. futures prices cannot affect the Chinese market quotes on the same-day t, but they can affect Chinese market quote on the following day, that is, on day t + 1. As such, when we analyze the effects of the U.S. and U.K. markets on Chinese traded sugar futures, the daily sugar futures prices in U.S. and U.K. markets are lagged 1 day (Zhou, Zhang, & Zhang, 2012).

#### Table 1. Descriptive statistics of key variables.

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Variable (unit)	Sample size	Mean	Standard deviation	Minimum	Maximum
ZEC (dollar/ton)	2,467	762.113	197.367	408.929	1168.133
NYBOT (dollar/ton)	2,467	379.400	113.273	194.006	695.558
LIFFE (dollar/ton)	2,467	478.694	129.502	259.5	876.3
Exchange rate (Yuan/Dollar)	2,467	6.768	0.563	6.093	8.070



Figure 1. Sugar price series in ZCE, NYBOT, and LIFFE.

#### 5. Empirical study

#### 5.1. Price bubbles analysis

We base the SADF on prices levels, which we must difference before conducting statistical tests. We perform price bubble tests on the sugar futures prices in ZCE, NYBOT, and LIFFE via EViews 8. We provide a brief description here, but please refer to Caspi (2017) for more details.

Table 2 presents the explosive periods identified by the SADF in sugar futures markets. Figure 2 presents the results of the SADF test, where we detect and date-stamp bubbles in the sugar futures prices using critical values (CV) developed with the recursive wild bootstrap procedure. In our article, we take sugar futures price in ZCE as an example to explain the main procedure of SADF test and bubble results. To date-stamp the bubbles, we compare the SADF sequence we calculate from each sugar futures price sequence with the critical value obtained from 1,000 Monte Carlo simulations. Figure 2 shows three lines – the green line is the sugar futures price, the red line represents the 95% CV sequence, and the blue line is the SADF sequence. When SADF is greater than CV, it denotes an explosive price that indicates the appearance of a price bubble. There are five periods when SADF is greater than CV, indicating there are seven bubbles in sugar futures prices in ZCE. It is worth mentioning that the specific date-stamping results based on the SADF test vary with the minimum bubble length (Etienne et al., 2014). We



Figure 2. Bubbles in sugar futures price series in ZCE.

choose a minimum bubble length of three days due to the short duration of the sugar futures bubbles. Applying the same process to the two other sugar futures markets (NYBOT and LIFFE), we detect a series of bubbles in all the three markets, as shown in Figures 3 and 4. Table 3 further summarizes the bubble test results for all three sugar futures markets. We find that there are some common bubble characteristics among these three markets.

There are 19 price bubbles in the three sugar futures markets – seven in ZCE and six in each of the NYBOT and LIFFE. During the period in question, there are 106 bubble days



Figure 3. Bubbles in sugar futures price series in NYBOT.



Figure 4. Bubbles in sugar futures price series in LIFFE.

in ZCE, 97 bubble days in NYBOT, and 79 bubble days in LIFFE. However, most of the bubbles in the sugar futures markets are not long-lived – 85% last fewer than 50 days, the two longest bubbles in ZCE and LIFFE last 53 days, and the smallest is only 3 days. On average, we identify about 3% of days as experiencing bubbles when using a minimum bubble length of 3 days. Obviously, bubbles occur at a similar time in all three markets in 2006, 2009, 2010, and 2011. Moreover, these sugar futures almost bubble together – co-bubbling occurs about 30.69% of the time (i.e., of the 189 days that sugar futures experience a bubble, there is a simultaneous bubble in at least two markets on 58 of those days).

Etienne et al. (2014) divide explosive periods into two groups – positive and negative bubbles. They define positive (negative) bubbles as occurring when the average price during the explosive period is greater (less) than the initial price at the start of the explosive period. Following this definition, we find the number of positive bubbles is more than negative bubbles (14 positive bubbles and five negative). To investigate the bubble size and shape, we adopt price at the origination, peak (through), and ending dates for each bubble period, and we calculate the returns (i.e., the percentage change in price) from start to peak (through) and the returns form peak (through) to the ending date, following Etienne et al. (2014):

$$\begin{aligned} r_{stat-peak} &= \frac{P_{\max/\min} - P_{start}}{P_{\max/\min}} * 100\%, \quad r_{peak-end} &= \frac{P_{end} - P_{\max/\min}}{P_{\max/\min}} * 100\%, \\ return &= r_{stat-peak} + r_{peak-end}. \end{aligned}$$

We also examine in detail the relationship between the magnitude of the initial price change and the correction. Figure 5 shows this relationship and provides a scatter plot of return (i.e., the percentage change in price) from start to peak (through) and return from peak (through) to end for each bubble period, along with a regression line. We confirm the expected relationship for the positive bubbles, with initial increases (x) "explaining"



Figure 5. Relationship between the magnitude of the initial price change and the correction.

larger corrections (y) in the opposite direction. As shown in Table 3, absolute values of returns are less than 7%, and the minimum is just 0.07%, so sugar futures prices are relatively stable during the bubble period. The return values of longer bubbles are greater than shorter ones, and the returns of positive bubbles are greater than negative bubbles. As we can see, negative bubbles are short-lived with the majority lasting fewer than 10 days – their return values are small too.

In conclusion, there are seven bubbles in ZCE, and both of NYBOT and LIFFE show six bubbles. All the bubbles episodes in these three sugar markets represent a very small portion period. Most bubbles in sugar markets are not long-lived – more than 85% last fewer than 50 days. The characteristics of price bubbles in these three sugar markets cover quantity, duration, price variation, and other aspects of price bubbles. Positive bubbles account for the majority of explosive episodes, and sugar prices often show a more violent tendency during positive bubbles.

#### 5.2. Market integration analysis

In this section, we explore whether sugar future prices in ZCE, NYBOT, and LIFFE are integrative from 2006 to 2017. More importantly, based on the bubble test, we examine the market integration in these three sugar futures markets during the explosive and unexplosive episodes using the DAG/SVAR hybrid method. By comparing the results of market integration in different periods, we find the impact of price bubbles on market integration and explore the causes of price bubbles based on a macro-economic environment.

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Table 2. E>	plosive pe	riods identified by the	SADF in s	ugar futures markets.								
			Length									
Exchange	Bubbles	Bubbles periods	(days)	Positive or negative	Average price	Initial price	End	Min	Max	rstat−peak	r <sub>peak-end</sub>	Return
ZCE	-	2006.8.22-2006.9.7	13	Negative	3351.846	3419	3375	3255	3419	-5.04%	3.69%	-1.35%
	2	2010.10.22-2010.11.12	16	Positive	6901.687	6533	6895	6518	7386	11.55%	-6.65%	4.90%
	m	2010.12.20-2011.3.10	53	Positive	7229.528	6886	7080	6874	7548	8.77%	-6.20%	2.57%
	4	2011.3.23-2011.3.25	m	Negative	7121	7133	7153	7077	7153	-0.79%	1.07%	0.28%
	5	2011.4.8–2011.4.13	4	Negative	7207	7255	7163	7163	7255	-1.28%	0.00%	-1.28%
	9	2011.7.21-2011.8.3	10	Positive	7397	7332	7327	7308	7504	2.29%	-2.36%	-0.07%
	7	2011.8.11–2011.8.18	7	Positive	7411.571	7389	7399	7349	7475	1.15%	-1.02%	0.13%
		Sum	106 (3.74%	()								
NYBOT	-	2006.9.22-2006.9.27	4	Negative	11.122	11.35	11.18	10.86	11.35	-4.51%	2.95%	-1.57%
	2	2009.8.7-2009.10.1	39	Positive	23.646	21.94	23.53	21.94	25.67	14.53%	-8.34%	6.19%
	m	2009.12.16-2010.2.19	44	Positive	26.352	24.32	26.05	24.15	28.5	14.67%	-8.60%	6.07%
	4	2010.11.4-2010.11.10	2	Positive	29.632	29.34	30.05	29.12	30.35	3.33%	~0.99%	2.34%
	9	2011.1.27-2011.2.2	S	positive	31.666	31.36	32.7	32.32	32.7	4.10%	0.00%	4.10%
		Sum	97 (3.47%									
LIFFE	-	2009.9.29–2009.10.1	Υ	Positive	612.766	611	609.3	609.3	618	1.13%	-1.41%	-0.28%
	2	2009.12.1–2009.12.3	m	Positive	623	619	623.3	619	626.8	1.24%	-0.56%	0.69%
	m	2009.12.11–2010.2.26	53	Positive	713.545	626.1	669.9	626.1	759	17.51%	-11.74%	5.77%
	4	2010.11.2-2010.11.11	8	Positive	776.875	745.5	797.3	745.5	805	7.39%	-0.96%	6.43%
	5	2010.12.17-2010.12.29	7	Positive	807.328	790.7	826.4	784.5	826.4	4.32%	-1.41%	4.32%
	9	2011.1.27-2011.2.2	5	Negative	822.840	824.5	844.5	811.6	844.5	-1.59%	4.05%	2.46%
		Sum	79 (7790/	( )								

Variance Decomposition of 7CE:	7CF	NYBOT	LIFFF
Deviad			
Period	100.000	0.000	0.000
	100.000	0.000	0.000
50	86.241	12.452	1.305
100	83.209	14.408	2.382
Variance Decomposition of NYBOT:	ZCE	NYBOT	LIFFE
Period			
1	2.292	97.707	0.000
50	4.762	92.364	2.872
100	4.706	90.013	5.280
Variance Decomposition of LIFFE:	ZCE	NYBOT	LIFFE
Period			
1	2.772	32.311	64.915
50	5.582	74.674	19.742
100	5.195	77.899	16.904

Table 3. Variance decomposition of sugar futures prices.

## 5.2.1. Market integration in full sample

Our empirical process of the market integration analysis is as follows. First, we conduct an Augmented Dickey–Fuller test on levels and first differences of the three prices series to test whether sugar futures prices are stable. The tests indicate that price levels are non-stationary and first differences are stationary in all three futures prices at the 5% level. Second, we select the optimal lag (3) based on AIC (Akaike information criterion). We then have one co-integration vector in the co-integration space among the three prices series. The result suggests there is one co-integration relationship in these three sugar futures markets at the 5% level. Third, we establish a VECM. By correcting parameters of our VECM, we obtain the residual correlation coefficient matrix (equation 7) between innovations in each of the three futures prices. Fourth, we apply a PC algorithm to the correlation given in equation 7. Figure 6 shows the



Figure 6. Causal pattern on innovations on sugar futures prices based on the PC algorithm.

results of the causal pattern on innovations of sugar futures prices based on the PC algorithm.

We can see that directed edges from LIFFE prices to NYBOT and ZCE prices. Obviously, there are no markets that cause LIFFE in contemporaneous time, while the NYBOT and LIFFE influence the ZCE directly through price transmission. Moreover, the NYBOT sugar futures prices are in very close contact with LIFFE prices. The relationship manifests that the daily sugar future prices in ZCE, NYBOT and LIFFE are integrative. However, this definite market integration relationship is not balanced – Chinese prices do not play a decisive role in this integration relationship and are easily susceptible. The LIFFE sugar futures prices also have an effect on ZCE by NYBOT through price transmission. The LIFFE plays a relatively independent role in these integration relationships, as the other two do not easily influence it. In contrast, ZCE and NYBOT market prices are more sensitive.

We facilitate a more complete study of the dynamic behavior of our sugar price series using standard innovation accounting techniques. Table 3 presents forecast error variance compositions and shows the results at horizons of 1, 50, and 100 days ahead. Consider, for example, we almost explain the uncertainty of ZCE sugar futures prices with surprises in all periods from its own region. The variation in ZCE futures prices is explained by the innovations from own price (100%), NYBOT (0) and LIFFE (0) in the contemporaneous period. Looking at the 50-days-ahead period, ZCE's own innovations (86.24%) and non-trivial influences from innovations from NYBOT (12.45%), as well as LIFFE (1.31%), primarily influence the uncertainty in ZCE sugar futures prices. Finally, at the long horizon of 100 days, earlier innovation from own price (83.21%), NYBOT (14.41%) and LIFFE (2.38%) explain the uncertainty in the ZCE region. As for NYBOT, the results are consistent with the ZCE, which shows the integration relationship among these three futures markets.

Table 3 shows the forecast-error variance compositions on LIFFE. As with the ZCE and NYBOT, we almost explain the uncertainty associated with LIFFE sugar futures prices in all periods from its own region. However, NYBOT (32.31%) at the one-day-ahead horizon primarily influences the uncertainty in the LIFFE sugar futures prices. In the long horizon of the 50-days-ahead period, we find that the NYBOT becomes the LIFFE's most important factor (74.67%), instead of the LIFFE own (19.74%). Moving ahead to the 100-days-ahead period, the influence of the NYBOT is greater.

In conclusion, in the initial period, the sugar futures prices are primarily owninfluenced. Moving to the longer periods, the other two markets become more influential due to international trade. There is an exact market integration relationship in these sugar futures markets, even though each market is relatively independent.

$$V = \begin{bmatrix} ZCE & NYBOT & LIFFE \\ ZCE & 1 & & \\ NYBOT & 0.1525 & 1 & \\ LIFFE & 0.1310 & 0.4587 & 1 \end{bmatrix}$$
(7)



**Figure 7.** Causal pattern on innovations on sugar futures prices based on the PC algorithm during the unexplosive and explosive episodes. (a) Unexplosive episodes (b) Explosive episodes.

**Table 4.** Variance decomposition of sugar futures prices during explosive episodes and unexplosive episodes.

	Unex	Unexplosive episodes Explosive episodes			es	
Variance Decomposition of ZCE:	ZCE	NYBOT	LIFFE	ZCE	NYBOT	LIFFE
Period						
1	100.000	0.000	0.000	100.000	0.000	0.000
50	97.917	0.119	1.963	61.711	24.853	13.434
100	95.941	0.932	3.125	57.805	25.226	16.968
Variance Decomposition of NYBOT:	ZCE	NYBOT	LIFFE	ZCE	NYBOT	LIFFE
Period						
1	1.673	98.326	0.000	0.000	100.000	0.000
50	4.276	93.000	2.723	14.133	36.499	49.367
100	4.444	91.114	4.440	15.637	29.998	54.363
Variance Decomposition of LIFFE:	ZCE	NYBOT	LIFFE	ZCE	NYBOT	LIFFE
Period						
1	2.473	33.462	64.064	1.971	27.570	70.457
50	4.501	76.290	19.207	8.662	8.087	83.249
100	4.432	79.948	15.619	9.554	6.886	83.560

#### 5.2.2. Market integration during the explosive and unexplosive episodes

We apply the same DAG and SVAR empirical process to the three sugar futures markets during explosive and unexplosive episodes, and reach conclusions by comparing the results of the two periods.

Figure 7 and Table 4 present outcomes of causal pattern on innovations and error variance decomposition during the unexplosive episodes, which have little difference from the results of the overall samples.

However, the results of error variance decomposition during the explosive episodes are worth discussing. The results suggest that the integration relationships among these sugar markets change when a price bubble occurs. ZCE's own innovations in all periods primarily influence the uncertainty in ZCE sugar futures prices. However, at the longer horizon, the other two price series, NYBOT (25.22% at the 100 days horizon) and LIFFE (16.96% at the 100 days horizon), more easily affect ZCE sugar futures prices during explosive episodes. As for the NYBOT, the LIFFE becomes the main factor, instead of the

prices own at the long horizons of 50 days and 100 days. While the LIFFE explains itself in all periods, the other two markets are not significant.

The above changes show that sugar futures markets are more integrative during the explosive period. In other words, the price bubbles influence market integration.

## 5.2.3. Discussion

In order to explore the factors that affect the price bubbles and market integration, this article sorts out the major events in the global sugar markets (see Figure 8). Coincidentally, several events may cause sugar futures prices to fluctuate during bubble periods.

For example, there was a price bubble in 2006 when global sugar production was excessive; sugar futures prices then fell sharply in the receiving season. While Sergey Gudoshnikov, an economist of the International Sugar Organization (ISO), said that although sugar cane is an energy crop, its relationship with energy prices is not very close;<sup>6</sup> thus, the energy crisis of 2006 did not have an important effect on sugar prices.

The shortage of global sugar production and inventory is the main reason for the bubbles in 2009–2011. The global food crisis reduced the acreage of sugar cane, and key sugar producers (Brazil and India) slashed production in severe weather. With investment funds pouring into commodity markets, the price of crude oil is pushing up sugar futures prices.<sup>7</sup>

It is worth noting that, once the price of sugar changed significantly, governments would introduce a series of policies to balance supply and demand. In 2006 and 2009, for example, China sold reserves of sugar at lower sugar prices. The EU agriculture commission approved a zero-tariff quota of 2,000,000 tons for 2006/07, increased the



Figure 8. Major events in the global sugar markets, 2006–2017.

<sup>&</sup>lt;sup>6</sup>http://www.ynsugar.com/Article/International/200609/82.html.

<sup>&</sup>lt;sup>7</sup>http://www.ynsugar.com/Article/International/200805/9482.html.

delivery of sugar by 500,000 tons, and imported 300,000 tons of raw and refined sugar in 2009.

Overall, the sugar futures price bubbles reflect the imbalance between supply and demand. However, unlike other agricultural commodities, sugar prices are relatively stable due to government regulation (customs duties, quotas, and stockpiles, etc.).

As we know, the LIFFE plays a more important role during the bubble period, which may relate to the mature sugar industry of EU. As the world's largest producer of beet sugar, the EU is a non-negligible part of the sugar market. Moreover, the reform in 2006–2009 made the sugar industry more perfect. During bubble periods, information transmits quickly and the market links more closely, making the role of LIFFE more obvious.

Sugar is self-sufficient in most countries – traded amounts are small, and sugar prices are highly regulated. Therefore, the global sugar market is relatively isolated due to various regulations. The contradiction between supply and demand determines the trend of sugar prices; with policies playing a certain role. The contradiction between market supply and demand worsening to a certain extent triggers a price bubble. At this time, market participants are extremely sensitive, and market information exchanges frequently, which strengthens the market connection. The influence of exchange rate and other factors is also more obvious. Prices reflect the overall changes of all markets, and prices in different countries show a consistency, which leads to market consolidation; thus, sugar futures markets are more integrative.

Obviously, the bubble period accelerates transmission of information, and the strengthening of market links makes the sugar price more valuable. Speeding up the transmission of information through continuous technological innovation is conducive to market integration.

### 6. Conclusions

The sugar market plays a key role in international agricultural trade. However, the international sugar spot prices have been exceptionally volatile over the past several years. In this case, the sugar futures market provides appropriate chances for hedgers and adventurers to participate in hedging, price discovery, and speculation.

In this article, we assume that market integration changes correspond to when a bubble occurs, which we confirm with several empirical studies on the world's three most important sugar futures markets. There are 19 price bubbles in these three sugar futures markets with similar characteristics in quantity, duration, price variation, and other aspects according to the SADF results. All the bubble episodes in these three sugar markets represent a very small period. Furthermore, positive bubbles account for the majority of explosive episodes; however, sugar prices often show a more violent tendency during the positive bubbles.

A definite market integration relationship exists in these three sugar futures markets. However, this integration relationship is not balanced – NYBOT and LIFFE play a more important role – but the bubbles affect the ZCE more. Overall these sugar futures prices are primarily influenced by these own in initial period. The results show the integration relationship and relative independence among sugar futures price series. While sugar futures markets are more integrative when there is a price bubble, price bubbles do influence the market integration. Price fluctuation reflects the imbalance between supply and demand and severe government regulation (customs duties, quota, and stockpile, etc.) in these sugar futures markets. Strengthening market links and promoting the speed of information dissemination may be conducive to market integration. Thus, market integration would provide market practitioners with an important defense or "hedge" against price risks through analyzing price trends in sugar markets, especially focusing on NYBOT and LIFFE. Similarly, market regulators would get more useful information about the determinants of price volatility and the implementation of market policy. In addition, the extent to which markets are integrated has crucial implications for regulation and economic policy. If the sugar markets considered in this study are internationally integrated, government should be cautious to intervene the domestic sugar market, because the intervention within one country may be ineffective or costly, and probably results in unexpected consequences.

#### **Disclosure statement**

No potential conflict of interest was reported by the authors.

#### Funding

This work was supported by the National Natural Science Foundation of China [71771101]; National Natural Science Foundation of China [71501079]; National Natural Science Foundation of China [71673103].

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