

# Testing for bubbles in agricultural commodity markets

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and George Rapsomanikis

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# Testing for bubbles in agricultural commodity markets

Francisco J. Areal, Kelvin G. Balcombe and George Rapsomanikis\*

## Abstract

Food price volatility spells have fuelled the debate about the reliability of world markets as a source of food. At the heart of this debate lies the question of whether food price spikes are generated by the forces of demand and supply, or by speculation. We test for ‘bubble’ behaviour – movements in the prices that cannot be explained by market fundamentals – by applying the generalized version of the *supremum* Augmented Dickey-Fuller to several food price indices and 28 agricultural commodity prices. Our findings suggest that few food commodities exhibited bubble behaviour during the 2008 food price episode, with the price surges of 2010 and 2011 being due to market fundamentals. These spells of explosive behaviour are, in general, short-lived. Other commodities, which are also traded in futures markets, appear to respond only to the forces of supply and demand. Market conditions, such as stagnant productivity growth and low carry-over stocks, tend to shape the effect of speculation on prices. In some markets, trade policies, such as export bans, also appear to be crucial in generating bubble behaviour in prices.

**Keywords:** food prices, commodity bubbles

**JEL codes:** G12, E30, C22, Q02

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## Introduction

Since 2007, the world experienced dramatic swings in internationally traded food commodity prices. Within the period of five years, food markets, and especially grains, have experienced a number of price surges. In June 2008, December 2010 and, more recently in the autumn of 2012, food prices increased sharply and subsequently declined from their peak, only to remain at relatively high levels, as compared with the 2005–2006 average.

Food prices are inherently volatile and addressing the consequences of such volatility is one of the most challenging issues facing policy makers, especially in developing countries. Since Gustafson's (1958) price behaviour model for a storable staple, over 50 years of empirical analysis have added a lot to our knowledge on the behaviour of commodity and food prices. Unrelated commodity prices move together (Pindyck and Rotemberg, 1990); they are highly autocorrelated and significantly volatile (Deaton and Laroque, 1992). Their long run downward trend (Grilli and Yang, 1988) is subject to violent upward spikes which are not matched by the few, or no downward spikes (Deaton and Laroque, 1992), while the shocks that generate these spikes tend to have a persistence effect on prices over the years (Cashin *et al.*, 2000). Finally, with regard to causes of commodity prices following cyclical patterns, there is little evidence that such cyclical patterns are determined by business cycles (Cashin *et al.*, 2002).

In spite of what we have learned about commodity price behaviour during the last 50 years, the 2008 commodities price episode revealed a gap in our knowledge on the drivers that determine commodity, and especially food prices. Since 2005 real food prices exhibit an upward trend, and in mid-2008 they increased in a violent surge by more than 60 percent, as compared to the 2007 levels. Since then, food prices remain at a level significantly higher than the average of the 2000–2005 period and exhibit large fluctuations, with slumps followed closely by booms in 2009, 2010 and 2012 as shown in Figure 1 which depicts the FAO Food Price Index. Indeed, the evidence so far suggests that volatility is both persistent and increasing (FAO, 2011; Rapsomanikis, 2011) with the macroeconomic environment and climatic shocks generating wide price movements.

Persistent food price volatility can have significant effects, especially on developing countries. In the short run, for net food importing developing countries price shocks can negatively affect the balance of payments, foreign currency reserves and worsen the ability to implement social safety programs. In the longer run, the diversification of activities to minimize exposure to price risk, inhibits efficiency gains from specialization in production and hinders the development of the agricultural sector (Kurosaki and Fafchamps, 2002). Income risks may also blunt the adoption of technologies necessary for agricultural production efficiency, as producers may decide to apply less productive technologies in exchange for greater stability (Larson and Plessman, 2002).

The violent spells of food price volatility in world markets strengthened the attention of policy makers to agriculture and fuelled the debate about the reliability of world markets as a source for food in the future. They have also generated a wide array of opinions concerning their nature and drivers, and have led to an equally wide array of policy proposals among policy makers. At the heart of the debate lies the question of whether such price surges are generated by the market fundamentals – the forces of food demand and supply, or by other drivers such as trend-following behaviour in both physical and financial markets.

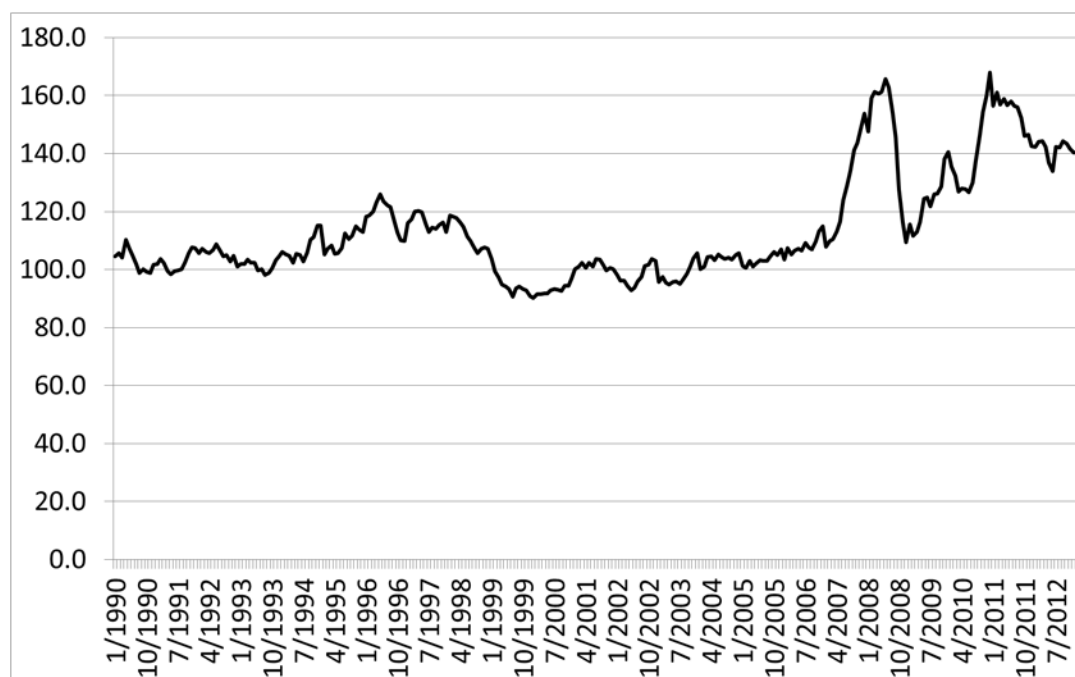
The debate on whether the drivers of food price volatility go beyond market fundamentals is reflected in the wide range of the policies proposed. Investing to accelerate agricultural

productivity growth and meet increasingly the growing demand for food to ease the pressure on prices (FAO, 2011) is a proposal founded on the understanding that supply, demand and stocks are the relevant drivers of volatility. Proposals such as the establishment of ‘virtual funds’ to intervene in the food futures markets by executing a number of progressive short sales are based on the surmise that changes in supply and demand fundamentals cannot fully explain volatility and speculation, especially in the futures markets, plays an important role in determining price movements (von Braun and Torero, 2009). There is no consensus between economists on the nature and drivers of food price volatility and, unsurprisingly, between policy makers on the policies to mitigate it.

In sum, the debate centres on whether agricultural and food prices experienced a ‘rational bubble’ which, as in the finance literature, reconciles trend-following behaviour with rational expectations on future earnings. Stiglitz (1990) presents a straightforward definition of a bubble: if the reason that the price is high today is only because investors believe that the selling price will be higher tomorrow – when fundamental factors do not seem to justify such a price – then a bubble exists (Stiglitz, 1990, p. 13).

A number of tests and dating algorithms have been developed and used to identify rapid increases in prices followed by a collapse, also known as explosive bubbles (Phillips, Wu and Yu, 2011; Phillips, Shi and Yu, 2012; Gilbert, 2009; Gutierrez, 2013). Previous analysis on agricultural commodities by Gilbert (2009) and Gutierrez (2013) applied the tests developed by Phillips, Wu and Yu (2011) and focused on four agricultural commodities. In this article, we apply the more recent generalized *supremum* augmented Dickey-Fuller (GSADF) test for explosive bubbles (Phillips, Shi and Yu, 2012) to monthly time-series for food, beverages, agricultural raw material, cereals, dairy, meat, oils and sugar price indices and a total of 28 agricultural commodity prices between 1980–2012. We found that price bubbles occurred for some commodities within food markets.<sup>1</sup>

**Figure 1. FAO Food price index**



<sup>1</sup> The *supremum* or *sup* test considers the maximum of the pointwise 1-step tests, appropriately normalised.

## The debate

Assessing the extent to which prices reflect fundamental values or not, is difficult. It entails testing the validity of the present value model. If this fails, the question is whether one can separate bubble behaviour from the possibility that the model itself is misspecified. With such difficulties, examining the evidence in an indirect manner, such as exploring both fundamental and non-fundamental factors and reconciling their movements with price variation, consists of an approach often encountered in the agricultural economics literature.

A number of authors underline the importance of the fundamental forces of supply and demand in explaining the food prices surges of 2008 and 2010. Growing population and income in emerging and developing countries adds significantly to the demand for food, while the rate of growth of agricultural production has not kept pace with demand (Alston *et al.*, 2010; Bioversity *et al.*, 2012). This alone is sufficient to exert pressure on commodity prices. The growing demand for food and feed crops for the production of biofuels is another significant factor, resulting in food and energy markets being integrated (Serra *et al.*, 2010; Balcombe and Rapsomanikis, 2008). Very inelastic derived demand for maize by the biofuel sector contributes to both higher prices and greater price volatility (Abbott, forthcoming). A response to the strong demand for grains by the livestock sector due to high income growth, and biofuels mandates is the decline of aggregate grain stocks relative to utilization. Indeed, the global grain market stocks-to-utilization ratio has been fluctuating at a low point since 2005–06, signifying a reduction in the buffer capacity of the global market. Even small supply and demand shocks, as well as trade policy changes can generate wide price variations in the price (Wright, 2010). Wright (2010) encapsulates the above strand of literature based on the competitive storage model, and concludes that the balance between consumption, available supply and stocks is sufficient to justify the recent wide grain price movements.

Beyond market fundamentals, dramatic increases in commodity futures investments by financial institutions coincided with the 2008 food price surge, giving rise to questions on whether the forces of demand and supply alone are sufficient to explain such price developments. While most of the speculative capital is invested in non-agricultural, especially energy futures, investments in agricultural futures, reflected by market open interest,<sup>2</sup> marked a significant increase from 2007 to 2008, a period with rapid increases in food prices, especially for maize, soybeans and wheat. Once again in 2010, although increases in the global market price of wheat were triggered by market fundamentals – reduced supply from Russia and the Black Sea region due to drought and export restrictions, open market interest in commodity exchanges increased significantly.

Robles *et al.* (2009) stress that, along with market fundamentals, rising expectations, speculation, hoarding, and hysteria played a significant role in the increasing level and volatility of food prices, attributing the 2008 food price episode partly to ‘speculative bubbles’. UNCTAD (2011), in a similar line, lay emphasis on the ‘financialization’ of commodities, a term which implies that the activities of ‘non-commercial’ financial participants tend to drive commodity prices away from levels justified by market fundamentals. Non-commercial investors do not engage in physical markets, as commercial investors do. The latter include producers and processors who hedge price risks, while the former view commodity futures as assets exhibiting relatively high returns which are negatively correlated with those from other assets, such as equities and bonds, providing effective portfolio diversification. However, these non-commercial investors are far from

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<sup>2</sup> Open market interest is a calculation of the number of active trades for a particular market calculated using futures and options contracts.



homogeneous and their behaviour in the market differs. Commodity index funds form the majority of financial investors on commodity futures and follow a passive positive-feedback strategy: they identify a trend and take a long position, purchasing commodity futures, when the trend is positive. Hedge funds follow discretionary trading strategies: they adjust their investments in commodity futures in line with changes in asset prices to stabilize and diversify their portfolio (Gilbert, 2010; UNCTAD, 2011). The concern is whether these non-commercial investors and their trend following behaviour feed price bubbles, thus detaching both cash and futures prices from their market fundamental values, and inevitably, the test for speculative bubbles becomes an investigation of the impact of non commercial traders on futures prices. Such an impact would be also reflected in the physical markets, as the information flow runs from futures to spot markets (Hernandez and Torero, 2010), thus distorting price signals.

Friedman's (1953) theory on efficient markets underlines that, given rational behaviour and rational expectations, the price of an asset will always reflect market fundamentals.<sup>3</sup> Any divergence of the price from its market fundamental value, caused by non informed traders, can be eliminated as it provides an opportunity to informed traders to trade against non-informed ones, make profit, and bring the price back to its fundamental value. Nevertheless, divergences may occur and although short-lived, can be frequent. There are many empirical exceptions to the theory of efficient markets. For example, informed traders may choose to follow positive-feedback trading strategies. If they expected prices to continue rising, they will chase the trend in the short run, thus feeding the bubble, instead of alleviating it (de Long *et al.*, 1990). DeMarzo *et al.* (2008) point out that even rational and informed traders may choose to join trend-chasing due to the risk underlying trading against the majority of participants. Dass *et al.* (2008) focus on the incentives fund managers have to trend-chase, as they are assessed against the performance of other fund managers. This provides strong incentives for herding and accentuating a bubble.

In the debate of whether agricultural and food commodity prices are unjustifiably volatile and detached from market fundamentals, the agricultural economics literature has mainly centred on analysing whether the 2008 dramatic food price increases were induced by speculative purchases of futures contracts by non-commercial institutional investors on prices. These analyses do not constitute tests for the detection of a bubble, but focus on identifying the possible avenues through which positive-feedback strategies in commodity exchanges contributed towards price increases that could not be explained by market fundamentals. Nevertheless, in these analyses the term 'bubble' is used liberally.

Irwin *et al.* (2009) assess the impact of speculative purchases of food commodity futures by index funds on futures prices by means of Granger causality tests and conclude against the argument that speculators caused the food price bubble. Sanders and Irwin (2010) investigate the effect of index funds' positions on the prices of a number of agricultural and food commodities, finding no impact when quarterly and monthly data were used, and only weak evidence when weekly data was analysed. They concluded that, overall, the evidence that non-commercial investors with passive strategies affect agricultural futures prices is scant. Sanders and Irwin (2011) find little evidence of an index-induced food price bubble for a number of markets with the exception of soybeans.

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<sup>3</sup> This year's Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel was awarded to Eugene Fama, Lars Peter Hansen and Robert Shiller for their empirical work aimed at understanding how asset prices are determined.

Gilbert (2010) assesses the impact of investment on an index of futures positions in twelve major agricultural futures markets on the International Monetary Fund (IMF) Food Price Index, in addition to the impact of other variables such as the price of oil, money supply and the US exchange rate. He concludes that index fund investment is sufficiently large to influence food prices. In another paper, Gilbert (2010) formally tests for a bubble in three food commodities, maize, wheat and soybean, using futures prices and applying the methodology of Phillips, Wu and Yu (2011). He finds clear evidence for a bubble in soybean prices in December 2009 and in January 2010, but no evidence for explosive behaviour in wheat and maize prices. Gilbert's (2010) finding concurs with that of Sanders and Irwin (2011) on the role of index funds in this market, but the interpretation of such results is not straightforward. First, the question relates to the avenue through which non commercial investment behaviour would generate a price surge. Gilbert (2010) notes that an increase in the demand for futures contracts will tend to raise long-dated futures prices and increase inventory demand, which in the short term will result to an increase in the cash price. Recently, Gutierrez (2013) found speculative bubbles in prices of wheat corn and rough rice and minor evidence for a bubble in soya bean prices. Such differences, as pointed out by Gutierrez (2013), may be due to different bootstrap methods used to define the critical values.

## Theory

Among the potential analytical frameworks for explosive price behaviour, the most widely applied are rational bubbles' models which can be illustrated on the basis of the present value model. We follow Pindyck's (1993) application of the present value model on rational commodity pricing, where the price of a commodity  $P_t$  is determined by the stream of current and expected future payoffs  $\varphi_{t+i}$ . Pindyck (1993) draws an analogy with the rational pricing of assets, such as stocks, and underlines that for a storable commodity the stream of payoffs  $\varphi_{t+i}$  is the convenience yield accruing to the owner of the inventory in terms of benefits related to the facilitation of processing, sales and the avoidance stock-outs. The convenience yield that accrues to the inventory owner is directly analogous to the dividend on a stock. Therefore, the standard arbitrage condition becomes:

$$P_t = E_t \left[ \frac{1}{(1+\delta)} (P_{t+1} + \varphi_{t+1}) \right] \quad (1)$$

where  $\delta$  denotes the discount rate and  $E$  is the expectation operator conditional on information at time  $t$ . For equation (1) to hold, stocks should be positive and no stock-outs occur as in the competitive storage model (Gustafson, 1958; Deaton and Laroque, 1992) where stock-outs play a central role in determining commodity prices in the absence of the convenience yield. The forward iteration of the difference equation (1) results in:

$$P_t = E_t \left[ \sum_{i=t+1}^T \frac{1}{(1+\delta)^i} (\varphi_i) \right] + E_t \left[ \frac{1}{(1+\delta)^{T-t}} P_T \right] \quad (2)$$

Equation (2) suggests that the equilibrium commodity price has two components: (i) a market *fundamental* component, the first term in the right hand side, which is the discounted value of the expected future convenience yields; and, (ii) a *bubble* component, the second term in the right hand side, which is the expected capital gains, or discounted resale value. The presence of the bubble, although reflects that the price of the commodity can exceed its fundamental value, is entirely consistent with rational expectations; however, it gives an infinite number of solutions for the price, hence the term 'rational bubble'. For example, as Shiller (1978) suggests, a rational bubble could start at any time and, as in the specification of Blanchard and Watson, could burst and restart repeatedly. This specification also echoes Keynes' thoughts on investors who forecast the yield over the life of the asset and speculators who forecast the

psychology of the market: if agents believe that the selling price of a commodity will be high in the future, then it will not be only the fundamentals that will determine the current price, but also the expected capital gains.

Typically, in order to obtain a unique solution, the bubble component, that is the discounted value of the commodity, is normally assumed to converge to zero in the indefinite future. This is the transversality condition which rules out rational bubbles on the basis of a general equilibrium zero-sum argument (Tirole, 1982): the purchase of one unit of the commodity would make an infinitely lived agent worse off, as her utility would increase only by the fundamental component, that is the discounted value of the expected future convenience yields. In other words, no one would be willing to buy an over-priced commodity.

If the transversality condition holds, equation (2) suggests that the price is determined by the discounted value of the expected future convenience yields, giving rise to the standard present value model for commodities, as in Pindyck (1993). This model underlines the importance of the convenience yield in reflecting the fundamental market forces: expectations on changes in supply and demand cause changes in the expected convenience yields, rendering the present value model a parsimonious and reduced form of a dynamic supply and demand system.

In spite of ruling bubbles out, many observers believe that bubbles exist and the literature treats such non-fundamental bubbles as possible within an empirical context. The possibility that bubbles could exist was stressed by Stiglitz (1990) who questioned that the transversality condition could be satisfied with agents that are not infinitely-lived and market institutions that do not support infinite planning, such as future markets extending infinitely into the future. More recently, Wang and Wen (2012) also show that, given incomplete financial markets and borrowing constraints, any inelastically supplied storable good can support a bubble, which can serve even infinitely-lived agents as a liquid asset.

Without imposing the transversality condition, any of the infinite solutions for the commodity price can be written as:

$$P_t = F_t + B_t,$$

$$\text{where } F_t = E_t \left[ \sum_{i=1}^{T-i} \frac{1}{(1+\delta)^i} (\varphi_{t+i}) \right] \text{ and } B_t = E_t \left[ \frac{1}{(1+\delta)} B_{t+1} \right]. \quad (3)$$

The statistical properties of  $P_t$  are determined by those of  $F_t$  and  $B_t$ . For example, if  $\varphi_t$  is an I(1) process,  $F_t$ , the discounted future stream of expected convenience yields is also an I(1). The relation  $B_t$  is an empirical expression which embodies an explosive property and introduces ‘bubble’ movements in the price  $P_t$  over the fundamental component  $F_t$ . In the absence of bubbles, a special case of (3) with  $B_t = 0$ , the current price of the commodity is determined according to market fundamentals, yielding the standard present value model with  $P_t = F_t$ , and if  $F_t$  is I(1), current prices are also I(1). If  $B_t \neq 0$ , current prices will exhibit explosive behaviour, as  $B_t$  reflects a submartingale process, that is a stochastic process in which the expected value of next period's value, as forecast on the basis of the current period's information, is greater than or equal to the current period's value.

## Testing for bubbles

Given the different stochastic properties of the fundamental and the bubble components, early tests for explosive behaviour in asset prices were based on standard Dickey-Fuller tests. As a series' explosive behaviour is still prevalent after differencing, Diba and Grossman (1988) tested both stock prices and dividends for nonstationarity. Evidence of stationarity after differencing was taken as providing no support for the existence of a bubble, while, cointegration between stock and dividends would support the conclusion that stock prices did not diverge from their fundamental values. Evans (1991) criticized this integration-based approach, stressing that unit root and non cointegration tests are not effective in making a distinction between a unit root or a stationary autoregression and a process which exhibits periodically collapsing bubble behaviour. The recursive tests proposed by Phillips, Wu and Yu (2011) are not subject to this criticism, being effective in distinguishing unit root processes from periodically collapsing bubbles and date-stamping their origin and collapse. Their methodology is based on a repeated application of the augmented Dickey-Fuller test (ADF), estimating through a recursive regression the specification:

$$\Delta y_t = \alpha_{r_w} + \beta_{r_w} y_{t-1} + \sum_{i=1}^k \varphi_{r_w}^i \Delta y_{t-i} + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma_{r_w}^2) \quad (4)$$

where  $y_t$  is the logged price of the commodity at time  $t$ ;  $\alpha, \beta, \varphi$  are parameters to be estimated;  $r_w$  is the sample window size; and,  $k$  is the lag order. The recursive regression involves the estimation of (4) by least squares starting with  $r_w = r_0$  fraction of the sample, and repeatedly expanding the sample forward, with the last regression utilizing the full sample  $T$ . For example, the first regression utilizes a subsample  $\tau_0 = [Tr_0]$  from the first observation of the sample to the  $k^{th}$  observation, selected to ensure estimation efficiency. This produces an ADF statistic denoted  $ADF_{r_0}$ . The second regression expands the sample by one observation to the  $(k+1)^{th}$  observation, utilizing a subsample  $\tau_1 = [Tr_1]$  and producing an ADF statistic denoted by  $ADF_{r_1}$ . Subsequent regressions expand the sample window size  $r_w$ , from  $r_0$  to 1, with 1 being the whole sample and  $ADF_1$  corresponding to the whole sample ADF statistic. Phillips, Wu and Yu (2011) by expanding the sample forward, generate a sample of ADF statistics and test the null hypothesis of a unit root against the right-tailed alternative of explosive behaviour with the supremum ADF,  $\sup_{r_w \in [r_0, 1]} ADF_{r_w}$ , utilizing the critical values.

Although the *sup* ADF detects periodically collapsing bubbles, date stamping their origination and subsequent collapse, Phillips, Shi and Yu (2012) underlined its weakness in the presence of multiple bubble episodes within the same sample period, a condition characterizing food commodity prices since 2007. The generalized version of the *sup* augmented Dickey-Fuller (GSADF), recently developed by Phillips, Shi and Yu (2012), tests for the possibility of periodically collapsing bubbles, using a moving window, rather than a fixed initialization window as in *sup* ADF, thus avoiding being sensitive to sample start data.

We use the generalized version of the *sup* augmented Dickey-Fuller (GSADF) test recently developed by Phillips, Shi and Yu (2012), which has not been applied using agricultural prices, to test for bubble phenomena. The first order Augmented Dickey-Fuller regression model used by Phillips, Shi and Yu (2012) is

$$\Delta y_t = \alpha_{r_1, r_2} + \beta_{r_1, r_2} y_{t-1} + \sum_{i=1}^k \varphi_{r_1, r_2}^i \Delta y_{t-i} + \varepsilon_t \quad (5)$$

Following the GSADF approach, we use variable window widths in the recursive regressions, allowing the starting points  $r_1$  to change within a feasible range. The standard Augmented

Dickey-Fuller (ADF) tests the null hypothesis of non-stationarity  $H_0: \beta_{r_1, r_2} = 0$  against the alternative hypothesis  $H_1: \beta_{r_1, r_2} > 0$ , which implies explosive behaviour. Significant ADF test statistics indicate a bubble episode. The estimated parameters  $\alpha, \beta, \varphi$  of model (5) are obtained through recursive ordinary least squares (OLS)<sup>4</sup>. The idea behind is that if an explosive behaviour exists this will be present over a subsample  $[r_1, r_2]$  of the entire sample  $[1, T]$ .

## Data

We analyse price indexes for food and beverage and agricultural raw materials, as well as 28 individual agriculture commodity prices (see appendix for list of price definitions).

We use monthly price indices data from the Food and Agriculture Organization of the United Nations (FAO), as well as from International Monetary Fund (IMF). The FAO indices include the food price index, as well as indices for meat, dairy, cereals, oils and sugar from January 1990 to August 2012 comprising 271 observations for each index. We also use the IMF indices which include the food and beverage index, and indices for food, beverages and agricultural raw materials from January 1980 and February 2012 comprising 386 observations.

Data on the 28 individual agricultural commodity prices are collected from the International Financial Statistics of the IMF from January 1980 and February 2012 and deflated using the US monthly CPI obtained from the US Department of Labour.

## Results

We follow the approach by Phillips, Shi and Yu (2012) and apply the generalized version of the supremum ADF to test for multiple bubble phenomena in food and agricultural raw materials prices. We estimate equation (4) allowing for variable window widths in the recursive regressions. Phillips, Shi and Yu (2012) provide critical values of GSADF tests against an explosive behaviour using Monte Carlo simulations, setting the lag order to be zero (i.e. zero lags). We obtained the asymptotic 90, 95 and 99% critical values for lag orders set from 0 to 12. As in Phillips, Shi and Yu (2012), the Wiener process is approximated by partial sums of 2,000 independent  $N(0,1)$  variates and the number of replications is 2,000. For our empirical application we use 10% of the sample, as our initial start-up sample,  $r_0=0.1$ , and set the smallest sample window  $r_w = 0.4$ . The asymptotic critical values obtained are shown in the Appendix.

Table 1 shows the maximum ADF test obtained from estimating the GSADF model (4) repeatedly over the feasible ranges  $r_1$  and  $r_2$ . Maximum values greater than the critical values reported show evidence of bubble behaviour in the particular index or price as the tests reject the null hypothesis  $H_0: \beta_{r_1}^{r_2} = 0$  in favour of the right tailed alternative hypothesis  $H_1: \beta_{r_1}^{r_2} > 0$ . The tests provide evidence for bubble behaviour at the 10% significance level for both the FAO and IMF food price indices, the IMF food and beverage price index, the FAO cereals, dairy and oils indices, and the prices of wheat, rice, soybean oil, rapeseed oil, sugar and coffee.

In order to date-stamp the origin and conclusion of the explosive behaviour in the series we plot the relevant recursive  $ADF_{r_1}^{r_2}$  statistics together with indices and prices we examine (Figure 2).

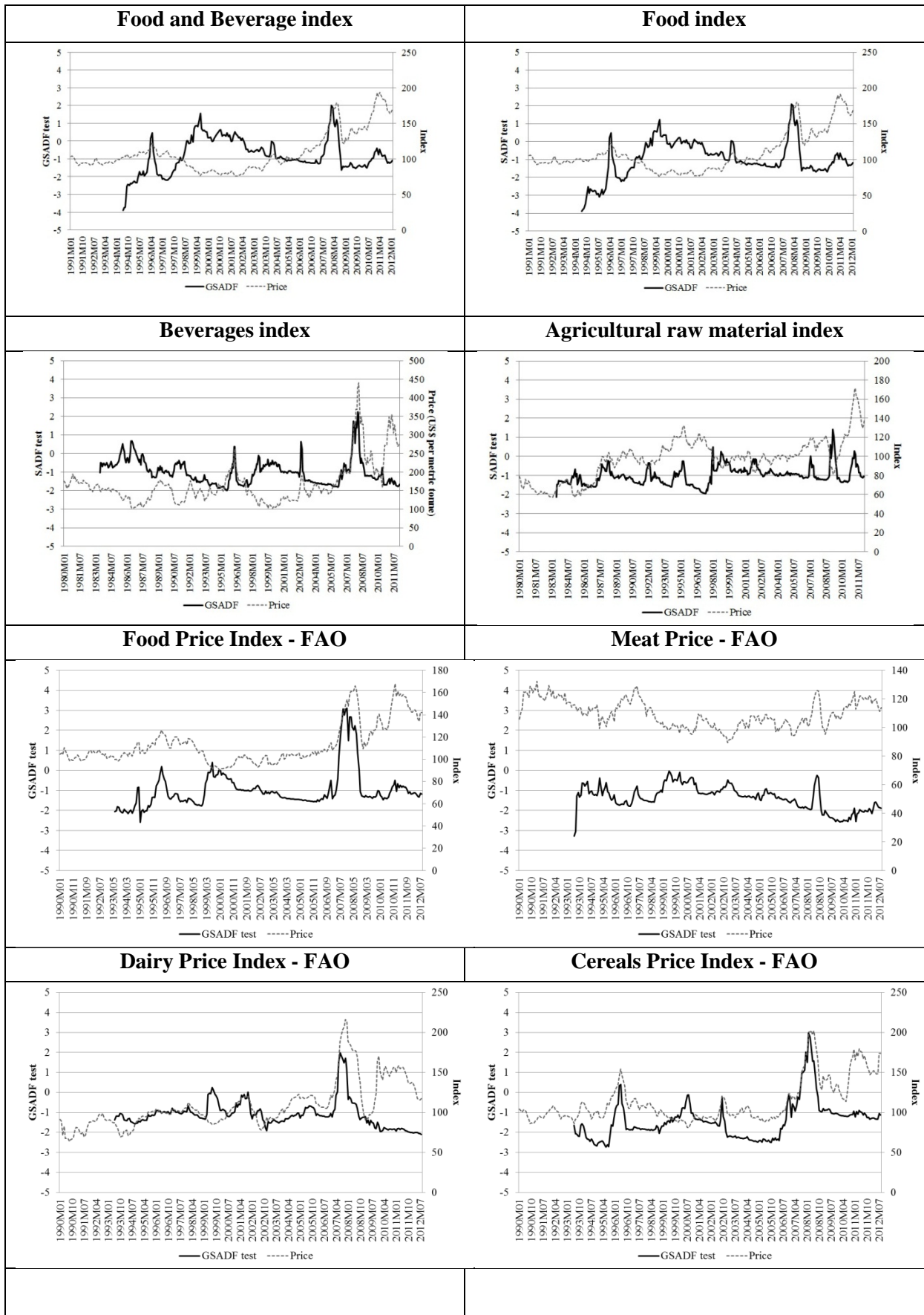
<sup>4</sup> We use 10% of the total sample as the starting sample.

Our results show bubble behaviour during the end of 2007 and the first months of 2008 in six out of the ten indices examined. For the FAO food price index, the evidence suggests persistent explosive behaviour from August 2007 until June 2008, with the value of the recursive  $ADF_{r_1}^{r_2}$  statistics exceeding the 90% critical value, 1.93 (Figure 2). For the IMF food and food and beverages price indices bubble behaviour is found during January, February and March 2008.

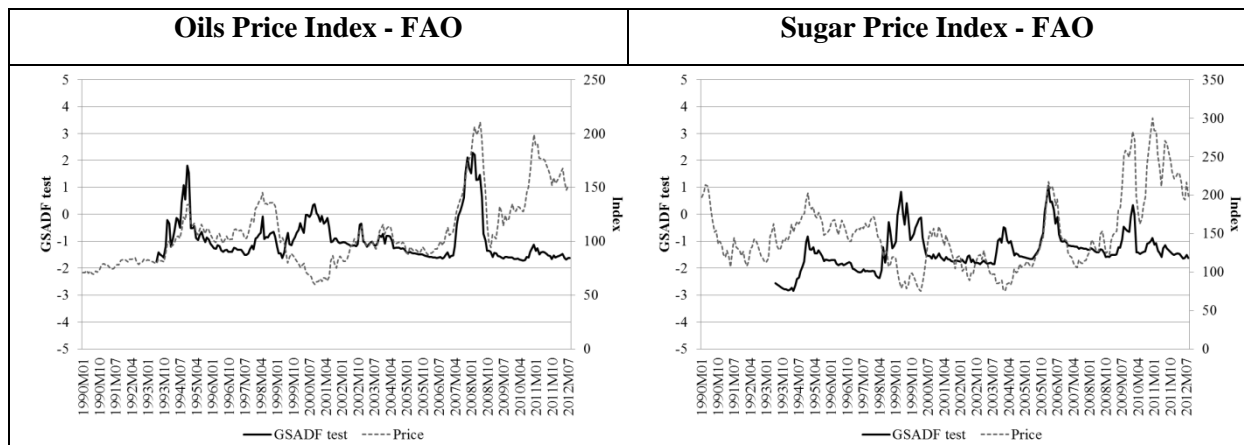
**Table 1. GSADF model results for agricultural commodities**

Commodities	Max	90% critical value	Lags	n	Commodities	Max	90% critical value	Lags	n	Commodities	Max	90% critical value	Lags	n
Food and beverage index	2	1.87	1	254	<b>Vegetable oils and protein meal</b>					<b>Seafood</b>				
Food Index	2.09	1.87	1	254	Soybean	1.28	2.11	1	386	Fish (salmon)	0.8	2.71	6	386
Beverages Index	0.88	2.11	1	386	Soybean meal	0.68	2.11	1	386	Shrimp	0	2.29	2	386
Agricultural Raw Material Index	1.41	2.11	1	386	Soybean oil	2.6	2.11	1	386	<b>Sugar</b>				
Food Price Index – FAO	3.1	1.93	1	271	Palm oil	1.9	2.53	4	386	Sugar, free market	1.56	2.11	1	386
Cereals Price Index – FAO	2.98	1.93	1	271	Fishmeal	2.01	2.11	1	386	Sugar, European import price	1.53	1.87	1	254
Meat Price Index – FAO	-0.04	1.93	1	271	Sunflower oil	1.11	2.29	2	386	Sugar, U.S. import price	3.5	2.11	1	386
Dairy Price Index – FAO	1.97	1.93	1	271	Olive oil	1.89	2.29	2	386	<b>Fruit</b>				
Oil Price Index – FAO	2.28	1.93	1	271	Groundnuts	0.8	2.11	1	386	Bananas	-1.44	1.96	0	386
Sugar Price Index – FAO	1.06	1.93	1	271	Rapeseed oil	2.09	1.96	0	386	Oranges	-0.61	2.11	1	386
<b>Cereals</b>					<b>Meat</b>					<b>Beverages</b>				
Wheat	2.24	2.11	1	386	Beef	1.36	2.29	2	386	Cocoa beans	2.07	2.29	2	386
Maize	1.13	2.11	1	386	Lamb	0.34	2.29	2	386	Coffee, other mild arabicas	1.7	2.11	1	386
Rice	4.09	2.29	2	386	Swine (pork)	1.51	1.96	0	386	Coffee, Robusta	2.15	2.11	1	386
Barley	0.85	2.11	1	386	Poultry (chicken)	0.89	2.11	1	386	Tea	0.38	2.11	1	386

Figure 2. Price trends and GSDAF test statistics







Within the food and beverage index (IMF) it is possible that the food component is the factor behind the bubble behaviour since no explosive behaviour is attributable neither to the beverage index, nor to any of the individual beverages analysed during the period 2007–2008. For the FAO cereals index, there is evidence for bubble behaviour from December 2007 to April 2008, and the FAO oils index shows explosive behaviour during February and March 2008. The not entirely synchronized explosive behaviour of indices may be attributable to different aggregation and weighting methods. The FAO food price index is trade-weighted and, as trade increased at a fast rate during the 2007–08 period, the results show persistent bubble behaviour. This trade-weighting also appears to strengthen the power of the index in predicting bubbles. Amongst food commodities the strongest evidence for a price bubble is for rice, for which the explosive behaviour lasted for three months, from February 2008 to April 2008, and again in July 2008. Prices of wheat, soybean oil and rapeseed oil show bubble behaviour during February and March 2008.<sup>5</sup>

The analysis provides some interesting findings. First, our recursive regressions suggest that the price surge of 2007–08 is of a different nature than that of 2010 and 2011: no evidence of explosive behaviour in indices and prices is found outside the period August 2007 to July 2008. Although in 2010 and 2011, wheat prices surged as a result of climatic factors and policies, such as the grains export ban by Russia in 2010, there is no evidence that prices exceeded their fundamental value. In sum, we do not detect multiple bubbles in the food price series after the summer of 2008, a finding that suggests that since that time, food prices respond to the fundamental forces of demand and supply. Second, the analysis suggests that price bubbles are relatively short lived. With the exception of the FAO food price index, explosive behaviour in food prices lasted for a limited period of time, lasting to two, three or, at most four months, before collapsing. Thirdly, for the individual commodity prices, the tests provide evidence for bubble behaviour in the wheat, rice, soybean oil and rapeseed oil price series, all of which have exhibited record increases during the first months of 2008 relative to other commodities. In their peak, wheat and rice prices were 350 and 530 percent higher, as compared to January 2002 levels, a point that marks the beginning of an upward trend in food prices.

Although our analysis provides answers as to if, and when food prices exhibited bubble behaviour, the results raise a number of important questions about the drivers of explosive behaviour. As far as the price of rice is concerned, the results concur with panic –driven trade

<sup>5</sup> Evidence for bubble behaviour was also found for sugar and robusta coffee, but is unrelated to the recent price increases in agricultural commodities prices and therefore is not presented here.

policy reactions of countries in Asia. Export restrictions, in the form of both taxes and bans, beginning during late 2007 were crucial in generating bubble behaviour in the price of rice. In late September 2007, Vietnam, the second largest exporter in rice, announced a ban on commercial sales. In October 2007, India, the third largest rice exporter, imposed an export tax on non-basmati rice and in March 2008 imposed a complete ban. These export bans, in conjunction with aggressive and panic-driven buying by the world's leading importer, Philippines, during March and April 2008 at prices over US\$ 1,100 per tonne, as compared to an average of US\$ 326 per tonne in 2007, contributed towards the price of rice being over-valued, detaching from market fundamentals.

The results for bubbles in the wheat and vegetable oil prices, though not surprising, are more difficult to interpret especially because no explosive behaviour was detected in the prices of maize and oilseeds. At their peak in 2008, soybean oil prices increased by 410 percent as compared with their January 2002 values, proportionally more than those of soybeans which increased by 350 percent. Maize prices also registered a significant increase at their peak in 2008 from their January 2002 level by about 300 percent, a rate lower than that of wheat prices. For all four commodities, markets were tight in 2007–08: oilseeds and oils markets suffered from poor growth and low stocks; in the wheat market, stagnant production in conjunction with very low carryover stocks resulted in an extremely tight global market; and, maize prices were also under pressure from strong demand from the biofuels industry, although the 2007 record crop lessened the strain on the market.

Beyond fundamentals, even if the GSDAF detects price bubbles, it does not provide sufficient evidence that these bubbles are the result of trend-following behaviour in the futures markets. Nevertheless, the lack of evidence on explosive behaviour in maize and oilseeds prices questions the conjecture that trend-following behaviour in futures markets has been the driver of food price increases. Maize and oilseeds futures are traded in commodity exchanges and, like wheat, their contracts are included in commodity indices. There are some differences in index investments movements across these commodities, but these do not correspond with our findings on explosive behaviour. Between December 2007 and June 2008, the index funds' net positions on wheat increased from 38.2% to 41.9% of the total open interest. During the same six-month period, the share of the index funds net positions on maize was not as substantial as that on wheat, but also increased from 25.8% to 27.4% of the total (Gilbert, 2010). With such a high share of the wheat open interest held by non-commercial traders, in an already tight market, the possibility that the demand for long-termed wheat futures contracts may have affected prices and generated bubbles through strengthening inventory demand, should not be ignored. The size of index funds' wheat net positions come second only to the share of open interest they held on live cattle and lean hogs, which amounted to over 40 percent of the total during 2007–08. In spite of this high share, no bubble is detected in beef and pork prices. Nevertheless, it is doubtful that index fund investments would have a direct impact on meat markets, through strengthening the demand for inventories (herds) in a period of high feed prices. The specificities of each food market, in conjunction with the wide diversity of traders, both non commercial and commercial, and their complex trading behaviour over a short period of time, makes the analysis of the role of futures markets in the 2007–08 price episode difficult and beyond the scope of this article.

## Conclusions

Recently there has been a rise in agriculture commodity price volatility which has had a wide range of implications. A number of tests and dating algorithms have been developed and used to identify rapid increases in prices followed by a collapse, also known as explosive bubbles

(Phillips, Wu and Yu, 2011; Phillips, Shi and Yu, 2012; Gilbert, 2009). We apply the GSADF test for explosive bubbles to monthly price indices of food, beverages, agricultural raw material, cereals, dairy, meat, oils and sugar, and a total of 28 agricultural commodity prices between 1980 and 2012.

These tests identified that price bubbles occurred for some commodities within food markets. These rapid changes in agricultural commodity prices may have important immediate effects on the income and welfare of producers, agents along the food chain and consumers, but also on the trading positions of countries (Balcombe, 2009). Two important questions arise, (a) are the price bubbles found in food commodities of speculative origin?; and, (b) are some commodities more prone to suffer price bubbles than others?

Looking forward, on question (a) there is need for further analysis of trading positions of commercial and non commercial participants in the futures markets. A price bubble was identified in the wheat market, where a large share of open interest was held by non-commercial traders. However, maize and other agricultural commodities are also traded in futures markets by non-commercial agents and further research, based on disaggregated data on the composition of both commercial and non commercial positions and their behaviour, during price surges is necessary to unravel their potential role in determining price movements.

Regarding question (b), we conclude that a number of agricultural commodities are prone to suffer price bubbles, and therefore, efforts in both identifying and tackling price bubbles should focus on those commodities that have shown explosive behaviour in the past. For example, the global rice market is quite thin, with major producers and exporters managing domestic markets through trade controls, combined with buffer stocks. Our results show that export restrictions can exacerbate, or even cause severe disruption and a collapse in confidence on international markets. Increased international trade policy coordination in times of crisis can reduce volatility, and ensure that global markets can be still a reliable source of food. Enhanced trade policy harmonization through more predictable and less discretionary policies would convey clearer information and render panic and hoarding less likely, resulting in more certainty.

From the methodological point of view, an important issue, also highlighted by Gilbert (2010), is that the frequency of the data (e.g. daily, monthly) used in the analysis may be important in detecting bubbles. The fact that we have not found more price bubbles may be precisely because of the data frequency used (i.e. using higher frequency data, such as daily prices, may have detected bubbles that are disguised under lower frequency data). Therefore, high frequency data of agricultural prices, particularly data of commodities that have shown bubble behaviour in the past, should be used to detect emerging trends of price spikes. Cereals, such as wheat and rice and vegetable oils, such as soybean and rapeseed oil, have shown bubble behaviour in the recent years and close attention should be paid to their price evolution. On the other hand, fruits, meat, seafood and to a large extent beverages have not shown any evidence of bubble behaviour and therefore the relative risk of bubble behaviour may be low.

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**Appendix I: Critical values**

Tables A.1, A.2 and A.3 show the critical values at 90, 95 and 99% level, respectively. Tables show the critical value by lags (0 to 12) and number of observations (100 to 500).

**Table A.1 Critical values at 90% level**

Number of lags	Number of observations								
	100	150	200	250	300	350	400	450	500
0	1.145	1.449	1.593	1.723	1.814	1.892	1.957	2.009	2.045
1	1.267	1.567	1.753	1.868	1.970	2.028	2.111	2.160	2.208
2	1.415	1.748	1.926	2.056	2.153	2.236	2.289	2.343	2.384
3	1.462	1.775	2.004	2.154	2.239	2.331	2.396	2.451	2.501
4	4.607	1.987	2.159	2.311	2.397	2.473	2.534	2.577	2.631
5	1.628	1.988	2.210	2.335	2.435	2.539	2.620	2.688	2.728
6	1.691	2.089	2.317	2.457	2.571	2.678	2.750	2.785	2.841
7	1.768	2.162	2.382	2.514	2.639	2.733	2.800	1.875	2.930
8	1.834	2.258	2.502	2.639	2.733	2.834	2.891	2.961	3.024
9	1.838	2.263	2.465	2.659	2.763	2.855	2.925	2.988	3.051
10	1.953	2.389	2.613	2.763	2.877	2.962	3.037	3.126	3.182
11	1.985	2.439	2.671	2.806	2.930	3.046	3.092	3.161	3.220
12	2.093	2.477	2.749	2.916	3.039	3.132	3.215	3.273	3.325

**Table A.2 Critical values at 95% level**

Number of lags	Number of observations								
	100	150	200	250	300	350	400	450	500
0	1.455	1.709	1.863	1.992	2.061	2.140	2.203	2.266	2.308
1	1.589	1.836	2.039	2.163	2.251	2.310	2.374	2.423	2.458
2	1.780	2.061	2.209	2.347	2.426	2.520	2.567	2.618	2.662
3	1.783	2.131	2.331	2.474	2.566	2.649	2.715	2.759	2.789
4	2.015	2.335	2.496	2.605	2.695	2.765	2.836	2.873	2.923
5	2.000	2.334	2.517	2.659	2.759	2.852	2.923	2.974	3.003
6	2.083	2.484	2.664	2.806	2.896	2.992	3.037	3.097	3.138
7	2.168	2.492	2.735	2.881	2.985	3.058	3.109	3.157	3.185
8	2.280	2.645	2.874	2.990	3.061	3.144	3.212	3.260	3.317
9	2.235	2.659	2.869	3.007	3.127	3.218	3.305	3.359	3.418
10	2.350	2.761	2.970	3.127	3.239	3.311	3.378	3.438	3.490
11	2.418	2.821	3.008	3.122	3.250	3.349	3.424	3.476	3.514
12	2.452	2.870	3.103	3.259	3.358	3.445	3.564	3.601	3.654

**Table A.3 Critical values at 99% level**

Number of lags	Number of observations								
	100	150	200	250	300	350	400	450	500
0	2.048	2.229	2.381	2.493	2.639	2.716	2.766	2.791	2.803
1	2.160	2.440	2.641	2.738	2.848	2.917	2.968	2.994	3.033
2	2.484	2.667	2.787	2.916	2.993	3.093	3.173	3.222	3.232
3	2.488	2.849	3.003	3.059	3.159	3.241	3.281	3.330	3.346
4	2.751	3.072	3.216	3.254	3.325	3.352	3.431	3.472	3.517
5	2.778	2.977	3.144	3.281	3.377	3.498	3.539	3.576	3.629
6	2.885	3.179	3.296	3.424	3.529	3.589	3.660	3.688	3.736
7	2.972	3.272	3.411	3.539	3.663	3.712	3.786	3.825	3.835
8	3.061	3.325	3.441	3.559	3.684	3.815	3.829	3.864	3.977
9	3.084	3.508	3.678	3.788	3.842	3.890	3.994	4.065	4.086
10	3.225	3.452	3.621	3.752	3.864	3.937	4.025	4.078	4.105
11	3.088	3.545	3.692	3.811	3.893	3.934	3.957	4.017	4.063
12	3.253	3.575	3.792	3.937	4.054	4.162	4.243	4.243	4.307



**Appendix II: List of agriculture commodities price definitions**

1. Bananas, Central American and Ecuador, FOB U.S. Ports, US\$ per metric tonne
2. Barley, Canadian no.1 Western Barley, spot price, US\$ per metric tonne
3. Beef, Australian and New Zealand 85% lean fores, CIF U.S. import price, US cents per pound
4. Cocoa beans, International Cocoa Organization cash price, CIF US and European ports, US\$ per metric tonne
5. Coffee, Other Mild Arabicas, International Coffee Organization New York cash price, ex-dock New York, US cents per pound
6. Coffee, Robusta, International Coffee Organization New York cash price, ex-dock New York, US cents per pound
7. Rapeseed oil, crude, fob Rotterdam, US\$ per metric tonne
8. Fishmeal, Peru Fish meal/pellets 65% protein, CIF, US\$ per metric tonne
9. Groundnuts (peanuts), 40/50 (40 to 50 count per ounce), cif Argentina, US\$ per metric tonne
10. Lamb, frozen carcass Smithfield London, US cents per pound
11. Maize (corn), U.S. No.2 Yellow, FOB Gulf of Mexico, U.S. price, US\$ per metric tonne
12. Olive Oil, extra virgin less than 1% free fatty acid, ex-tanker price U.K., US\$ per metric tonne
13. Oranges, miscellaneous oranges CIF French import price, US\$ per metric tonne
14. Palm oil, Malaysia Palm Oil Futures (first contract forward) 4–5 percent FFA, US\$ per metric tonne
15. Swine (pork), 51–52% lean Hogs, U.S. price, US cents per pound.
16. Poultry (chicken), Whole bird spot price, Ready-to-cook, whole, iced, Georgia docks, US cents per pound
17. Rice, 5 percent broken milled white rice, Thailand nominal price quote, US\$ per metric tonne
18. Fish (salmon), Farm Bred Norwegian Salmon, export price, US\$ per kilogram
19. Shrimp, No.1 shell-on headless, 26–30 count per pound, Mexican origina, New York port, US cents per pound
20. Soybean Meal, Chicago Soybean Meal Futures (first contract forward) Minimum 48 percent protein, US\$ per metric tonne
21. Soybean Oil, Chicago Soybean Oil Futures (first contract forward) exchange approved grades, US\$ per metric tonne
22. Soybeans, U.S. soybeans, Chicago Soybean futures contract (first contract forward) No. 2 yellow and par, US\$ per metric tone
23. Sugar, European import price, CIF Europe, US cents per pound
24. Sugar, Free Market, Coffee Sugar and Cocoa Exchange (CSCE) contract no.11 nearest future position, US cents per pound
25. Sugar, U.S. import price, contract no.14 nearest futures position, US cents per pound (Footnote: No. 14 revised to No. 16)
26. Sunflower oil, Sunflower Oil, US export price from Gulf of Mexico, US\$ per metric tonne
27. Tea, Mombasa, Kenya, Auction Price, US cents per kilogram, From July 1998, Kenya auctions, Best Pekoe Fannings. Prior, London auctions, c.i.f. U.K. warehouses
28. Wheat, No.1 Hard Red Winter, ordinary protein, FOB Gulf of Mexico, US\$ per metric tonne

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