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Review Article

Commodity Food Prices: Review and Empirics

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The present paper provides a literature review of studies examining the potential causes and consequences of recent surges in food and agricultural commodity prices. Furthermore, this paper uses the structural trend methodology proposed by Koopman et al. (2009) to analyze movements in the IMF monthly commodity food price index for the period 1992(11)–2012(10) and to provide forecasts for the period 2012(11)–2014(12). The empirical results indicate that commodity food prices present seasonality and cyclicality with the longest periodicity of two years. The empirical findings identify certain structural breaks in commodity food price series as well as outliers. These structural breaks seem to capture the trend component of the price series well, while the outliers take account of temporal effects, that is, short-lived spikes. Finally, the presented forecasts show high and volatile commodity food prices.

1. Introduction

Commodity food prices have surged upwards in dramatic fashion in recent years after several decades of relative stability and low levels. In particular, commodity food prices increased dramatically between late 2006 and mid-2008, and by reaching high levels later on (i.e., during 2010, early 2011, and the third quarter of 2012), they caused serious concerns about a repeat of the 2006–2008 food crisis. This phenomenon has motivated several analyses of the factors that have caused commodity food prices to increase in recent years.

The purpose of the present paper is twofold. First, it reviews the empirical studies that identify and analyze the possible causes of the recent food and agricultural commodity spikes. Second, it uses a structural time series approach to analyze the behavior of the monthly commodity food price index for the past 20 years. In the empirical part, the present paper departs from previous detrending methods and employs a structural time series approach [1], which provides the possibility of discovering commodity price cycles. Furthermore, this approach permits not only the possibility of stochastic cycles but also the presence of stochastic trends in levels and growth rates and provides efficient forecasts on the commodity food price index.

The remainder of this paper is organized as follows. Section 2 presents and discusses the literature on the causes of commodity food price increases in recent years. In Section 2.1, specific discussion is devoted to the possible linkages between fuel and food prices, while in Section 2.2 the possible relation between speculation and food prices is provided. Section 3 presents the empirical part of the paper. In Section 3.1, the specification of the structural time series model used in the present paper is provided, while Section 3.2 discusses the data used in the estimation of the model. In Section 3.3, the discussion of the empirical results is presented. Conclusions are drawn in Section 4.

2. Literature Review and Main Findings

The literature distinguishes between agreed and disputed causes of the food price spikes that have characterized the new millennium (see, e.g., [2–4]). The former can be further articulated according to their operational time horizons and natures. Following Wiggins et al. [5], the evolution of the

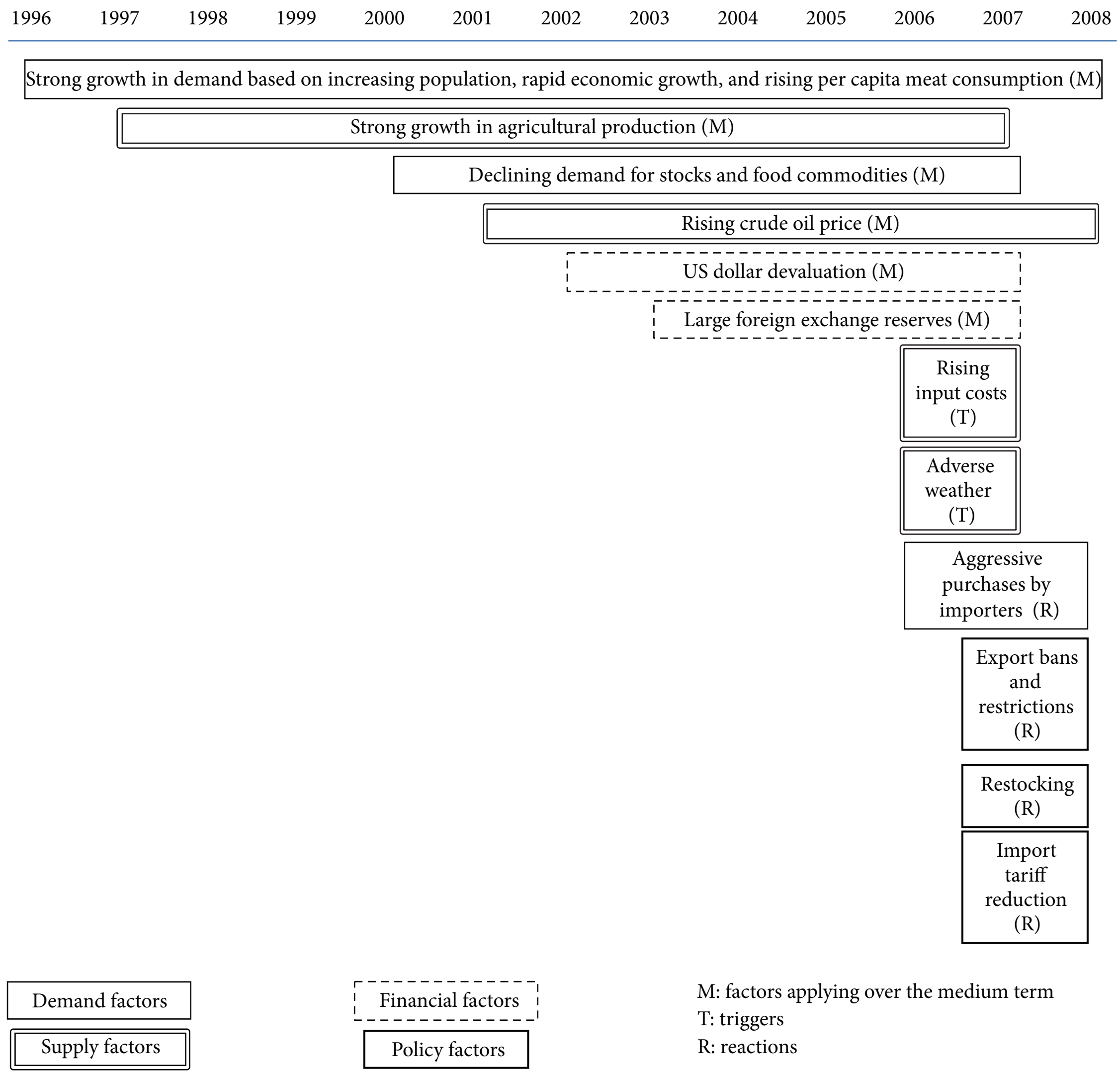

Figure 1: Timeline for the 2006–2008 price spike. Source: adapted from [6].

first price spike can be described as a combination of factors affecting the medium term from 2000 to 2006, triggers applying to the short (2006-2007) and very short (mid-2007-2008) periods during the spike, and panic reactions to the initial price increase that exacerbated the rise. The major common factors and triggers have a demand; supply and financial nature are illustrated in Figure 1.

Prakash and Gilbert [6] compare these factors with those at the basis of the 1973-1974 food crisis to highlight the similarities. However, the consequences were more severe in the 2007-2008 turmoil due to a different scenario. The 2007-2008 shock arose in a different context, characterized by at least two new elements. The former refers to the fact that the increase in commodity food prices on international markets was transmitted into the domestic market, contributing to making inflationary pressure more severe, particularly in developing countries (for a review of Sub-Saharan Africa see, e.g., [7]).

Despite the emphasis placed on this mechanism, the empirical literature suggests that at the level of each single country, the transmission of changes in international food prices on domestic food prices is far from straightforward. Further, the extent of such a transmission varies a lot according to several factors, such as dependence on food imports, transport costs, pass-through margins, the tradability of domestic foods, and exchange rate variations [8].

The second new element that distinguished the 2007-2008 food crisis context refers to the net trade position of developing countries, which become net importers from the 1990s, from the net exporters of agricultural and food commodities. The increase in commodity food prices means that these countries have to spend more for providing food on their domestic markets with the deterioration of the food trade balance, other macroeconomic difficulties, and an increase in food dependence from highly volatile international commodity markets.

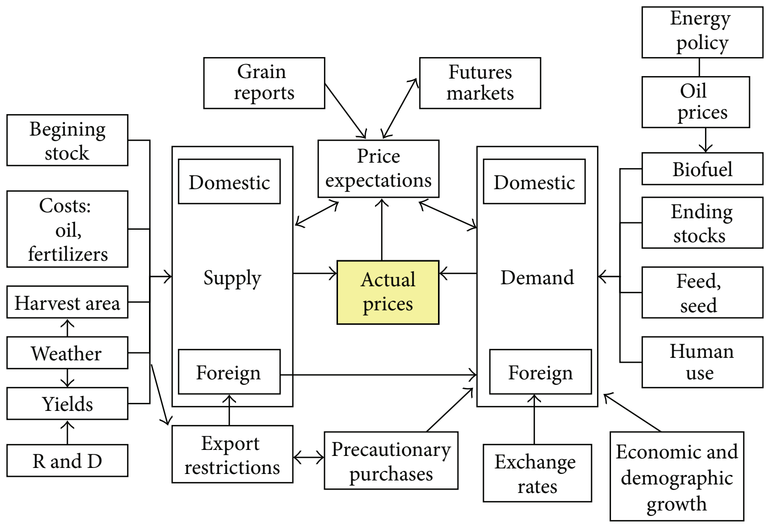

Figure 2: The nature of grain commodity price formation. Source: [9].

In the 2011 price spike, the above-mentioned factors find confirmation but with some differences related to the fact that international price increases are more widespread across agricultural commodities, weather-induced production shortfalls are more of a factor now, price volatility is greater, and policy responses are amplifiers of exceptional shocks.

If there is consensus on the role of the above-mentioned factors in affecting the 2007-2008 and 2011 food crises, the isolation of the extent of their impacts on food and agricultural commodity prices is a difficult task. As suggested by Headey and Fan [9], this is because of the complicated nature of grain price formation on the international market. As shown in Figure 2, this is the result of complex interactions among supply, demand, actual prices, and price expectations.

These complexities complicate the identification of the specific causes of price spikes and the intensity of their impacts. Table 1 provides a selection of contributions that investigate the fundamental drivers of food price spikes.

Important gaps in the literature include the so-called disputed causes of food price spikes, namely, biofuels and speculation on food and agricultural commodity markets.

2.1. Food Prices and Biofuels. The literature on food prices and biofuels (e.g., bioethanol and biodiesel) can be organized into two main bodies according to the focus of the analysis. On one side, there are studies that use time series techniques to investigate the dynamic linkages between biofuels and food commodities by referring to historical data on commodity prices and food indexes. Table 2 provides a selection of the results found by these studies in terms of the percentage weighting assigned to biofuels in rising food prices.

The linkages between fuel and food prices vary from 5% to 75% depending on the country analyzed, the typology of food and fuel taken into consideration, the reference price (indices, national, farm, or world prices), the methodology and assumptions adopted, and the time dimension of data. All these aspects make the findings from these studies difficult to compare [10]. However, a common aspect underlined by the majority of them is the identification of expanding biofuel consumption as a driver of rising food prices [11].

A second part of the literature is based on numerical models. These project the impact of the introduction of various biofuel trade and policy scenarios on food and commodity quantities and prices in the medium term, that is, between 2015 and 2020. Their findings are based on partial equilibrium (PE) or computable general equilibrium (CGE) models and, as in the case of the previous body of the literature, they generally, but not always, underline an increase in agricultural commodity prices as a consequence of expanded biofuel production. Apart from the expected smaller price effect in CGE models than in PE models due to their incorporation of the almost complete adjustment throughout the economy to the initial stimulus, the scale of the effects varies widely across studies.

The results based on the PE model elaborated by IFPRI—the IFPRI IMPACT model—suggest price increases, by 2020 with respect to 1997, of between 16% and 43% at best and between 30% and 76% at worst, depending upon the commodity [12]. Rosegrant [13] finds that with respect to 2007, freezing or eliminating biofuel production has a positive impact on commodity food prices by 2010 and 2015, projecting a decrease of between 1% and 20%. Wiggins et al. [14], using a CGE model, show the projected food commodity export price change by 2020 with respect to 2007 assuming that the EU and North America and Brazil follow their major biofuel mandates, targets, and support policies. The major findings are presented in Table 3.

As underlined by Pfuderer et al. [15], PE and CGE models show many limitations. Among them, four seem to be the most relevant. These models

(i) explain annual variation in prices and for this reason they do not consider volatility, a phenomena observed in some commodity markets that need monthly, weekly, and sometimes daily prices in order to be understood;

Table 1: Selection of studies aimed at investigating fundamental drivers for food price spikes.

Potential driver	Economic rationale	References
	Supply side factors	
Shocks in production	Production shortfalls caused by adverse weather conditions result in lower levels of global supply and stocks	[32]
Energy and fertilizer prices	High input prices increase agricultural production and transportation costs	[3, 4, 33]
Export policies	Some of the net exporting countries introduced restrictive trade policies aimed at isolating their economies and controlling the pass-through mechanism	[4]
Low level of global inventories	A consequence of production shortfalls and political decisions	[34, 35]
Neglected investment in R & D and infrastructure	A limit to the growth in agricultural productivity	[33]
	Demand side factors	
Emerging economies and structural change in global demand	Economic growth in BRIC raises individual welfare as well as urban population with a consequent shift in consumption patterns towards an increasing global demand for superior agricultural products. Effect on food prices is indirect via demand for crude oil	[36]
High oil prices	Reduction in price advantage of fossil fuels relative to biofuels and consequent increase in demand for competitive renewable energies	[33]
Global biofuels production	Increase in demand for crops used as input factors in biofuels production; driving prices of other crops through substitution effects in food utilization and through competition in the use of agricultural land	[3, 33, 34, 36, 37]
Import policies	Some of the importing countries lift import restrictions and taxes in order to alleviate domestic consumption; no decrease in aggregated global trade despite food inflation	[34, 37]
	Macroeconomic factors and market conditions	
Depreciation of USD	On the international level grains are traded in USD; due to the USD's depreciation price increases less in other countries' currencies relative to U.S. prices and import remained constant	[3, 4, 33]
Inelastic markets	Due to prevailing market conditions neither supply nor demand responded to price incentives; no expansion of supply or reduction of global demand	[37]

Table 2: Influence of bio-fuels on rising food prices.

Studies	Institution	Percentage change in food prices assigned to bio-fuels
[3]	World Bank	70–75
[38]	OECD	5–16
[13]	IFPRI	25–30

Source: [17].

(ii) estimate medium-term elasticities and for this reason are suitable for the analysis of medium-term market variations rather than short-term supply shocks;

(iii) are misleading because in order to generate the significant impact of biofuels on agricultural commodity prices they should introduce the two inconsistent assumptions of inelastic supply and large direct effects;

(iv) underestimate the role of other factors than biofuels representing important drivers of food price spikes.

Table 3: Projected food commodity export price percentage change by 2020—baseline 2007 prices (FOB prices).

Crops	EU-27	NAFTA	Brazil	Sub-Saharan Africa
Rice	−2.0	−0.6	−0.8	0.2
Wheat	−2.6	−0.7	0.2	0.1
Grains	14.9	21.3	4.8	10.8
Oilseeds	53.2	71.8	25.2	24.9
Sugar	−0.7	1.6	−0.5	2.5
Vegetable oil and fat	5.1	22.0	−1.4	3.0

In the study the world is aggregated into the four listed regions.
Source: [14].

As far as this latter issue is concerned, a body of the literature attempts to assess the relative importance of biofuel expansion in combination with other possible factors that contributed to the food price increases in 2007-2008 and 2011. Among them, Hochman et al. [16] include economic growth, exchange rate fluctuation, the rise in energy costs and inventory levels, and cross-price elasticity in Hochman et al. [10], while Arseneau and Leduc [17] take into consideration

Table 4: Selection of studies supporting the Masters' hypothesis.

Studies	Object of investigation	Econometric approach	Time series range
[27]	Potential feedback loop of high food prices driven by excessive speculation	Rolling window Granger causality tests	01/2002–02/2008
[39]	Supply, demand, and market factors affecting food prices	OLS regression; rolling window Granger causality tests	1/2002–06/2009
[2]	Impacts of demand and supply shocks on commodity prices	Univariate Granger causality tests; regression analysis	1971–2009
[40]	Linkage between commodity markets; special focus on rice markets	Daily rolling window Granger causality tests	31/12/1999–02/07/2008

the interest rate. These simulation models suggest that the impact of biofuel expansion on commodity prices can be amplified or reduced according to the factors included in the analysis. Hochman et al. [16] also show the important role of US biofuel production in affecting the price of several food commodities between 2001 and 2007.

2.2. Food Prices and Speculation. The literature on the role of speculation in food price crises can be articulated into two main bodies. On one side, there are the empirical studies that find evidence of a commodity price bubble due to excessive speculation and, on the other, there are those refuting this hypothesis. The analyses by bubble proponents find their origin in Masters' hypothesis [18]. Observing the comovements between commodity indices and the total amount of financial resources involved in commodity index funds from 1970 to 2008, Masters argues that commodity prices in 2007-2008 were mainly driven by the rapidly increased engagement of common index traders in futures markets. In contrast to those for physical and financial assets, hedgers and speculators coexist in commodity futures markets; as soon as speculators start to dominate markets, price bubbles may come into existence if trade is detached from fundamental movements. Following this line of thought, a group of studies investigates Masters' hypothesis using more rigorous econometric approaches. The majority of these are based on evidence derived from Granger causality tests (Table 4).

This body of the literature interprets speculation on futures markets as a factor that amplifies price spikes and volatility during food crises without measuring the intensity of the effect. Bass [19] sheds light on this aspect. Forecasting fundamental prices and assessing their divergence from historical trends, he estimates that speculation raised international food prices by around 10% to 15% from 1978 to 2008, particularly from 2004 to 2006 and from 2007 to 2009. However, it should be noted that this analysis shows many limitations, as Bass [19, page 52] himself admits, particularly because it adopts an ordinary least squares regression on annual data with a low number of observations. A final major contribution is by von Braun and Tadesse [20] that, among other aspects, detects the conditions for the emergence of price bubbles. The analysis concludes that short-term price spikes can be related to excessive speculative activity on futures markets, while volatility is better explained by demand shocks since oil price spikes increase demand for agricultural commodities.

Bubble opponents argue that the view of the proponents of this hypothesis lacks explanatory power and is rather unrealistic; in particular, they suggest that it requires a better understanding of the essential mechanisms of futures markets [21]. The main argument is that additional money on futures markets does not equal more demand. Futures markets are different from physical markets, since supply on long positions in theory is unlimited and to every additional long position held by index traders there exists a short counterpart. Moreover, opponents criticize the strict differentiation between hedgers and speculators and argue that today noncommercials as well as commercials strategically invest in long and short positions. Since all informed participants could easily react to index traders' mechanical behavior, it seems to be unlikely that such traders possess the power to dominate or even manipulate futures markets. This issue is investigated by Irwin and Sanders [22]. Introducing a new econometric approach into the relevant literature, namely, the Fama-MacBeth regression procedure, the results confirm earlier achievements [23, 24], pointing out that, from 2007 to 2011, there are no signals of excessive speculation and no potential positive causation between financial engagement and price volatility in futures markets.

Most of the speculative positions held by index traders are offset before the expiration date. They are detached from the delivery process and do not affect physical supply and demand. Krugman's argument directly addresses the transmission of futures to spot prices [20]. In his view, transmission only works by means of arbitrage and the physical hoarding of commodities. If detached high prices were transmitted from futures to spot markets, this would be indicated by means of an accelerated accumulation of global stocks. Bubble opponents also critically discuss the degree of reliance of the used Commodity Futures Trading Commission data, stating that they only provide a fair approximation of the realized position changes of commodity index traders [25].

The close examination of the econometric analyses conducted in different studies finds that some studies have not clearly differentiated between different market levels and their relations. In many of them, the link between speculative activities, futures markets, and spot prices remains undefined. An attempt to consider these aspects is the study by Sassi and Werner [26] that focuses on the speculative activity of different typologies of speculators on the futures market of the Hard Red Winter wheat from 2000 to 2012, introducing a methodology that distinguishes between the realized effects of futures and spot prices. Their evidence supports the hypothesis by Robles et al. [27] in the sense that speculation may have been influential on futures price returns of the analyzed commodity at least for certain periods of time.

3. Empirics

This section investigates the long-run and short-run fluctuations in commodity food prices by adopting a structural time series model, that is, the unobservable component time series model. This approach consists of useful components, such as trends, cycles, seasonal, and irregular, for analyzing the time series under consideration. Each component can be modeled as a stochastic process that depends on normally distributed disturbances. The unobservable component model used in the present paper has the additional advantage that it can also be used to generate effective forecasts, since more weights are given to the most recent observations. Previous empirical work employing structural time series models to analyze commodity prices includes that by Labys et al. [28]. (The study by Labys et al. [25] examines short-term cycles in primary commodity prices including the prices of corn, rice, soybeans, sugar, tea, and wheat.) Furthermore, the study by Cashin and McDermott [29] provides a literature review of the empirical work on the behavior of real commodity prices. The aforementioned work indicates that the most common model used to analyze commodity price movements is the unit root model or the stationary autoregressive model. The present paper, however, employs the unobserved component model, which has not been extensively used in the literature, to analyze and forecast movements in commodity food prices.

3.1. Model. To obtain a better understanding of the evolution of commodity food prices, the structural trend methodology of Koopman et al. [1] is used, which decomposes commodity food price series into components (trends, seasonal, cycles, interventions, and irregular). Let the logarithm of the commodity food price index be presented as y_t, and then a structural model is given as

$$y_t = \mu_t + \gamma_t + \psi_t + \sum_{\tau=1}^{p} \phi_\tau y_{t-\tau} + \sum_{i=1}^{k} \sum_{\tau=0}^{q} \Delta_{i\tau} x_{i,t-\tau} + \sum_{j=1}^{h} \lambda_j d_{j,t} + \varepsilon_t, \quad \varepsilon_t \sim N\left(0, \sigma_\varepsilon^2\right), \tag{1}$$

where μ_t is the trend; γ_t is the seasonal; ψ_t is the cycle; x_{it} is an exogenous variable; d_{jt} is an intervention (dummy) variable; ε_t is the irregular; and ϕ_τ, $\Delta_{i\tau}$, and λ_j are unknown parameters.

The trend (μ_t) indicates the long-run permanent component of the series and shows the direction towards which the series is moving. In particular, the trend component captures permanent demand and supply changes as well as changes in any unobserved factor that are considered to be permanent. In the present analysis, the empirical results support the fact that the trend component should be better specified as a fixed term and given by

$$\mu_t = \mu_{t-1} + \eta_t, \quad \eta_t \sim \text{NID}\left(0, \sigma_\eta^2\right) \quad \text{with } \sigma_\eta^2 = 0. \tag{2}$$

The seasonal component (γ_t) captures the fact that agricultural commodities are influenced by the weather. Furthermore, most primary crops (wheat, soybeans, and corn) are harvested once per year, which causes seasonal fluctuations in prices. In the present model specification, the seasonal component has a trigonometric deterministic seasonal form, which is given by

$$\gamma_t = \sum_{j=1}^{[s/2]} \gamma_{j,t}, \tag{3}$$

where each $\gamma_{j,t}$ is given by

$$\begin{bmatrix} \gamma_{j,t} \\ \gamma_{j,t}^* \end{bmatrix} = \begin{bmatrix} \cos\lambda_j & \sin\lambda_j \\ -\sin\lambda_j & \cos\lambda_j \end{bmatrix} \begin{bmatrix} \gamma_{j,t-1} \\ \gamma_{j,t-1}^* \end{bmatrix} + \begin{bmatrix} \omega_{j,t} \\ \omega_{j,t-1}^* \end{bmatrix}. \tag{4}$$

Note that $j = 1, \ldots, [s/2]$, $t = 1, \ldots, T$, $\lambda_j = 2\pi j/s$ is the frequency, in radians, while the seasonal disturbances ω_t and ω_t^* are two mutually uncorrelated normally and independently distributed disturbances with zero mean and common variance σ_ω^2. Since, in the present model specification, the seasonal component has a deterministic form, then $\sigma_\omega^2 = 0$.

Agricultural commodity prices are known for exhibiting price cycles beyond that explained by seasonality. In particular, livestock prices, such as hog and cattle prices, exhibit cyclical behavior. According to Sterns and Petry [30], hog cycles last for about four years, while based on Lawrence [31], cattle price cycles last for about 10 years. In this model, the cycle component (ψ_t) has a stochastic form that is given by

$$\begin{bmatrix} \psi_t \\ \psi_t^* \end{bmatrix} = \rho_\psi \begin{bmatrix} \cos\lambda_c & \sin\lambda_c \\ -\sin\lambda_c & \cos\lambda_c \end{bmatrix} \begin{bmatrix} \psi_{t-1} \\ \psi_{t-1}^* \end{bmatrix} + \begin{bmatrix} \kappa_t \\ \kappa_t^* \end{bmatrix}, \tag{5}$$

where ρ_ψ $(0 < \rho_\psi \leq 1)$ is the damping factor that reflects the speed with which various food price swings are dampened; λ_c $(0 < \lambda_c \leq \pi)$ is the frequency in radians that defines the basic cycle underlying the fluctuating food price series; and κ_t, κ_t^* are two mutually uncorrelated normally and independently distributed disturbances with zero mean and common variance σ_κ^2. The period of the cycle is $2\pi/\lambda_c$ and this indicates the time taken to go through its complete sequence of values. In estimating the model, the variance of the cycle itself (σ_ψ^2), rather than σ_κ^2, is taken to be the fixed parameter. (Note that $\sigma_\kappa^2 = (1-\rho^2)\sigma_\psi^2$.) Note that in the present model two cycles are considered, that is, cycle 1 and cycle 2.

The variable $y_{t-\tau}$ indicates the lagged values of the dependent variable. In the present model, four lagged values,

Table 5: Descriptive statistics.

Variables	Means	Standard deviations	Variables (logarithms)	Means	Standard deviations
cfpi	111.97	30.451	lcfpi	4.6855	0.24925
coil	83.247	59.802	lcoil	4.1745	0.70054
reer	105.55	8.1379	lreer	4.6563	0.075735

cfpi stands for the commodity monthly food price index (2005 = 100), coil stands for crude oil (petroleum) monthly price and is measured in U.S. dollar per barrel, reer stands for the U.S. real effective exchange rate (2010 = 100).

that is, 1, 3, 4, and 5, are included because these are found to be statistically significant. Two exogenous variables (x_{it}), such as crude oil (petroleum) and the US real effective exchange rate, are included in structural model (1). The crude oil (petroleum) price is considered because when it increases farmers face higher prices for fuel and fertilizer and thus livestock and crop production costs increase. Furthermore, high oil prices make biofuel production more profitable and this causes increases in the prices of grain, sugar, and vegetable oils, which are used not only in food production but also in biofuel production. The US real effective exchange rate is used because the US dollar is the main currency for the global trade of most commodities and other goods. Commodity food prices measured in dollars increase when the dollar depreciates against other currencies and decrease when the dollar appreciates. The inverse relationship between the exchange rate and commodity food prices can also be attributed to inflation. More specifically, when the dollar depreciates, investors and speculators concerned about higher inflation rates invest in commodities futures such as grains, thereby driving up commodity food prices.

Intervention variables (d_{jt}) are dummy (or indicator) variables that are used to capture structural breaks or outlying (irregular) observations. A structural break is modeled by a step intervention variable that takes the value of zero before the event and one after. The structural break dummy variable shifts the level of the series (μ_t) up or down and can be attributed to permanent events, such as changes in economic policies and structural reforms. An outlier (irregular) is modeled by an impulse intervention variable that takes the value of one at the time of the outlier and zero otherwise. An outlier can be considered to be a temporally large value of the irregular disturbance at a given time and can be attributed to temporary events such as oil price or weather shocks.

3.2. Data. The data set used is monthly data on the logarithm of the commodity food price index (lcfpi) from 1992(11) to 2012(10), with 2005 = 100. The commodity food price index includes the price indices for cereals, vegetable oils, meat, seafood, sugar, bananas, and oranges, and it is obtained from the International Monetary Fund (IMF). Two exogenous variables are used in the present model: the logarithm of crude oil monthly prices (lcoil) and the logarithm of the US monthly real effective exchange rate (lreer). The crude oil (petroleum) price is measured in US dollars per barrel and is a simple average of three spot prices, that is, Dated Brent, West Texas Intermediate, and the Dubai Fateh. It is obtained from the World Bank. The US real effective exchange rate is a real (CPI-based) narrow monthly index (2010 = 100) comprising 27 economies that is obtained from the Bank of International Settlements. Thus, the US real effective exchange rate measures the overall value of the dollar against a basket of 27 currencies. The descriptive statistics (means and standard deviations) of the data set used in the present paper are reported in Table 5.

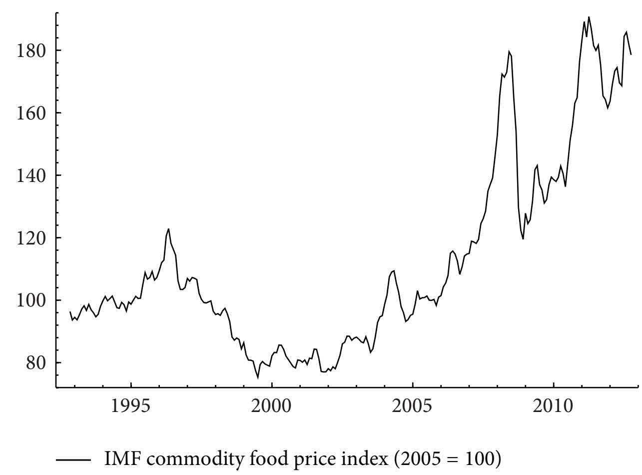

Figure 3: Evolution of the IMF commodity food price index 1992(11)–2012(10).

Figure 3 presents the evolution of the IMF commodity food price index from 1992(11) to 2012(10). Commodity food prices increased dramatically between late 2006 and mid-2008. Prices then fell drastically in the final months of 2008, after peaking at their highest level in 30 years in the second quarter of 2008. They reached at a level slightly higher than that of 2008 in the first months of 2011 and then rose in the first half of 2009 and during 2010. They decreased in the second half of 2011 but increased again during 2012 and by the third quarter of 2012 reached the 2008 price level. The resurgence of high commodity food prices in 2010, early 2011, and by the third quarter of 2012 prompted concerns of a repeat of the 2006–2008 food crisis, threatening increasing food insecurity, food price inflation, and civil unrest. (Note that the causes of the 2006–2008 food crisis have been discussed in detail in previous sections of the present paper.)

Table 6: Diagnostics and goodness-of-fit statistics.

Statistics	Values
Log L	759.049
$N(\chi_2^2)$	1.3586 [0.5069]
$H_{63}(F_{63,63})$	1.2753 [0.1685]
DW	2.0077
Q(24, 18)	25.286 [0.1172]
R^2	0.8054

Values in brackets are P values.

Table 7: Variance of disturbances: values and q-ratio.

Variance of disturbances	Values	q-ratio
σ_η^2	0.00000	0.0000
σ_ω^2	0.00000	0.0000
$\sigma_{\kappa_1}^2$	3.015×10^{-5}	0.2283
$\sigma_{\kappa_2}^2$	0.00013	1.0000
σ_ε^2	0.00000	0.0000

q-ratio is the ratio of each variance to the largest.

3.3. Results. Models (1) to (5) can be estimated using the maximum likelihood approach, as shown in Harvey [41]. In the estimation, the variance hyperparameters, that is, $\sigma_{\kappa_1}^2$ and $\sigma_{\kappa_2}^2$, are first obtained and then the trend, seasonal, and two cycle components can be extracted by a smoothing algorithm, as in Koopman [42]. The empirical results obtained using the STAMP 8.2 package of Koopman et al. [1] indicate strong convergence.

Table 6 presents some diagnostics and goodness-of-fit statistics, such as the Log L (log-likelihood), $N(\chi_2^2)$ (normality test statistic having an χ^2 distribution with two degrees of freedom), $H_{63}(F_{63,63})$ (heteroskedasticity test statistic having an F distribution with (63, 63) degrees of freedom), DW (the classical Durbin-Watson test statistic), Q(24, 18) (the Box-Ljung statistic based on the first 24 autocorrelations and tested against an χ^2 distribution with 18 degrees of freedom), and R^2 (coefficient of determination). The aforementioned statistics do not indicate any deficiencies in the estimated model.

Figure 4 presents additional information about the estimated model, namely, graphs of the standardized residuals, residual correlogram, spectral density, and density. The residuals are the standardized one-step-ahead perdition errors or innovations, as defined in Koopman et al. [43], and for a correctly specified model, they are assumed to be normally and independently distributed. Thus, the aforementioned statistics (Table 6) and graphs presented in Figure 4 are the means of checking the validity of the model. In particular, the correlogram and spectral density graphs presented in Figure 4 indicate that the residuals are not autocorrelated. (Note that the theoretical spectrum is a horizontal straight line for white-noise residuals.)

Figure 5 shows the extracted unobserved components for trend (level, regression, and interventions), seasonal, and the two cycles, that is, cycle 1 and cycle 2.

As indicated from the q-ratios in Table 7, the fluctuations in the irregular component are zero, implying that all variations in the series are attributed to cycles 1 and 2, since the level and seasonal components are fixed. Furthermore, the q-ratios indicate that the fluctuations in cycle 2 are a more important source of variations than those in cycle 1.

Table 8 presents the cyclical parameters in more detail and indicates that the shorter cycle, that is, cycle 1, has a variance ($\sigma_{\psi_1}^2$) of 0.0001, a period of 0.5375 years, and a damping factor (ρ_{ψ_1}) of 0.8420, while the longer cycle, that is, cycle 2, has a variance ($\sigma_{\psi_1}^2$) of 0.0009, a period of 2.0970 years, and a damping factor (ρ_{ψ_1}) of 0.9196. These results indicate that even though both cycles show a high degree of persistence, they are stationary, since their damping factors are less than one. Thus, in the long run the cyclical components dissipate, and the forecast of the commodity food price series converges towards its trend value. The estimated periodicity of cycle 2 is about two years, which could be considered to be the result of the averaging process in which the cyclical values of individual commodity food price series constituting the aggregate commodity food price index interact. More specifically, the cyclical activity in agricultural food prices is often the result obtained with a one-year cycle for annual crops, up to two-year cycles for livestock production, and up to six-year cycles for perennial crops. (The empirical results of the present paper related to the cyclical activity of commodity food prices are comparable with those proposed by Labys et al. [25].) An inspection of the graph corresponding to the long cycle (cycle 2) in Figure 5 indicates that the more pronounced cycle activity occurred after 2003. This finding is consistent with the literature which indicates that factors causing higher and more volatile commodity food prices came into effect in 2003 and eventually these factors caused the 2006–2008 food crisis as well as the subsequent food price variability.

Table 8: Parameters of cycles 1 and 2.

Parameters	Values
$\sigma_{\psi_1}^2$	0.0001
$2\pi/\lambda_{c_1}$	6.4499 (0.5375 years)
λ_{c_1}	0.9741
ρ_{ψ_1}	0.8420
$\sigma_{\psi_2}^2$	0.0009
$2\pi/\lambda_{c_2}$	25.1651 (2.0970 years)
λ_{c_2}	0.2496
ρ_{ψ_2}	0.9196

The maximum likelihood estimates of the final state vector and regression effects (lagged endogenous variables,

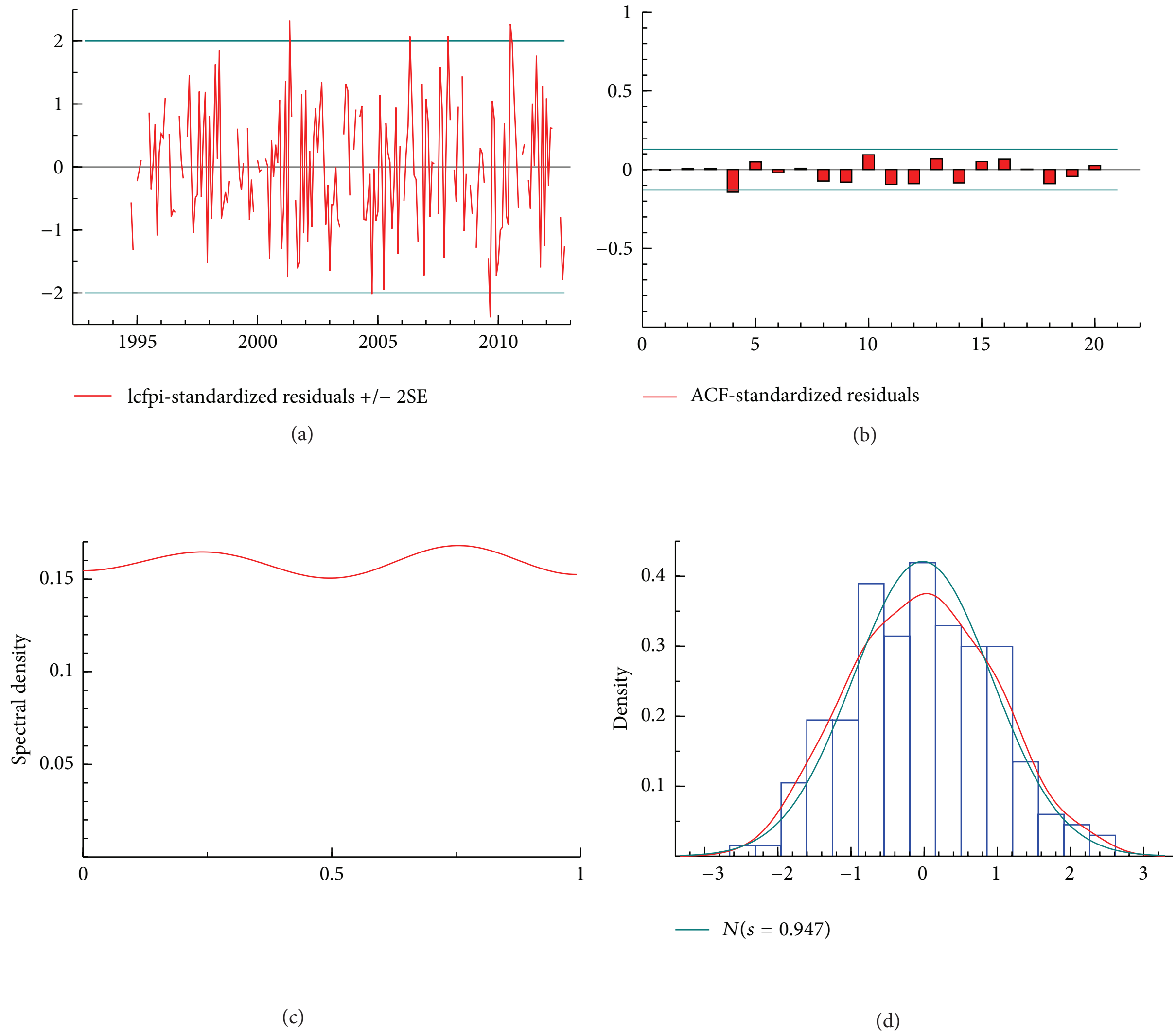

Figure 4: Commodity food price index (lcfpi) residuals.

exogenous variables, and intervention dummies) are presented in Table 9.

Taking the exponential of μ_T(=6.469) yields the level value of the commodity food price index at the end of the period (651.837). The results also indicate that the amplitude of cycle 1 as a percent of the level is 3.279%. The importance of seasonal effects is statistically significant since the χ^2-statistic presented in Table 9 is significant. In particular, seven out of 12 seasonal effects are statistically significant at conventional levels of significance. These effects indicate that from August to December commodity food prices drop below the trend level; from February to May they are above the trend level; and for the months of January, June, and July they are at the trend level. (Seasonal effects can be provided as factors of proportionality by using "antilog" analysis. Thus, the commodity food price index is, on average, lower than the trend level by 0.82% in August, 1.11% in September, 1.85% in October, 1.88% in November, and 0.62% in December. However, it is, on average, higher than the trend level by 1.65% in February, 1.61% in March, 0.96% in April, and 1.41% in May.) The impact of seasonality might be mainly attributed to crop production such as corn, soybeans, and wheat. Most of these crops are harvested once per year, in fall, and thus the price level drops below the trend line in the fall, as indicated by the empirical results presented in Table 9. By contrast, the price level is above the trend line earlier in the year, that is, from February to May, since food manufacturers buy high quantities of crops to protect themselves against possible tight crop supplies later in the year, that is, after the harvest. Note that this drives up commodity food prices earlier in the year, but as harvest time approaches, that is, June and July, commodity food prices approach the trend price level.

The empirical results in Table 9 show that the effects of the four lagged values on the commodity food price index, that is, y_{t-1}, y_{t-3}, y_{t-4}, and y_{t-5}, are statistically significant,

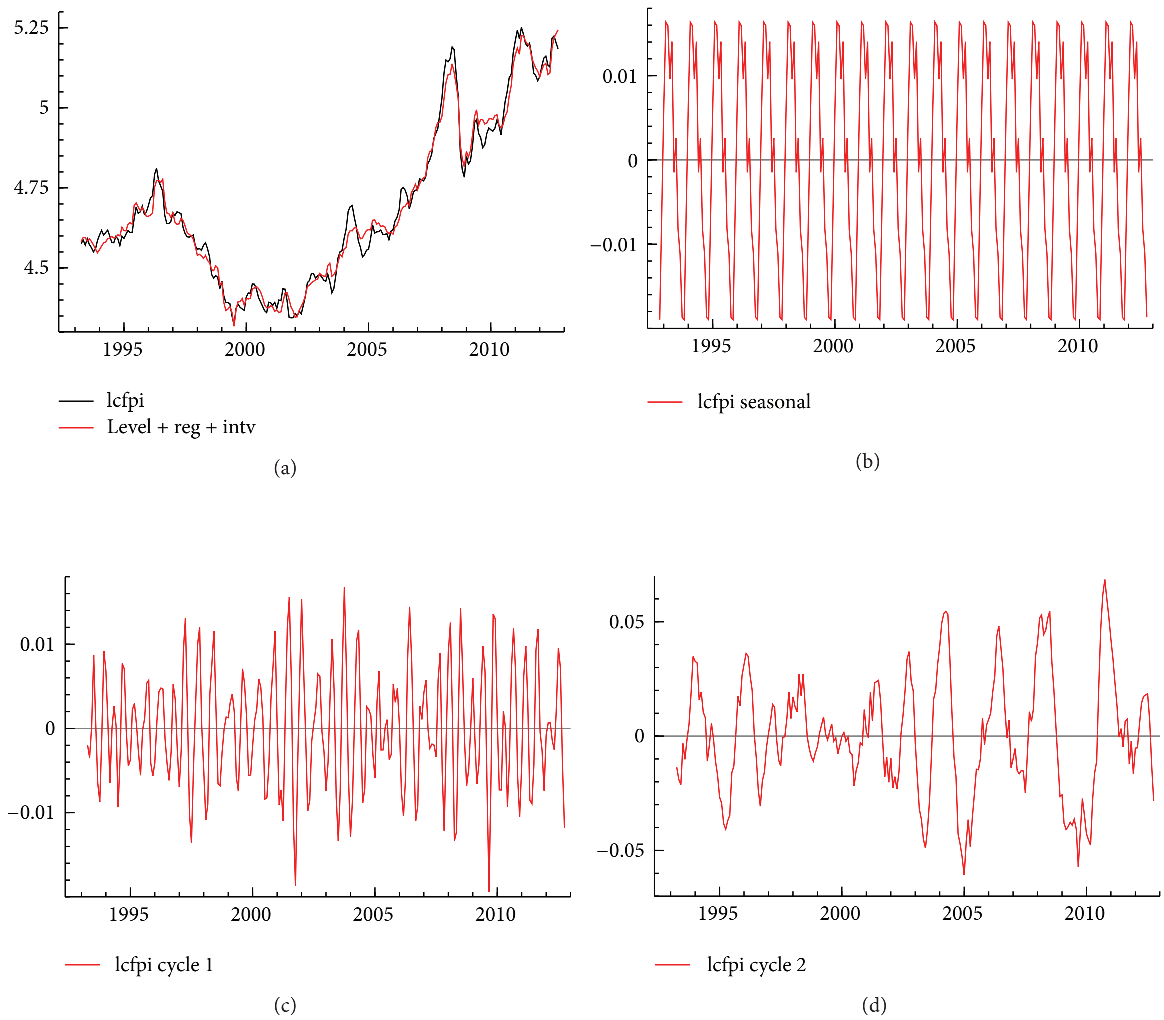

Figure 5: Commodity food price index (lcfpi) decomposition.

indicating that past prices affect the current price level. In the same manner, the effects of the two explanatory variables, that is, crude oil (lcoil) and the US real effective exchange rate (lreer), are statistically significant and they have the expected signs. Further, the diagnostic tests on the auxiliary residuals are presented in Table 10 and these indicate that they are generally well behaved. (Auxiliary residuals are smoothed estimates of irregular and level disturbances [44].)

Figure 6 shows the graphs of the t values corresponding to the estimated auxiliary residuals. These graphs show that the t values do not exceed three in absolute value, indicating that the most extreme interventions have been included in the model.

The empirical results on the intervention effects reported in Table 9 show that 18 effects are related to structural breaks while nine are related to outliers. Most of the structural breaks, that is, 12 out of 18, have a positive effect on the price level, while most of the outliers, that is, seven out of nine, have a negative effect. It is worth noting that the 2006–2008 food crisis is captured by the structural break interventions, that is, 2006(10), 2007(6), 2008(2), and 2009(1), while the 2009 price decrease (due to the dollar appreciation) is captured by the 2009(7) break intervention. Furthermore, the 2010 and 2012 price increases are captured by the corresponding break dummies, 2010(12) and 2012(7), respectively. It should also be stated that the remaining structural break dummies take into account the trend of the price level series quite well. For example, the 1996(9), 1998(12), and 1999(2) structural break interventions take into account the downward trend in the commodity food price level from 1996 to 1999, while the 1995(6) and 1996(4) ones capture the upward trend in price level. Finally, the outliers capture some temporal effects, that is, short-lived spikes, well.

Figure 7 shows the prediction graphics created by estimating the model from 1992(11) to 2010(11) and reserving 2010(12) to 2012(10) for the out-of-sample forecast. Predictions are made using the information at the end of 2010 and are updated with the arrival of each new observation. The predicted values of the commodity food price index (lcfpi) and residuals are inside the prediction intervals, set at two

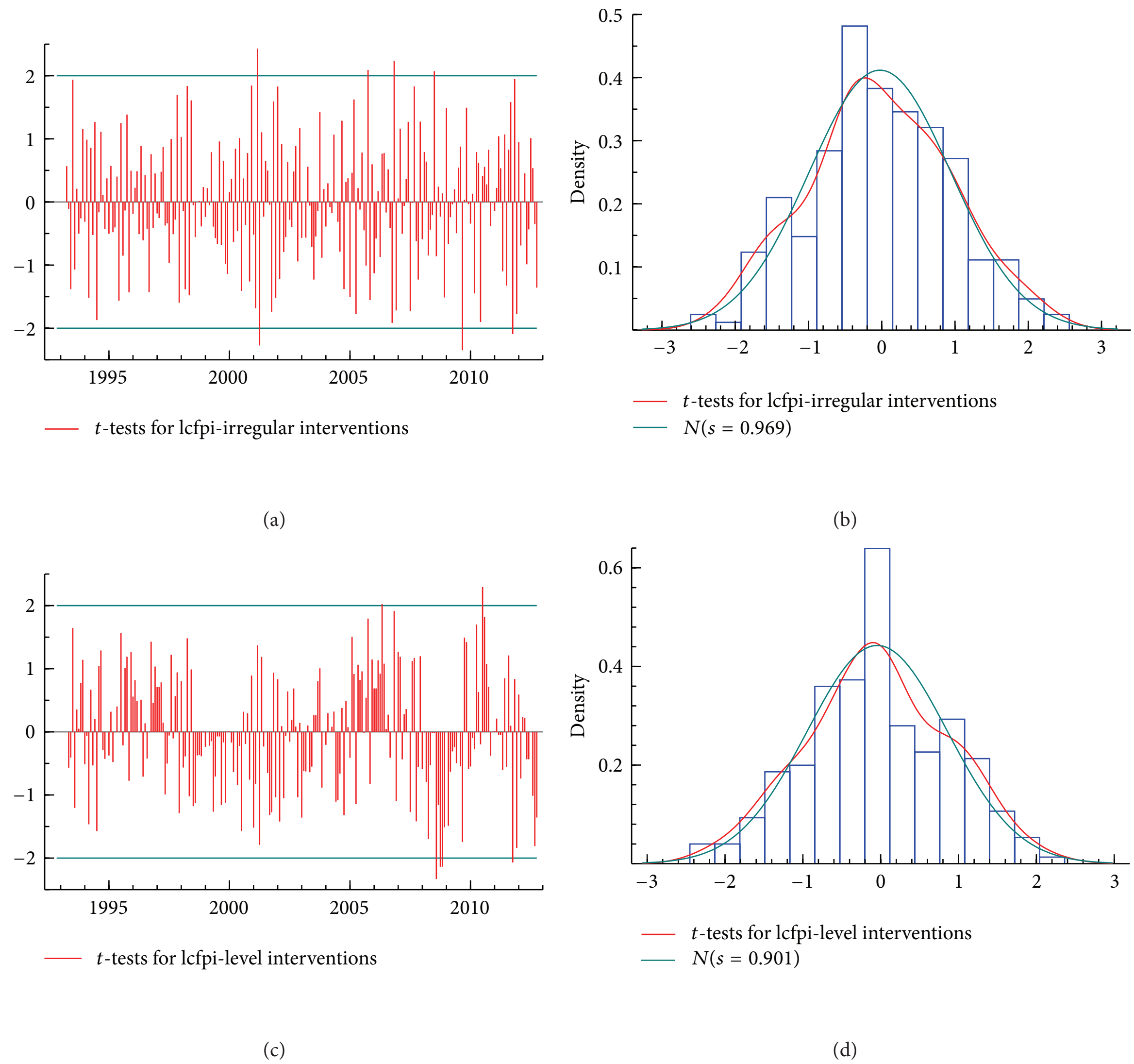

FIGURE 6: Auxiliary residuals: irregular and level.

root mean square errors (RMSEs). The CUSUM plots testing parameter stability and forecast accuracy indicate that the model specified in the present paper is a good one and that its forecasting performance is generally accurate.

Furthermore, the post-sample predictive tests presented in Table 11 reconfirm the aforementioned argument.

Figure 8 provides forecasts of the commodity food price index (lcfpi) from 2012(11) to 2014(12). The forecasted values are given within a forecasting interval of one RMSE on either side. The forecasts indicate that commodity food prices are expected to remain above their historical trend levels at least until late 2014.

4. Conclusions

A considerable number of empirical studies identify and analyze the possible causes of recent food and agricultural commodity spikes. Several of these factors are commonly identified as being responsible for the price shift, while other potential explanations are controversially discussed or even negated. Moreover, the literature argues about the econometric approaches adopted for the investigation of how these factors affect food and agricultural commodity price formation. These different positions are often difficult to reconcile and perhaps should be interpreted in order to understand common global trends in a series of food crises that are not the result of a single casual event but rather the consequence of a momentous combination of distinct but strongly interrelated factors.

This paper uses the structural time series approach to analyze movements in the monthly commodity food price index for the period 1992(11)–2012(10). The price series is decomposed into components such as trend, seasonal, cycle, interventions (dummies), and irregular. Then, forecasts are obtained for each month of the period 2013-2014. The empirical results indicate that the price series is best described

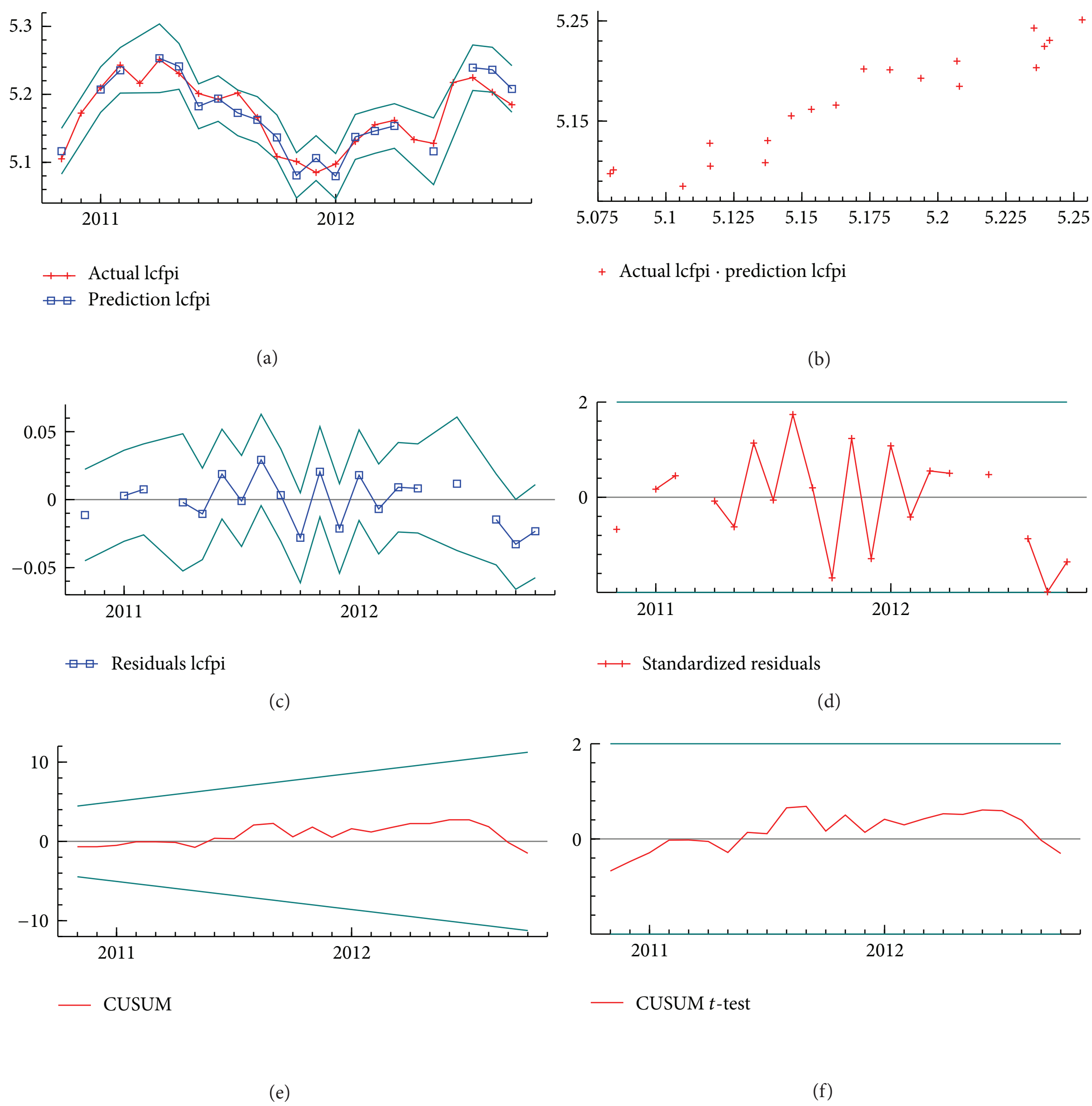

Figure 7: Prediction testing for the commodity food price index (lcfpi).

by a fixed level; fixed seasonal; two stochastic cycles; two explanatory variables, that is, crude oil and the US real effective exchange rate; and several intervention dummies, that is, structural breaks and outliers. Both cycles show a high degree of persistence but they dissipate in the long run. The longer cycle shows a periodicity of two years, and the more intense cyclical activity takes place after 2003, which is consistent with the literature and indicates that the consequences of that factors affecting commodity food prices began to appear after 2003. The effect of the explanatory variables on commodity food prices is the expected one and this finding is supported by the literature. In particular, crude oil has a positive effect, while the US real effective exchange rate has a negative effect. The structural break dummies capture the trend component of the price series adequately, while the outliers capture some temporal effects, that is, short-lived spikes, well. The structural break dummies generated by the estimation process also coincide with the years that are most extensively discussed by the literature analyzing movements in commodity food prices. Finally, the model presented in the present paper provides monthly forecasted values of the commodity food price series from 2012(11) to 2014(12). The forecast shows high and volatile commodity food prices for the medium term, that is, the next two years. High and volatile commodity food prices have a devastating effect on developing countries and the world's poor. Some short- and long-term strategies for coping with food price volatility in ACP counties are stabilizing food prices, setting up emerging food stocks at a regional level, facilitating the exchange of agricultural data, protecting the most vulnerable populations, and raising smallholder productivity [45].

Table 9: State vector analysis and regression effects in final state at time 2012(10).

State vector analysis at period 2012(10)		
	Value	Probability
Level (μ_T)	6.47980	[0.0000]
Seasonal χ^2 test	57.32373	[0.0000]
Cycle 1 (ψ_T) amplitude	0.03280	.NaN

Seasonal effects (γ_T)		
Period	Value	Probability
1	0.00616	[0.1813]
2	0.01636	[0.0004]
3	0.01594	[0.0006]
4	0.00958	[0.0358]
5	0.01404	[0.0022]
6	−0.00147	[0.7401]
7	0.00260	[0.5499]
8	−0.00819	[0.0616]
9	−0.01116	[0.0124]
10	−0.01867	[0.0000]
11	−0.01896	[0.0000]
12	−0.00620	[0.1889]

Regression effects in final state at time 2012(10)		
	Coefficient	Probability
y_{t-1}	0.32500	[0.0000]
y_{t-3}	0.12425	[0.0033]
y_{t-4}	0.10608	[0.0177]
y_{t-5}	−0.21217	[0.0000]
lcoil	0.03990	[0.0021]
lreer	−0.78676	[0.0000]

Interventions (d_j)					
	Coefficient	Probability		Coefficient	Probability
Level break 1994(12)	0.05223	[0.0006]	Outlier 1997(1)	0.02872	[0.0102]
Level break 1995(4)	−0.04487	[0.0033]	Outlier 1999(7)	−0.04228	[0.0001]
Level break 1995(6)	0.05778	[0.0002]	Outlier 1999(12)	−0.03371	[0.0028]
Level break 1996(4)	0.06678	[0.0000]	Outlier 2003(7)	−0.02340	[0.0322]
Level break 1996(9)	−0.04478	[0.0020]	Outlier 2006(1)	−0.02928	[0.0078]
Level break 1998(12)	−0.05266	[0.0004]	Outlier 2008(6)	0.03060	[0.0057]
Level break 1999(2)	−0.03371	[0.0028]	Outlier 2008(10)	−0.05242	[0.0000]
Level break 2000(4)	0.03415	[0.0127]	Outlier 2011(3)	−0.04188	[0.0002]
Level break 2001(7)	0.03540	[0.0037]	Outlier 2012(5)	−0.02677	[0.0155]
Level break 2003(12)	−0.04459	[0.0027]			
Level break 2004(3)	0.05025	[0.0006]			
Level break 2006(10)	0.07013	[0.0000]			
Level break 2007(6)	0.04911	[0.0014]			
Level break 2008(2)	0.03841	[0.0124]			
Level break 2009(1)	0.07851	[0.0000]			
Level break 2009(7)	−0.06275	[0.0000]			
Level break 2010(12)	0.07104	[0.0000]			
Level break 2012(7)	0.07473	[0.0000]			

Values in brackets are P values.

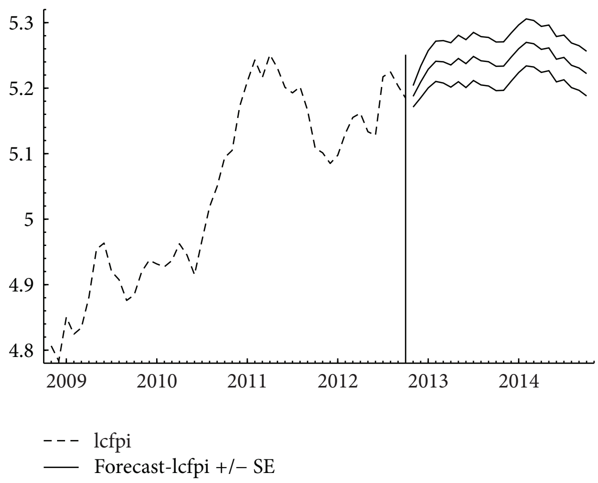

Figure 8: Commodity food price index (lcfpi) forecast.

Table 10: Normality tests (χ^2 tests) for auxiliary residuals: irregular and level.

	Skewness	Kurtosis	Bowman-Shenton
Irregular	0.04860 [0.8255]	1.44640 [0.2291]	1.49500 [0.4735]
Level	0.00765 [0.9303]	1.24770 [0.2640]	1.25540 [0.5338]

Values in brackets are P values.

Table 11: Postsample prediction tests on commodity food price index (lcfpi).

Failure χ^2_{20} test	20.1958 [0.4457]
CUSUM $t(20)$ test	−0.3339 [1.2581]

Values in brackets are P values.

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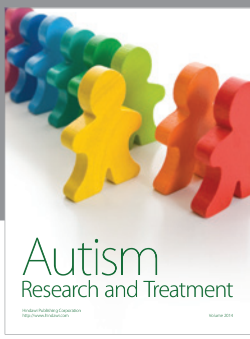
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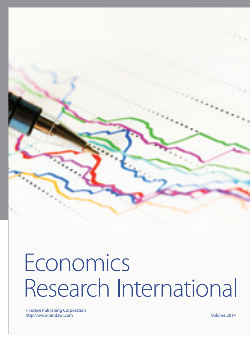
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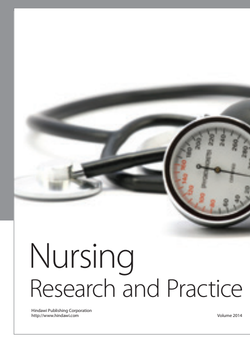
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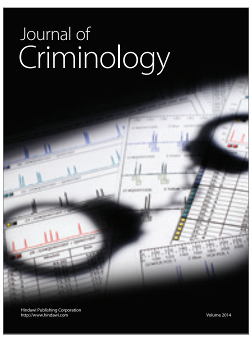
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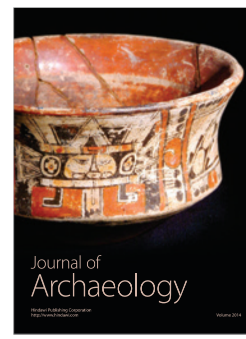
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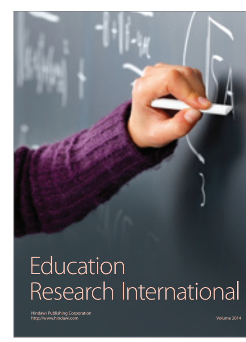
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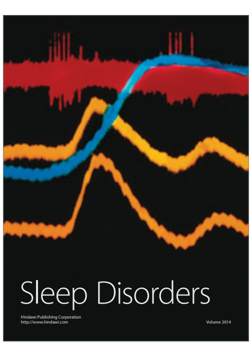
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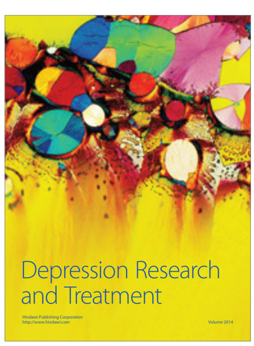
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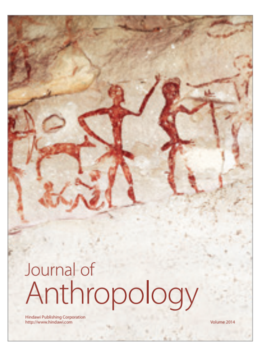
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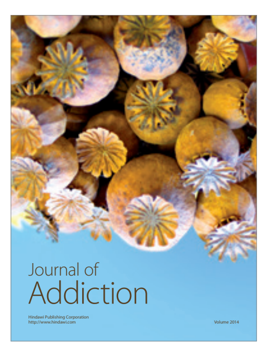
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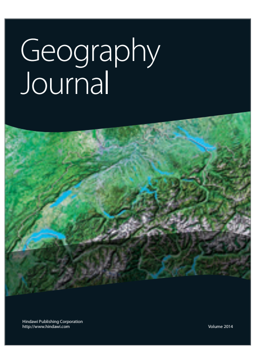
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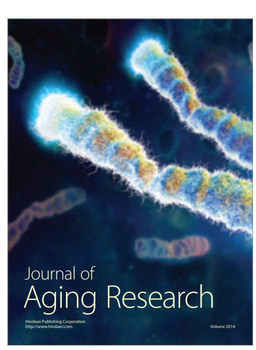
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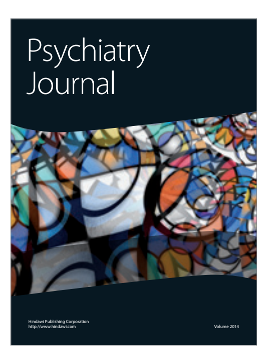
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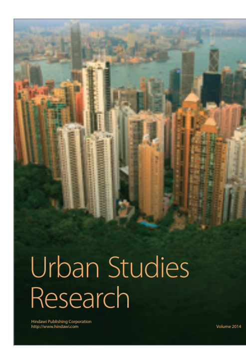
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