5. Do International Relative Commodity Prices Support the Prebisch-Singer Hypothesis? A Nonlinear Panel Unit Root Testing

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Abstract

This study investigates whether shocks to the real international commodity prices are transitory or permanent within the context of the recent developments in panel unit root testing procedures. We employ a composite panel unit root procedure -incorporates nonlinearity, gradual structural shifts, and cross-section dependency- with a sequential panel selection model which classifies stationary and non-stationary series in the panel. The analysis covering 24 real commodity prices for 1900-2010 identifies that when the behavior of commodity prices is investigated under the composite panel unit root perspective, the number of trend-stationary series increased dramatically and revealed 16 out 24 commodity prices to be stationary. A more careful examination of the findings shows that the majority of stationary prices (11 out of 16) are for livestock and agricultural commodities. However, we find only partial support for the Prebisch-Singer Hypothesis, where only 7 out of 24 commodities display negative long-term trend.

Keywords: commodity prices, unit root, structural shift, panel data
JEL Classification*:* C2, E3, F4

1. Introduction

Economists have a long history of interest in understanding the behavior of real commodity prices, because the behavior of primary commodity prices with respect to price of manufacturing (real commodity prices, *henceforth*) is important in designing economic policies. *The classical economists* (*e.g.,* David Ricardo and John Stuart Mill) stated that due to various factors (on both the demand and the supply side), the real commodity prices will

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rise in the long term (Sarkar, 1986 and 2001). However, in 1950, two prominent empirical works (Prebisch, 1950, and Singer, 1950) challenged the classical paradigm and provided robust evidences showing that the real commodity prices had a long term tendency towards decline and the evidence was labeled as "the *Prebisch-Singer hypothesis*" or PSH[3].

The PSH literature compromises two interconnected research goals: (1) the long-term behavior of real commodity prices and (2) the equilibrium theory. The characterization of the data generation process of the real commodity prices is very difficult and very complex; and the complexity boils down to two major issues: the stochastic trend and the parameter instability (due to, among other things, structural breaks, nonlinearity, asymmetric pattern, and volatility). Up to late 1980, the empirical researches (*i.e.,* Sapsford, 1985; Grilli and Yang, 1988) were conducted by utilizing the conventional method (*i.e.,* OLS) to estimate the long-term trend parameter. However, in regression analysis, it is critical to determine unit root properties of the underlying series. The search for unit root properties of relative commodity prices has brought about testing another relevant research question: the equilibrium theory. To be more exact, *the equilibrium theory of economics* suggests that the supply and demand forces will push commodity prices towards stable equilibrium in the long-run; that is, the relative prices are stationary. If commodity prices, on the other hand, are nonstationary or I(1), then in the long run they follow stochastic trends; that is, the price theory of economics is not valid. From the policy perspective, if the prices are consistent with unit root process or with non-mean-reversion, then the counter stabilization measures are not effective.

Although unit root tests with a variety of forms and specifications were used, there is no compelling evidence either of PSH or of equilibrium theory. Some studies have found relatively firm evidence of a negative trend for the majority of primary commodity prices (*i.e.*, Sapsford, 1985; Grilli and Yang, 1988; Leon and Sato, 1997). Other studies found evidence that only partially support the PSH (*i.e.,* Newbold and Vougas, 1996; Kim *et al.*, 2003; Kellard and Wohar, 2006; Ghoshray, 2011). Yet, some of the studies found evidence that either do not support the PSH or contradicts it entirely (*i.e.*, Cuddington and Urzua, 1989; Zanias, 2005; Balagtas and Holt, 2009).

Although the equilibrium theory of economics is intuitively quite clear and reasonable, the empirical studies do not yet reach a consensus about whether the commodity prices are compatible with stationary processes. Kim *et al.* (2003), for example, apply the conventional ADF test and find that the majority of commodities are not stationary. As shown in Perron (1989), if the data contains structural shifts, the early unit root tests tend to give biased results favoring the mean reversion. To account for structural shifts in the commodity prices, Cuddington and Urzúa (1989) and Newbold and Vougas (1996) employ the single exogenous structural break unit root test proposed by Perron (1989). Endogenously determined one structural break unit root test of Zivot and Andrews (1992) is utilized in Leon and Sato (1997). According to the study, the majority of relative prices in the Grilli-Yang data are in accordance with the trend-stationary behavior. Endogenously determined two structural break unit root tests of Lumsdaine and Papel (1997) and Lee and Strazicich (2003) are also utilized in the PSH literature. Zanias (2005) and Kellard and Wohar (2006) used the former, while Ghoshray (2011) used the latter. Utilizing the Grilli-Yang index as reference data, Zanias (2005) reports that the index is adequately described by a trend-stationary process with intercept shifts. Kellard and Wohar (2006) uncover that 14 out of the 24

[3] *The implication of the hypothesis is that the gains from international trade are distributed unequally and unfairly between the nations exporting mainly primary products and those exporting mainly manufactures.*

commodities are trend stationary. Similarly, Ghoshray (2011) identifies 13 out of 24 commodities to be trend stationary.

The number of studies using panel unit root tests in the commodity price literature is scant; we have practically encountered only three studies (*i.e.*, Yang *et al*., 2012; Iregui and Otero, 2013; Arezki *et al*., 2014) which account for structural shifts and cross-section dependency in similar treatments. While Arezki *et al*. (2014) and Iregui and Otero (2013) use the panel unit root test of Hadri and Rao (2008), Yang *et al*. (2012) employ the panel unit root test of Carrion-i-Silvestre *et al*. (2005). Yang *et al*. (2012) discover that 17 out of 24 commodities are compatible with mean-reversion and also find that the majority of structural breaks occurred around 1940s and 1980s. Iregui and Otero (2013) and Arezki *et al*. (2014) find that commodity prices are jointly stationary after accommodating structural break(s) and cross-sectional dependence.

This study has two interconnected objectives: (1) to investigate whether shocks on international commodity prices are transitory or permanent and (2) to analyze the long-term behavior of real commodity prices. To fulfill these objectives, we utilize a composite panel unit root test that incorporates some novel features. By employing an updated version of Grilli and Yang (1988) data that covers the period from 1900 to 2010 for 24 real international commodity prices, we find that when structural breaks are controlled via a Fourier function, the number of series identified as stationary increases dramatically relatively to the alternative approaches. Secondly, this study shows that a large number of commodity prices are in tune with the price theory of economics. Finally, we find only partial support regarding the PSH. According to our best knowledge, the current study is the first that incorporates these four features (controlling nonlinearity, cross-sectional correlation, structural breaks via Fourier approximation, and SPSM) in addressing the behavior of real commodity prices.

The largest share of export earnings of many developing counties depends on the export of a few primary commodities. Their short and medium terms economic policies are directly or indirectly linked with the commodity prices and, therefore, examining the behavior of real commodity prices (long term trend as well as mean reversion property) is extremely important. Due to significance of the relative prices for a large number of countries, one of the main motivations of this research is to improve our understanding about long-term dynamics of real commodity prices. The nonlinear method with Fourier approximation has not been employed in the PSH literature and, therefore, we believe the study will contribute to our understanindg about the long-term behavior of real commodity prices.

There are four major novel features of our methodological tool. In the economic theory, comovements among economic variables are important. It is often suggested that two variables have co-movements if they are affected by a common factor. The commodity markets are not isolated one from the other and, therefore, a vigorous empirical approach should incorporate this interconnectedness. However, the univariate unit root tests assume that individual price series is independent, implying that the commodity prices are isolated one from the other. In the PSH literature, the use of panel unit root testing which incorporates the interconnectedness is very rare. Our second motivation is the inclusion of nonlinearity. Although Kellard and Wohar (2006) and Balagtas and Holt (2009) provide considerable evidences in favor of nonlinearity for a large number of commodity prices, the previous studies that employ the panel unit framework do not consider the asymmetric (nonlinear) behavior of the commodity prices. Another novelty about the methodological tool used and also the contribution of this study is to use the Fourier approximation to control the effects of structural changes in the data generation process. In the literature on the commodity price dynamics, in order to account for the effects of structural breaks the dummy variable approach is used to capture level or slope shifts. However, the use of dummies to take into account the structural breaks involves some shortcomings (mainly due to difficulty in determining the location, duration and weight of the breaks)[4]. In this study, following Becker *et al*. (2006), Liu (2013) and also Zhang *et al*. (2013), the structural breaks are formulated as a gradual and smooth process via the Fourier approximation, where Becker *et al*. (2006) and Jones and Enders (2014) show that structural breaks with unknown dates can be captured quite well with the Fourier function. Finally, the SPSM proposed by Chortareas and Kapetanios (2009) is the other important novelty of the methodological tool. The standard panel unit root tests with either first or the second generation group are unsuitable to classify individual time series into non-stationary and stationary ones. The SPSM can determine the mix of I(0) and I(1) series in a panel setting, so as to group a whole panel into stationary and non-stationary series.

The rest of paper is organized as follows. The next section outlines the methodology; and Section 3 briefly explains the data set. Section 4 is devoted to the presentation of the empirical findings. In Section 5, the findings are discussed and compared with other studies; and the study ends with the conclusion section.

2. Empirical Methodology

In order to incorporate a nonlinear framework in a panel framework, Ucar and Omay (2009) proposed a nonlinear panel unit root test by combining the nonlinear framework of Kapetanios *et al*. (2003) with the panel unit root testing procedure of Im *et al*. (2003). A panel version of exponential smooth transition autoregressive process (PESTAR) model is given by:

$$\Delta y_{it} = d_i + \gamma_i \Delta y_{it-1}\{1 - exp(-\theta_i y_{it-1}^2)\} + \varepsilon_{it}$$

$$\Delta y_{it} = d_i + \gamma_i y_{it-1}\{1 - \exp(-\theta_i y_{it-1}^2)\} + \varepsilon_{it} \quad i = 1, 2, 3, \dots, N \text{ and } t = 1, 2, 3, \dots, T \tag{1}$$

where: y_{it} is the series of interest, d_i is deterministic component considered for constant (α_i) or constant and trend ($\alpha_i + \beta_i t$), θ_i is the transition parameter[5], and ε_{it} is an *i.i.d.* error with zero mean and constant variance. Direct testing of the null hypothesis of unit root ($\theta_i = 0$) in equation (1) is somewhat problematic, because γ_i is not identified under the null. Kapetanios *et al*. (2003) apply the first-order Taylor series approximation around $\theta_i = 0$ for all *i*, and hence the auxiliary regression is obtained as:

$$\Delta y_{it} = d_i + \delta_i y_{it-1}^3 + \varepsilon_{it} \tag{2}$$

where: $\delta_i = \theta_i \gamma_i$. From equation (2), an extended PESTAR model which allows including lagged differences can be written as:

$$\Delta y_{it} = d_i + \delta_i y_{it-1}^3 + \sum_{j=1}^{p_i} \lambda_{ij} \Delta y_{it-j} + \varepsilon_{it} \tag{3}$$

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[4] *To save space, we only touch these limitations briefly. However, interested readers can see, for example, Jones and Enders (2014).*

[5] *The exponential transition function* $\{1 - \exp(-\theta_i y_{it-1}^2)\}$ *determines the degree of mean reversion and is governed by the parameter θ. As θ goes zero or infinity, the smooth transition function reduces to a linear model (Enders, 2010, p.458).*

where: *p* denotes lag length(s)[6]. The hypotheses for unit root testing based on Equation 3 are as follows:

$H_0 : \delta_i = 0$ (linear non-stationary) for all *i*

$H_0 : \delta_i < 0$ (non-linear stationary) for some *i*

The panel KSS unit root test developed by Ucar and Omay (2009) is the average of individual KSS statistics. The KSS statistic is the t-ratio ($t_{i,NL}$) associated with δ_i in equation (3). The panel KSS statistic is written as: $\bar{t}_{NL} = 1/N \sum_{i=1}^{N} t_{i,NL}$. The individual KSS statistics are independently and identically distributed (*i.i.d.)* with finite means and variances, and hence the panel statistic has standard normal distribution. Therefore, it is important to note here that the panel KSS statistic assumes cross-sectional independency to ensure the asymptotic normality. However, as touched upon above, this assumption seems not to hold, due to the fact that a shock to a commodity market may spill over other prices through market dependencies. In order to take into account this dependency, Ucar and Omay (2009) compute critical values and their corresponding p-values from the bootstrap distribution.

In order to account for structural shifts as smooth process, following Liu (2013) and Zhang *et al*. (2013) we extend the panel KSS unit root test by augmenting the PESTAR model with a Fourier function as:

$$\Delta y_{it} = d_i + \delta_i y^3_{it-1} + \sum_{j=1}^{p_i} \lambda_{ij} \Delta y_{it-j} + a_i \sin(\frac{2\pi kt}{T}) + b_i \cos(\frac{2\pi kt}{T}) + \varepsilon_{it} \quad (4)$$

where: *k* is frequency selected for the approximation, and $[a_i, b_i]'$ measures the amplitude and displacement of the frequency component[7]. The Fourier approximation can often capture the behavior of an unknown function even if the function itself is not periodic. One should note that the hypotheses for unit root testing with Fourier function are equivalent to those presented for Equation 3.

To determine whether a series is stationary, the SPSM procedure proposed by Chortareas and Kapetanios (2009) carries out a sequence of panel unit root test by reducing the dataset. This reduction is conducted by dropping stationary series from the panel. There are three successive steps in carrying out the SPSM procedure to integrate equation (4):

Step 1) Apply the panel KSS test with a Fourier function to all the series in the panel. Stop procedure if the null hypothesis of unit root cannot be rejected and conclude that all series are non-stationary. If the null is rejected, proceed to step 2.

Step 2) Drop the series with the minimum KSS statistic, since it is identified as being stationary.

Step 3) Turn back to Step 1 for the remaining series and carry out this procedure until finding evidence of stationarity. Consequently, the whole panel is separated into a set of stationary series and a set of non-stationary series.

[6] Determining optimal lag(s) through information criterions in unit root analysis is the common way we use Schwarz information criterion.

[7] Enders and Lee (2009) suggest that k could be obtained via the minimization of the sum of squared residuals. It also follows that at least one frequency component must be present if there is a structural break.

Data

The study uses an updated Grilli and Yang (1988) data for the 1900-2010 period for 24 real international commodity prices[8]. Figure 1 depicts the log relative commodity prices. At first glance, the trend behavior of the commodity prices does not appear to be similar to each other and the commodity prices appear to have different trend dynamics over different time spans. Moreover, the figure also shows structural shifts in the data trend. The estimated time paths of the time-varying intercepts (Fourier function) based on equation (7) are also shown in Figure (1). The examination of the figures indicates that all the Fourier approximations appear reasonable and support the notion of long swings in real commodity prices.

4. Empirical Results

The results of the univariate unit root tests are reported in Table 1. As it is well known, while the null hypothesis of the ADF test is non-stationary, the KPSS test considers the null of hypothesis of stationarity. The ADF test cannot reject the unit root null hypothesis of the unit root for half of the series (banana, beef, cocoa, coffee, copper, lamb, lead, rubber, silver, tea, tin, and tobacco). The KPSS test by switching the null hypothesis rejects stationarity for 15 out of the 24 price series. Both the ADF test and the KPSS test show that six commodity prices (banana, coffee, rubber, silver, tea, and tin) are characterized by a unit process, implying that shocks are permanent. The estimated trend model based on the ADF test indicates that 9 commodity goods (aluminum, cotton, hides, maize, palm oil, rice, sugar, wheat, and wool) have significant negative trend and, thereby, are found to be consistent with the PSH. The KPSS test fails to reject the stationary null hypothesis for 9 out of the 24 price series and three real commodity prices of those nine series (banana, sugar, and wheat) support the PSH. The estimated difference stationary models based on the KPSS test, on the other hand, show that ten commodities contain significant negative trend (aluminum, cotton, hides, jute, lead, maize, palm oil, rice, rubber, tea, and wool).

Since the univariate unit root tests are not able to control the interdependency in the commodity markets, we proceed to panel unit root testing procedure. We first start with testing for cross-sectional dependency by conducting four formal tests; namely, i) the *LM* test of Breusch and Pagan (1980), ii) the CD_{lm} Pesaran (2004), iii) the CD tests proposed by Pesaran (2004), and iv) the LM_{adj} test advocated by Pesaran *et al.* (2008). The results of the cross-sectional dependence tests are reported in Table 2. The null hypothesis of no cross-sectional dependence is rejected by all the tests at a 1% significance level.

We then continue with utilizing the SPSM mixed with the Panel KSS unit root test with a Fourier function to investigate the trends in the international commodity prices. To expand our benchmarks, we also carry out the Panel KSS unit root test without a Fourier function based on Equation 3 (Model-A, *hereafter*). Table 3 reports the results of Model-A. In sequential elimination procedure, the successive calculation-elimination loop is continued until the Panel KSS unit root test fails to reject the unit root null hypothesis at the 10% significance level.[9] Through this loop, 10 relative commodity prices are removed from the

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[8] *See Pfaffenzeller, Newbold and Rayner (2007) for a detailed description. Note that Stephan Pfaffenzeller does not continue updating data after 2011: Available at: <http://www.stephan-pfaffenzeller.com/new-layout-and-old-material> [Access date: November 2, 2017].*

[9] *To save space, we do not provide the steps we followed in sequential elimination procedure. Interested readers can see Chortareas and Kapetanios (2009).*

panel; that is, these 10 commodity prices are identified as stationary processes. These commodity prices are: maize, sugar, cotton, wheat, hides, jute, palm oil, zinc, rice, and wool. The critical p-value for the remaining 14 commodity prices is more than 10% threshold; and, therefore, we failed to reject the null hypothesis for the remaining 14 relative commodity price sequences.

After conducting our benchmark model or Model-A, the study proceeds with the Panel KSS unit root test with a Fourier function (Model-B, *hereafter*), which is based on Equation 4. A grid search is first performed to find the best frequency because there is no a priori knowledge concerning the shape of the breaks in the data. We estimate Equation (4) for each integer $k = 1,...,5$ and following the recommendation of Enders and Lee (2009 and 2012), the minimization of residual sum of squares is used to determine the optimal frequency for the series. Table 4 reports the results of Model-B applied on the price of these 24 commodity prices; the table also shows a sequence of the Panel KSS statistics with their bootstrap p-values on a reducing panel, the individual minimum KSS statistic, and the stationary series identified by this procedure each time. We apply the same successive calculation-elimination loop procedure for Model-B. The successive loop procedure is carried out until the Panel KSS unit root test fails to reject the unit root null hypothesis at the 10% significance level. For Model-B, 16 commodity prices are identified to be stationary. The relative commodity prices distinguished as stationary lined up according to the loping sequence of Model-B are: maize, sugar, cotton, wheat, hides, jute, palm oil, zinc, rice, wool, tin, coffee, lamb, cooper, beef, and aluminum.

In order to produce some additional evidence to strengthen our motivational underpinnings about the composite tool that we employ in this study, we also apply a linear second generation panel unit root test proposed by Pesaran (2007). As shown in Table-5, Pesaran (2007) test rejects the null of unit root for eight commodities (beef, coffee, maize, palm oil, rice, sugar, wheat, and zinc). This implies the remaining 16 commodities are non-stationary. However, close examination shows that the estimated statistics for the whole panel is actually pointing towards trend-stationary pattern. In other words, two-thirds of the individual test statistics is compatible with stochastic trend, but the panel test statistics (calculated by combining the information of individual test statistics) suggests the opposite. In sum, the SPSM approach by differentiating the whole panel into a series of I(0) and series of I(1) seems to produce more sensible and informative results as compared to other panel unit root tests.

In order to estimate the trend parameter, we apply trend stationary specification for stationary prices, and difference stationary specification for the non-stationary series. For model A, among 10 stationary commodity goods, we find that 7 of them support the PSH. The estimated 14 difference stationary models support that non-stationary commodity prices is not consistent with the PSH. For Model-B; among the 16 trend-stationary commodity prices, we found that only 7 commodity prices have significant negative trend (maize, cotton, wheat, hides, palm oil, rice and wool); and one commodity price has an upward trend (beef). For the remaining 8 trend stationary commodity prices, we are unable to find any significant positive or negative trend. Finally, for the 8 commodities that are non-stationary, we proceed to estimate the trend by using the difference specification. For the difference specification, however, we are not able to find statistically significant positive or negative trend; simply they are trendless.

5. Discussion

The empirical analysis in this study supports that if the real commodity prices temporarily deviate from the equilibrium, the real commodity prices, in general, have a tendency to revert back to their long-term equilibrium and this tendency is more prominent if structural breaks are captured via a Fourier approximation. Results thereby imply that model specification regarding data generation process plays a crucial role for whether the international commodity prices are trend or difference stationary.

When analyzing more carefully the results of stationarity test reported in Model-B, the majority of commodity prices (11 out of 16) identified as stationary is for livestock and agricultural commodities (*i.e.,* beef, coffee, cotton, hides, jute, lamb, maize, palm oil, rice, wheat and wool); that is, the real prices of agricultural and livestock products are in tune with the price theory; hence, the exports are expected to move back towards the long-run trend.

In terms of PSH, an interesting finding is that for both model-A and model-B, the same 7 commodity prices have significant negative trend and, hence, are consistent with the PSH. Therefore, even though the long-term behavior of commodity prices is the key for the model specification in testing the PSH, the trend behavior of commodity prices seems to be persistent irrespective of whether the data generation process is characterized by trend or difference stationary.

The estimation results for testing the PSH show that agricultural products are mainly consistent with the PSH. The behavior of agricultural commodity prices is of great importance for the trade and stabilization policies in the developing countries, because the trade and spending levels are determined mainly by the price of these products. Higher prices lead to increases in export earnings, and the predictability of the commodity prices is one of the key concerns in policy making. If shocks to commodity prices are temporary, it is not required to react to international shocks quickly. The agricultural products which are in tune with the PSH are mean reverting; hence, the export behavior tends towards long-run equilibrium. It is very common to suggest that the countries depending on the trade of agricultural products pay attention to and concentrate on an export diversification policy which is based on shifting from primary commodities to manufacturing. Our study finds that the agricultural commodities consistent with the PSH have secular negative trend in the long-term; therefore, the results do not necessarily support the stabilization policies.

6. Conclusion

This paper analyzes the behavior of international commodity prices and questions the relevancy of the PSH; and, moreover, to what extend the shock to international commodity prices are permanent. In examining the stationary pattern of the real commodity prices, this study adopts an integrated panel unit root approach for 24 international commodity prices during 1900-2010. By using a composite panel unit root test with Fourier approximation, the study identifies 16 commodity prices to be stationary. Thus, the findings support the equilibrium price theory, implying that the shocks to most of the real prices of primary commodities have the tendency to be temporary. In addition to that, the trend parameter estimations for testing the PSH indicate that the real prices of 7 commodities display a negative trend; and, hence, the long-term trend of behavior of these commodities (maize, cotton, wheat, hides, palm oil, rice and wool) is consistent with the PSH. So, the findings partially support the PSH, implying that the real prices of some primary commodities have tendency to decline.

The panel unit root test this study employs is augmented with some novel attributes, including nonlinearity, a measure to control cross-sectional correlation, a Fourier approximation to control the effects of structural breaks and also SPSM to differentiate I(0) and I(1) series in the panel. We observe that although some of these features (*i.e.,* nonlinearity and means to control cross-sectional correlation) are important on their own account, the Fourier approximation plays the key role in detecting a large number of real prices to be stationary. Therefore, we believe the use of new developments in determining the behavior of data generating process (particularly the way the structural breaks are formulated) would further improve our understanding about the long-term behavior of international commodity prices. In addition to this, the study uncovers interesting points suggesting that the majority of real prices identified as stationary are those of agricultural and livestock commodities. Morever, our study shows that some of the real prices of these agricultural products exhibit historical negative tendency. Both the agricultural and live stock commodities are main value added prospects in the rural areas of the developing nations, and the uncertainty in their prices may be accompanied by social and political tensions. Therefore, the political stance with no active measures in response to price slump in these commodities may have some political and social consequences. In addition to these factors, the current study finds that the real prices of agricultural and livestock commodities are consistent with the price theory and with the PSH, and, therefore, the stabilization policies (albeit the effectiveness of these policies is questioned) may have some reasonable grounds.

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Appendix

Table 1

Univariate Unit Root Tests

	ADF			KPSS		
	Test statistic	**Trend coefficient**	**PSH**	**Test statistic**	**Trend coefficient**	**PSH**
Aluminum	-3.472**	-0.0024***	Yes	0.1957**	-0.0150***	Yes
		(-2.63)			(-16.79)	
Banana	-3.067	-0.0003	No	0.210	-0.0017***	Yes
		(-1.06)			(-2.79)	
Beef	-3.018	0.0026**	No	0.091	0.0167***	No
		(2.44)			(14.56)	
Cocoa	-2.378	0.0003	No	0.116	-0.0013	No
		(0.45)			(-0.93)	
Coffee	-3.139	0.0001	No	0.173**	0.0015	No
		(0.24)			(1.19)	
Copper	-2.296	0.0004	No	0.112	-0.0007	No
		(0.88)			(-0.71)	
Cotton	-3.2848*	-0.0022***	Yes	0.2523***	-0.0123***	Yes
		(-2.89)			(-13.71)	
Hides	-5.182***	-0.0032***	Yes	0.1339*	-0.0079***	Yes
		(-3.55)			(-9.30)	
Jute	-3.387*	-0.0012	No	0.2211***	-0.0060***	Yes
		(-1.59)			(-5.78)	
Lamb	-3.092	0.0029**	No	0.0481	0.0176***	Yes
		(2.55)			(15.08)	
Lead	-2.571	-0.0002	No	0.1263*	-0.0036***	Yes
		(-0.44)			(-3.82)	
Maize	-4.788***	-0.0037***	Yes	0.2265***	-0.010***	Yes
		(-3.95)			(-12.93)	
Palm oil	-4.462***	-0.0034***	Yes	0.1779**	-0.0109***	Yes
		(-3.42)			(-11.55)	
Rice	-4.343***	-0.003***	Yes	0.1516**	-0.0113***	Yes
		(-3.50)			(-13.16)	
Rubber	-2.437	-0.0024	No	0.1634**	-0.0233***	Yes
		(-1.55)			(-15.87)	
Silver	-2.011	0.0009	No	0.1458*	0.0037***	No
		(1.64)			(3.11)	
Sugar	-4.589***	-0.0031**	Yes	0.0650	-0.010***	Yes
		(-2.61)			(-8.32)	
Tea	-2.850	-0.0008	No	0.2435***	-0.0059***	Yes
		(-1.47)			(-6.88)	
Timber	-3.7277**	0.0020***	No	0.0971	0.0092***	No
		(2.96)			(15.96)	
Tin	-2.513	0.0004	No	0.1240*	0.0025**	No
		(0.78)			(2.20)	
Tobacco	-2.926	0.0006	No	0.2876***	0.0076***	No
		(1.41)			(7.87)	
Wheat	-5.036***	-0.0031***	Yes	0.0731	-0.0085***	Yes
		(-4.01)			(-12.18)	
Wool	-3.450**	-0.0032***	Yes	0.2508***	-0.0163***	Yes

	ADF			KPSS		
	Test statistic	**Trend coefficient**	**PSH**	**Test statistic**	**Trend coefficient**	**PSH**
		(-3.01)			(-16.06)	
Zinc	-5.525***	0.0004	No	0.0772	0.0010	No
		(0.82)			(1.37)	

Notes: Numbers in parenthesis are the t-ratios. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level, respectively.

Table 2

Cross-section Dependence Tests

		Constant			Constant and Trend	
Study	**Test**	**Statistic**	**p-value**		**Statistic**	**p-value**
Breusch and Pagan (1980)	LM	664.99**	0.000		675.91***	0.000
Pesaran (2004)	CD_{LM}	16.55***	0.000		17.02***	0.000
	CD	-6.65***	0.000		-6.61***	0.000
Pesaran, Ullah and Yamagata(2008)	LM_{adj}	20.86***	0.000		20.74***	0.000

Notes: *** denotes statistical significance at the 1 percent level.

Table 3

Panel KSS Unit Root Test without a Fourier Function

		Unit Root (Stationary)				Long-run Trend (PSH)		
Sequence	Com-modity	Panel KSS	p-value	Min. KSS	Stationary	Trend coefficient	p-value	PSH
1	Maize	-2.794***	0.00	-5.066	Yes	-0.00214***	0.00	Yes
2	Sugar	-2.696***	0.00	-4.675	Yes	-0.00096	0.32	No
3	Cotton	-2.606***	0.00	-4.086	Yes	-0.00194***	0.00	Yes
4	Wheat	-2.535***	0.00	-3.999	Yes	-0.00110*	0.06	Yes
5	Hides	-2.462***	0.00	-3.906	Yes	-0.00161*	0.05	Yes
6	Jute	-2.386***	0.00	-3.810	Yes	-0.00082	0.23	No
7	Palm oil	-2.307***	0.00	-3.589	Yes	-0.00140*	0.06	Yes
8	Zinc	-2.231***	0.00	-3.578	Yes	0.00034	0.58	No
9	Rice	-2.147***	0.00	-3.559	Yes	-0.00131*	0.06	Yes
10	Wool	-2.053**	0.06	-3.486	Yes	-0.00190**	0.02	Yes
11	Tin	-1.951	0.16	-3.302	No	0.00022	0.70	No
12	Coffee	-1.847	0.18	-3.129	No	-0.00002	0.98	No
13	Lamb	-1.740	0.28	-2.594	No	0.00154	0.08	No
14	Copper	-1.662	0.32	-2.395	No	0.00070	0.18	No
15	Beef	-1.589	0.32	-2.237	No	0.00142	0.11	No
16	Aluminum	-1.517	0.46	-2.216	No	-0.00064	0.32	No
17	Cocoa	-1.430	0.52	-2.090	No	0.00031	0.68	No
18	Tea	-1.336	0.66	-2.023	No	-0.00042	0.41	No
19	Lead	-1.221	0.66	-1.986	No	0.00231	0.45	No
20	Silver	-1.068	0.70	-1.635	No	0.00076	0.17	No
21	Timber	-0.926	0.82	-1.302	No	0.00047	0.42	No
22	Banana	-0.801	0.78	-1.282	No	-0.00022	0.52	No
23	Tobacco	-0.560	0.64	-0.679	No	-0.00007	0.86	No
24	Rubber	-0.442	0.80	-0.442	No	0.00046	0.68	No

Notes: ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels, respectively. The maximum lag was set to be 8 and optimal lag(s) was selected by minimizing Schwarz information criterion. The p-values are based on 5000 bootstrap replications.

Table 4

Panel KSS Unit Root Test with a Fourier Function

		Unit Root (Stationary)				Long-run Trend (PSH)		
Sequence	Commodity	Panel KSS	p-value	Min. KSS	Stationary	Trend coefficient	p-value	PSH
1	Maize	-3.191***	0.00	-5.066	Yes	-0.00230***	0.0018	Yes
2	Sugar	-3.091***	0.00	-4.675	Yes	-0.00094	0.3464	No
3	Cotton	-3.003***	0.00	-4.086	Yes	-0.00196***	0.0022	Yes
4	Wheat	-2.934***	0.00	-3.999	Yes	-0.00117*	0.0559	Yes
5	Hides	-2.843***	0.00	-3.906	Yes	-0.00182**	0.0361	Yes
6	Jute	-2.779***	0.00	-3.810	Yes	-0.00091	0.1917	No
7	Palm oil	-2.708***	0.00	-3.589	Yes	-0.00150**	0.0564	Yes
8	Zinc	-2.693***	0.00	-3.578	Yes	0.00026	0.6860	No
9	Rice	-2.625***	0.00	-3.559	Yes	-0.00129*	0.0721	Yes
10	Wool	-2.554***	0.00	-3.486	Yes	-0.00205**	0.0113	Yes
11	Tin	-2.430***	0.00	-3.302	Yes	0.00021	0.7205	No
12	Coffee	-2.334***	0.01	-3.129	Yes	0.00017	0.8189	No
13	Lamb	-2.260**	0.02	-2.594	Yes	0.00142	0.1138	No
14	Copper	-2.183**	0.03	-2.395	Yes	0.00066	0.2203	No
15	Beef	-2.105*	0.06	-2.237	Yes	0.00155*	0.0907	No
16	Aluminum	-2.044*	0.09	-2.216	Yes	-0.00064	0.3310	No
17	Cocoa	-1.824	0.18	-2.090	No	0.00049	0.5200	No
18	Tea	-1.656	0.26	-2.023	No	-0.00044	0.4116	No
19	Lead	-1.542	0.28	-1.986	No	0.00297	0.3433	No
20	Silver	-1.430	0.38	-1.635	No	0.00077	0.1762	No
21	Timber	-1.122	0.73	-1.302	No	0.00044	0.4621	No
22	Banana	-1.027	0.60	-1.282	No	-0.00020	0.5586	No
23	Tobacco	-0.853	0.47	-0.679	No	-0.00010	0.8116	No
24	Rubber	-0.664	0.63	-0.442	No	0.00045	0.6962	No

Notes: Fourier (k) is set to be 5 and optimal Fourier was chosen by the minimum sum square of the residual for the Fourier function. The maximum lag is set to be 8 and optimal lag(s) was selected by minimizing Schwarz information criterion. The p-values are based on 5000 bootstrap replications. ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels, respectively.

Table 5

Panel Unit Root Test with Cross-section Dependency (Pesaran, 2007)

	CADF statistic		**p-value**
Aluminum	-2.622		0.360
Banana	-2.199		0.565
Beef	-3.477	*	0.085
Cocoa	-3.115		0.170
Coffee	-3.715	**	0.050
Copper	-2.684		0.330
Cotton	-2.938		0.230
Hides	-2.321		0.505
Jute	-3.009		0.205
Lamb	-2.555		0.390
Lead	-3.391		0.100
Maize	-3.65	*	0.055
Palmoil	-3.436	*	0.090
Rice	-4.236	*	0.015
Rubber	-2.859		0.260
Silver	-1.952		0.685
Sugar	-4.066	**	0.020
Tea	-2.393		0.470
Timber	-2.828		0.270
Tin	-3.251		0.130
Tobacco	-2.96		0.220
Wheat	-4.852	***	0.010
Wool	-2.69		0.330
Zinc	-4.594	***	0.010
Panel Statistic	-3.158	***	0.010

Notes: *The optimum lag is selected by the Schwarz Information Criterion for individual cross-sectionally augmented ADF statistics. CIPS is the mean of CADF statistics. ***, **, and * denote statistical significance at 1, 5, and 10 percent level, respectively.*

Figure 1

The Log Relative Commodity Prices and Their Fourier Approximations