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Abstract

In this paper, we re-examine two important aspects of the dynamics of relative primary commodity prices, namely the secular trend and the short run volatility. To do so, we employ 25 series, some of them starting as far back as 1650 and powerful panel data stationarity tests that allow for endogenous multiple structural breaks. Results show that all the series are stationary after allowing for endogeneous multiple breaks. Test results on the Prebisch-Singer hypothesis, which states that relative commodity prices follow a downward secular trend, are mixed but with a majority of series showing negative trends. We also make a first attempt at identifying the potential drivers of the structural breaks. We end by investigating the dynamics of the volatility of the 25 relative primary commodity prices also allowing for endogenous multiple breaks. We describe the often time-varying volatility in commodity prices and show that it has increased in recent years.

JEL Classification Numbers: O13, C22.

Keywords: Primary commodities; Unit root tests; Multiple Structural breaks ; Volatility.

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1 Introduction

The present paper re-examines two important aspects of the dynamics of relative primary commodity prices using long time series, some of them starting as far back as 1650. The dynamics of relative primary commodity prices can be decomposed into essentially three components: The secular trend which Prebisch (1950) and Singer (1950) have conjectured should be declining, the long cycles that affect relative primary commodity prices and finally the volatility which has been found often time varying and generally increasing in recent years.[2] In this paper, we do not examine the long cycles component for lack of space (cf. Erten and Ocampo, 2012 and references therein). We focus on the Prebisch-Singer hypothesis (thereafter PSH) and the volatility of relative primary commodity prices using recent panel data technology.

The first step in testing the PSH is to test for the stationarity of the series. This is important because depending on whether or not the series are stationary we must use the appropriate regression framework to test for the PSH. If y_t, the logarithm of the relative commodity price is generated by a stationary process around a time trend, then the following equation is:

$$y_t = \alpha + \beta t + \varepsilon_t, \ t = 1, \ldots, T, \tag{1}$$

where t is a linear trend and the random variable ε_t is stationary with mean 0 and variance σ_ε^2. The parameter of interest is the slope β, which is predicted to be negative under the PSH. If the real commodity prices were generated by a so called difference-stationary or $I(1)$ (thereafter DS) model, implying that y_t is non-stationary, then we should employ the following equation:

$$\Delta y_t = \beta + v_t, \ t = 1, \ldots, T, \tag{2}$$

where v_t is stationary. It is well known that if y_t is a DS process, then using equation (1) to test the null hypothesis of $\beta = 0$ will result in acute size distortions, leading to a wrong rejection of the null when no trend is present, even asymptotically. Alternatively, if the true generating process is given by equation (1) and we base our test on equation (2), our test becomes inefficient and less powerful than the one based on the correct equation. Therefore, when testing the PSH we have first to test the order of integration of our relative commodity prices in order to use the right regression. In this paper, we use the Hadri and Rao (2008) panel stationarity test in order to test jointly for the stationarity of our series, in turn increasing the power of the test relatively to individually testing each time series. Using the Hadri and Rao (2008) panel stationarity test also allows us to incorporate the information contained in the cross sectional dependence of our series. It is well known that there are generally positive and significant correlations between real primary commodity prices. Pindyck and Rotemberg (1990) noted this strong correlation in the real prices of unrelated commodities which they refer to as "excess co-movement". They found that

[2] See Hadri (2011) for an analysis of the implications of these components for policymakers.

even after controlling for current and expected future values of macroeconomic variables this excess co-movement remains.

We use long time series, some of them starting in 1650. It is thus highly likely that they will show multiple breaks. Since the pioneering work of Perron (1989), it is widely accepted that the failure of taking into account structural breaks is likely to lead to a significant loss of power in unit root tests. Similarly, stationarity tests ignoring the existence of breaks diverge and thus are biased toward rejecting the null hypothesis of stationarity in favour of the false alternative of a unit root hypothesis. This is due to severe size distortion caused by the presence of breaks (see *inter alia* Lee *et al.* (1997). Therefore in our panel stationarity tests, we allow for endogenous multiple breaks in order to avoid biases in our tests. The other innovation in this paper compared to most previous papers is that not only do we use very long series but we also use relative primary commodity prices instead of aggregate indices. By doing so, we avoid the aggregation bias and the generally ad-hoc weighting rule to combine the commodity prices involved.The final step deals with testing the significance and finding the sign of the slopes of the appropriate regressions in order to find out if the PSH is not rejected by the data. We also make a first attempt at identifying the potential drivers of those breaks by exploiting information related to the break dates and the change of the signs in the piecewise regressions of the trend.

We end by examining the volatility of primary commodity prices. It is well known that primary commodity prices are highly volatile (c.f. Mintz, 1967, Reinhart and Wickham, 1994 and for oil, Dvir and Rogoff, 2009). Using long series, we also test for data driven structural breaks in volatility employing Bai and Perron (1998) methodology.

2 Panel stationarity tests with multiple structural breaks

In this paper, we extend Hadri and Rao (2008) to deal with multiple breaks. In Hadri and Rao (2008) we considered four possibilities of effects that a single break may cause on the deterministic parts of the model under the null hypothesis. Model 0 has a break in the level (α_i) and no trend ($\beta_i = 0$). Model 1 allows for a break in the level and a time trend without a break ("crash model" in Perron's terminology) and model 2 permits a break in the slope only. In model 3, a break is admitted in both the level and the slope. Model 3 is the most general model which encompasses the three other models. Model 3 is specified as follows:

$$\text{Model 3:} \quad y_{it} = \alpha_i + r_{it} + \delta_i D_{it}(\omega^*) + \beta_i t + \gamma_i DT_{it}(\omega^*) + \epsilon_{it}, \tag{3}$$

with

$$r_{it} = r_{it-1} + u_{it}, \tag{4}$$

where y_{it}, $i = 1, ..., N$ cross-section units and $t = 1, ..., T$ time periods, are the observed series for which we wish to test stationarity. For all i, $\alpha_i' s$, $\beta_i' s$, $\delta_i' s$ and $\gamma_i' s$ are unknown parameters. r_{it} is a random walk with initial values $r_{i0} = 0$ $\forall i$. $DT_{it}(\omega^*) = t - T^*$ when $t > T^*$ and 0 otherwise, $D_{it}(\omega^*) = 1$ if $t = T^* + 1$ and 0 otherwise, with $T^* = [\omega^* T]$ the break date with the associated break fraction $\omega^* \epsilon (0, 1)$ and $[.]$ denotes the integer part of the argument.Under the null hypothesis of y_{it} being stationary r_{it} reduces to zero and Model 3 becomes:

$$y_{it} = \alpha_i + \delta_i D_{it}(\omega^*) + \beta_i t + \gamma_i DT_{it}(\omega^*) + \epsilon_{it},$$

For testing the PSH on the basis of the general to specific methodology we shall be using solely model 3. Within the panel data framework, two models among the four models proposed in Hadri and Rao (2008) were able to allow for multiple breaks (see also Carrion-i-Silvestre, Del Barrio and López-Bazo (2005), thereafter CDL). Each of the two models is based on different break effects, i.e. breaks in the level and no trend (model 0) and breaks in both the level and the trend (model 3). The general model considered here can be written as follows:

$$y_{i,t} = \alpha_{i,t} + \beta_i t + \varepsilon_{i,t},$$

$$\alpha_{i,t} = \sum_{k=1}^{m_i} \theta_{i,k} DU_{i,k,t} + \sum_{k=1}^{m_i} \gamma_{i,k} D(T_{b,k}^i)_t + \alpha_{i,t-1} + \nu_{i,t},$$

where $\nu_{i,t} \sim i.i.d(0, \sigma_{v,i}^2)$, $\varepsilon_{i,t}$ is allowed to be serially correlated. $\{\nu_{i,t}\}$ and $\{\varepsilon_{i,t}\}$ are assumed to be mutually independent across i and over t. This assumption is relaxed later to allow for cross-sectional dependence. $D(T_{b,k}^i)_t$ and $DU_{i,k,t}$ are defined as $D(T_{b,k}^i)_t = 1$ for $t = T_{b,k}^i + 1$ and 0 elsewhere, and $DU_{i,k,t} = 1$ for $t > T_{b,k}^i$ and 0 elsewhere with $T_{b,k}^i$ denoting the kth date of break for the ith individual, $k = 1, ..., m_i$. The null hypothesis is specified as $\sigma_{v,i}^2 = 0$ for all i, under which we obtain:

$$y_{i,t} = \alpha_i + \sum_{k=1}^{m_i} \theta_{i,k} DU_{i,k,t} + \beta_i t + \sum_{k=1}^{m_i} \gamma_{i,k} D(T_{b,k}^i)_t + \nu_{i,t}. \tag{5}$$

Hence, model 0 is obtained when $\beta_i = \gamma_{i,k} = 0$, and model 3 is defined if $\beta_i \neq 0$ and $\gamma_{i,k} \neq 0$, α_i is the initial value of $\alpha_{i,t}$.

The proposed test statistic, which is based on the Hadri (2000) LM test, is expressed as:

$$LM(\lambda) = N^{-1} \sum_{i=1}^{N} (\hat{\omega}_i^{-2} T^{-2} \sum_{t=1}^{T} \hat{S}_{i,t}^2), \tag{6}$$

where $\hat{S}_{i,t}^2 = \sum_{j=1}^{t} \hat{\varepsilon}_{i,t}$ denotes the partial sum of OLS estimated residuals $\hat{\varepsilon}_{i,t}$. For each i, $\lambda_i = (\lambda_{i,1}, ..., \lambda_{i,m_i})' = (T_{b,1}^i/T, .., T_{b,m_i}^i/T)'$ indicates the locations of the breaks over T. Since autocorrelation is allowed in the residuals, $\hat{\omega}_i^2$ is a consistent long-run variance (LRV) estimate of $\hat{\varepsilon}_{i,t}$ for each i. To obtain a consistent estimator of $\hat{\omega}_i^2$, we use a nonparametric method jointly with the boundary condition rule suggested by Sul *et al.* (2003) which is shown to be effective in avoiding inconsistency problems in the KPSS-type test. Using appropriate moments and applying a Central Limit Theorem (CLT), the limiting distribution of the statistic (6) is shown to be a standard normal, that is,

$$Z(\lambda) = \frac{\sqrt{N}(LM(\lambda) - \bar{\xi})}{\bar{\varsigma}} \Longrightarrow N(0,1),$$

with

$$\bar{\xi} = N^{-1} \sum_{i=1}^{N} \xi_i, \ \overline{\varsigma^2} = N^{-1} \sum_{i=1}^{N} \varsigma_i^2.$$

The asymptotic mean and variances for each individual have been provided in CBL (2005) as follows:

$$\xi_i = A \sum_{k=1}^{m_i+1} (\lambda_{i,k} - \lambda_{i,k-1})^2; \ \varsigma_i^2 = B \sum_{k=1}^{m_i+1} (\lambda_{i,k} - \lambda_{i,k-1})^4.$$

The values of A and B equal the values of moments in Hadri (2000), that is, for model 0, $A = \frac{1}{6}$, $B = \frac{1}{45}$; for model 3, $A = \frac{1}{15}$, $B = \frac{11}{6300}$.

In the situation where break dates are unknown, the SSR procedure is employed to estimate the break points, that is, the estimated break dates are obtained by minimizing the sum of squared residuals. To estimate multiple break dates we employ the method of Bai and Perron (1998) that computes the global minimization of the sum of squared residuals (SSR), so that all the break dates are estimated via minimizing the sequence of individual $SSR(T_{b,1}^i, ..., T_{b,m_i}^i)$ computed from (5)

$$(\hat{T}_{b,1}^i, ..., \hat{T}_{b,m_i}^i) = \arg \min_{T_{b,1}^i, ..., T_{b,m_i}^i} SSR(T_{b,1}^i, ..., T_{b,m_i}^i).$$

2.1 Testing the presence of multiple structural changes

In order to obtain a consistent estimation of the number and dates of the breaks we have first to test for the presence of breaks in the series of interest. Bai and Perron (1998) suggest a sup Wald type test for the null hypothesis of no change against an alternative containing an arbitrary number of changes. They also propose a sequential test. In this paper, we use the double maximum tests which have the advantage that a pre-specification of a particular number of breaks is not required before testing the significance of the breaks. Therefore, we can test the null hypothesis of no structural break against an unknown number of breaks with given bound M of number of breaks. It is pointed out by Perron (2005) that double maximum tests can play a significant role in testing for structural changes and they are the most useful tests to apply when we want to determine if structural changes are present. In addition, it is also shown in Bai and Perron

(2005) by simulations that the double maximum tests is as powerful as the best power that can be achieved using the test that accounts for the correct number of breaks. For the Double maximum tests, the UDmax and WDmax are used and are defined as follows:

$$UD\max F_T(M,q) = \max_{1\le m\le M} \sup_{(\lambda_1,...,\lambda_m)\in\Lambda_\epsilon} F_T(\lambda_1,...,\lambda_m;q)$$

$$WD\max F_T(M,q) = \max_{1\le m\le M} \frac{c(q,\alpha,1)}{c(q,\alpha,m)} \times \sup_{(\lambda_1,...,\lambda_m)\in\Lambda_\epsilon} F_T(\lambda_1,...,\lambda_m;q)$$

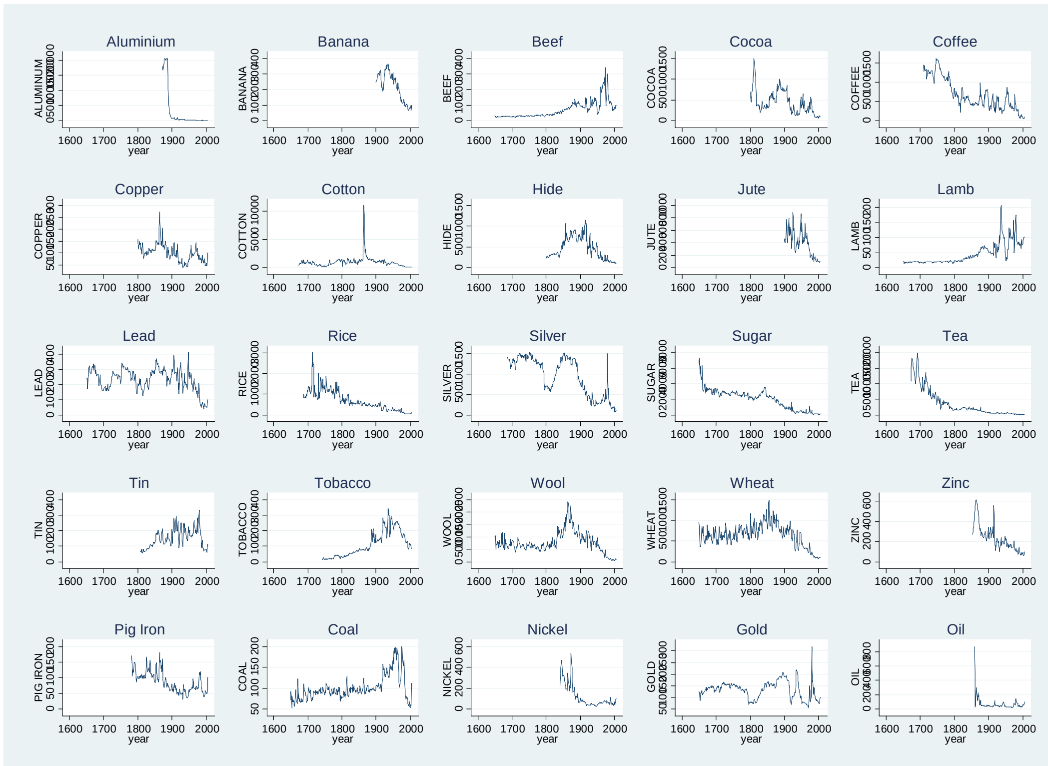
The $UDmax$ is an equal version of double maximum tests which assuming equal weights to the possible number of structural changes. And $WDmax$ applies weights to the individual tests such that the marginal p-values are equal across values of number of breaks. The values of these two tests are reported in the appropriate tables. All the $UDmax$ and $WDmax$ tests are significant at 1% significance level . This clearly shows that at least one structural break is present for any of the real primary commodity price.

3 Data

We employ 25 relative commodity prices constructed by Harvey, Kellard Madsen and Wohar (2010)[3]. They calculate these relative commodity prices by deflating the nominal commodity series with the manufacturing value-added price index. Eight relative commodity prices cover the period 1650-2005. These are: Beef, lamb, lead, sugar, wheat, wool, coal and gold. We call this set 1.The relative prices of aluminum, cocoa, coffee, copper, cotton, hide, rice, silver, tea, tin, tobacco, zinc, pig iron, nickel, and oil cover the period 1872-2005. We call this set 2, the set including all the commodity prices for which we have observations during the period 1872-2005 including set 1. Finally, the relative commodity prices of banana and jute cover the period 1900-2005. We call this set 3, the balanced panel including all the 25 relative commodity prices covering the period 1900-2005. Figure 1 shows the evolution of the natural logarithm of the 25 relative commodity prices covering the period 1900-2005. Table 1 gives the cross-sectional correlations between all the commodity prices. Overall, prices of the various commodities are positively and highly correlated indicating the presence of a common component.

[3] We thank David Harvey for providing the data.

Figure 1. Evolution of relative primary commodity prices



4 Empirical Results

4.1 Testing the Prebisch-Singer hypothesis

4.1.1 Testing the stationarity of relative commodity prices

The first step when testing the PSH is to test for the stationarity of the series in order to use the right equation to estimate the significance and the sign of the coefficient of the time trend β. As explained above, we employ a panel stationarity test allowing for serial correlation, cross-sectional dependence and endogenous multiple breaks. The maximum breaks allowed are specified as $m\max = 5$ and 8. But we report only $m\max = 5$ as the difference between the two sets of results is negligible. The numbers of breaks are determined by using the modified Schwarz Information Criterion (LWZ). The Bootstrap method is employed to correct for cross-sectional dependence. The critical values, with numbers of replications equal to 5000, are reported in the tables below. The correction for cross-sectional dependence is essential as the relative commodity prices have been shown in Table 1 to be highly correlated.

The following tables summarize the results of break $m\max = 5$ estimations. To make the best use of the information contained in the data, we consider three sets of data. In Table 2 we report the results of the panel stationarity tests for 25 commodities prices for the period 1900-2005. We first test for the presence of structural breaks in the series using $UD\max$ and $WD\max$. Both tests are significant at 1% significance level. This clearly shows that at least one structural break is present for all the relative primary commodity prices. (Similar results apply for the other sets and therefore we do not report the critical values). Then we determine the number of breaks and the break dates. The bootstrap critical values show clearly that the null hypothesis of joint stationarity of the series is not rejected at the 5% and 10% levels. In Tables 3 and 4 we carry the same tests for respectively set 1 and set 2 and for both the null hypothesis of joint stationarity of the series is not rejected at the the 5% and 10% levels. Finally, Tables 5, 6 and 7 report the piecewise regressions for respectively set 3, set 1 and set 2.

Table 1: Cross-sectional correlations between all the commodity prices

Aluminium	1.0																								
Banana	0.7	1.0																							
Beef	−0.2	−0.1	1.0																						
Cocoa	0.5	0.5	0.0	1.0																					
Coffee	0.4	0.7	0.0	0.7	1.0																				
Copper	0.2	0.0	0.3	0.6	0.4	1.0																			
Cotton	0.7	0.9	−0.1	0.7	0.8	0.2	1.0																		
Hide	0.9	0.8	−0.2	0.6	0.6	0.1	0.9	1.0																	
Jute	0.6	0.9	−0.0	0.6	0.8	0.3	0.9	0.8	1.0																
Lamb	−0.3	−0.2	0.7	−0.4	−0.3	−0.2	−0.3	−0.3	−0.3	1.0															
Lead	0.7	0.9	−0.0	0.7	0.8	0.3	0.9	0.8	0.9	−0.3	1.0														
Rice	0.8	0.9	−0.1	0.7	0.7	0.2	0.9	0.8	0.9	−0.3	0.9	1.0													
Silver	0.6	0.5	0.2	0.7	0.6	0.4	0.6	0.6	0.6	−0.1	0.6	0.6	1.0												
Sugar	0.7	0.7	−0.1	0.7	0.6	0.3	0.9	0.8	0.8	−0.3	0.8	0.9	0.7	1.0											
Tea	0.7	0.9	−0.0	0.7	0.8	0.2	0.9	0.8	0.9	−0.2	0.9	0.9	0.6	0.7	1.0										
Tin	0.4	0.6	0.3	0.7	0.7	0.4	0.7	0.5	0.7	0.0	0.7	0.7	0.8	0.6	0.7	1.0									
Tobacco	0.1	0.6	0.2	0.2	0.6	−0.1	0.6	0.3	0.6	0.1	0.6	0.5	0.3	0.4	0.7	0.5	1.0								
Wheat	0.8	0.9	−0.1	0.7	0.7	0.2	0.9	0.9	0.9	−0.3	0.9	0.9	0.7	0.9	0.9	0.6	0.5	1.0							
Wool	0.8	0.9	−0.2	0.6	0.7	0.1	0.9	0.9	0.9	−0.3	0.9	0.9	0.6	0.8	0.9	0.6	0.6	0.9	1.0						
Zinc	0.8	0.8	−0.1	0.7	0.6	0.4	0.9	0.9	0.8	−0.3	0.9	0.9	0.7	0.9	0.8	0.7	0.4	0.9	0.8	1.0					
Pig iron	−0.1	−0.1	0.4	0.3	0.2	0.5	−0.1	−0.2	0.0	0.1	0.0	0.0	0.4	0.0	0.0	0.4	0.0	−0.1	−0.1	0.0	1.0				
Coal	0.1	0.6	0.2	0.4	0.7	0.1	0.6	0.3	0.6	0.0	0.6	0.5	0.4	0.4	0.6	0.6	0.8	0.5	0.6	0.4	0.2	1.0			
Nickel	0.1	−0.2	0.2	0.3	−0.0	0.7	−0.2	−0.2	−0.2	0.0	−0.1	0.0	0.2	0.0	−0.1	0.1	−0.4	−0.2	−0.2	0.0	0.6	−0.1	1.0		
Gold	0.5	0.3	0.0	0.3	0.1	−0.1	0.2	0.4	0.1	0.1	0.2	0.4	0.5	0.4	0.2	0.4	−0.1	0.3	0.3	0.4	0.2	0.0	0.1	1.0	
Oil	−0.1	−0.2	0.1	−0.1	−0.2	−0.3	−0.1	0.0	−0.3	0.2	−0.2	−0.1	0.1	0.0	−0.2	0.1	−0.1	−0.1	−0.1	−0.1	0.1	0.0	−0.1	0.4	1.0

Table 2. Summary of estimated numbers and location of structural breaks
(m max=5)
(25 commodities from 1900-2005, set 3)

Commodities	Estimated Break Dates ($m\max = 5$)					$UDmax$	$WDmax$
	TB_1	TB_2	TB_3	TB_4	TB_5		
Aluminum	1918	1941				78.26	171.84
Banana	1916	1931	1971			238.01	425.41
Beef	1950	1965				140.58	177.83
Cocoa	1947	1973	1989			85.27	187.22
Coffee	1949	1987				131.79	175.55
Copper	1947	1975				111.57	141.14
Cotton	1930	1946				319.80	568.25
Hide	1921	1952				32.57	35.92
Jute	1947					104.15	209.73
Lamb	1935	1950	1965			285.48	427.24
Lead	1947	1982				120.11	151.94
Rice	1982					75.66	113.09
Silver	1940	1979				139.94	177.02
Sugar	1925	1965	1982			31.01	68.08
Tea	1922	1954	1986			321.52	571.30
Tin	1986					75.54	95.56
Tobacco	1918	1968				497.30	629.10
Wheat	1946					34.91	57.25
Wool	1948	1991				187.97	237.78
Zinc	1918	1948				23.42	46.14
Pig Iron	1933	1948	1987			56.43	100.28
Coal	1966	1984				166.29	365.12
Nickel	1931	1950	1991			142.47	312.81
Gold	1917	1934	1957	1979		288.03	632.42
Oil	1946	1974	1991			76.22	122.49

Panel Stationarity test	Statistics Value	Bootstrap Critical Values	
		10%	5%
Homogeneous variance	5.498	12.521	12.911
Heterogeneous variance	3.009	4.939	5.414

Table 3. Summary of estimated numbers and location of structural breaks
($m\,\text{max}$=5)
(8 commodities from 1650-2005, set 1)

Commodities	Estimated Break Dates ($m\,\text{max} = 5$)				
	TB_1	TB_2	TB_3	TB_4	TB_5
Beef	1793	1876	1952		
Lamb	1793	1894	1947		
Lead	1721	1793	1851	1946	
Sugar	1833				
Wheat	1837	1945			
Wool	1793	1875	1947		
Coal	1892	1952			
Gold	1793	1913			

Panel Stationarity test	Statistics Value	Bootstrap Critical Values	
		10%	5%
Homogeneous variance	0.176	2.706	3.290
Heterogeneous variance	2.207	2.526	3.096

Table 4. Summary of estimated numbers and location of structural breaks
(m max=5)
(23 commodities from 1872-2005, set 2)

Commodities	Estimated Break Dates ($m\max = 5$)				
	TB_1	TB_2	TB_3	TB_4	TB_5
Aluminum	1891	1918	1940		
Beef	1949	1969			
Cocoa	1907	1946	1985		
Coffee	1949				
Copper	1898	1946	1974		
Cotton	1945				
Hide	1920	1951			
Lamb	1934	1955			
Lead	1946	1981			
Rice	1981				
Silver	1939	1978			
Sugar	1928	1981			
Tea	1922	1953	1985		
Tin	1985				
Tobacco	1894	1917	1967		
Wheat	1945				
Wool	1947	1982			
Zinc	1917	1947			
Pig Iron	1948	1985			
Coal	1964	1984			
Nickel	1899	1949			
Gold	1916	1938	1958	1978	
Oil	1915	1973			

Panel Stationarity test	Statistics Value	Bootstrap Critical Values	
		10%	5%
Homogeneous variance	1.849	4.380	5.103
Heterogeneous variance	2.624	3.988	4.619

4.1.2 Piecewise regressions

After determining the presence, the numbers and the locations of structural breaks for the above relative commodity prices, we consider piecewise regressions to examine the signs, the significance and change of signs over time of the slopes of these regressions. The logarithm of the relative commodity prices are used in the regressions. For each commodity we fit a linear trend model, i.e., $y_t = \alpha + \beta t + \varepsilon_t$ before and after the break dates. The results are summarized in tables 5, 6 and 7 for the three sets considered in this paper. $\hat{\beta}_m$ represents the estimated slope for the linear regression model before the m^{th} structural break. The values in bracket are the p-values for the corresponding parameters.

Table 5. Piecewise regression results (m max=5)
(25 commodities from 1900-2005, set 3)

Commodities	Piecewise Regression				
	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$	$\hat{\beta}_5$
Aluminum	-0.03*(0.01)	-0.01(0.18)	-0.01*(0.00)		
Banana	0.01(0.00)	0.04(0.00)	-0.02*(0.00)	-0.02*(0.00)	
Beef	0.01(0.00)	0.12(0.00)	-0.03*(0.00)		
Cocoa	-0.04*(0.00)	-0.02*(0.00)	-0.05*(0.00)	0.004(0.32)	
Coffee	-0.006*(0.02)	-0.02*(0.00)	-0.044*(0.00)		
Copper	-0.02*(0.00)	0.02(0.00)	-0.02*(0.00)		
Cotton	0.00(0.19)	0.01(0.21)	-0.04*(0.00)		
Hide	0.02(0.00)	-0.001(0.39)	-0.02*(0.00)		
Jute	-0.01*(0.00)	-0.04*(0.00)			
Lamb	0.02(0.00)	-0.07*(0.00)	0.12(0.00)	-0.01*(0.01)	
Lead	-0.01*(0.00)	-0.02*(0.00)	-0.01(0.17)		
Rice	-0 .01*(0.00)	-0.01(0.21)			
Silver	-0.02*(0.00)	0.02(0.00)	-0.08*(0.00)		
Sugar	-0.004(0.27)	-0.002(0.30)	0.04(0.09)	-0.02*(0.00)	
Tea	-0.04*(0.00)	-0.004(0.18)	-0.05*(0.00)	-0.01(0.12)	
Tin	0.001(0.18)	-0.02*(0.00)			
Tobacco	0.004(0.07)	0.003(0.049)	-0.03*(0.00)		
Wheat	-0.02*(0.00)	-0.03*(0.00)			
Wool	-0.006*(0.00)	-0.05*(0.00)	0.02(0.05)		
Zinc	0.02(0.03)	0.00(0.49)	-0.02*(0.00)		
Pig Iron	-0.014*(0.00)	-0.04*(0.00)	0.01(0.00)	0.003(0.36)	
Coal	0.01(0.00)	0.02(0.01)	-0.02*(0.01)		
Nickel	-0.04*(0.00)	-0.04*(0.00)	0.01(0.00)	0.03(0.02)	
Gold	-0.02*(0.00)	0.02(0.00)	-0.05*(0.00)	0.01(0.02)	-0.03*(0.00)
Oil	0.01(0.00)	-0.02*(0.00)	-0.02(0.17)	0.05(0.00)	

Table 6. Piecewise regression results (m max=5)
(8 commodities from 1650-2005, set 1)

Commodities	Piecewise Regression				
	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$	$\hat{\beta}_5$
Beef	0.002(0.00)	0.014(0.00)	-0..002*(0.03)	-0.01*(0.02)	
Lamb	0.001(0.00)	0.014(0.00)	0.02(0.00)	0.018(0.00)	
Lead	-0.01*(0.00)	0.00(0.05)	0.01(0.00)	-0.01*(0.00)	-0.03*(0.00)
Sugar	-0.003*(0.00)	-0.02*(0.00)			
Wheat	0.00(0.00)	-0.01*(0.00)	-0.03*(0.00)		
Wool	-0.002*(0.00)	0.02(0.00)	-0.01*(0.00)	-0.05*(0.00)	
Coal	0.001(0.00)	0.01(0.00)	-0.02*(0.00)		
Gold	0.001(0.001)	0.01(0.00)	-0.003*(0.01)		

Table 7. Piecewise regression results ($m\,\mathrm{max}$=5)
(23 commodities from 1872-2005, set 2)

Commodities	Piecewise Regression				
	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$	$\hat{\beta}_5$
Aluminum	-0.03*(0.003)	-0.07*(0.00)	-0.01(0.18)	-0.012*(0.00)	
Beef	0.00(0.358)	0.10(0.00)	-0.04*(0.00)		
Cocoa	0.01(0.002)	-0.04*(0.00)	-0.01*(0.04)	-0.02*(0.012)	
Coffee	-0.01*(0.00)	-0.04*(0.00)			
Copper	-0.02*(0.00)	-0.02*(0.00)	0.02(0.00)	-0.02*(0.00)	
Cotton	-0.01*(0.00)	-0.04*(0.00)			
Hide	0.002(0.14)	-0.001(0.39)	-0.02*(0.00)		
Lamb	0.001(0.16)	-0.10*(0.00)	0.00(0.46)		
Lead	-0.004*(0.00)	-0.02*(0.00)	-0.01(0.17)		
Rice	-0.01*(0.00)	-0.01(0.21)			
Silver	-0.024*(0.00)	0.02(0.00)	-0.08*(0.00)		
Sugar	-0.02*(0.00)	-0.003(0.22)	-0.02*(0.00)		
Tea	-0.03*(0.00)	-0.01*(0.01)	-0.05*(0.00)	-0.01(0.12)	
Tin	0.004(0.00)	-0.02*(0.00)			
Tobacco	0.05(0.00)	-0.00(0.35)	0.003(0.05)	-0.03*(0.00)	
Wheat	-0.012*(0.00)	-0.03*(0.00)			
Wool	-0.01*(0.00)	-0.05*(0.00)	-0.02*(0.02)		
Zinc	0.001(0.294)	0.00(0.49)	-0.02*(0.00)		
Pig Iron	-0.01*(0.00)	0.01(0.00)	-0.004(0.32)		
Coal	0.01(0.00)	0.01(0.17)	-0.012*(0.05)		
Nickel	-0.07*(0.00)	-0.02*(0.00)	0.002(0.16)		
Gold	0.00(0.37)	0.04(0.00)	-0.05*(0.00)	0.02(0.01)	-0.04*(0.00)
Oil	-0.02*(0.00)	-0.02*(0.00)	-0.02*(0.02)		

4.1.3 Analysis of the results of the Prebisch-Singer testing

Tables 2 and 5 report the results for set 3. Table 2 indicates the timing and the number of breaks for the 25 primary commodities whereas Table 5 shows the corresponding significance and sign of the slopes of the piecewise regressions. Four commodities have 1 break, thirteen have 2 breaks, seven register 3 breaks and only one (gold) has 4 breaks. Out of the total of 80 slope estimates, 41 are negative and significant, 11 are negative but insignificant, 21 are positive and significant finally, 7 are positive and insignificant. Tables 3 and 6 concern set 1. One commodity has one break (sugar), three commodities have 2 breaks, three other commodities are affected by 3 breaks and one commodity has 4 breaks. Of the 27 slope estimates, 13 are negative and significant, 13 other are positive and significant and one is positive but insignificant. Table 4 and Table 7 deal with set 2. Five commodities have one break, twelve have 2 breaks, five have 3 breaks and one commodity has four breaks. Of the 71 slope estimates. forty four are negative and significant, 7 are negative but insignificant, 11 are positive and significant and 9 are positive but insignificant. These results seem to indicate that in the majority of cases the PSH is not rejected.

4.1.4 Drivers of structural breaks

We make a first attempt at identifying the potential drivers of those breaks by simply matching breaks to historical events(see Appendix Table). For the investigation of the drivers of the breaks, we shall consider for each commodity price only its longest series. The appendix table presents a tentative list of drivers behind those breaks based on historical accounts of the development in primary commodity markets. We draw from various sources including Radetzki (2011). In the following, we summarize the main take aways from those historical developments which help explain the presence of breaks in commodity prices series.

The share of the primary sector in GDP has declined steadily overtime in advanced economies (see Radetzki, 2011). Recently, most of the total consumption growth of primary commodities has taken place in emerging economies like China. For instance, its share of total consumption growth in this century was 50%. In the case of copper China's utilization between 2000 and 2008 corresponds to 113% of total increase Cochilco (2009). Also, China's import growth of iron ore between 2000 and 2009 corresponded to 125% of total import growth (UNCTAD, 2010). The decline in the share of the commodity sector in GDP can also be explained by the growing ability to create man made substitutes.

Another aspect analysed by Radetzki (2011) is the role of relentlessly falling transport costs in shaping and expanding primary commodity markets since the 19th century. Up to mid-19th century, shipment rates on long hauls were prohibitively high. Only high value primary commodities like coffee, cocoa, spices and precious or semi-precious metals could be transported. However, towards the end of the second-half of the 19th century, the use of the steam technology made long hauls transport more affordable and benefited primary commodities like cotton, wheat and wool. Also, the introduction around 1880s of refrigeration made possible the transport of meat and fruit over long distances. Between 1950 and 1970 steady improvements in specialized bulk carriers lead to dramatic fall in the transport costs of heavy primary commodities like iron ore, coal, bauzite and oil.

Finally, state intervention starting early 1930s and beginning to fade in 1970s may had some effects on the formation of prices of primary commodities. Radetzki (2011) considers four main factors explaining state intrusion in primary commodity production and commerce: (1) the Great Depression of 1930s led to the price collapse of many primary commodities like wheat, sugar and rubber. (2) the second world war provoked havoc in the supply routes of numerous commodities including sugar, wheat, coffee and tin. (3) the breakup of colonial empires affected greatly the functioning of primary commodity markets (buying at above market prices, food aid...), (4) the period 1925 to 1975 witnessed the wide spread belief in collectivism. But since the 1980s government control started to fade except notably in oil industries where it remains strong.

The appendix tables provide numerous examples of cases where we identified that changes in transportation technology and in the structure of commodity markets coincide with structural breaks in commodity prices.

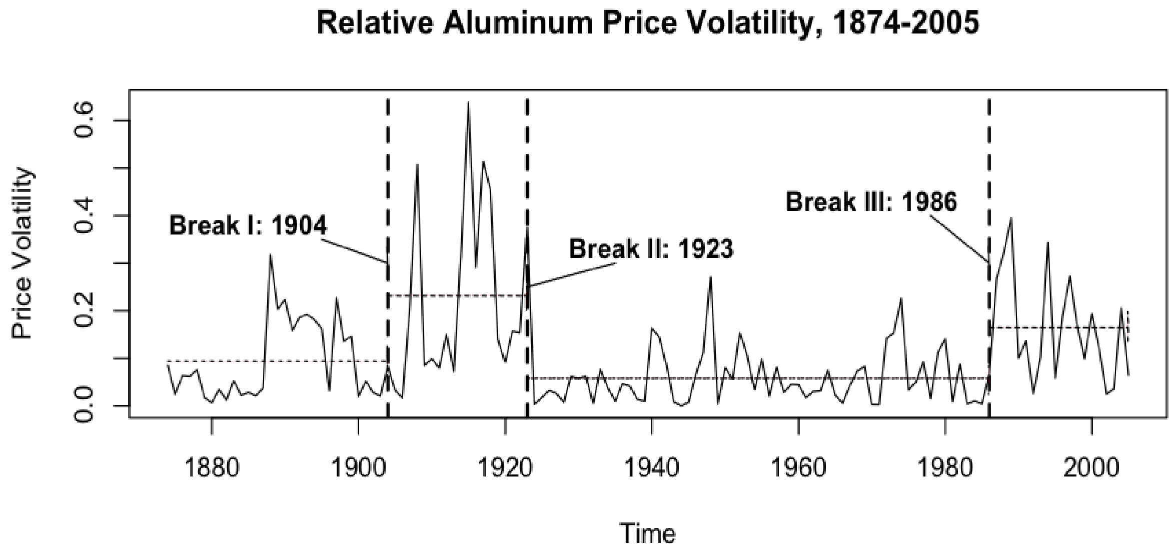
4.2 Volatility of relative commodity prices

We now turn to examining the volatility of commodity prices. As in Dvir and Rogoff (2009), we define volatility as the mean absolute residual from a regression of a given relative primary commodity price growth on its lagged value. It is well documented that primary commodity prices are relatively highly volatile and this volatility is time varying (Mintz (1967), Reinhart and Wickham (1994) and Dvir and Rogoff (2009) for oil). In contrast, manufactured good prices have been found to be less volatile. By volatility, we refer to short term movements of primary commodity prices to be distinguished from medium and long term cycles that are another characteristics of primary commodity prices. It has also been found that commodity price variability is large relatively to the secular trend.

In order to find periods of high price instability, we test for multiple breaks in commodity price volatility employing the methods proposed by Bai and Perron (1998, 2003).The results are reported graphically below

4.2.1 Analysis of the volatility results

Ten price volatilities are found without breaks. These include copper, pig iron, silver, tin, banana, coffee, jute, tobacco, wheat, and oil. This is surprising particularly concerning the price volatility of oil which is perceived to be very volatile. Dvir and Rogoff (2009) find three break points for the price volatility of oil. However, it should be noted that (1) they use real oil price whereas we use oil price relative to a price index of manufactures, (2) they consider the period 1861-2008, while we use observations starting in 1874 and ending in 2005

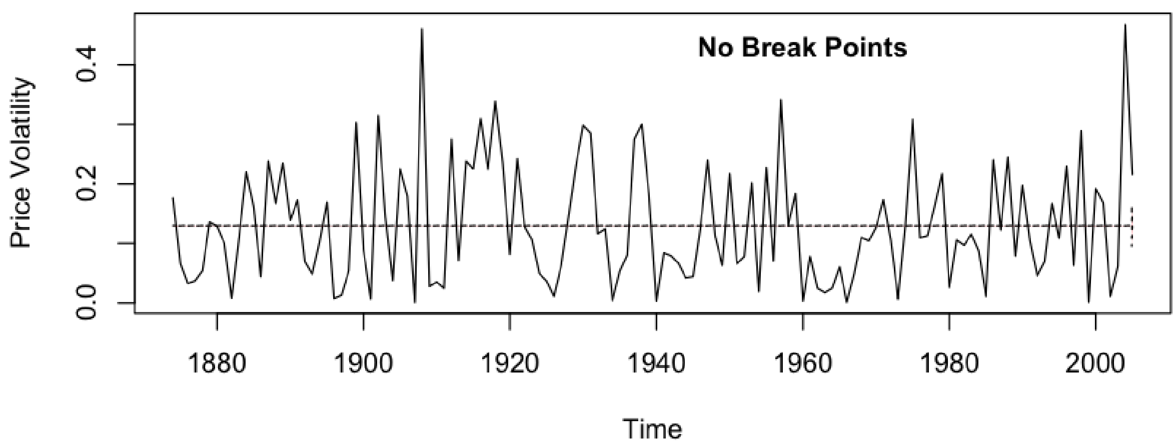


and (3) the results may depend on the various criteria used by Bai and Perron (2008) which do not always agree as noted by Dvir and Rogoff (2009). Eight price volatilities are affected by one break: gold in 1932, lead in 1913, cocoa in 1913, rice in 1965, sugar in 1912, beef in 1913, lamb in 1914 and coal in 1704. Three primary commodity relative price volatilities indicates two breaks. These are; nickel (1902 and 1985), zinc (1911 and 1938), hide (1917 and 1938), wool (1713 and 1966). Finally, only aluminium has three break points in 1904, 1923 and 1986. Some more research is needed to find the cause of these breaks. In general, it seems that volatility has increased for most primary commodities in recent years.

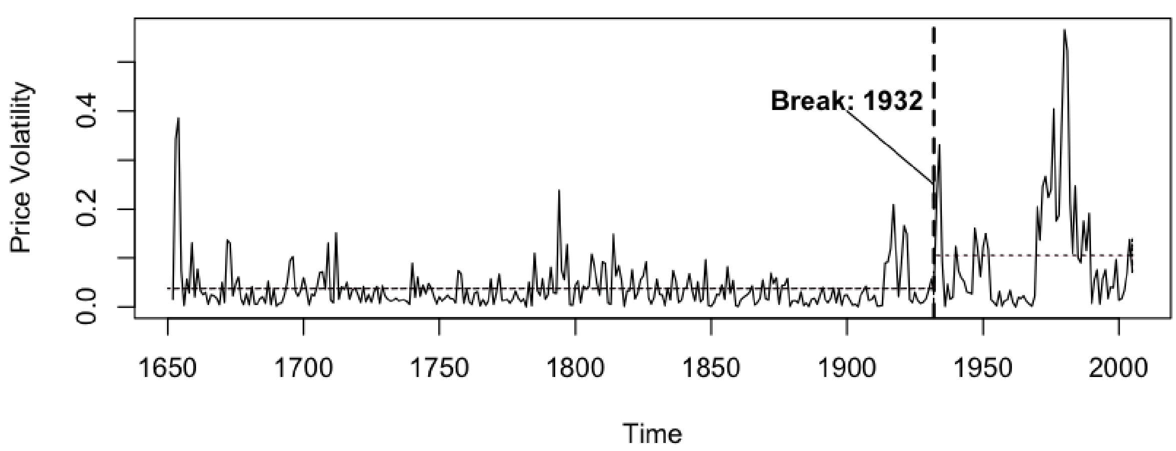
In this section, we do not attempt to match systematically the breaks in the volatility in commodity price series with historical developments. However, we summarize the main findings from the literature on the potential drivers of volatility.

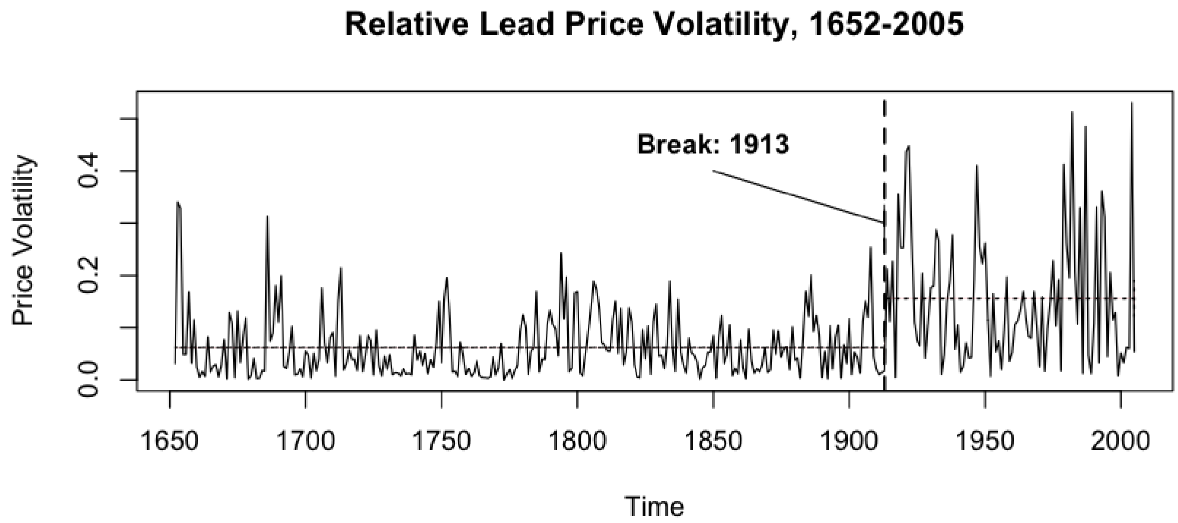
Cashin and McDermott (2002) describe primary commodity price volatilities as rapid, unexpected and often as large changes in primary commodity prices. They noted an increase in the amplitude of price movements around 1899. Some authors found that since the breakdown of the Bretton Woods exchange regime, real commodity prices have exhibited increasing variability since early 1970 (Chu and Morrisson (1984), Reinhart and Wickham (1994) and Cuddington and Liang (1999)). The price elasticity of demand for raw materials is generally small because its cost represents only a tiny fraction of the final product price. Therefore, an increase in the demand for finished products will cause a greater increase in the demand for the primary materials used due to

Relative Copper Price Volatility, 1874-2005

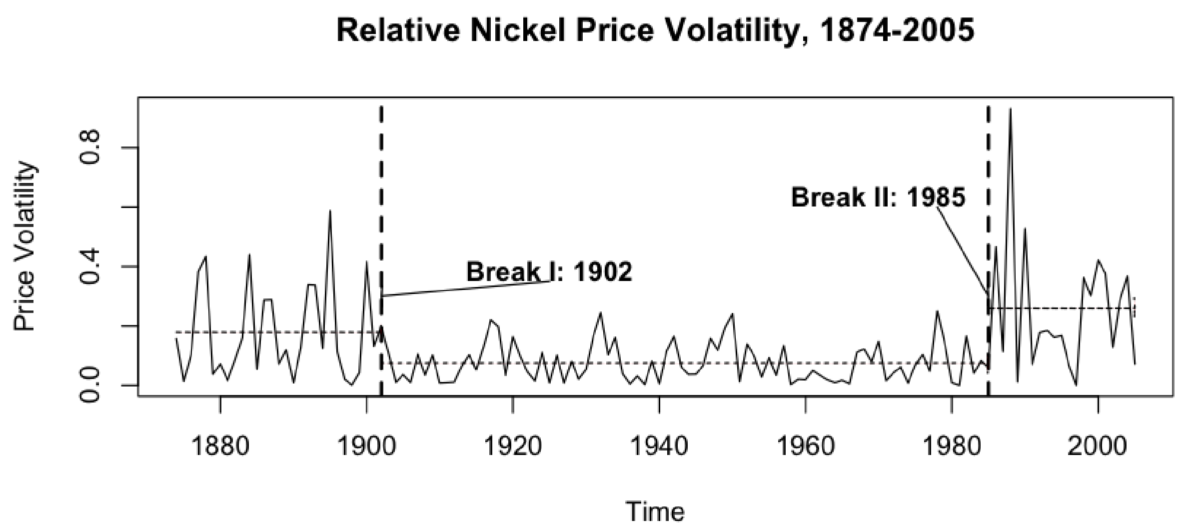


Relative Gold Price Volatility, 1652-2005

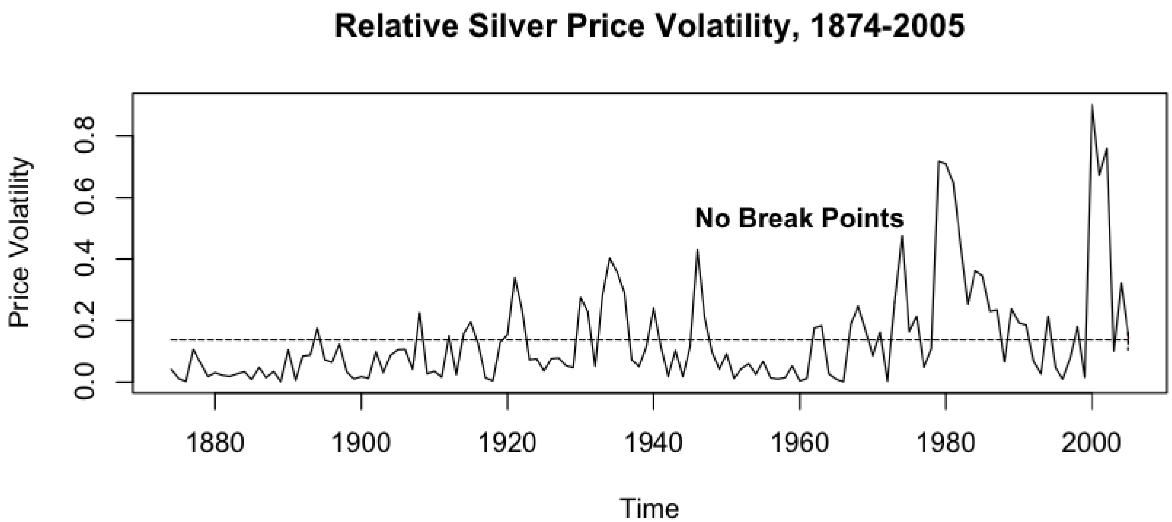




Relative Lead Price Volatility, 1652-2005
Break: 1913
Price Volatility
0.0
0.2
0.4
1650
1700
1750
1800
1850
1900
1950
2000
Time



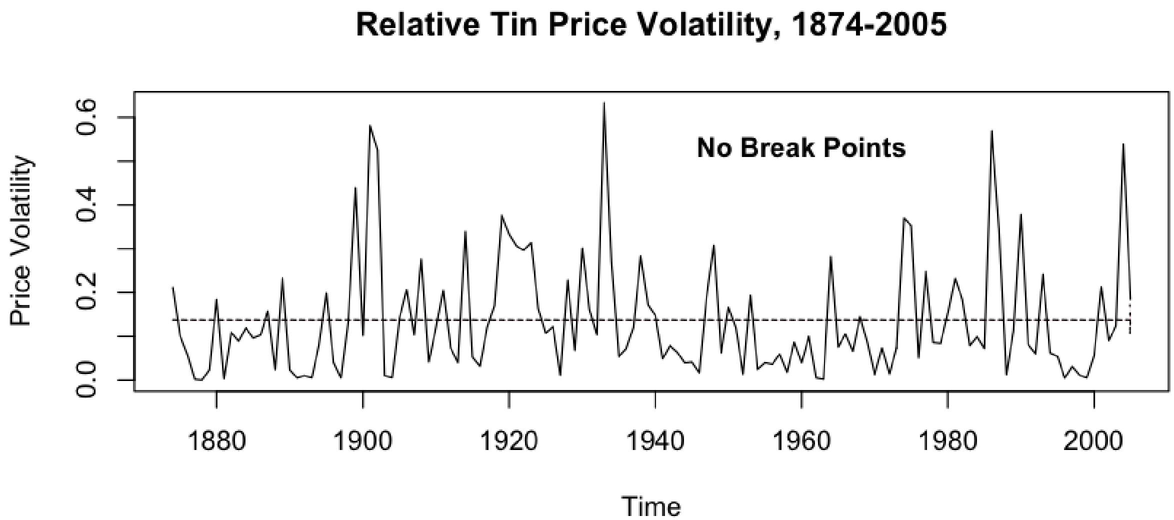
Relative Nickel Price Volatility, 1874-2005
Break I: 1902
Break II: 1985
Price Volatility
0.0
0.4
0.8
1880
1900
1920
1940
1960
1980
2000
Time

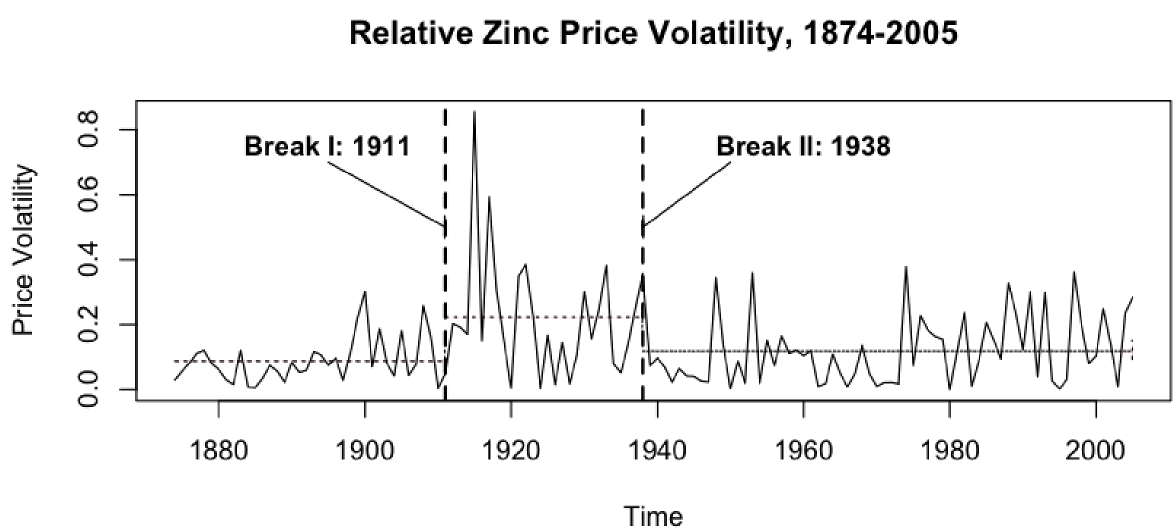


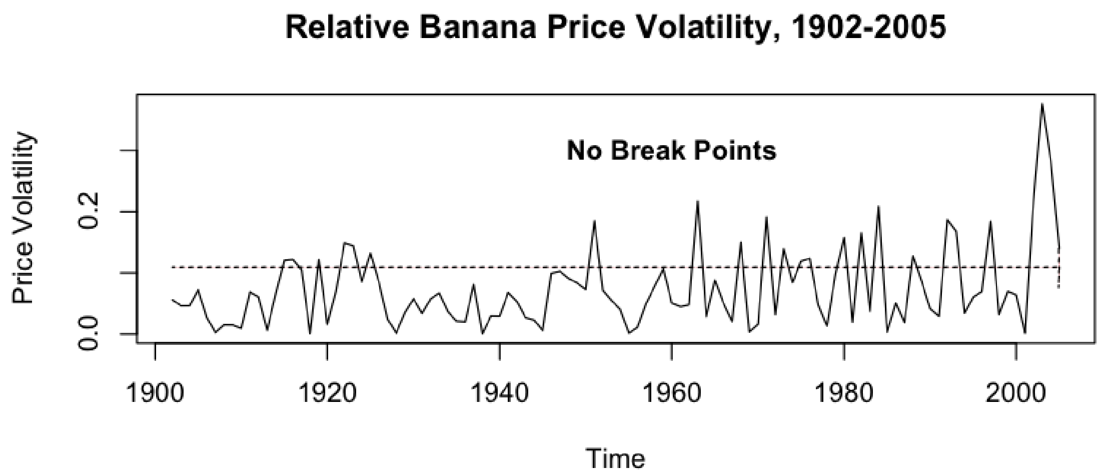
the necessary increase of inventories of finished product which will affect the entire production chain.

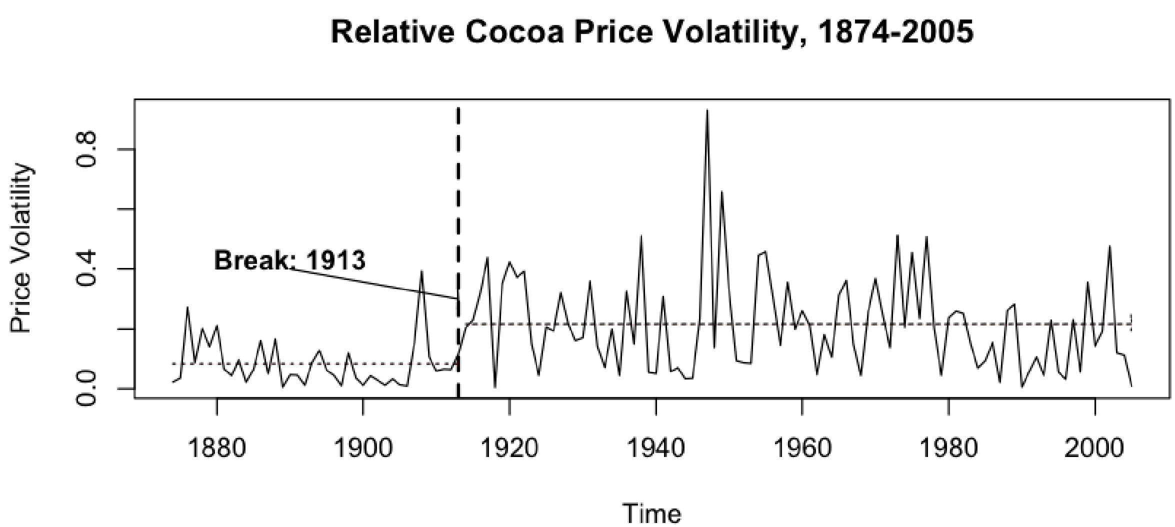
Fluctuations in supply also contribute to price volatility. The weather is a factor that can affect the price stability of agricultural products although its importance has diminished in recent decades due to the geographical diversification of production. Important strikes or major technical accidents can be the cause of significant decrease in mineral supply. The price elasticity of supply is generally low, particularly at around full capacity which is often the case in competitive markets. Consequently, it takes considerable time to increase supply capacity and in the interim even tiny variations in demand will result in considerable change in price. Wars or expected wars are another cause of sharp change in primary commodity prices.

Since World War II, three commodity booms have occurred, 1950, 1973 and 2003 (see Radetzki, 2006). They were all generated by demand shocks due to rapid macroeconomic expansion. The first two commodity booms subsided in 1952 and 1974 respectively, less than two years after their birth. During the more recent boom, prices increased sharply (food prices by more than 50% and fuel prices doubled) from 2003 and lasted until the first-half of 2008. This was followed in the second-half of 2008 by a severe global contraction which stayed until the end of 2009. Then, commodity prices increased dramatically again. This commodity price recovery is thought to be due to the major emerging economies and possibly to slack monetary policy and the recent inflows of speculative capital into commodity markets.

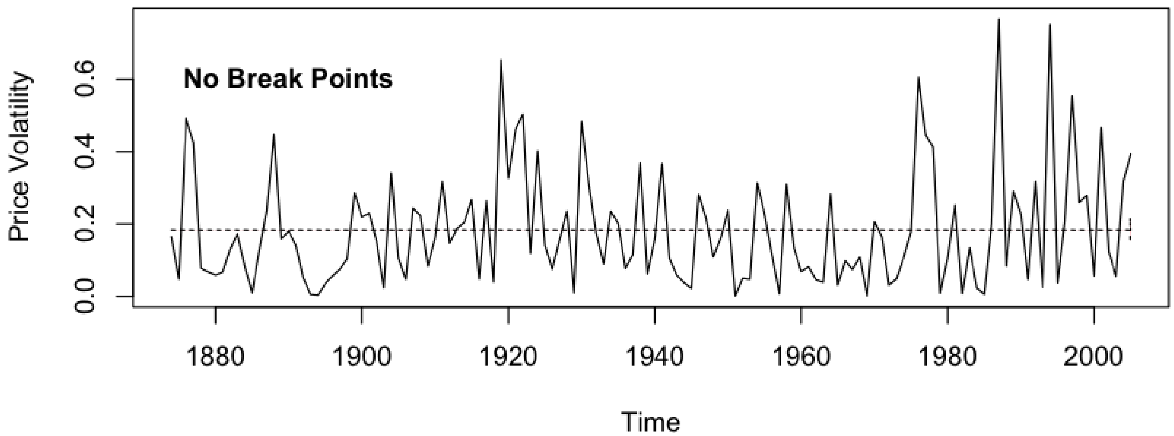

Relative Tin Price Volatility, 1874-2005
No Break Points
Price Volatility
0.0
0.2
0.4
0.6
1880
1900
1920
1940
1960
1980
2000
Time


Relative Zinc Price Volatility, 1874-2005
Break I: 1911
Break II: 1938
Price Volatility
0.0
0.2
0.4
0.6
0.8
1880
1900
1920
1940
1960
1980
2000
Time

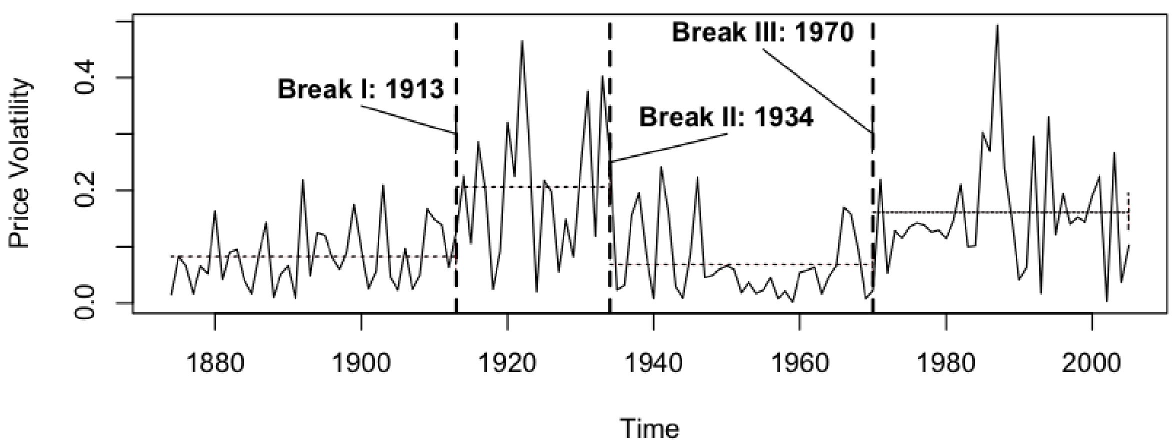

Relative Banana Price Volatility, 1902-2005
No Break Points
Price Volatility
0.0
0.2
1900
1920
1940
1960
1980
2000
Time

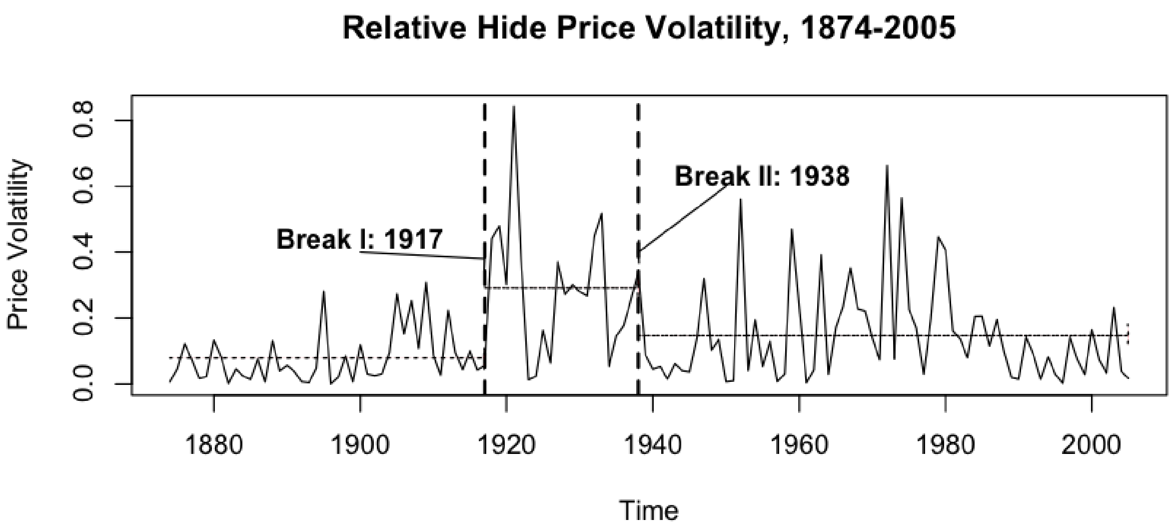

Relative Cocoa Price Volatility, 1874-2005
Break: 1913
Price Volatility
0.0
0.4
0.8
1880
1900
1920
1940
1960
1980
2000
Time

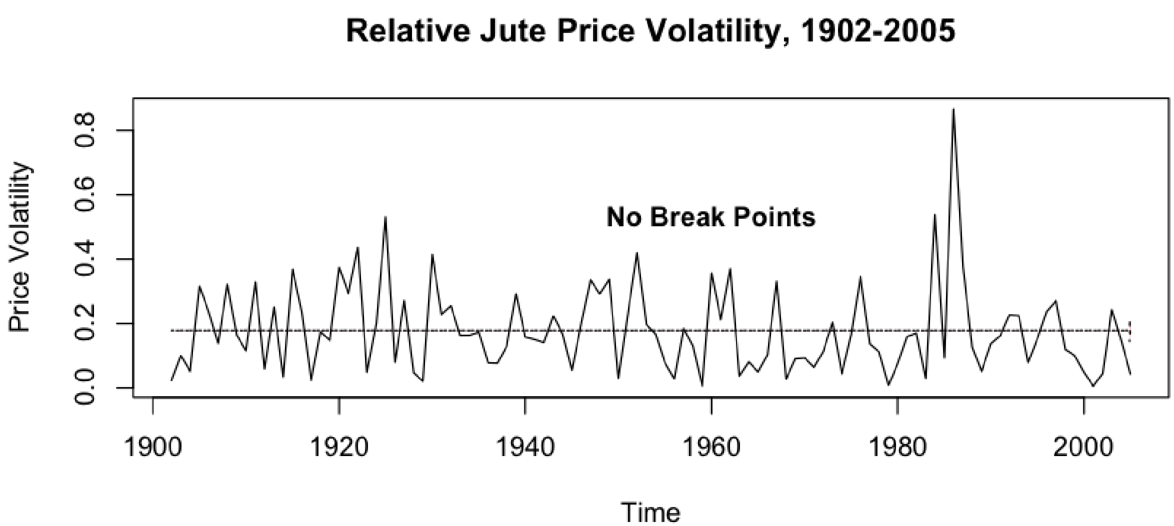
Relative Coffee Price Volatility, 1874-2005

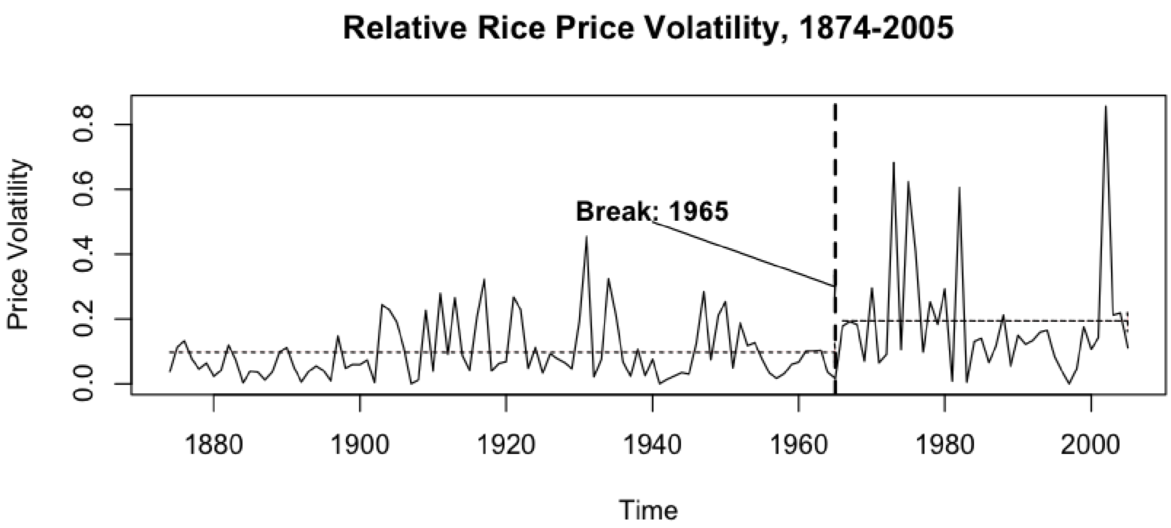


Relative Cotton Price Volatility, 1874-2005

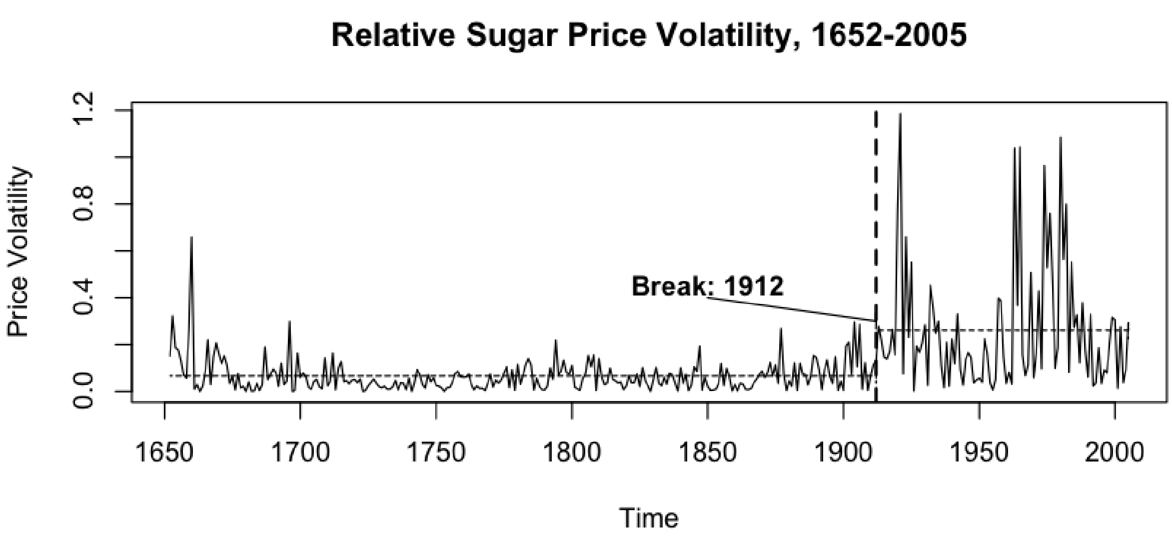



Relative Hide Price Volatility, 1874-2005
Price Volatility
0.0
0.2
0.4
0.6
0.8
Break I: 1917
Break II: 1938
1880
1900
1920
1940
1960
1980
2000
Time

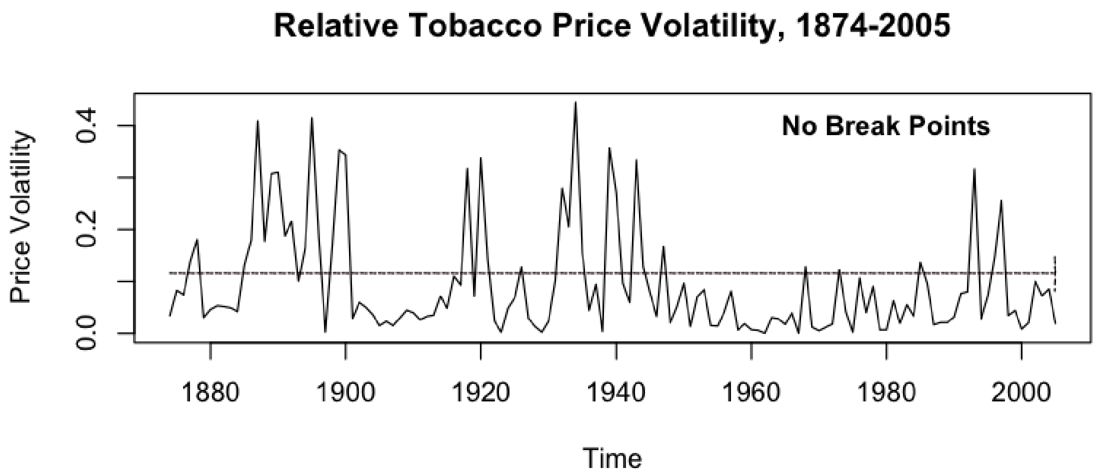

Relative Jute Price Volatility, 1902-2005
Price Volatility
0.0
0.2
0.4
0.6
0.8
No Break Points
1900
1920
1940
1960
1980
2000
Time

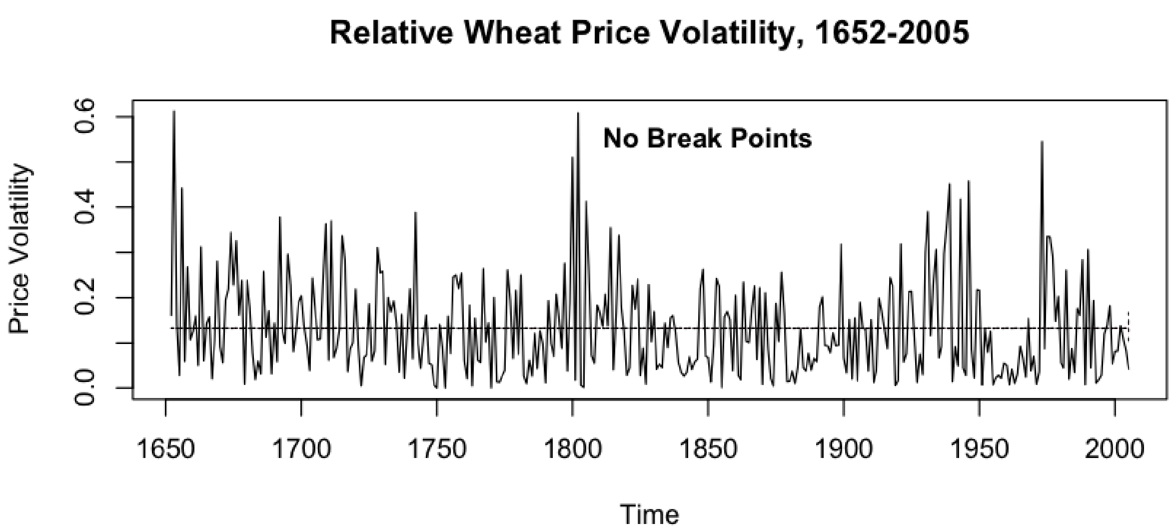


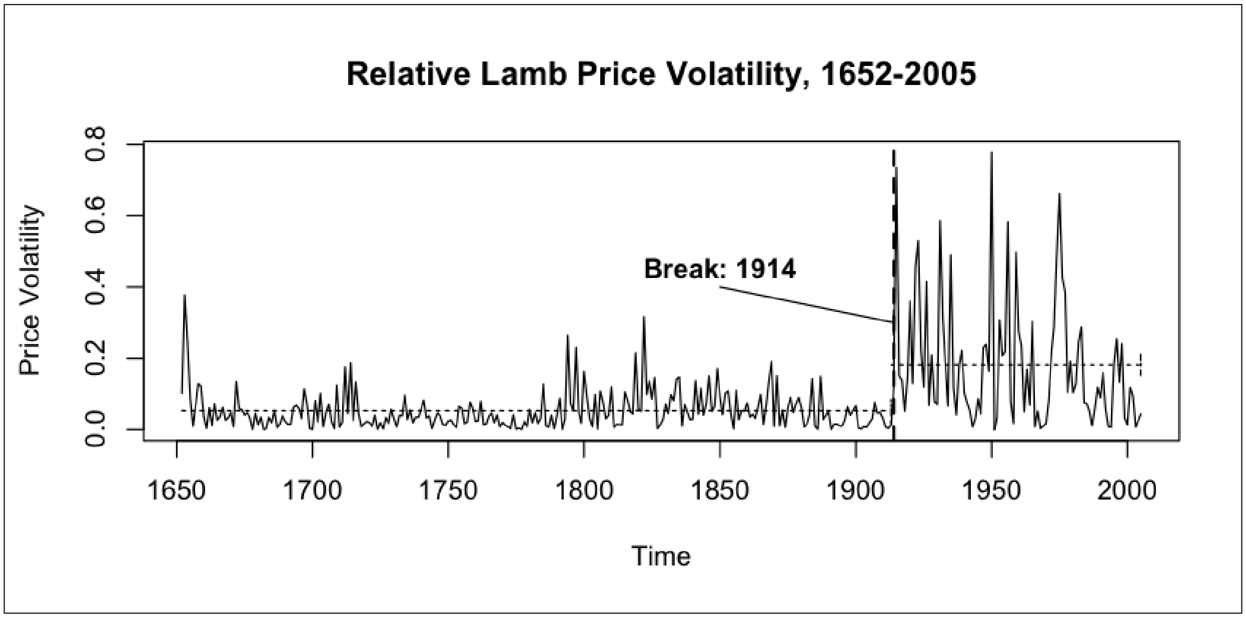
Relative Rice Price Volatility, 1874-2005
Price Volatility
0.0
0.2
0.4
0.6
0.8
Break: 1965
1880
1900
1920
1940
1960
1980
2000
Time

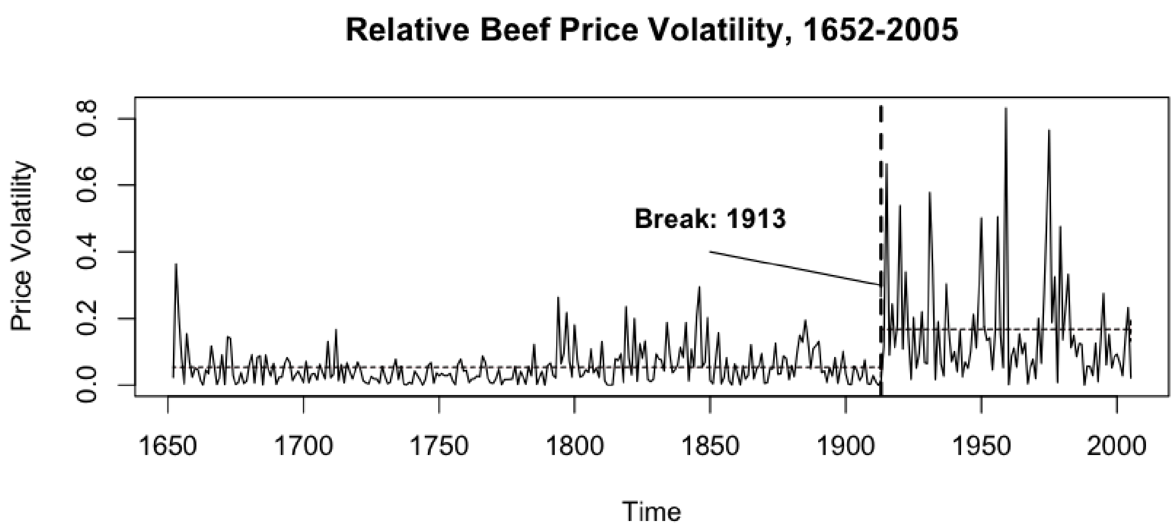


Relative Sugar Price Volatility, 1652-2005
Price Volatility
0.0
0.4
0.8
1.2
Break: 1912
1650
1700
1750
1800
1850
1900
1950
2000
Time

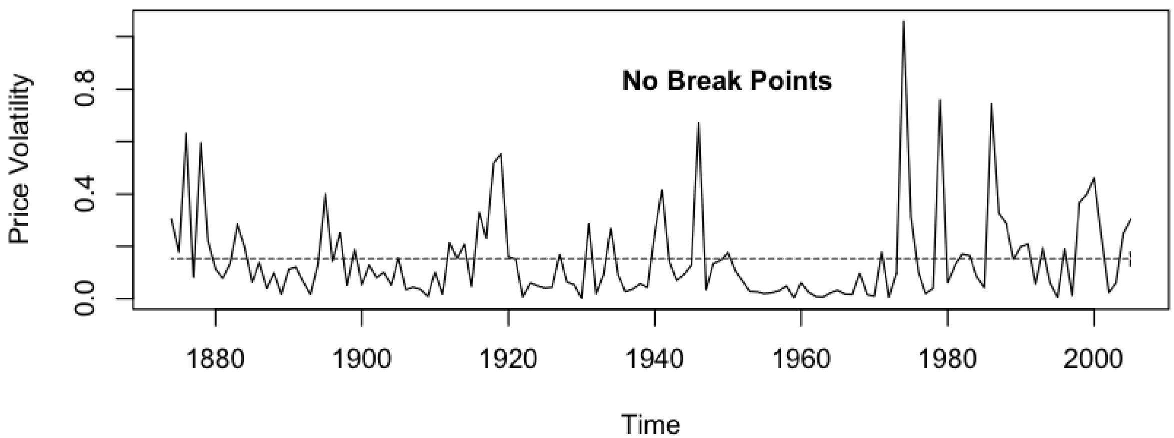

Relative Tobacco Price Volatility, 1874-2005
No Break Points
Price Volatility
0.0
0.2
0.4
1880
1900
1920
1940
1960
1980
2000
Time


Relative Wheat Price Volatility, 1652-2005
No Break Points
Price Volatility
0.0
0.2
0.4
0.6
1650
1700
1750
1800
1850
1900
1950
2000
Time

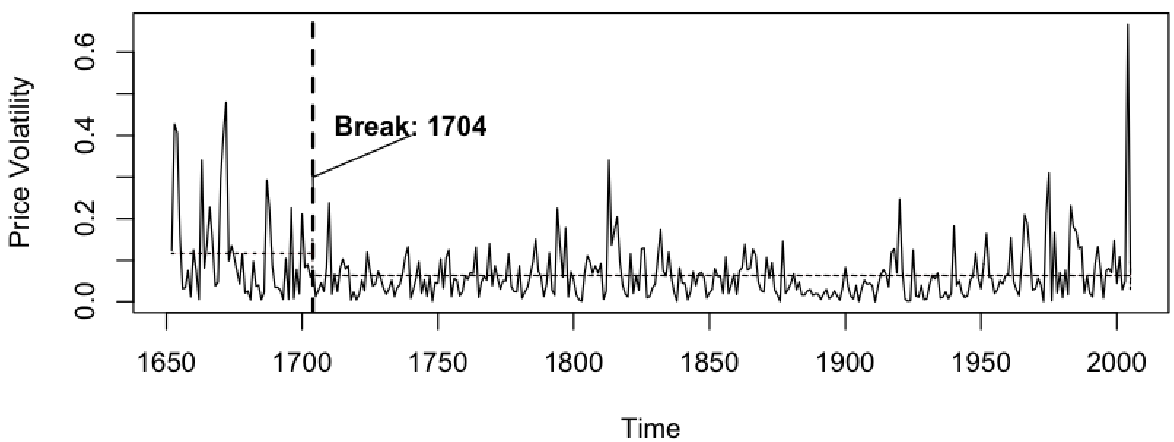

Relative Lamb Price Volatility, 1652-2005
Price Volatility
0.0
0.2
0.4
0.6
0.8
Break: 1914
1650
1700
1750
1800
1850
1900
1950
2000
Time


Relative Beef Price Volatility, 1652-2005
Price Volatility
0.0
0.2
0.4
0.6
0.8
Break: 1913
1650
1700
1750
1800
1850
1900
1950
2000
Time

Relative Oil Price Volatility, 1874-2005



Relative Coal Price Volatility, 1652-2005



5 Conclusions

In this paper, we re-examined the Prebisch-Singer hypothesis employing 25 relative primary commodity prices observed over more than three-and-half centuries. We found that all the series are stationary employing powerful panel stationarity tests accounting for data driven structural breaks. The results on the Prebisch-Singer hypothesis tests are mixed. However, the majority of the piecewise regressions have downward slopes. We also reviewed some potential drivers of structural breaks.We also investigated the volatility and data driven structural breaks of primary commodity prices. Primary commodity prices are found to be highly volatile with often time varying volatility. In general the volatility has the tendency to increase during the recent years.

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Beef 1650-2005	1793 Start of the Industrial Revolution	1876 First shipment of frozen beef arrived in New Orleans(June 1869); steam technology	1952 Specialised bulk carrier	
Lamb 1650-2005	1793 Start of the Industrial revolution	1894 Steam technology and refrigeration	1947 Specialised bulk carrier and refrigeration	
Lead 1650-2005	1721 End of war between Russia and Sweden, South Sea bubble	1793 Start of the Industrial Revolution	1851 Invention of battery (lead plates)	1946 Specialized bulk carrier
Sugar 1650-2005	1833 Abolition of slavery in the British empire(the sugar cane trade of the 18th and 19th century relied on slave labour)			
Wheat 1650-2005	1837 Poor wheat harvest in Great Britain; improvement in transport (canals in the US).	1945 End of second world war, improvement in transport.		
Wool 1650-2005	1793 Start of the Industrial Revolution; Production of wool in Australia	1875 Loss of ships transporting wool from Australia; bad weather also hampered transport of wool	1947 Abnormal demand for wool; Decrease in wool production in Australia and South Africa due to drought; Decline in U.S. production	
Coal 1650-2005	1892 Coal Creek War; Post-war railroad construction, meanwhile, had opened up the state's coalfields to major mining operations; Coal strike in UK	1952 Treaty establishing the European Coal and Steel Community; Specialized bulk carrier		
Gold 1650-2005	1793 Start of the Industrial Revolution	1913 The Federal Reserve was instituted in December 1913; The last of the true Gold Certificates		
Aluminium 1872-2005	1891 First used for building a steam passenger boat in 1891; The Cowles process increased dramatically the	1918 Use of Duralumin in aviation ; First World War	1940 Greater use of aluminium; Second World War	

Cocoa 1872-2005	1907 Boycott against Portuguese continued used of slavery to grow cocoa in West Africa	1946 Ghana Cocoa Board (1947); Ghana is the second largest producer of cocoa; End of World War II	1985 Major plantation fires in Ivory Coast	
Coffee 1872-2005	1949 The Havana charter on primary commodity agreement; Improvement in transport technology			
Copper 1872-2005	1898 A financial and commodity derivatives trading platform headquartered in Chicago; In Alaska found a high grade deposit of copper	1946 End of World War II	1974 The price of copper reached a pick (commodity boom)	
Cotton 1872-2005	1945 End of World War II			
Hide 1872-2005	1920 Depression of 1920–21 created a shock in agricultural commodity prices	1951 Trade Agreement between India and Pakistan		
Rice 1872-2005	1981 Dramatic decline in prices			
Silver 1872-2005	1939 The Great Depression	1978 Attempt to corner the silver market		
Tea 1872-2005	1922	1953 Tea Act 1953	1985 Price peaked at 165 pence/kg in October 1989; the highest level since October 1985.	
Tin 1872-2005	1985 Market collapse of the market of tin due to the failure of the International Tin Agreement			
Tobacco 1872-2005	1894 F – Billmyer Warehouse (destroyed by arson in 1894); Start of production of tobacco in New Zeland	1917 End of First World War	1967 1965: The Federal Cigarette Labeling and advertising Act is passed requiring health warnings on cigarette packages; As many as 10,000,000 Americans	

Zinc 1872-2005	1917 End of First World War	1947, End of Second World War		
Pig iron 1872-2005	1948 End of the Second World War	1985		
Nickel 1872-2005	1899	1949 Reconstruction after Second World War		
Oil 1872-2005	1915 First world war	1973 Oil embargo shock		
Banana 1900-2005	1916 Banana wars	1931 The Banana massacre in Colombia on December 6, 1928, The Banana Wars	1971 The period since 1971 has seen major changes in both the world banana economy and the economic environment within which banana production and trade take place (The world of economy 1970-1984, FAO economic and social development.	
Jute 1900-2005	1947 The jute industry was affected greatly by the independence of India and Pakistan in 1947.			