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Unit roots, flexible trends and the Prebisch-Singer hypothesis

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Outline

Motivation

- Two theories (hypotheses) on the dynamics of primary commodity prices:

  1. *The Prebisch-Singer hypothesis* (Cuddington, Ludema and Jayasuriya, 2008): relative prices of primary commodities in terms of manufactures are driven by a secular downward trend.

  2. *The Supercycle hypothesis* (Cuddington and Jerrett, 2008): *long swings* in primary commodity markets driven by the surge of industrial economies.

- Testing the validity of the Prebisch-Singer hypothesis has always been a subject of great empirical interest (Cuddington and Urzua, 1989; Cuddington, 1992).
  A negative estimated time slope or drift of the relative price y_t is taken as supportive evidence of the Prebisch-Singer hypothesis. To this end, it is necessary to decide first whether y_t should be modeled as a trend stationary or as a difference stationary process.

- Conclusions are sensitive to the instabilities, such as structural breaks, that affect the performance of unit root tests. See Ghoshray (2011) for a review. Refinements to unit root tests always find the Prebisch-Singer hypothesis to be an interesting application.

- This paper: Reexamination of the Prebisch-Singer hypothesis, using a new generation of unit root tests based on "flexible trends". These trends may be interpreted as the long swings induced by Supercycles.

Outline

1. Motivation

2. Unit root econometrics

3. Testing for unit roots

4. Prebisch-Singer hypothesis

5. Closing remarks

Unit roots econometrics I

- Time series model for y_t

$$y_t = \tau(t) + u_t, \quad \text{where} \quad \Phi(L)u_t = \varepsilon_t \, .$$

$\tau(t)$ is the *trend function* of y_t. Define the slope as

$$\delta(t) = \tau(t) - \tau(t-1) \, .$$

- Objective: To model $\delta(t)$.

- Trend stationary model (TS): $\Phi(z) = 0$ contains no unit root, $u_t \sim I(0)$. In this case,

$$\mathrm{E}(y_t) = \tau(t) \quad \text{and} \quad \mathrm{E}(\Delta y_t) = \delta(t) \, .$$

The trend function is explicitly estimated from the data in levels.

- Difference stationary model (DS): $\Phi(1) = 0$ so $u_t \sim I(1)$. Here,

$$\mathrm{E}(\Delta y_t) = \delta(t) \, .$$

The slope is directly modeled from the first differences of the data.

- Whether to use TS or DS depends on the results of unit root tests (H_0 : DS model).

Unit roots econometrics II

- Usual choices

  $\tau(t) = \alpha_1 + \alpha_2 t + \textit{Dummies}$ for breaks in the intercept $+ \textit{Dummies}$ for breaks in the slope .

- Unit root tests, in general, are known to have low power (a high probability *not* to reject H_0, when it is false) if $\tau(t)$ is misspecified:

  1. When $\tau(t)$ *excludes* important terms (critical). The leading example occurs when there are unmodeled structural breaks. In this case, the test confounds the breaks with a unit root.

  2. When $\tau(t)$ *includes* redundant terms (important but less critical). The leading example is the linear trend term t. Here, overfitting leads to a loss in power.

- Results are sensitive to whether the presence of structural breaks is considered in the alternative model, and how many breaks are modeled. This inconclusive picture is exactly what is found in the empirical literature of primary commodity prices.

Unit root tests under a flexible approach I

- Flexible trend approach (Becker, Enders and Hurn, 2004; Becker, Enders and Lee, 2006; Enders and Lee, 2012a,b):

$$\tau(t) = \alpha_1 + \alpha_2 t + \sum_{k=1}^{n} \beta_{1k} \cos\left(\frac{2\pi k}{T} t\right) + \sum_{k=1}^{n} \beta_{2k} \sin\left(\frac{2\pi k}{T} t\right) .$$

- The cosine and sine terms form a *Fourier expansion* of an unknown and arbitrary function of t. The larger the n is, the better approximation.

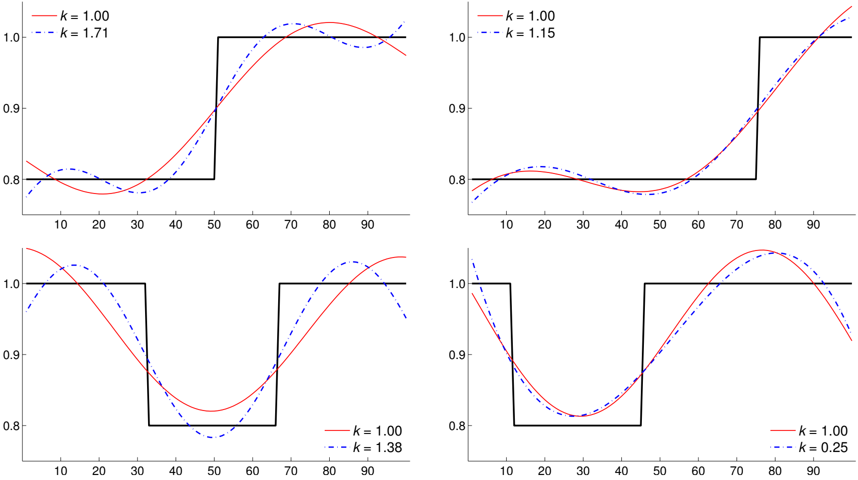
- In practice, the instabilities brought by structural breaks are captured by the first few terms in the Fourier expansion. The unit root tests under the flexible approach use

$$\tau(t) = \alpha_1 + \alpha_2 t + \beta_1 \cos\left(\frac{2\pi k}{T} t\right) + \beta_2 \sin\left(\frac{2\pi k}{T} t\right) ,$$

  where k is small (say, $k = 1, 2$).

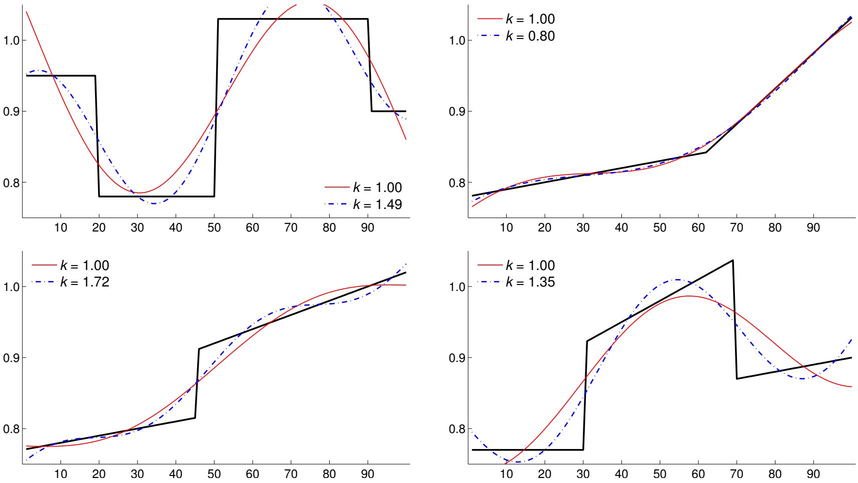
  - Controls for the effects of breaks of unknown form.
  - Prevents overfitting.
  - The (difficult) task of estimating the unknown break dates is changed by the (straightforward, linear) estimation of β_1 and β_2.

Flexible trends: Fourier approximations I



Notes: Fitted values of the function $\tau(t) = \alpha_1 + \alpha_2 t + \beta_1 \cos(\theta t) + \beta_2 \sin(\theta t)$, where $\theta = 2\pi k/T$.
The red (continuous) line shows the approximation for a given $k = 1$, whereas the blue (dotted) line gives the "best" single-frequency approximation by estimating k.

Flexible trends: Fourier approximations II



Notes: Fitted values of the function $\tau(t) = \alpha_1 + \alpha_2 t + \beta_1 \cos(\theta t) + \beta_2 \sin(\theta t)$, where $\theta = 2\pi k/T$.
The red (continuous) line shows the approximation for a given $k = 1$, whereas the blue (dotted) line gives the "best" single-frequency approximation by estimating k.

Unit root tests under a flexible approach II

- Augmented Dickey-Fuller type test:

$$\Delta y_t = c_1 + c_2 t + c_3 \cos\left(\frac{2\pi k}{T} t\right) + c_4 \sin\left(\frac{2\pi k}{T} t\right) + \rho y_{t-1} + \sum_{i=0}^{p} c_{4+i} \Delta y_{t-i} + \text{error}_t \, .$$

- The critical values depend on whether $c_2 = 0$, and on k.

- Interpretation:
  $H_0 : y_t$ is DS,
  $H_1 : y_t$ is TS around a flexible trend, which can be rationalized by the Supercycle notion.

- Test for nonlinearities. F test for $\beta_1 = \beta_2 = 0$ under H_0. The critical values depend on whether $\alpha_1 = 0$, and on k. These critical values are much larger (more than double) than those coming from an F distribution.

- The purpose is to enchance the power of unit root tests.
  Various simulation studies in Becker, Enders and Hurn (2004), Becker, Enders and Lee (2006) and Enders and Lee (2012a,b) support this conclusion.

Outline

Data

- Annual data, over the period from 1900 to 2010 ($T = 111$ observations), for 24 primary commodities (11 food, 7 nonfood and 6 metals).

- The dataset is the major extension of the popular Grilli and Yang (1988) dataset documented in Pfaffenzeller, Newbold and Rayner (2007).

- The series of interest:

$$y_t = 100 \log \left(\frac{\text{Prices of the primary commodity}}{\text{Manufacturing unit value index}} \right) .$$

- Empirical strategy:

  1. Begin with the most parameterized test (which is the least powerful). Rejections are conclusive.

  2. Upon non-rejection, use the F test to verify whether the nonlinearities are important. Rejections for the particular k selected by the F test are conclusive.

  3. Upon non-rejection, evaluate whether the linear time trend term can be excluded and repeat the testing cycle.

- The 24 commodity prices are classified into 4 groups, according to the results of this procedure.

Group I: No unit root, weak instabilities

- 9 commodities.
- Strong UR rejection in the least powerful test (includes a linear trend) for *all* k (and, especially, for the relevant k pointed out by the F test).
- Evidence of slight nonlinearities.

	p	$k = 0$			$k = 1$			$k = 2$	
		ρ	t stat	F stat	ρ	t stat	F stat	ρ	t stat
Hides	0	0.59	-5.15^{**}	6.61	0.51	-5.82^{**}	1.87	0.56	-5.32^{**}
Jute	1	0.76	-3.70^{**}	6.11	0.61	-4.34^{*}	5.91^{*}	0.70	-4.24^{**}
Maize	1	0.64	-4.67^{**}	7.55^{*}	0.50	-5.47^{**}	1.21	0.63	-4.71^{**}
Palmoil	1	0.68	-4.48^{**}	4.08	0.61	-4.88^{**}	4.49	0.64	-4.90^{**}
Rice	1	0.74	-4.39^{**}	3.60	0.67	-4.76^{**}	5.37^{*}	0.68	-4.89^{**}
Sugar	1	0.60	-4.83^{**}	1.17	0.57	-4.90^{**}	6.05^{**}	0.52	-5.44^{**}
Timber	4	0.68	-4.09^{**}	1.99	0.64	-4.32^{*}	0.39	0.67	-4.08^{**}
Wheat	1	0.65	-4.88^{**}	0.44	0.64	-4.85^{**}	4.52	0.59	-5.31^{**}
Zinc	1	0.55	-5.38^{**}	1.22	0.53	-5.46^{**}	4.98^{*}	0.49	-5.87^{**}
Critical values (5%)			−3.45	8.65		−4.34	5.97		−4.04
Critical values (10%)			−3.15	7.18		−4.04	4.61		−3.71

Group II: No unit root, instabilities

- 9 commodities.
- UR rejection in the least powerful test for *some* k.
  Especially, strong rejection for the k supported by the F test.
- Evidence of nonlinearities in the underlying mean.

	p	$k=0$			$k=1$			$k=2$	
		ρ	t stat	F stat	ρ	t stat	F stat	ρ	t stat
Aluminum	1	0.81	-3.57^{**}	5.56	0.72	-4.33^{*}	1.39	0.80	-3.69
Lamb	4	0.78	-3.69^{**}	0.23	0.78	-3.68	3.78	0.72	-4.04^{**}
Cotton	1	0.81	-3.46^{**}	9.85^{**}	0.63	-4.63^{**}	1.77	0.80	-3.57
Wool	1	0.78	-3.57^{**}	17.68^{**}	0.48	-5.51^{**}	1.39	0.77	-3.65
Banana	1	0.84	-2.97	13.23^{**}	0.63	-4.53^{**}	1.21	0.82	-3.16
Tea	1	0.85	-2.98	15.53^{**}	0.62	-4.79^{**}	0.98	0.84	-3.07
Tobacco	1	0.87	-3.05	11.01^{**}	0.71	-4.53^{**}	0.60	0.87	-3.02
Beef	4	0.80	-3.22^{*}	3.70	0.72	-3.73	7.26^{**}	0.68	-4.10^{**}
Copper	1	0.86	-2.64	0.58	0.85	-2.55	14.18^{**}	0.69	-4.33^{**}
Critical values (5%)			-3.45	8.65		-4.34	5.97		-4.04
Critical values (10%)			-3.15	7.18		-4.04	4.61		-3.71

Group III: No unit root, no time trend

- 2 commodities.
- UR non-rejection in model with linear trend. This may be due to lack of power. Strong UR rejection in model *without* linear trend (no obvious drift in the data).

	p	$k = 0$		$k = 1$			$k = 2$		
		ρ	t stat	F stat	ρ	t stat	F stat	ρ	t stat
Including a linear trend									
Coffee	1	0.81	−3.23*	4.27	0.73	−3.80	2.46	0.78	−3.44
Cocoa	1	0.83	−3.30*	3.84	0.75	−3.70	5.10*	0.76	−3.95*
Critical values (5%)			−3.45	8.65		−4.34	5.97		−4.04
Critical values (10%)			−3.15	7.18		−4.04	4.61		−3.71
Excluding a linear trend									
Coffee	1	0.81	−3.25**	3.89	0.74	−3.78*	2.14	0.79	−3.41**
Cocoa	1	0.83	−3.34**	2.44	0.80	−3.65*	4.14*	0.77	−3.82**
Critical values (5%)			−2.89	7.10		−3.80	4.25		−3.26
Critical values (10%)			−2.58	5.73		−3.48	3.20		−2.91

Group IV: Unit root

- 4 commodities.
- Weak evidence against a unit root. However, if we were less conservative Rubber would belong to Group II, and Lead and Tin to Group III.

	p	$k = 0$		$k = 1$			$k = 2$		
		ρ	t stat	F stat	ρ	t stat	F stat	ρ	t stat
				Including a linear trend					
Rubber	1	0.84	−2.78	1.84	0.80	−2.96	6.96**	0.74	−3.74*
Lead	1	0.85	−2.63	2.60	0.83	−2.62	4.98*	0.80	−3.19
Tin	1	0.87	−2.72	0.73	0.85	−2.61	5.52*	0.83	−3.17
Silver	1	0.90	−2.25	1.02	0.86	−2.34	8.30**	0.82	−3.11
Critical values (5%)			−3.45	8.65		−4.34	5.97		−4.04
Critical values (10%)			−3.15	7.18		−4.04	4.61		−3.71
				Excluding a linear trend					
Rubber	1	0.92	−2.45	2.28	0.89	−2.85	2.13	0.91	−2.54
Lead	1	0.86	−2.66*	2.36	0.82	−2.94	4.85**	0.81	−3.15*
Tin	1	0.88	−2.66*	1.14	0.85	−2.81	3.43*	0.86	−2.76
Silver	1	0.92	−1.81	3.57	0.85	−2.60	2.94	0.91	−1.78
Critical values (5%)			−2.89	7.10		−3.80	4.25		−3.26
Critical values (10%)			−2.58	5.73		−3.48	3.20		−2.91

Taking stock

- UR rejection in (at least) 20 out of 24 cases (almost the probability of type I error).
- Previous literature is much more supportive of the unit root hypothesis.
- Nonlinearities. The critical value for the F test $H_0 : \beta_1 = \beta_2 = 0$ is about 3 for $I(0)$ series (it does not depend on k), and about twice as much for $I(1)$ series (it does depend on k). Thus, the hypothesis of linearity is *rejected*, in order of appearance, for

  $k = 1$: Hides, Jute, Maize, Aluminum, Cotton, Wool, Banana, Tea, Tobacco, Coffee.

  $k = 2$: Palmoil, Rice, Sugar, Wheat, Zinc, Lamb, Beef, Copper, Cocoa, Rubber, Lead, Tin, Silver.

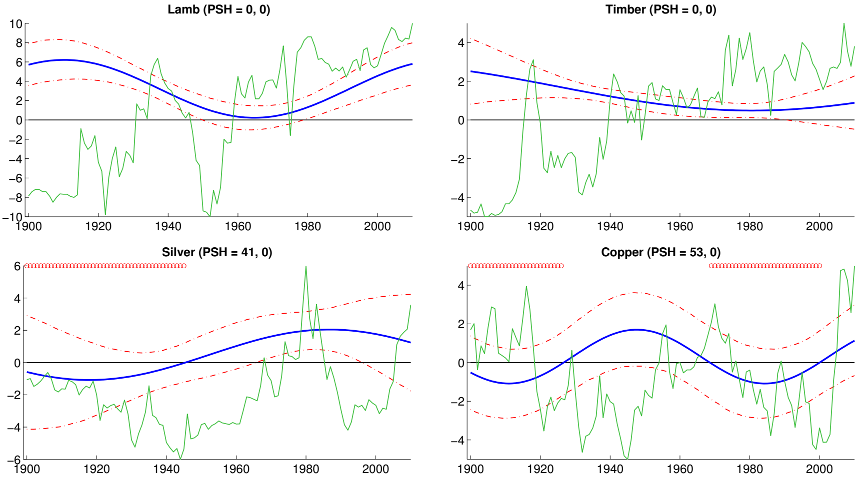
  It is *not rejected* only for Timber.
- "Sharp" structural breaks or supercycles?

Outline

Evaluation of the Prebisch-Singer hypothesis (preliminary)

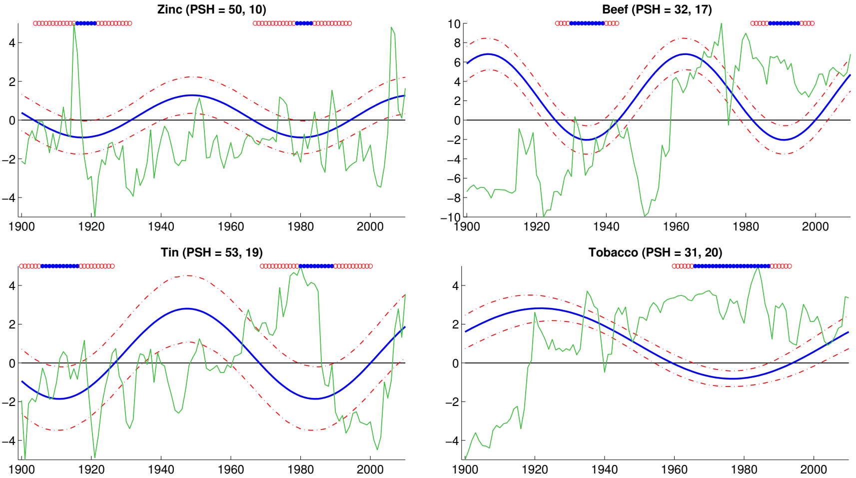
- After we decide whether to use a DS or a TS representation, we estimate the slope $\delta(t)$.
- Define $\text{PSH}_t = 1$ if $\delta(t) < 0$ and $\text{PSH}_t = 0$ if $\delta(t) \geq 0$.
- Standard errors by bootstrapping.
- The 24 commodity prices are classified into 5 groups, according to the prevalence of the Prebisch-Singer hypothesis.

Group A: PSH does not hold (4 prices)



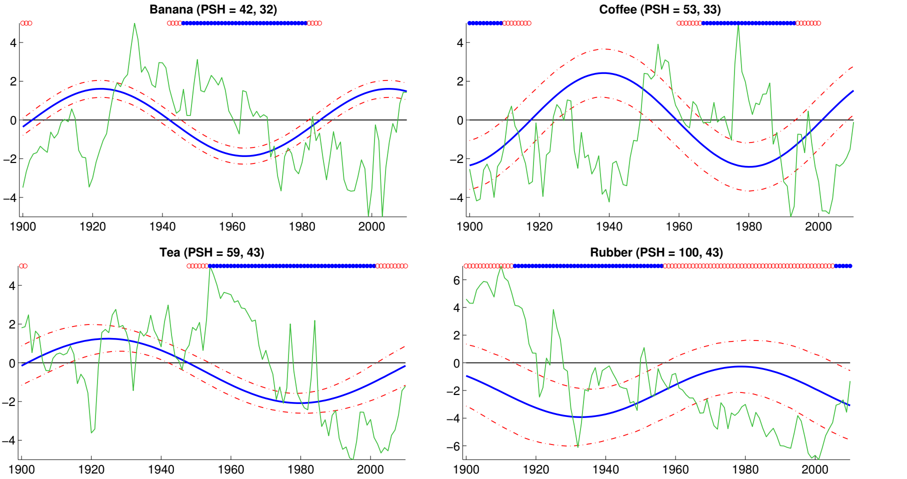
Notes: Green line: Data (rescaled); Blue line: point estimate of $\delta(t)$; red (dotted) lines: confidence bounds of $\delta(t)$. In the title: PSH = (P_1,P_2), where P_1 is the frequency of $\delta(t) < 0$ (dates marked by a hollow circle), and P_2 is the frequency of a negative upper confidence bound (dates marked by a filled circle).

Group B: PSH barely holds (4 prices)



Notes: Green line: Data (rescaled); Blue line: point estimate of $\delta(t)$; red (dotted) lines: confidence bounds of $\delta(t)$. In the title: PSH = (P_1,P_2), where P_1 is the frequency of $\delta(t) < 0$ (dates marked by a hollow circle), and P_2 is the frequency of a negative upper confidence bound (dates marked by a filled circle).

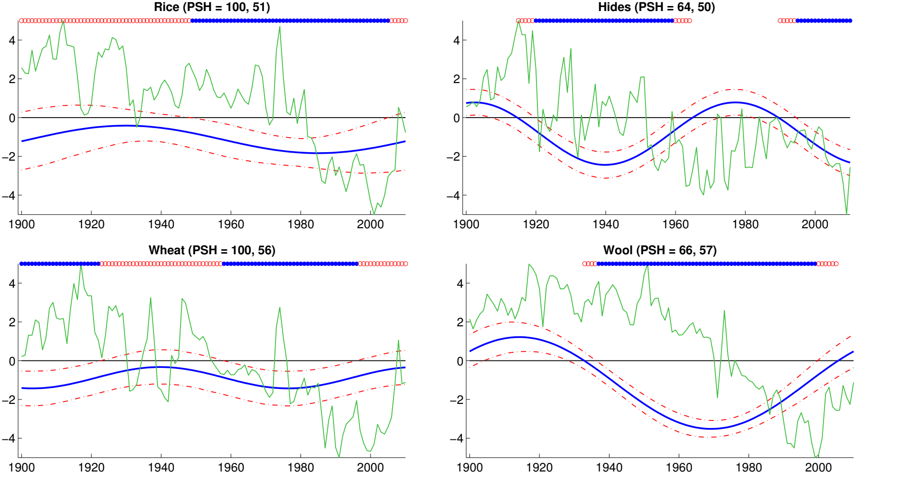
Group C: PSH seldomly holds (7 prices)



Other cases: Lead, Cocoa and Jute.

Notes: Green line: Data (rescaled); Blue line: point estimate of $\delta(t)$; red (dotted) lines: confidence bounds of $\delta(t)$. In the title: PSH = (P_1,P_2), where P_1 is the frequency of $\delta(t) < 0$ (dates marked by a hollow circle), and P_2 is the frequency of a negative upper confidence bound (dates marked by a filled circle).

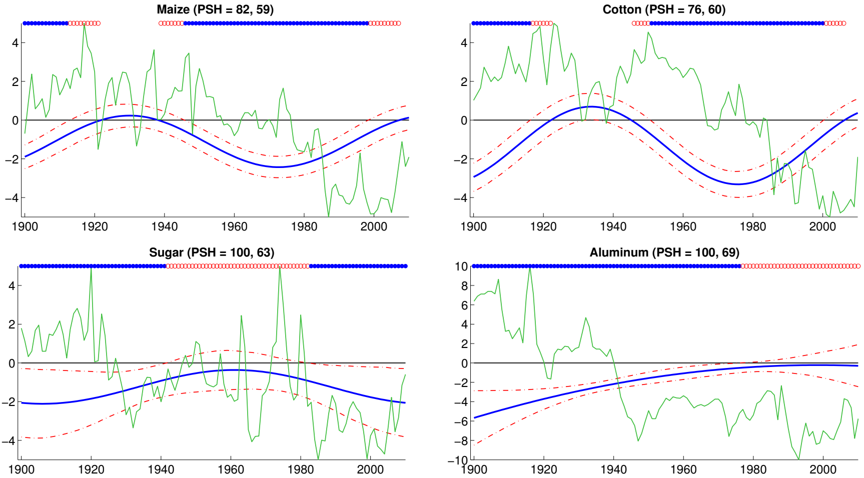
Group D: PSH holds sometimes (5 prices)



Other cases: Palmoil.

Notes: Green line: Data (rescaled); Blue line: point estimate of $\delta(t)$; red (dotted) lines: confidence bounds of $\delta(t)$. In the title: PSH = (P_1, P_2), where P_1 is the frequency of $\delta(t) < 0$ (dates marked by a hollow circle), and P_2 is the frequency of a negative upper confidence bound (dates marked by a filled circle).

Group E: PSH often holds (4 prices)



Notes: Green line: Data (rescaled); Blue line: point estimate of $\delta(t)$; red (dotted) lines: confidence bounds of $\delta(t)$. In the title: PSH = (P_1, P_2), where P_1 is the frequency of $\delta(t) < 0$ (dates marked by a hollow circle), and P_2 is the frequency of a negative upper confidence bound (dates marked by a filled circle).

Outline

Closing remarks

- The Supercycle story points out to the existence of *very persistent* cycles in primary commodity prices. Each phase of the cycle may last decades (as opposed to the common notion of "business cycles").
- Standard unit root tests will inevitably confound such a persistent component with the nonstationary behavior underlying a unit root.
- However, once we control for something that looks like a long-lasting cycle, the evidence *against* unit roots is much stronger.
- By construction, $\delta(t)$ is deterministic, and we may want to model the Supercycle as a stochastic process. This is part of our research agenda.
- The Prebisch-Singer hypothesis is weakened under the (complementary) notion of the Supercycle.

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