Variable Long-Term Trends in 100+ Mineral Prices

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- CSM is a small, elite university focusing on engineering and applied science
- CSM's Division of Economics and Business Programs
  - BS - Economics
  - MS – Engineering and Technology Mgt (ETM)
  - MS, PhD – Mineral and Energy Economics
- I'd show you pictures, but we all can't live there!

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Long-Run Trends in Mineral Prices: Overview

- Motivation: policy, theory, empirics
- Objective: to explore the use of band-pass filters for extracting LR trends
- Empirical results for some long-span data
- Conclusions
- Extensions: Super Cycles (20-70 years)

Motivation - Policy

- Policy makers – keen interest during periods of sharply rising resource prices, perceived 'shortages' or geo-political threats to availability
- Will we run out of various nonrenewable resources? (Limit to Growth debate)
- Will they be exhausted before they become economically obsolete, or vice versa?
- Real prices are a key measure of economic scarcity; long-span mineral price data is readily available

Tilton (2003) RFF Book: *On Borrowed Time? Assessing the Threat of Mineral Depletion*

- "Mining and the consumption of nonrenewable mineral resources date back to the Bronze Age, indeed even the Stone Age…(p.1)

- "What is new is the pace of exploitation. Humankind has consumed more aluminum, copper, iron and steel, phosphate rock, diamonds, sulfur, coal, oil, natural gas, and even sand and gravel during the past century than all earlier centuries together. (p.1)

Causes of Explosion in Mineral Use

- **Advances in technology** allow [exploration and] extraction…at lower and lower cost. [Shifts mineral supply curves down]

- Advances in technology also permit new and better mineral commodities serving a range of needs.[Shifts mineral demand curves out/up]

- **Rapidly rising living standards** in many parts of the globe are increasing demand across the board for goods and services, including many that use mineral commodities intensively in their production [Shifts the derived demand for minerals out/up]

- **Surge in world population** means more and more people with needs to satisfy. [Shift the derived demand for mineral in or out depending on the relative mineral intensity of various goods.

Source: (Tilton 2003, p.1)

Hotelling Theory of Nonrenewable Resources

- Hotelling's (1931) 'benchmark' theory of nonrenewable resources
  - Shadow price of resource stock (in the ground) = price – marginal extraction and production cost
  - **Hotelling model implies the r percent rule: shadow price should rise at a rate equal to the interest rate**
  - Hotelling also predicted that resource consumption would decline monotonically over time.
  - The competitive market outcome was Pareto efficient: Don't worry everything will work out fine!

Extensions of the Hotelling Model: Getting the theory to match the fact!

- See Gaudet (2007) and Slade and Thille (2009) for recent discussions
- Declining resource quality (Ore grade, accessibility)
- Exploration for additional reserves
- Recycling – in effect, adds to reserves
- Technological advances that impact demand or supply of nonrenewables
- Theoretical models developed by Pindyck (1978), Heal (1981), and Slade (1982) predict a **U-shaped time pattern** for prices with technological advance initially dominating, but ultimately being overpowered by depletion.

Empirical Evidence on Long-Term Price Trends

- The 'game' is to get the longest data span possible and apply the most robust univariate time series techniques. For some nonrenewables, data go back to the mid 1800s
- Much of the literature focuses on estimating either TS or DS specifications in order to estimate the constant long-term trend (albeit it with the possible search for occasional breaks).

- TS Model

$$\ln P_t = a + bt + e_t$$

- DS Model

$$D(\ln P_t) = b + u_t$$

U-Shaped Price Paths

- Margaret Slade (1982 JEEM) fit (deterministic) linear and quadratic trend models for eleven nonrenewables from 1870 through 1978 [Aluminum, Copper, Iron, Lead, Nickel, Silver, Tin, Zinc, Coal, Natural Gas, Petroleum].

- Quadratic trend model is flexible enough to allow for up to one change in direction of the time trend line, including the U-shape behavior

- Concerns:
  - *Linear and (presumably) quadratic trend model are subject to spurious regression issues in the presence of unit roots.*

Overall conclusions from review of empirical work

- Conclusions on the significance of the time trend depend critically on presence/absence of unit roots and/or breaks

- Any trend is small and difficult to estimate precisely, given the huge year-to-year volatility in the price series.

Continued…

- Tilton (2003, p. 54) summarizes his survey of literature on long-term price trends this way:

- "History also strongly suggests that the long-run trends in mineral prices…are not fixed. Rather they shift from time to time in response to changes in the pace at which new technology is introduced, in the rate of world economic growth, and in the other underlying determinants of mineral supply and demand.

- "This not only complicates the task of identifying the long-run trends that have prevailed in the past, but cautions against using those trends to predict the future. Because the trends have changed in the past, they presumably can do so as well in the future."

- Empirics should allow for *variable* trends – that is, the gradual evolution in LT trends without constraining the trends to be constant (or u-shaped) over time.
- Band-pass filters provide one way of doing this if our objective is data description and historical analysis, rather than hypothesis testing.

Our departure point: *Variable* Long-run Trends

- Nonrenewable prices in the long run will reflect the tug-of-war between exploration, depletion and technological change.
- There is no reason to expect that balance among these forces should remain constant over the longest available data span.

Band-Pass Filters

- "When confronting data, empirical economists must somehow isolate features of interest and eliminate elements that are a nuisance from the point of view of the theoretical models they are studying. Data filters are sometimes used to do that." (Cogley, 2008, p. 68)

- Explaining how data filters work, Cogley (2008, p.70) notes: "The starting point is the Cramer representation theorem,… which provides a basis for decomposing x_t and its variance by frequency. It is perfectly sensible to speak of long- and short-run variation by identifying the long run with low-frequency components and the short run with high-frequency oscillations."

- "Many economists are more comfortable working in the time domain, and for purposes it is helpful to express the cyclical component as a two-sided moving average [with infinitely many leads and lags]." (Cogley, 2008, p.71)

- Although the 'ideal' filters have infinitely many leads and lags, actual filters necessarily involve lead/lag truncation. There are different methods for doing this (e.g., Baxter-King, Christiano-Fitzgerald)
- Actual filters may be symmetric (centered) or asymmetric (uncentered).
  - *Symmetric – no phase shift*
  - *Asymmetric - allow the filtered series to be calculated all the way to the ends of the data set*

Applications

- Band-pass (BP) filters allows us to:
  - Extract cyclical components within a specified range of periods (or frequencies) from an economic time series.
  - Decompose any time series into a set of mutually exclusive and completely exhaustive cyclical components that sum to the series itself.
    - *Note: The highest-frequency (or shortest period) cycle that can be identified equals 2 times the data frequency*
- Initial application: Baxter and King define 'business cycle fluctuations' as lying in a 'period window' between 6 and 32 months.
- Comin-Gertler (2006) Medium-Term Macroeconomic Cycles
- Cuddington and coauthors: super cycles in mineral prices

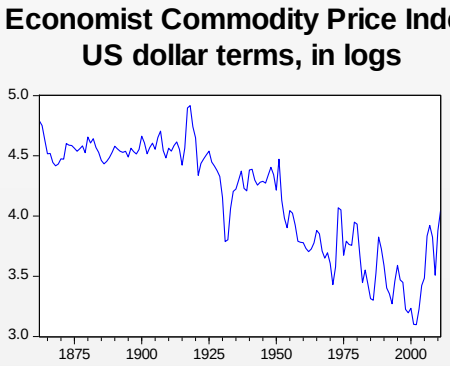
Our Definition of the 'Long Run'

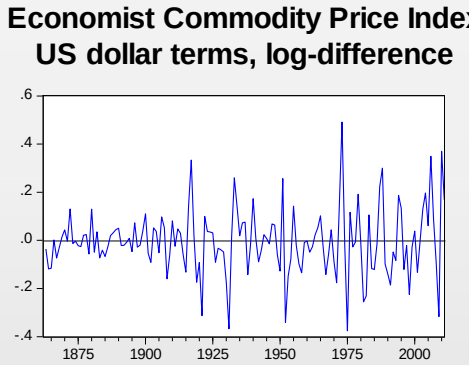
$$P_t \circ P_t(2,70) + P_t(70,\infty)$$

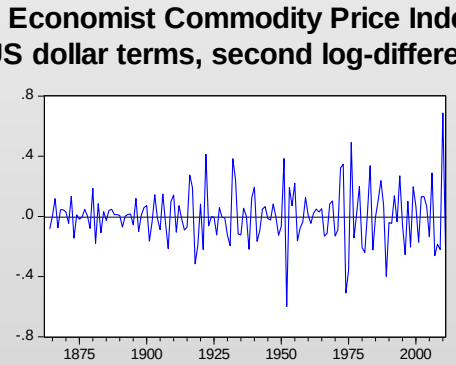
$$P_t(2,70) = \text{'aggregate' cyclical component}$$

$$P_t(70,\infty) = \text{long-term trend component}$$

Preliminary Look at The Economist *Industrials* Commodity Index

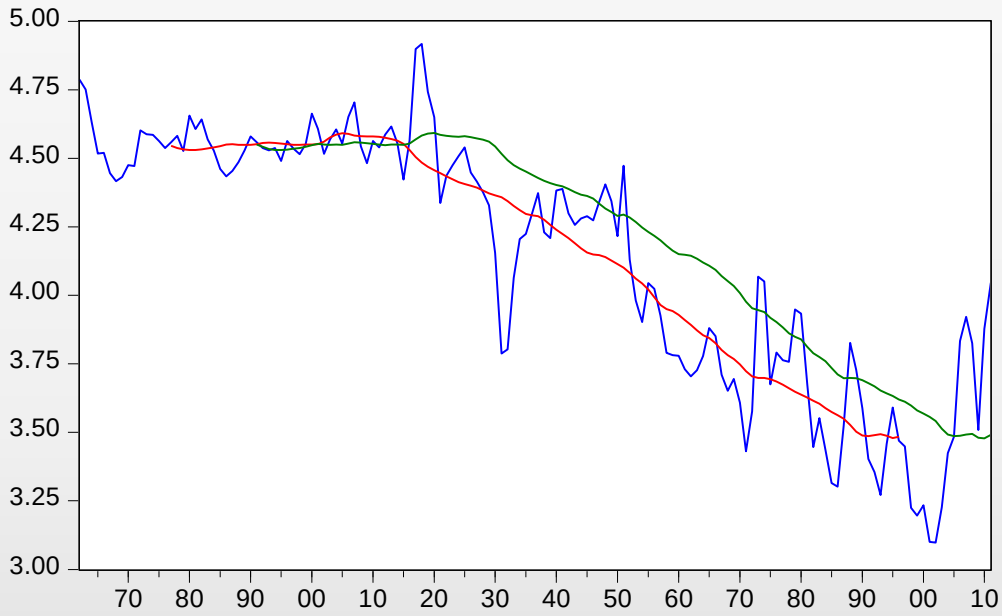






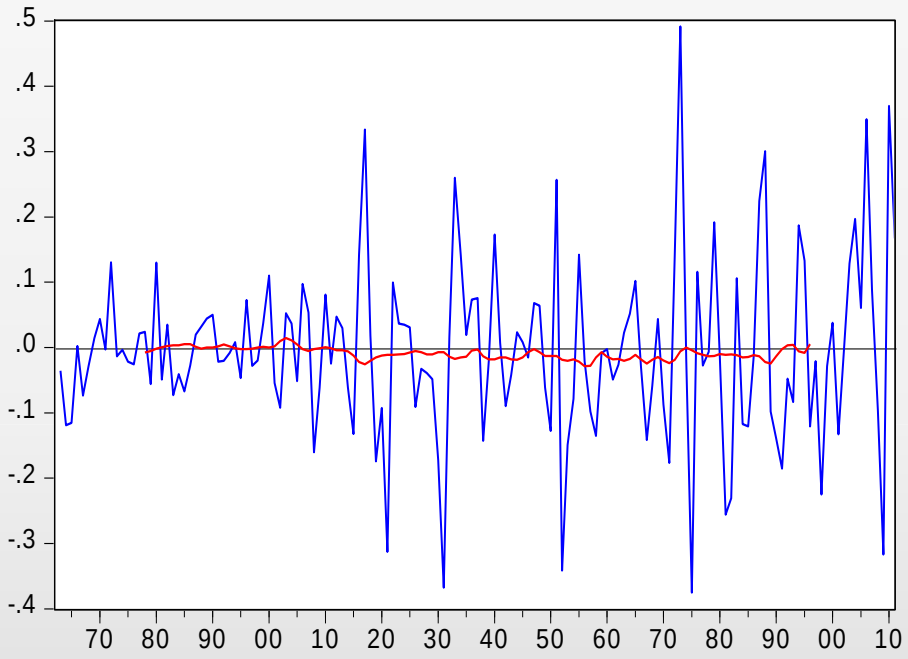
- Apparent downward trend after early 1920s
- Annual percentage changes range from -40% to +40%
- Increase in volatility after early 1920s
- Average annual growth rate is not statistically different from zero

30-Year Moving Average: Centered vs. Trailing

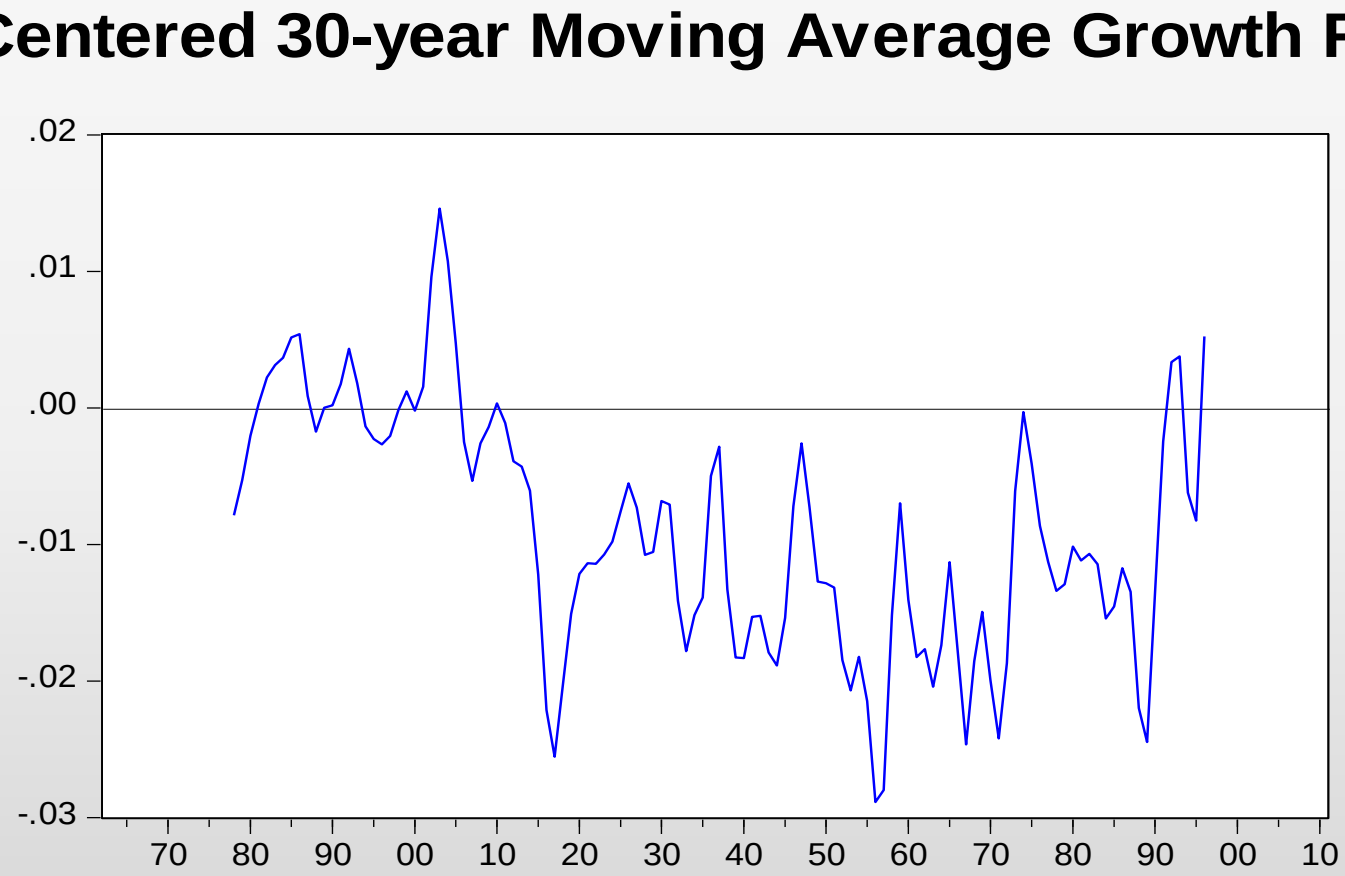


Economist Commodity Price Index (US dollar terms, in logs)
Centered 30-Year Moving Average
Trailing 30-Year Moving Average -- Note severe phase shift!

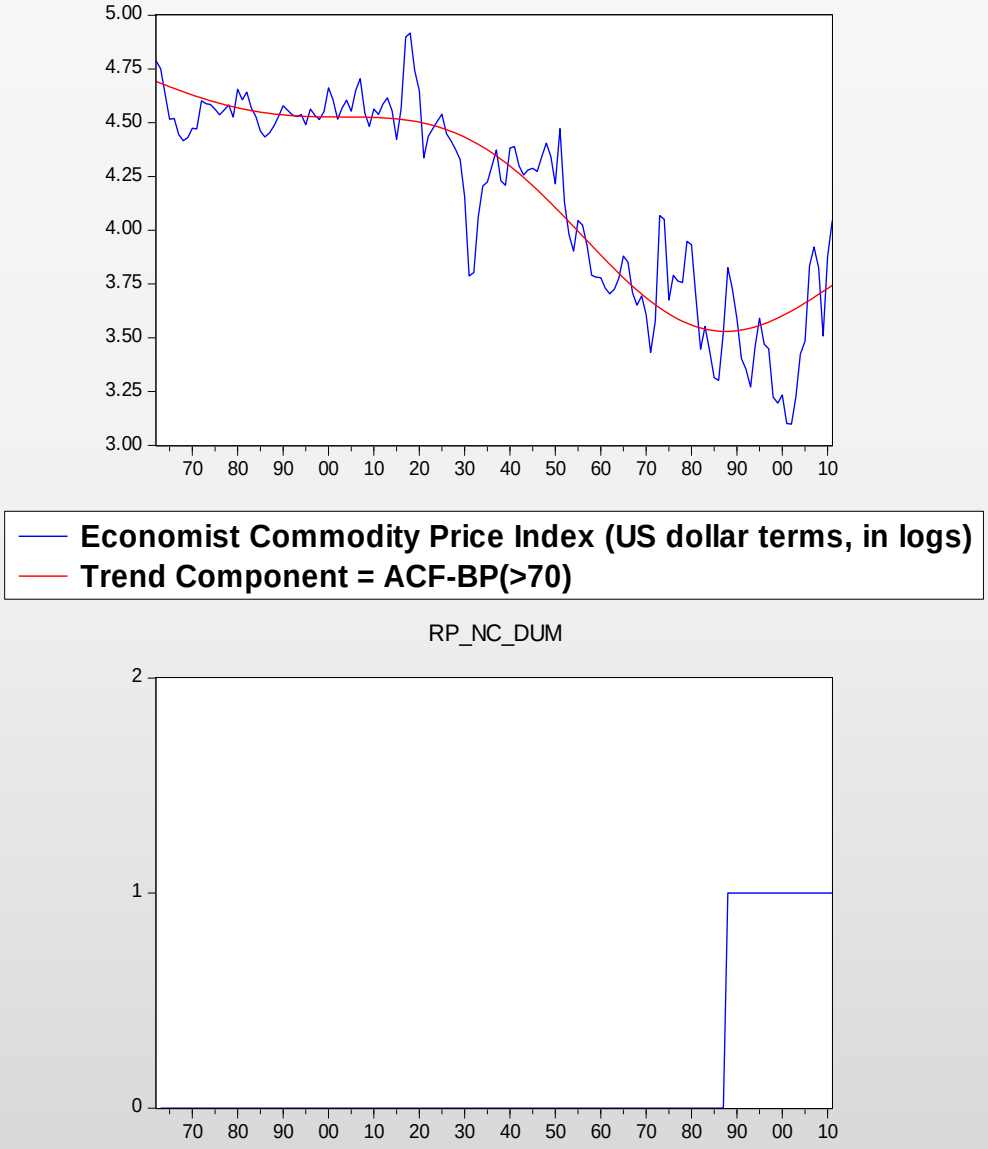
Economist Industrial Commodity Index (EICI): Annual Growth Rates



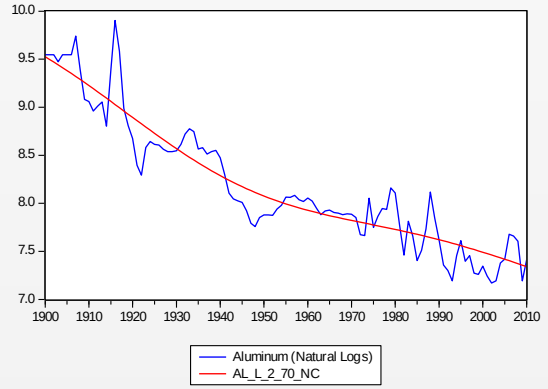
EICI:

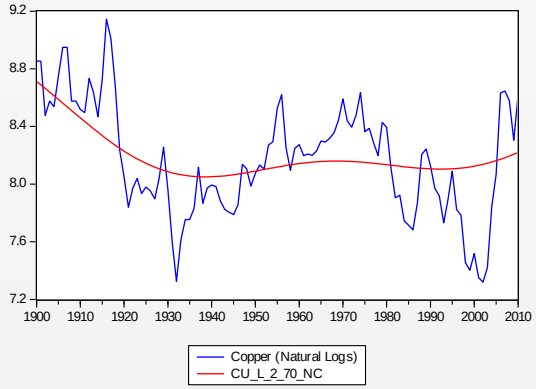

Centered 30-year Moving Average Growth Rate
.02
.01
.00
-.01
-.02
-.03
70
80
90
00
10
20
30
40
50
60
70
80
90
00
10

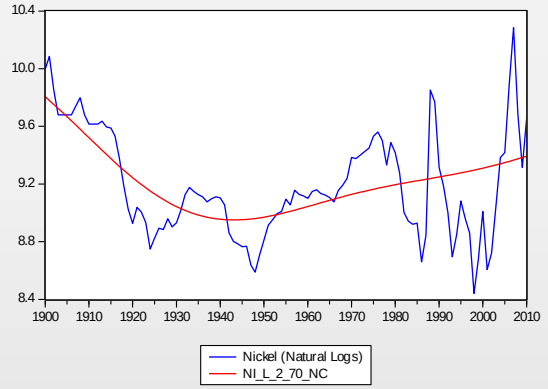
ACF-Band-Pass Filter Results on Long-run Trend

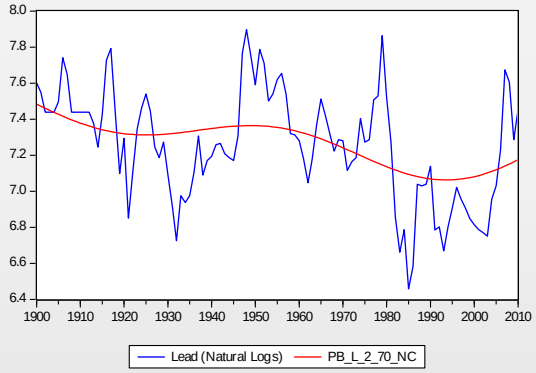


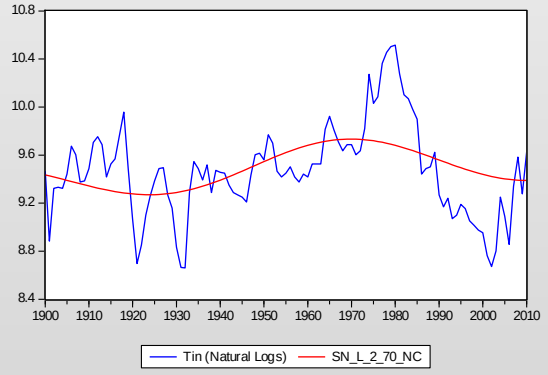
- Long-run Trend in EICI is negative until mid-1980s, then turns upward
- One one change in direction
- Not the classic U-shape that Pindyck-Heal-Slade would predict
- Remember: EICI contains both renewable and nonrenewable resources

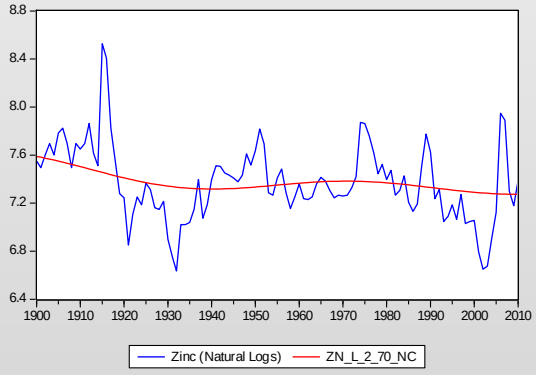










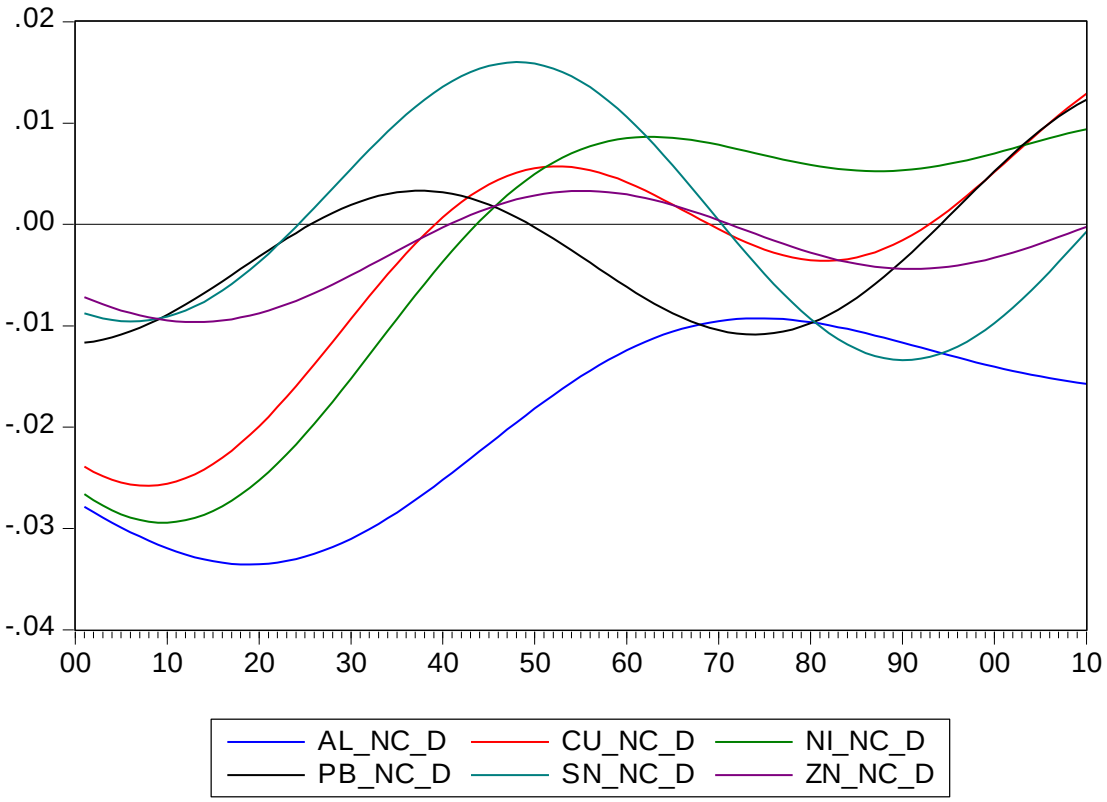


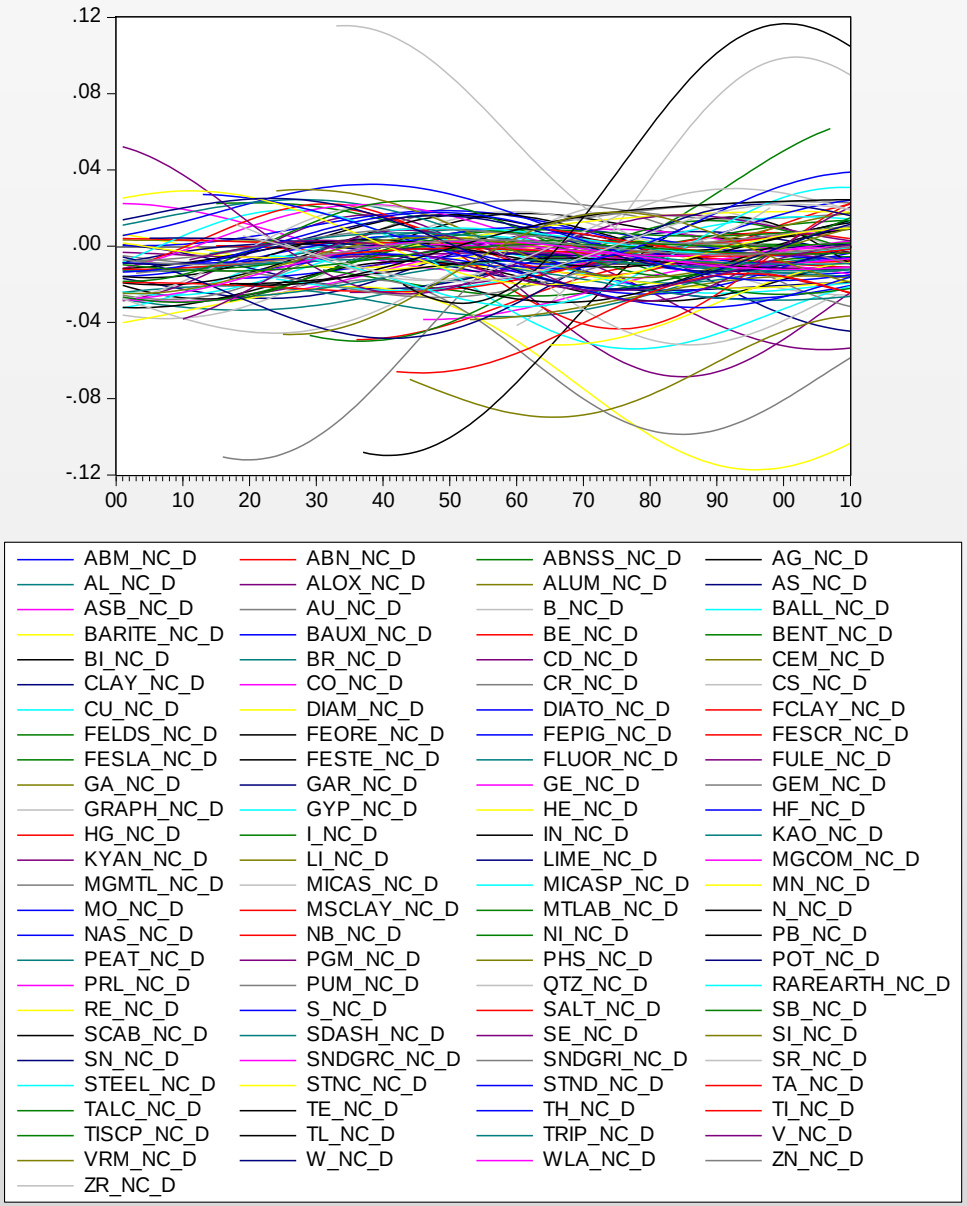
Long-run Trends in LME6:

Aluminum, Copper Nickel, Lead Tin, Zinc

- Wide variety of price paths
- Some have more than one change in direction
- Can we tell metal specific stories about the roles of exploration/discovery, depletion, and technological change?

Long-Run Variable Trend Rates for LME6

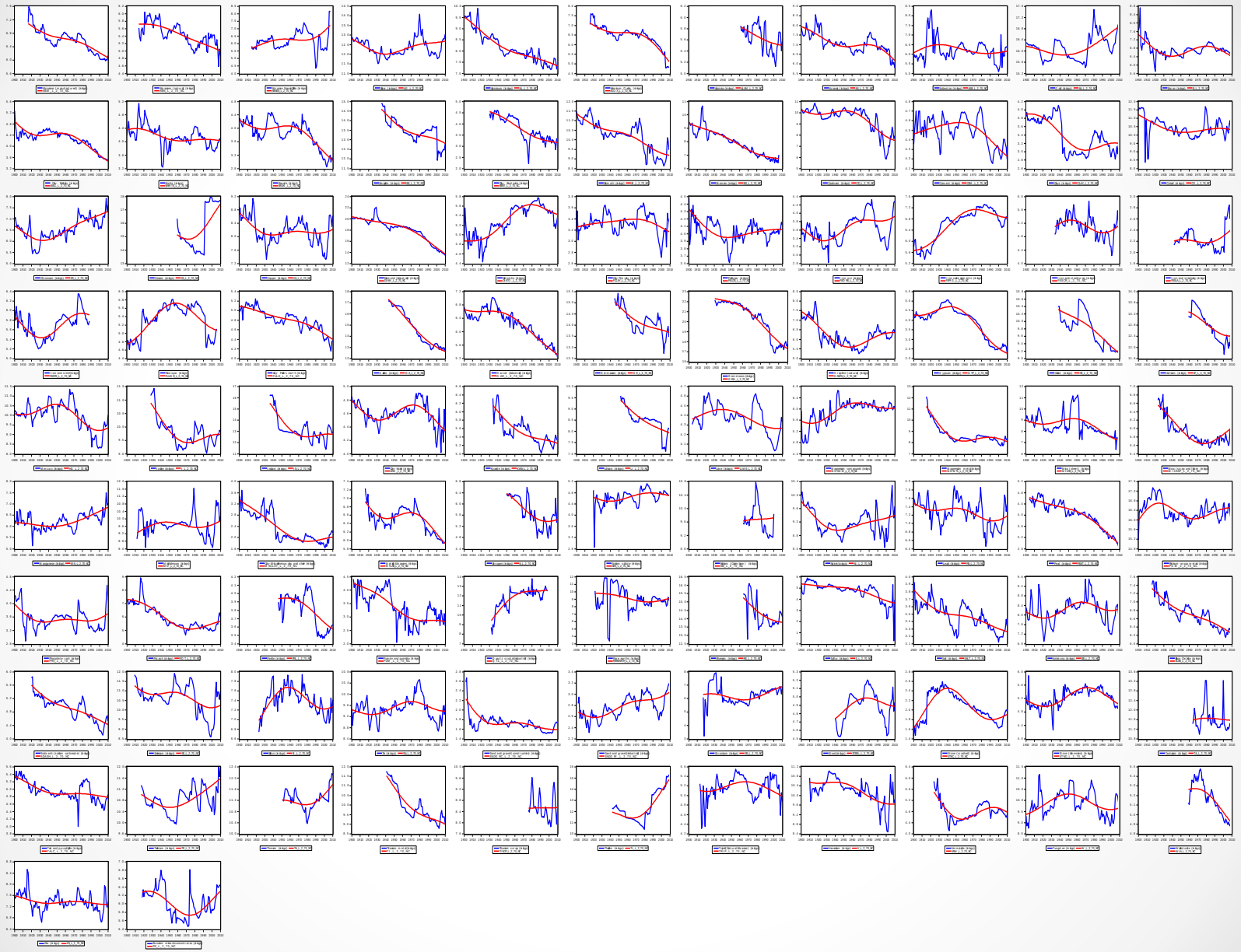




Variable Trend RATES in the USGS 101 Minerals

Hmmm?

What am I supposed to learn from this?

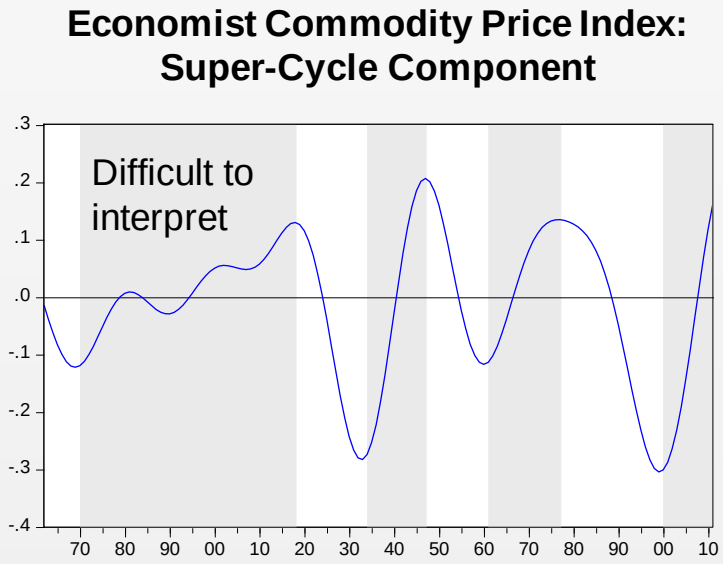


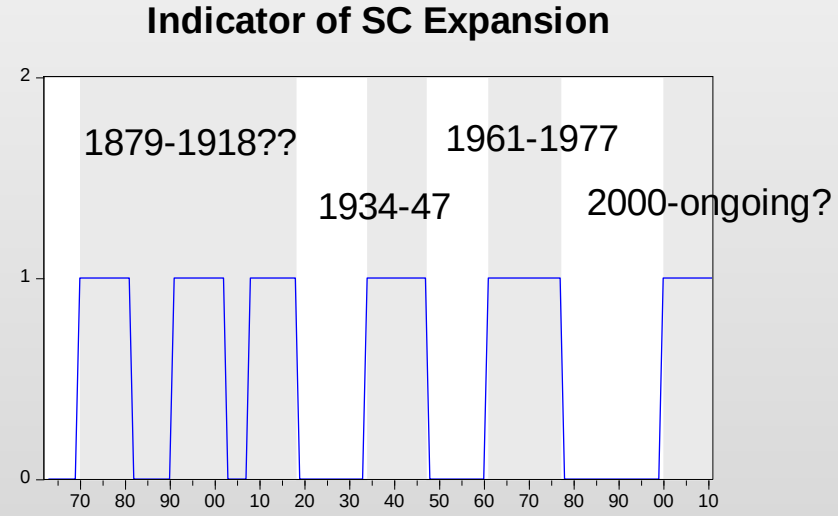
Conclusions

- The extreme volatility of mineral prices (even w annual frequency data) makes it very difficult to say anything definitive about long-term trends

- Our band-pass filter analysis suggests that long-term trends vary widely over time, often changing direction more than once rather than following the U-shaped pattern suggest by (some) theory

- Studying aggregate commodity indexes is a dubious activity, given variety of underlying price behaviors





Extensions: Bass-pass Filter Analysis of Super Cycles (20-70 Years)

- Cuddington-Jerrett (2008) on LME6
- Jerrett-Cuddington (2008) on Steel, Pig iron, and Molybdenum
- Zellou-Cuddington (2012) on crude oil and coal

Appendix: USGS Data

- The USGS website has annual data for 101 non-energy minerals from 1900 (in many cases) through 2010. Both nominal unit values and real unit values, using the U.S. CPI as the deflator, are available. This allows for a rather exhaustive coverage of the mineral commodities.

- Source: http://minerals.usgs.gov/ds/2005/140/#data

- "The U.S. Geological Survey (USGS) provides information to the public and to policy-makers concerning the current use and flow of minerals and materials in the United States economy. The USGS collects, analyzes, and disseminates minerals information on most nonfuel mineral commodities.

- "This USGS digital database is an online compilation of historical U.S. statistics on mineral and material commodities. The database contains information on approximately 90 mineral commodities, including production, imports, exports, and stocks; reported and apparent consumption; and unit value (the real and nominal price in U.S. dollars of a metric ton of apparent consumption). For many of the commodities, data are reported as far back as 1900. Each commodity file includes a document that describes the units of measure, defines terms, and lists USGS contacts for additional information. [Accessed August 2, 2012]

- Insert List and years covered for each (to do) ***

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Comments welcome

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