

# Broadening the Statistical Search for Metal Price Super Cycles to Steel and Related Metals

by

Daniel Jerrett and John T. Cuddington<sup>1</sup>

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## Abstract

During the past five years, industry analysts have proclaimed that metal prices are in the early phase of a ‘super cycle,’ driven primarily by Chinese industrial expansion. Academic economists have generally been very skeptical about the presence of long cycles. A time-series econometric analysis by Cuddington and Jerrett (2008), however, has used band-pass filtering techniques to isolate super cycles in the prices of six metals traded on the London Metal Exchange (the ‘LME6’). This paper extends the search for super-cycle behavior to three additional metal products that are critical in the early phases of industrial development and urbanization: steel, pig iron, and molybdenum (a key ingredient in many steel alloys). There is strong evidence of super cycles in these three metals, although their timing differs to some extent from the super cycles found for the LME6.

*Keywords:* Super cycles, trends and cycles in metals prices, commodity prices, band-pass filters

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<sup>1</sup> PhD candidate ([djerrett@mines.edu](mailto:djerrett@mines.edu)) and W.J. Coulter Professor of Mineral Economics ([jcudding@mines.edu](mailto:jcudding@mines.edu)), respectively, at the Colorado School of Mines.

## 1. Overview

Recently, financial and metals industry analysts have paid considerable attention to the sustained run up in metal prices, allegedly fueled by industrial development and urbanization in China, India, and other emerging economies. Some have argued that the world economy has entered the early phases of a ‘super-cycle’ expansion, defined as ‘decades long’ above-trend movements in a wide range of base material prices. (See, e.g., Rogers (2004) and Heap (2005) (2007)) ‘Super’ cycles are ‘super’ in a couple of senses. They are very long in total duration -- i.e. ten to thirty-five year expansions, implying twenty to seventy year cycles if one assumes symmetric expansions and contractions phases. They are also ‘super’ in the sense that a wide range of non-renewable (and maybe other) commodities are presumably involved. Super-cycle proponents attribute these sustained strong prices to broad-based, demand-side expansions as major economies move through a metals-intensive phase during their industrialization and urbanization.

Who cares about the presence of super cycles? Understanding super cycles in metals prices is important for a variety of economic actors in both the private and public sectors. Obviously, mining companies making production and capital investment decisions should have a great interest in current price levels relative to expected longer-term trends and cycles. Davis and Samis (2006) and Sillitoe (1995) both point out the unique nature of the mining sector in terms of the very long lead times necessary to bring new projects online (fourteen to twenty-two years in the projects they study). On Wall Street, investors are seeing a rapidly increasing number of innovative financial instruments linked to metals. Individual investors, pension fund portfolio managers, and hedge funds are among those that have fueled the demand for these metal plays.

Governments in countries where mining offers significant tax revenues and royalties also have a keen interest in metals prices and metals price forecasts.

The objective of this paper is to extend Cuddington and Jerrett's (2008) econometric search for super cycles in metals prices to our 'steel group', defined here as steel, pig iron, and molybdenum, three metals for which we have been able to obtain the necessary long span of data. The same methodology used in Cuddington and Jerrett (2008) is employed on annual price series for steel, pig iron and molybdenum to extract their long-term trends, super cycles and other shorter cyclical components. We then ask: is there a high degree of concordance among the individual super-cycle components for the steel group? Evidence based on both correlation and principal component analysis is presented. Finally, the paper investigates the degree of concordance among the LME6 and the steel group metals.

Cuddington and Jerrett's contribution involves an effort to measure super cycles, as well as long-term trends, by applying a relatively new time-series econometric technique called band-pass filtering, developed by Baxter-King (1999) and Christiano-Fitzgerald (2003). Band-pass (BP) filters allow the researcher to decompose any time series into a number of mutually exclusive and completely exhaustive components, each of which captures cycles in a specified band of frequencies or periodicities.<sup>2</sup>

Cuddington and Jerrett apply band-pass filtering to some 100-150 years of data on metals traded on the London Metal Exchange (aluminum, copper, lead, nickel, tin, and zinc) to extract their super cycle (SC) as well as other components. Their analysis goes on to demonstrate that

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<sup>2</sup> The Spectral Representation Theorem tells us that any time series can be decomposed into a collection of underlying cyclical components and that the 'ideal' band pass filter is the appropriate tool for carrying out such decompositions.

the super-cycle components of the six LME metals are substantial in magnitude, variable in length, and highly correlated with each other in terms of timing. Moreover, the timing of the super cycles matches reasonably well the dating proposed in less formal analyses by Heap (2005, 2007). Cuddington and Jerrett identify three prior super cycles since the late 1800s, breaking Heap's second super cycle into two separate cycles, and suggest that a fourth super cycle is current under way early in the 21<sup>st</sup> century. Thus, their evidence is generally supportive of the super-cycle hypothesis.

Figure 1 summarizes Cuddington and Jerrett's findings by reporting the first principal component from the LME six-metal analysis, as well as their similar analysis for the subset of three metals (copper, nickel, and zinc) that had longer price series dating back to almost 1870. The vertical axis shows the natural log of the real prices, so a value of 0.40, for example, indicates that the super-cycle component is 40% above the long-term trend. The three- and six metal analyses imply similar timing for past super cycles: approximately 1890-1911, 1930-51, and 1962-77.

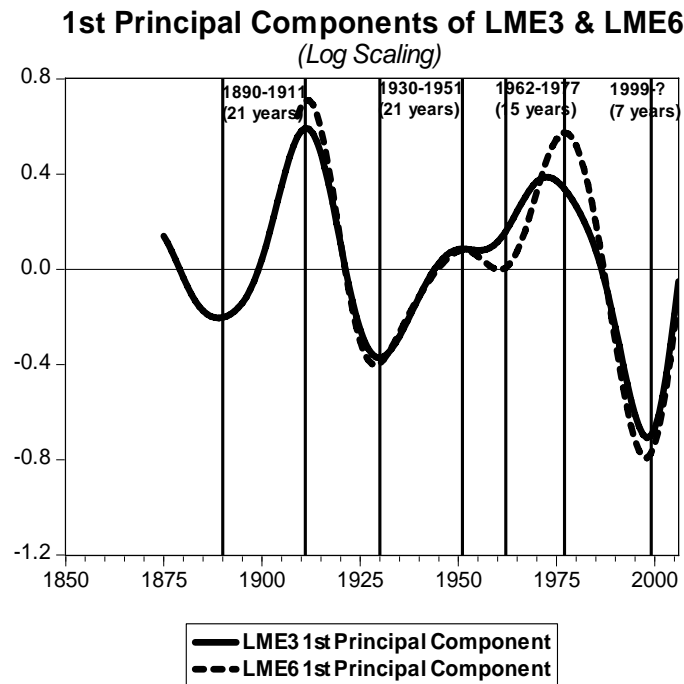


Fig. 1: Real Super Cycles of the LME6 Metals and the LME3 subset (copper-nickel-zinc subset) from Cuddington-Jerrett (2008). The shading corresponds to the expansion phase of each super cycle. The six-metal group is used for dating when both principal components are available.

Even to non-specialists surveying the dramatic change in the urban landscapes of China and India over the last decade or so, it is readily apparent that steel products have been a key ingredient in these countries' surging economic activity. Indeed, dramatic increases in steel consumption are virtually synonymous with industrialization and urbanization. Steel prices have increased sharply since 2000, as have some of the underlying metals used as inputs in steel making, such as pig iron and molybdenum. Are these recent price movements further evidence in favor of the super-cycle hypothesis?

In developing band-pass filters to study *business* cycle fluctuations, Baxter and King (1999) stressed the need for accurate measurement before detailed theorizing: "The study of

business cycles necessarily begins with the measurement of business cycles.” Our motive is the same in this paper, although our interest is in lower frequency super cycles rather than high frequency (2-8 year) business cycles. If one is interested in studying alleged super cycles, the first step is to attempt to measure them. Measurement without theorizing about possible underlying causes of super cycles may be frustrating for some readers and thought provoking for others. Our goal to understand the super cycle facts leads naturally to the desire for a ‘slick structural model’ to explain them!

Unfortunately, the development of a formal model of super cycles is a daunting task. Although we don’t attempt to provide such a model, some initial thoughts in that direction are provided here as a backdrop for our statistical analysis. What seems to be required in terms of a formal super cycle model is a multi-sectoral macroeconomic model of growth and stages of development. Suppose the economy has three broad sectors -- agriculture, manufacturing/construction, and services – and that the production technology in the manufacturing sector is very metals intensive relative to agriculture or services. During the typical ‘development process,’ domestic expenditure shares on agriculture gradually decline while the manufacturing share rises. This transition should be accompanied by strong growth in metal demand, given the plausible factor intensity assumption above. Hence, real metal prices should rise (assuming a positively sloped long-run metal supply schedule). In later development stages, the expenditure share on services begins to rise, with a commensurate fall in the manufacturing and agriculture sector shares. A fall in real metal prices should ensue as the super-cycle expansion comes to an end.

Current explanations of metal price super cycles are typically based on a ‘conceptual framework’ like that described above, albeit no complete general equilibrium model, except that the story invariably involves several regions in the global economy at different phases in their development processes. With the present super cycle, it is China and to a lesser extent India and other developing economies that are in the metals-intensive industrialization and urbanization phases. This phase is characterized by rapid growth in manufacturing and construction with a concomitant surge in metals demand.

In order to study the co-movement among metal prices during super cycles, one would have to further extend the model sketched above to include supplies and demands for several metals and link them – with subtleties in timing – to stages of development. Of course, lead-lag relationships among metals that were relevant during the first metal super cycle caused by U.S. industrialization in the late 19<sup>th</sup> century could differ from those prevailing during the post-WWII booms in Western Europe and Japan. These lead-lag relationships presumably reflect evolving uses and applications for various metals as well as supply-side linkages due to, for example, increasingly sophisticated mining technologies that allow for co-production of several metals from poly-metallic ore bodies.

Hopefully, this sketch of a *medium-term* analytical framework, rather than a discussion rooted in short-term business cycle dynamics, will assist readers in studying the empirical evidence on super cycles presented in this paper. Regarding the current boom, and technical modeling details aside, super-cycle proponents would argue that various (perhaps hard to isolate) factors have jump started the manufacturing and construction intensive phase of Chinese economic development. This will invariably bring about a sustained increase in the demands for

many metals and other raw materials, albeit it with possible timing differences. Above-trend metals prices could result for a prolonged period, depending on the speeds of long-run supply responses across various sectors of the economy.

In modern macroeconomics, theories of the business cycle (i.e. short-term fluctuations) are invariably superimposed on longer-term trends or growth paths. Similar considerations are relevant in the modeling of metal market supplies, demands and prices. Short-term business cycle fluctuations in the presence of inelastic metal supply and demand functions can result in large short-term price volatility that may obscure for several quarters or years any longer-term super cycles and trends of the sort that we attempt to identify in this paper.

## **2. Cycles**

There has been a significant amount of past work on economic fluctuations and price cycles. Cycles studied have ranged from the well-known business-cycle frequency of two to eight years to the 45-60 year cycles referred to as Kondratiev Waves. Some economists have argued that long-term cycles may, in fact, be statistical artifacts caused by inappropriate detrending techniques. See, e.g., Nelson and Kang (1981) on “spurious periodicity.” Recently, attention has returned to studying longer cycles. Comin and Gertler (2006), for example, use band-pass filtering techniques to measure so-called ‘medium term’ cycles in various macroeconomic series. They then go on to develop a highly aggregated structural model to help explain the interaction between medium term cycles and traditional business cycle fluctuations through technology shocks.

The literature on commodity price cycles is diverse in its methods of analysis. Numerous studies apply fundamental market analysis combined with solid industry knowledge of the metal in question. See, e.g., Maxwell (1999), Radetzki (2006), and Tilton (2006), among many others. Another strand of literature focuses on econometric analysis of commodity price behavior. See, e.g., Cuddington et al (2007), Cuddington and Urzua (1989), Cashin & McDermott (2002), Gilbert (2007), and Labys et al (2000).

The Cuddington and Jerrett (2008) paper is the first to apply the band-pass filters developed by Baxter and King (1999) and Christiano and Fitzgerald (2003) to the study of cyclical behavior of metals prices. These band-pass filters are sophisticated two-sided moving averages of the underlying (price) series where the weights are determined analytically using spectral analysis with the objective of extracting cyclical components within a specified range of frequencies. That is, the band-pass filter is applied to the time series in question to let certain specified frequencies ‘pass through’ the filter, while removing or ‘filtering out’ higher and lower frequency components. Baxter-King and Christiano-Fitzgerald develop symmetric filters, which by definition assume equal weights on each lead and its corresponding lag ( $w_{t-s} = w_{t+s}$ ). The advantage of symmetric filters is that they insure that there is no phase-shifting of the filtered series relative to the original series. The use of symmetric filters, however, inevitably means that the analyst loses a number of observations at both the beginning and end of the data sample. The longer the cycle one wishes to study, the more data points are lost. Christiano and Fitzgerald address this issue by developing asymmetric filters, which allow one to calculate the filtered series over the complete data sample. This is a key advantage when one wishes to look for possible super cycles that emerge near the end of the currently available data sample, as we do.

Christiano and Fitzgerald show that the phase-shifting caused by the use of an asymmetric filter is relatively minor, at least in the applications they consider.

This paper uses the asymmetric Christiano-Fitzgerald band-pass (ACF) filter to decompose the natural logarithms of real metal prices into three components: (1) the long-term trend (LP\_T), (2) the super cycle component (LP\_SC), and (3) other shorter cyclical components (LP\_O):

$$LP_t \equiv LP\_T_t + LP\_SC_t + LP\_O_t \quad (1)$$

One must first decide what cycle periods encompass super cycles. Cuddington and Jerrett interpret Heap's (2005, 2007) discussion to imply that super cycles have upswings from ten to thirty-five years, implying that the complete cycle (if symmetric) has a period of roughly twice that amount. Thus, the super cycles are assumed to have periodicities from twenty through seventy years. The BP(20,70) filter is applied to each price series to extract its super-cycle component:

$$LP\_SC \equiv LP\_BP(20,70) \quad (2)$$

With this definition of the super cycle, it is natural to define the long-run trend as all cyclical components with periods in excess of seventy years:

$$LP\_T \equiv LP\_BP(70,\infty) \quad (3)$$

Note that this approach does not make the incredible assumption that the long-term trend is constant over the 100-150 years span of our dataset. Rather it can evolve slowly over time.

Having identified the long-term trend and the super cycle, what remains are other shorter cyclical components, which therefore include cycles with periods from two (the minimum measurable period) through twenty years:<sup>3</sup>

$$LP\_O \equiv LP\_BP(2,20) \quad (4)$$

It will be convenient in the graphical analysis below to examine the total ‘non-trend’ component of prices, which is the total deviation from the long-term trend. That is, it is the sum of the super cycle plus the other shorter cycles:

$$\begin{aligned} BP(2,70) &\equiv BP(2,20) + BP(20,70) \\ \text{or equivalently} & \\ LP\_NT &\equiv LP\_O + LP\_SC \end{aligned} \quad (5)$$

Note that the decomposition in equation (1) can be written in band-pass filter notation as:

$$\begin{aligned} LP_t &\equiv LRP\_T_t + LRP\_SC_t + LRP\_O_t \\ LP_t &\equiv LP\_BP(70,\infty) + LP\_BP(20,70) + LP\_BP(2,20) \end{aligned} \quad (6)$$

By construction, our three components sum to the price series itself:

### 3. Empirical Results

The nominal price series for the steel group come from three sources. The 109-year annual steel series is from Alan Heap’s database. The International Molybdenum Association (IMOA) provided a 92-year molybdenum price series. Robert Hunter and the International Pig

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<sup>3</sup> It is straightforward to decompose these ‘other shorter’ cycles into business cycles with periods between two and eight years and intermediate cycles from eight to twenty years. This is not necessary however for the study of super cycles, the main focus of the present paper.

Iron Association (IPIA) provided 156 years of pig iron data.<sup>4</sup> All three series were deflated by Heap's U.S. consumer price index (CPI) series (2006=100) to obtain the real series used below.<sup>5</sup>

This paper works with the natural logarithm of the three-metal steel group price series. The ACF filter is applied to each to extract the long-term trend, non-cyclical trend, and super-cycle components. As an illustration, Fig. 2 shows the decomposition of the real steel price series. The top portion of Fig.2 shows the natural log of the real steel price, with the long term trend superimposed. Hence the slope of the line at any point equals the growth rate. Note that real steel prices trended downward from 1850 through to the mid 1920s, trended upward until 1970, and then trended downward through the end of the sample.

The non-trend component, which is defined as the difference between the actual series and the long-run trend, is shown in the lower panel of Fig.2. The left scaling is again in logarithms, so a value of 0.50 represents a fifty percent deviation from the long-term trend. Note that the cyclical fluctuations in the total non-trend component from the long-term trend are huge. The fluctuations capture the sum of other shorter cycles (2-20 years) and the super cycle (20-70 years). The super cycle is superimposed on the total non-trend component in the lower panel. It is interesting to note that the super cycles in steel are not as pronounced in the early part of the

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<sup>4</sup> Our pig iron series was constructed by splicing together three separate prices series provided by the Robert Hunter and the IPIA. All units were U.S. dollars per long ton.

<sup>5</sup> Discussions of real commodity price behavior invariably raise the question of the 'appropriate' deflator. Common U.S. dollar based indices include the consumer price index (CPI), the producer price index for final goods (PPI) and the manufacturing unit value index (MUV). Our choice of the CPI here was driven primarily by the ready availability of a long-span CPI in Heap's dataset. As Cuddington and Jerrett (2008, p. (TBD)) note: "It is not clear which deflator is 'more relevant.' Ultimately, this depends on what relative prices one is most interested in for the questions at hand. For example, suppose a U.S. financial investor is considering investments in commodities (or industrial metals, or precious metals) as an asset class. Presumably she wants to know how their prices move over time relative to the CPI. Percentage changes in the metals prices deflated by the CPI would be the relevant 'real' return. On the other hand, if one is looking for the relative price of metal inputs relative to particular output prices, then one would want to select the particular outputs of interest. Here the PPI for final goods (or chosen sub-category) might be viewed as more relevant, because the PPI includes capital as well as consumption goods and excludes distribution costs and indirect taxes."

sample as they are during the later years. Moreover, their amplitude seems to be increasing over time. One might speculate as to whether this could be due in part to steel's later development as a primary metal for infrastructure.

The deviations between the total non-trend component and the super cycle in the lower panel reflect the importance of other shorter cycles (i.e. business and intermediate-term cycles). The latter are quite large. Thus, even during a super-cycle expansion, one could be caught in periods of extreme volatility due to the presence of business and intermediate cycles. Clearly, the total non-trend component is comprised of much more than just the super cycle. This has important implications for those contemplating major metal industry investments because they believe that the world economy is in the early phase of a metals super cycle. Our price decompositions show clearly that super-cycle behavior can be buried for several years in sharp business-cycle downturns!

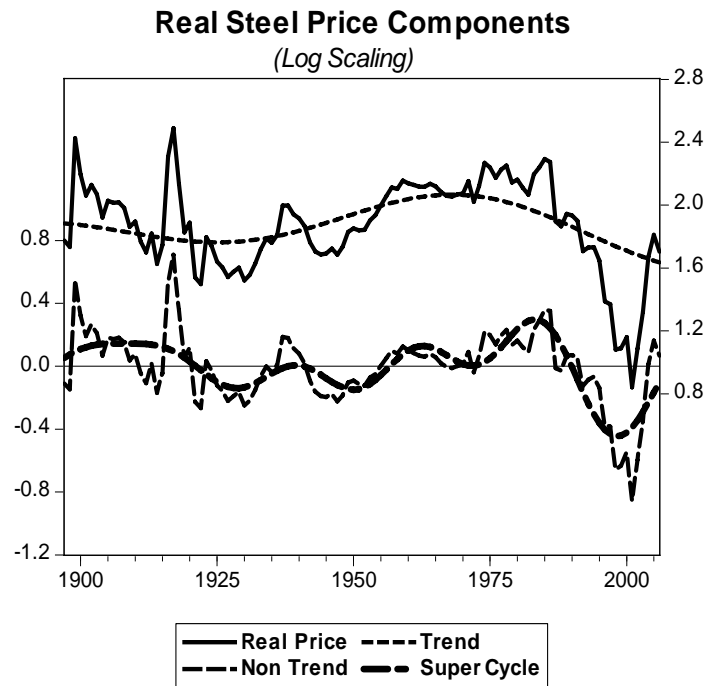


Fig. 2: Real Price Decomposition of Steel. This graph shows the decomposition of the natural log of the real price of steel into its various components: the long-term trend, the non-trend, and super cycle.

The corresponding decompositions for pig iron and molybdenum prices are shown in Fig.3. The time span covered by the three metals differs due to data availability. Fig. 3 shows that the molybdenum prices trended upward until roughly 1950, but then declined through about 1985.<sup>6</sup> Pig iron's price trend is sharply negative until about 1925. Thereafter it drifted upward through the 1960s before resuming its downward trend.

<sup>6</sup> The decomposition of molybdenum looks strikingly like the copper decomposition from Cuddington and Jerrett (2008). Molybdenum is increasingly produced as a by-product or co-product with copper, so this is perhaps not surprising. On the other hand, the demand-side factors driving their prices are quite distinct given their generally unrelated end-use applications.

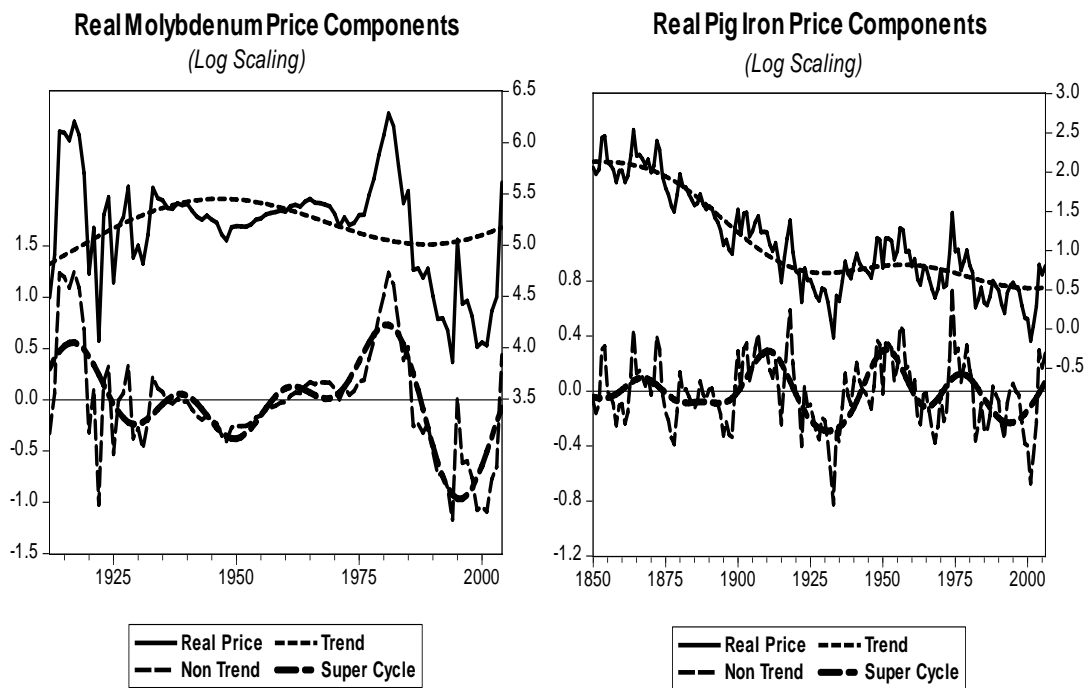


Fig. 3: Real Price Decompositions for Pig Iron and Molybdenum. This graph shows the decomposition of the natural log of real prices of pig iron and molybdenum into long-term trend, the non-trend, and super-cycle components.

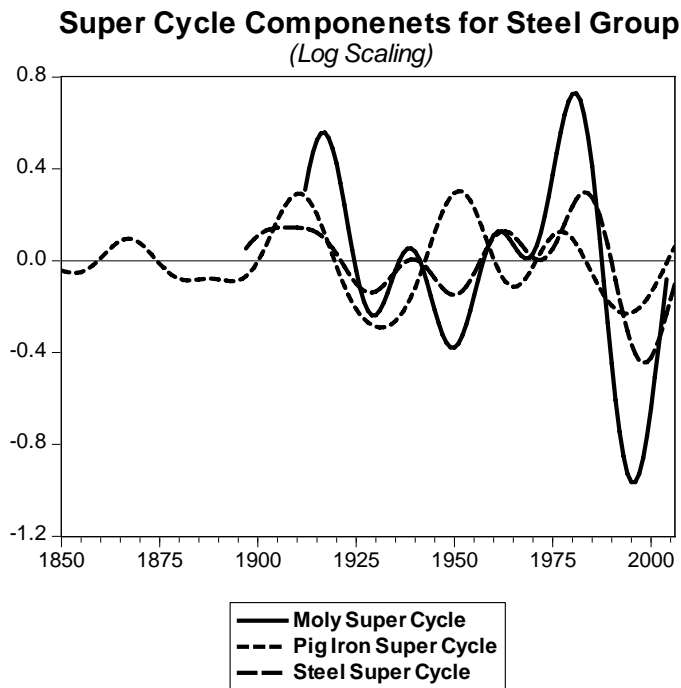


Fig. 4: Super-Cycle Components of Real Metals Prices. This graph contains super-cycle components for molybdenum, pig iron, and steel.

#### 4. Co-Movement of Metals Prices

As various economies in the world undergo metals-intensive surges in their manufacturing and construction activities – a typical phase in the overall development process, the demand for various industrial-use metals will expand in tandem. Thus, if super cycles are in large part demand driven, then there should be strong co-movement across metals. For example, steel, pig iron, and molybdenum should be roughly ‘in phase’ during the various super cycles. On the other hand, if metal-specific supply and/or demand developments dominate, their price patterns will differ. Collecting the steel group super cycle components in Fig.4 provides a visual check. Graphically, one gets the general impression that the super cycles have different

amplitudes, but move upward together in the early 1900s. After that episode, there is a period of time (1940-60) where the pig iron super cycle is moving out of phase with the other two metals. After the mid 1960s, the super-cycle components for pig iron, steel, and molybdenum come back into phase, showing a high degree of concurrence in the latest super cycle beginning in 2000. We searched the literature for possible reasons why pig iron super cycles fell out of phase with steel and moly during the 1940-60 period, but can't find a definitive explanation. Regarding this period, however, Nester (1997) observes that the U.S. government imposed price controls on many commodities, but steel in particular, from 1941-1947. When the price controls were removed the steel industry saw a large increase in wage pressure along with price increases. This led to erosion in the competitiveness of the U.S. steel industry in the mid 1950s and, ultimately, a period of flat prices. How these factors might have affected the long-term (super cycle) relationship between pig iron and steel prices is unclear.

A more formal statistical analysis can be performed to assess the extent of co-movement of metal prices. Simple correlations for the balanced sample 1912-2004 are shown in Table 1. (This insures comparability with the principal component analysis where a balanced sample must be used.)

Table 1: Correlations: Super-Cycle Components of Real Prices.

This table reports the contemporaneous correlations for the three super-cycle components for the balanced sample 1912-2004. Significance at the 95% level is indicated by asterisks, based on the asymptotic standard errors.

Correlation	Molybdenum	Pig Iron	Steel
Molybdenum	1.00		
Pig Iron	0.38*	1.00	
Steel	0.87*	0.30*	1.00

Asymptotic Standard Error= 0.104

All three correlations are statistically significant at the 1% level. The correlation between steel and molybdenum super cycles (0.87) is much stronger than the other correlations, which is somewhat surprising, given the key role of pig iron has as an input in steel making. On the other hand, molybdenum is a key ingredient in many steel alloys (as it is a hardening agent).

Regarding possible lead-lag relationships among the super cycle components for the steel group, it is interesting to study the cross correlograms shown in Fig.5. Generally, the contemporaneous correlations are higher than correlations at various leads or lags. Notable exceptions involve pig iron, where the super-cycle components of molybdenum and steel are more correlated with lags of the pig iron super cycle. (This can be seen in the first and third graphs in column 2 of Fig.5.) This suggests that the pig iron super cycle has, on average, led the super cycles in molybdenum and steel by roughly three and six years, respectively. Again detailed analysis of the interaction among these three markets would be required to provide a possible explanation for this pattern.

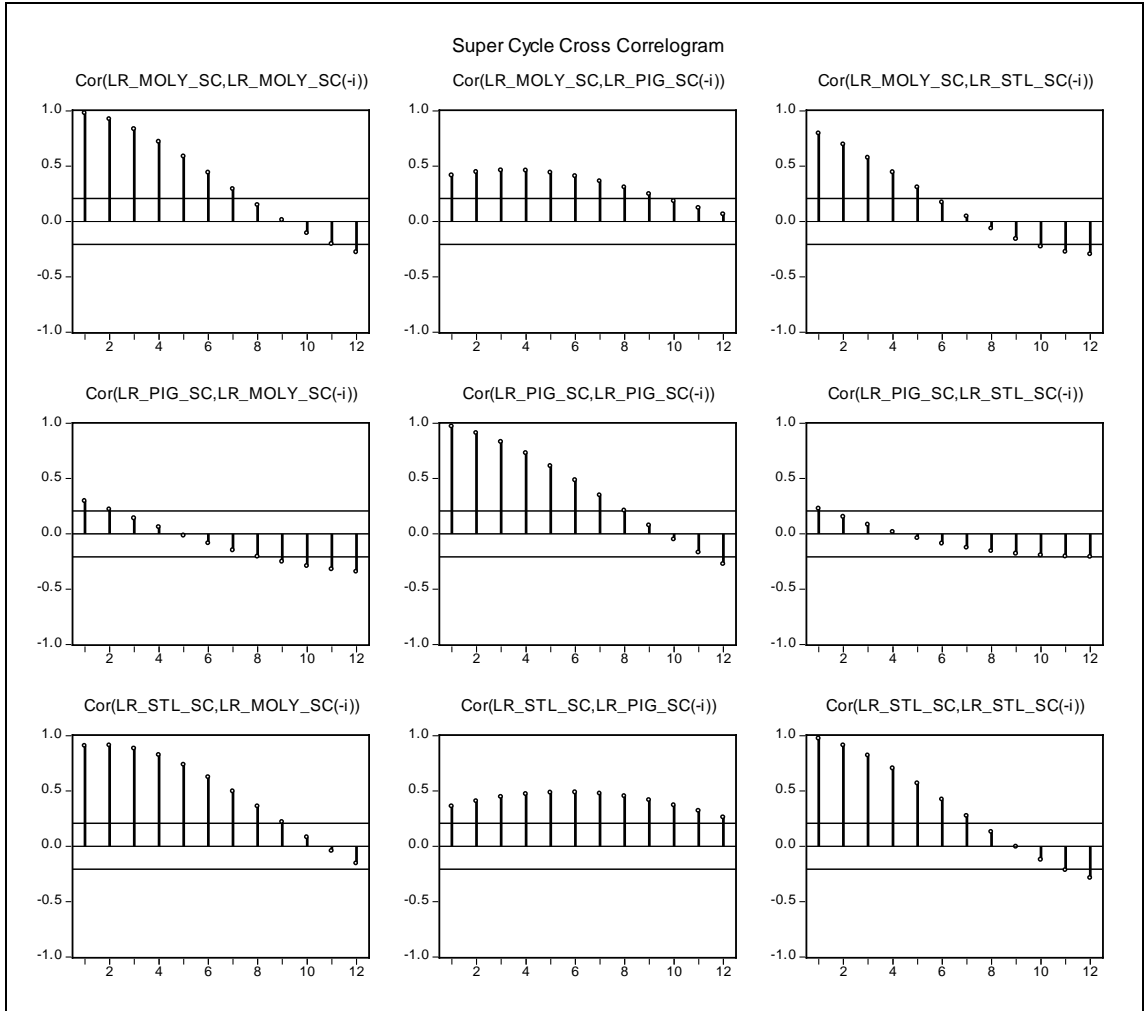


Fig. 5: Cross Correlograms for the Super-Cycle Components of Steel, Molybdenum, and Pig Iron. This figure shows the cross correlograms for the steel, molybdenum, and pig iron super-cycle components. Note that most cross correlations at lag zero are highly significant indicating strong co-movement among the super cycles in the three metals.

Principal component analysis can be used to identify one to three common, unobservable factors that are jointly driving the three metals. Here, principal component analysis (PC) is used to decompose the variance-covariance matrix of the super-cycle components of the three real metal price series. Results are shown in Table 2.

Table 2: Principal Components: Super-Cycle Components for Real Metal Prices.

This table gives results for the principal-component analysis for the three metals over the balanced sample 1912-2004. The first principal component (PC1) explains 86% of the variation in the co-movement of the three metals. PC1 has positive and rather high factor loading for 2 of the 3 metals (steel and moly).

PC Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
PC1	0.20	0.17	0.86	0.20	0.86
PC2	0.03	0.02	0.11	0.22	0.97
PC3	0.00	0.00	0.00	0.23	1.00

Eigenvalues: Sum=0.23, Average=0.08

Variable	PC1	PC2
Molybdenum	0.92	-0.14
Pig Iron	0.16	0.98
Steel	0.32	-0.10

The first principal component (PC1) explains 86% of the co-variation in the steel group's super-cycle components. This strongly supports the notion of co-movement of the super cycles in these metal prices. In addition to the high cumulative proportion explained by the first principal component, the factor loadings on all three metals are positive giving additional support to the co-movement hypothesis. (Note the relatively high factor loading on molybdenum, the metal with the higher super-cycle variance). The first principal component is graphed along with the individual super-cycle components for the steel group in Fig.6.

### Steel Group Super Cycles & 1st Principal Component (Log Scaling)

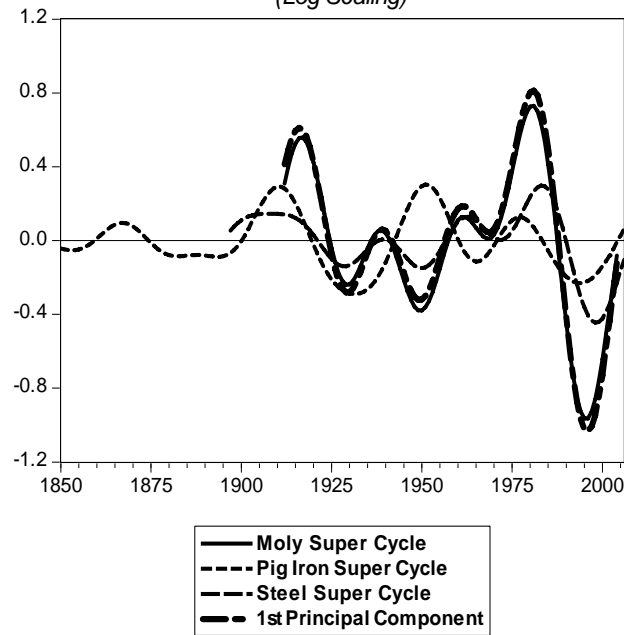


Fig. 6: Super-Cycle Components for the Real Prices of Steel, Pig Iron, and Molybdenum and their First Principal Component (PC1). This figure contains the three metals' super-cycle components along with their 1st principal component. It can be seen that PC1 is highly correlated with the super-cycle components from the three metals.

## 5. Result Comparison to Cuddington and Jerrett (2008)

As a test of the robustness of the super cycle filtering methodology, as well as the overall super-cycle hypothesis, the results for the steel group in this paper can be compared to the results for the LME6 base metals in Cuddington and Jerrett (2008). Fig.7 shows the first principal component from the LME metals analysis along with the first principal component from the steel group super cycles. The first principal components for the two groups are reasonably highly correlated in the early part of the sample through 1930.

**1st Principal Components for Steel Group & LME6 Group**  
(Log Scaling)

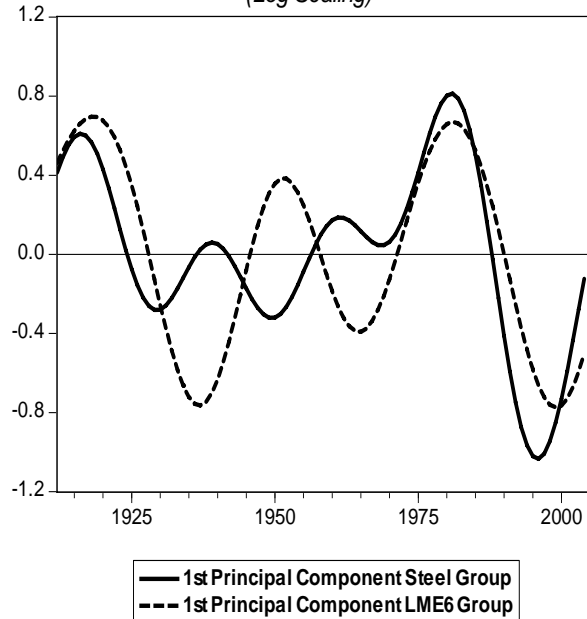


Fig. 7: Comparison of the 1st Principal Components from the Steel3 Group and the LME6 Group. This graph contains the first principal component for the three steel group metals studied here and the LME6 metals from Cuddington-Jerrett (2008).

From the 1930s through 1965-70, on the other hand, the principal components are almost perfectly out of phase. This could be in part due to copper's significance in driving the super cycle in LME metals, as well as steel price controls present during this period. The super cycle in molybdenum follows the principal component from the LME metal analysis throughout this thirty-five year period, perhaps again reflecting the fact that moly is often a co- or by-product in copper mining.

The LME and steel group principal components in Fig.7 come into concurrence again in the early 1970s and follow each other closely through the rest of the sample. One conclusion

that can be drawn is that the most recent super cycle in all metals prices begins sometime between 1995 and 2000. This roughly matches the super-cycle timing identified by Heap, but with the start of the super cycle occurring somewhat earlier – especially for the steel group. Although there are periods in the past 100 years where the super cycles for the individual metals are out of sync, they come into strong concurrence in the late 20<sup>th</sup> century. (It might be interesting to investigate the possible change in the role that steel played in construction activities in the early and mid 1900s compared with the present. This and other hypotheses to explain this divergent behavior is left as a topic for future research.)

To get a broader assessment of the presence of super cycles, we combine the LME6 metals studied in Cuddington and Jerrett (2008) and the steel group studied here. The resulting correlation matrix for all nine metal price super cycles is shown in Table 3. Thirty-one of the thirty-six correlations are large, positive and statistically significant; many are in excess of 0.50.

Table 3: Correlations: Super-Cycle Components of Real Prices.

This table reports the contemporaneous correlations for nine metals' super-cycle components for the balanced sample 1912-2004. Significance at the 95% level is indicated by asterisks, based on the asymptotic standard errors.

Correlation	AL	CU	MOLY	NI	PB	PIG	SN	STEEL	ZN
AL	1.00								
CU	0.20*	1.00							
MOLY	0.63*	0.67*	1.00						
NI	0.82*	0.68*	0.81*	1.00					
PB	-0.48*	0.55*	0.15	0.00	1.00				

Table 4: Principal Component Analysis for 9 Super-Cycle Components (Steel3+LME6).

This table gives results for the principal-component analysis for the nine metals over the balanced sample 1912-2004. The first principal component explains 71% of the variation in the co-movement of the nine metals.

<b>Number</b>	<b>Value</b>	<b>Difference</b>	<b>Proportion</b>	<b>Cumulative Value</b>	<b>Cumulative Proportion</b>
<b>PC1</b>	0.32	0.25	0.71	0.32	0.71

It is striking that the first principal component for the nine metals, both industrial and bulk, explains such a large percentage of their joint covariances. Fig.8 shows the first principal component of the nine-metal series with implied super-cycle dating. Comparing the dating of the nine-metal group in Fig.8 with Cuddington and Jerrett's LME six group analysis in Fig.1, it is evident that both analyses suggest that there have been three rather than two previous super cycles, with a fourth one now underway. The Cuddington-Jerrett dating of the super-cycle expansion phases in Fig.1 changes somewhat when the steel group is added to the analysis. Most notably, the first super cycle rise from the trough in 1929. The earlier super cycle beginning in the 1890s can't be identified due to lack of complete data for the earlier years. The evidence in the Figure (which seems to begin with the end of a long cycle), however, is consistent with the hypothesized underlying cause for the first super cycle identified by Alan Heap, namely U.S. industrial expansion at the turn of the twentieth century.

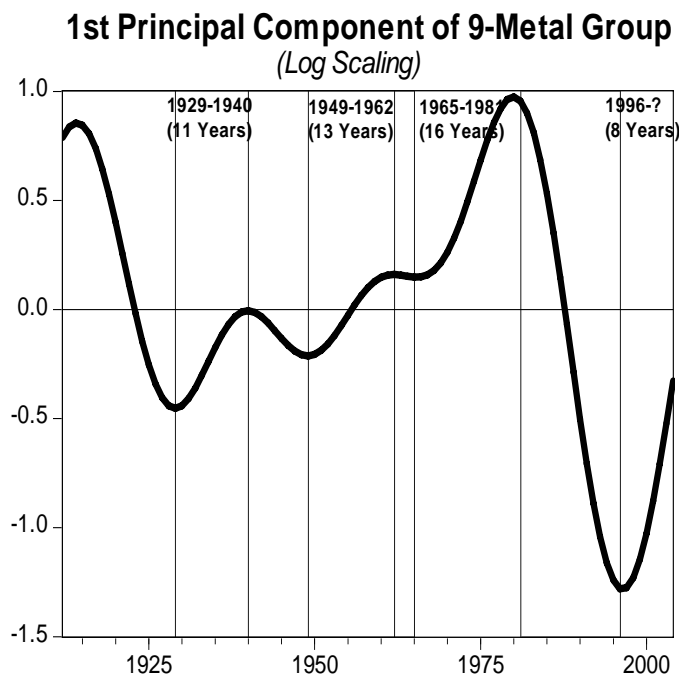


Fig. 8: Principal Component from Nine-Metal Super-Cycle Component (Steel3 plus LME6). This graph shows the first principal component for the nine-metal super-cycle component. The dating corresponds to the expansion of each super cycle.

Comparing the LME6 principal component with the nine-metal principal component over the period from 1940 through 1960 it is much more difficult to line up Heap's dating of the various super-cycles once the steel group is included. It is plausible that U.S. price controls on steel (alluded to above) explain the 'distortion' in the super cycle for the steel group, relative to that observed for the LME6.

## 6. Concluding Remarks

The presence of super cycles in the prices of steel, pig iron and molybdenum is clearly shown in this paper. The band-pass filtering technique garners additional support for the existence of these long cycles with periodicity of thirty-five to seventy years. The amplitude of

super cycles is large with variations of fifteen to seventy-five percent. Statistical evidence of co-movement is supported by correlation analysis and strong co-movement measured by principal component analysis of both the three-metal steel group and the broader nine-metal group (including the steel group and six LME metals).

Now that super cycles have been measured and detected, explaining the factors driving these large price cycles becomes a high priority task. Building a multi-sectoral model of the structural changes accompanying economic development, with explicit supply and demand roles for metals, would appear to be a productive approach to this modeling effort. Allowing for plausible lags in capacity expansion in the metals industry, as discussed in Radetzki et al (2008), is clearly an important aspect to incorporate if one is to distinguish between short-run and long-run effects.

One truth regarding current super cycles is that if these cycles are indeed demand driven, as long as there are continued outward shifts of the demand curve along an upward sloping supply curve, above-trend prices can be sustained. The analytical task is trying to understand the *very* protracted supply response to sustained high demand. World Bank and Wall Street analysts both conjecture that the supply response to current high prices will be very different than that of past cycles. The lack of investment in new mining projects during the 1990s, stricter environmental standards, increasing dependence of higher-cost underground mining (as opposed to open-pit mining) due to declining ore grade, and inadequate port capacity will all have a role in limiting the speed of capacity expansion in the metals industry.

Understanding super cycles is very important not only the mining industry, but also to the investment industry and fiscal authorities in mineral-abundant countries. As the above figures for

individual metals illustrate, deviations from the long-run price trend can be large in amplitude. The more knowledge all three groups have regarding long-term trends and cycles in metals prices, the more informed each can be in making long-term investment decisions. Correctly extracting longer term super cycles in the current global economic environment, where some major economies probably in the midst of business cycle downturns, will further complicate investment decisions in the mining industry.

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