



ISSUE 36

Copper Price Outlook – Update

Reflecting on the Copper Price Cycle - How Good Are Consensus Forecast?

INTRODUCTION

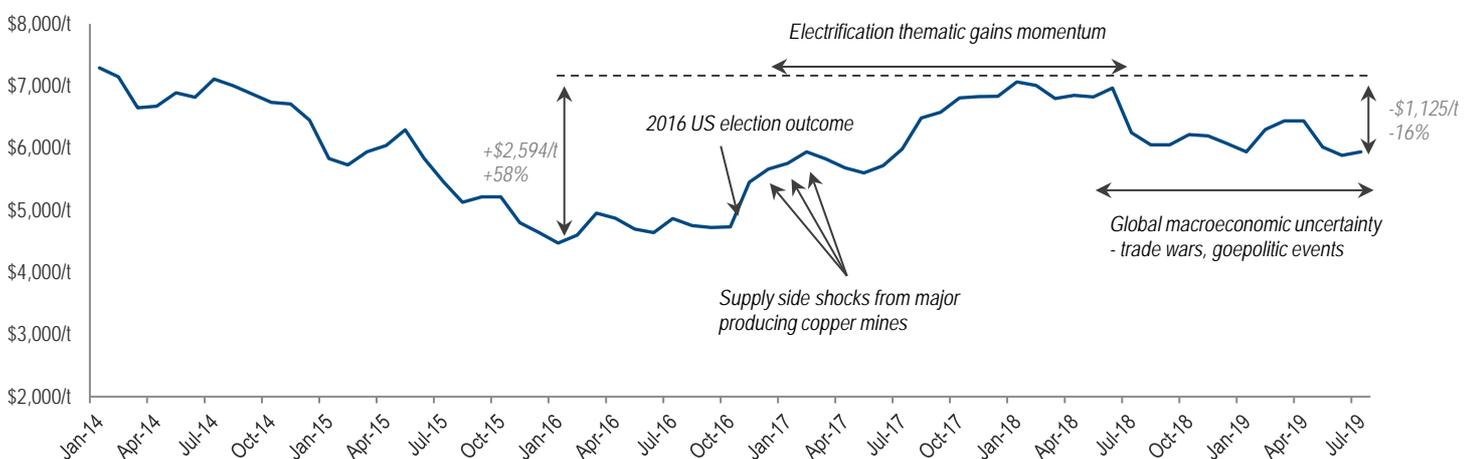
Where we are in the commodity price cycle is one of the most often discussed and relevant questions for the industry. In January 2016 The Alchemist provided a statistical and mathematical approach to provide insights into the cyclicity of copper prices [Issue 27 Copper Price Outlook: Any Sign of a Copper Bottom](#). Copper prices at the time were at 7 year lows of US\$4,500/t with the consensus copper price outlook remaining subdued on the back of weak demand growth and expectations of future oversupply following commissioning of large scale developments.

In the interim period the copper price has indeed bottomed and we have witnessed its subsequent resurgence – peaking at US\$7,000/t in early 2018 before landing at current levels of circa US\$5,800/t. This Issue of The Alchemist considers copper price movements since January 2016 in order to evaluate the usefulness of the methodology outlined in Issue 27 as a forecasting tool and reflect on the copper price cycle.

COPPER PRICE RECAP (2016 – CURRENT)

The recent price history of copper is illustrated in Figure 1. Copper price activity during the first three quarters of 2016 was largely uneventful - copper prices remaining range bound between \$4,500 - \$5,000/t as a result of sluggish demand outlook. In an unexpected turn, the final quarter of 2016 brought about a wave of demand optimism for copper sparked by Donald Trump's victory in the 2016 US presidential election and the President-elect's promises of fiscal stimulus. Robust manufacturing data figures from China continued to fuel price increases, leading to a copper bull market as prices closed the year above \$5,600/t. Copper prices were supported through the first half of 2017 by several supply side shocks at major copper mines (Grasberg – 38 days lost production on concentrate export ban; Escondida – 43 day employee strike; Cerro Verde – 21 day employee strike).

Figure 1: Monthly Copper Price and Key Events (2016 – Current, nominal USD)



Source: World Bank, RFC Ambrian

Several themes played out in the second half of 2017 which served to underpin coppers steady march upwards to \$6,800/t in December of that year. Positive price reactions were driven by renewed optimism for China's copper demand and general global supply concerns. Importantly, 2017 marked the emergence of the electric vehicle and electrification thematic. As the most prolific commodity in electrification, copper stood to benefit from positive long-term demand growth and this likely contributed to a positive demand outlook for it.

Copper prices peaked at a little over \$7,000/t in January 2018, coinciding with macroeconomic and geopolitical tremors threatening to derail global growth in the first quarter of 2018. Against this soft global macroeconomic backdrop, copper slid in the second half of 2018 to finish the year at \$6,075/t. 2019 has followed a similar theme as global macroeconomic tensions continue to rein in the demand outlook for copper – tariffs, trade and currency wars; central banks competing for the title of lowest interest rates; and several unresolved geopolitics events (Brexit, US-Iran conflict etc.).

PRICE CYCLES AND FOURIER ANALYSIS (a quick refresher)

Long term price trends tend to be driven by the investment cycle – sustained periods of over and under investment driven primarily in response to current and expected future prices. This supply-demand and price feedback creates a tendency for prices to overshoot their equilibrium levels – creating price cycles. These often manifest in 'life-events', e.g. the development of leach/solvent extraction in the early 1960's, the rise of Chile as a major producer and most recently, the advent of China as the dominant consumer which stoked demand.

Fourier Analysis involves decomposing the copper price series into a number of oscillating signals, enabling dominant periodicities (ie cycle lengths) to be determined. Periods corresponding to high-amplitude harmonics should align with the duration of the overriding commodity

price cycle. Short-term volatility introduces considerable noise in prices and as a result a low level of granularity is desirable, making Fourier Analysis useful for long-term forecasting (Issue 27 provides complete methodology).

ISSUE 27 TAKEAWAYS

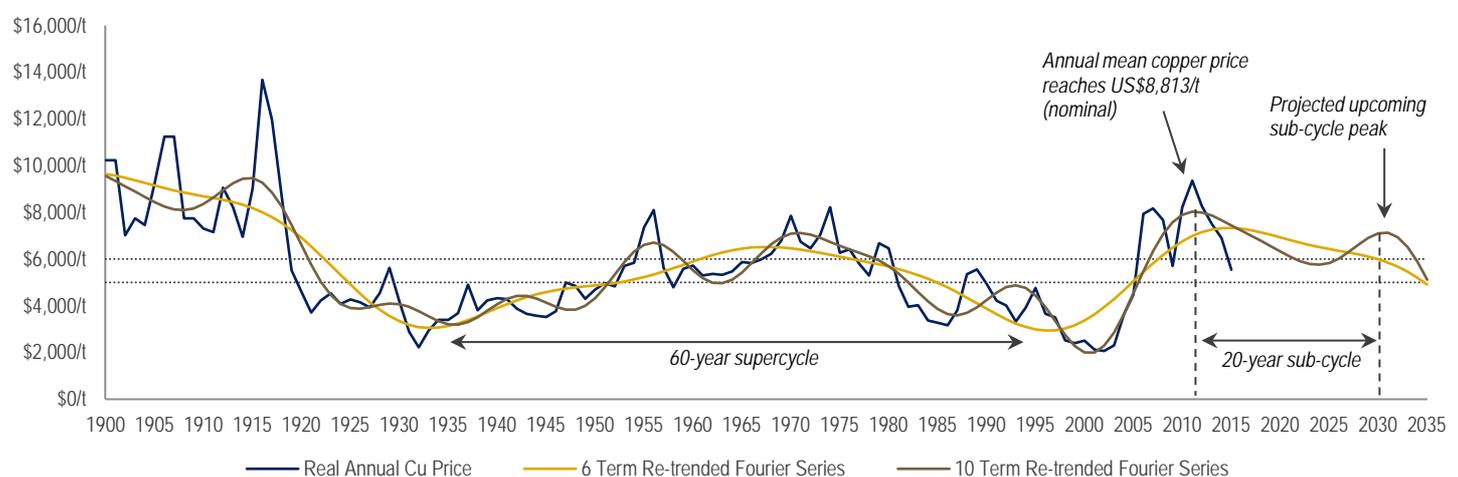
[The Alchemist, Issue 27 Copper Price Outlook: Any Sign of a Copper Bottom](#) provided four key takeaways from an in-depth analysis of long-term copper prices via the use of Fourier Analysis:

1. Long term historic copper prices exhibit two distinct periodicities; a 60-year copper price supercycle (peak around 2015) and a weaker 20-year sub-cycle (peak 2011).
2. The price decline since the 2011 sub-cycle peak has far outstripped what would be expected by Fourier Analysis – suggesting a correction may be due.
3. Real long-term price trends support prices above US\$4,000/t (2016 real dollars) in 2035.
4. High levels of near-term price variation are still fairly rare, but still 6x over-represented compared to normal distribution leading to significant optionality in fat tail events for long life assets.

The analysis found the 60-year supercycle was best represented by the 6-term re-trended Fourier Series and similarly the 10-term series was used as a proxy for the 20-year sub-cycle (Figure 2).

Both the 6 and 10-term Fourier Series indicated the commencement of a downward trend in the cyclicity of copper prices from their respective peaks, towards a long-term price of US\$5,000/t (2016 real dollars). It is evident in Figure 2 that the copper price correction observed in 2015 and 2016 overshot the price levels predicted by the Fourier Analysis. Consequently, The Alchemist suggested that the copper price had bottomed in early 2016 and will likely correct to the long term predicted trend.

Figure 2: Flashback: The Alchemist Issue 27 - 6 & 10-term Fourier Series Representations of the Historical Copper Price (Real 2016 USD)



Source: World bank, Bloomberg, RFC Ambrian analysis

HOW USEFUL IS FOURIER ANALYSIS?

More specifically, how useful is it in determining the current point in the price cycle and understanding long term pricing trends in order to make informed decisions?

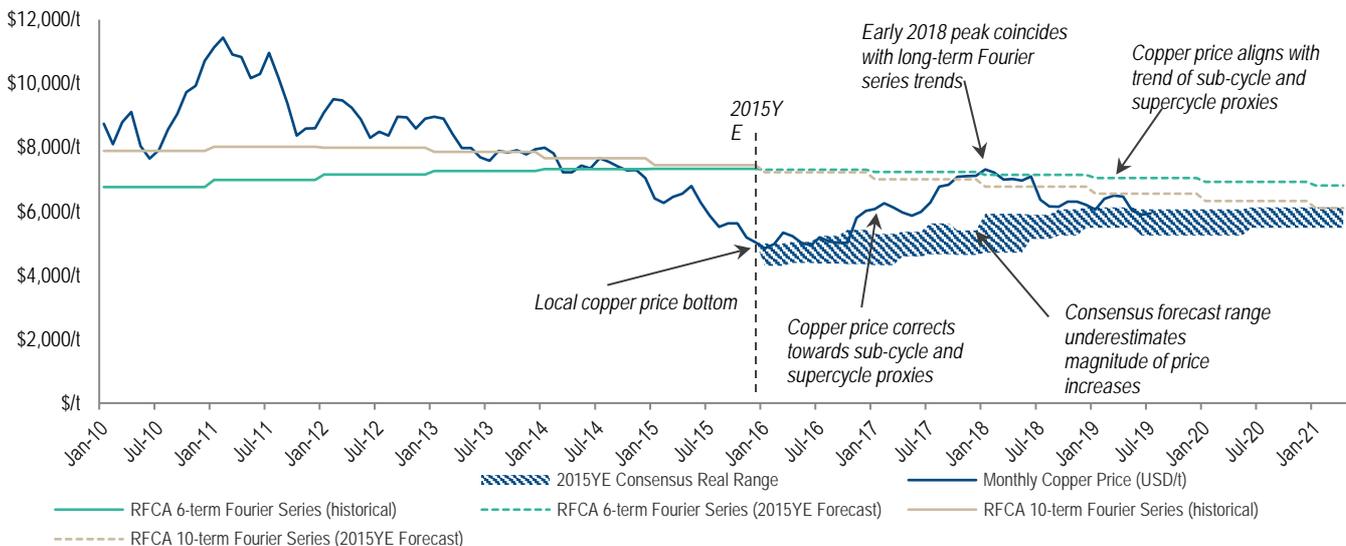
As discussed, the copper price bottomed in the first quarter of 2016 and we saw a marked correction over an 18-month period starting in the second half of 2016. The copper price reached levels which corresponded to both the sub-cycle and supercycle proxies – i.e. the copper price peak in early 2018 coincided with the expected price levels predicted by both the 6 and 10 term series (Figure 3).

Following the correction, copper prices have gradually trended downward at a price level coincident with the rate of decline of the sub cycle and supercycle proxies.

So, what does all this mean? The Fourier Analysis appears to have predicted the rebound in copper prices since 2015YE, and notwithstanding some shorter-term oscillation is aligning reasonably well with the super-cycle and sub-cycle proxies.

Analyst consensus forecast at 2015YE correctly predicted the upward price correction as well, however some apparent price anchoring may have caused consensus to miss the scale of the rebound, instead converging over time with the actual copper prices and copper price levels expected by the sub-cycle and supercycle proxies by around 2021. We would argue that this provides support for the use of Fourier Analysis as a longer term and trend forecasting tool for copper prices.

Figure 3: Real Copper Price vs. 6-term and 10-term Fourier Series vs. 2015YE Analyst Consensus

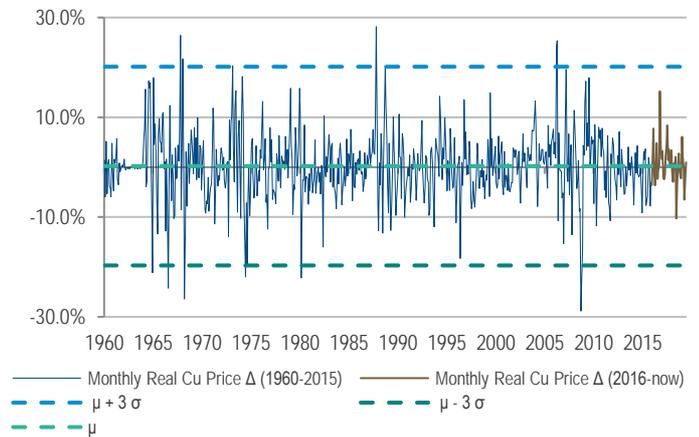


Source: World bank, Bloomberg, RFC Ambrian analysis

WHAT ABOUT VOLATILITY?

As discussed, Fourier Analysis is suitable for determining the periodicity and duration of underlying price cycles – which manifest in long term trends. The Alchemist Issue 27 demonstrated that copper prices exhibit a right skewed distribution, with a long positive ‘tail’ to the right. Price events residing in the positive tail, whilst infrequent, have the potential to greatly enhance project economics if captured, lending support to the notion that higher quality long life projects contain significant option value. The forecast derived from the Fourier Analysis may not capture month-to-month volatility, but it provides a means to predict periods of longer and shorter cyclical super-pricing that consensus and more typical long-term forecasting does not.

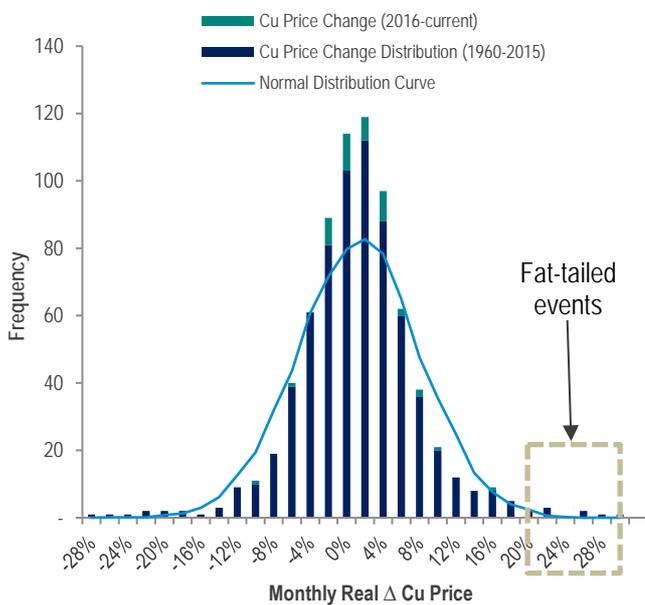
Figure 4: Month-on-Month Copper Price Movement Time Series



Source: RFC Ambrian analysis

Despite the recent influx of news, both negative and positive contributing to copper volatility, the copper price has exhibited a relatively 'normal', if not subdued amount of volatility since 2015YE (Figure 4). Variations outside of two and one standard deviations respectively have been rare, at less than half the expected frequency given the time period and assuming a normal price distribution (Figure 5). Only the November 2016 price spike resided outside of two standard deviations. It must be noted however that a series of "expected variations" can lead to a cyclical and "fat tail" event at a longer time scale, as observed in the super-cycle and sub-cycle.

Figure 5: Month-on-Month Copper Price Change Distribution vs. Normal Bell Curve (1960-present)



Source: RFC Ambrian analysis

CONCLUSION

Utilising Fourier Analysis to understand price cycles provides a useful long-term forecast which can capture pricing aspects more traditional approaches do not; Fourier Analysis differentiates itself by capturing the underlying cyclicity providing a valuable tool for:

1. understanding the long-term trend and the current phase of the commodity price cycle to critique existing price forecasts; and
2. developing an alternative price deck for the assessment and valuation of long-life natural resources projects which are exposed to the longer-term cycles and the benefits of "fat tail" pricing events.

Volatility continues to play its part in response to global macroeconomic, commodity specific and geopolitics events, and while the current state of the global macroeconomic and political environment may not appear to be supportive of strong demand stimulus, a number of persistent themes appear to underpin positive fundamentals.

The electrification of energy and battery revolution is expected to be the driving demand force as the global community grapples with a carbon constrained future to find a sustainable (and economic) replacement for the world's current annual fossil fuel consumption of 11.4 billion tonnes of oil equivalent (roughly equivalent to 16 billion tonnes of coal). On the supply side there has been a sharp reduction in meaningful copper discoveries with only a hand full of tier-one and tier-two orebodies found in the past decade, with those discoveries tending to be deeper and lower grade.

Given the very long-term data set underpinning its conclusions, the Fourier analysis is not seeking to measure and forecast the copper price response to the battery revolution specifically, but rather to measure (and so forecast) the propensity of a system to respond to large systemic drivers over time. This provides an understanding of the push-pull relationship between supply and demand given the need to support significant capital investments over multi-decade horizons.

Since the end of 2015 we have witnessed the bottom of the copper price cycle and a return to price levels coincident with our proxies for the sub-cycle and supercycles. The sub-cycle is expected to remerge in 2030, with price levels expected to reach above \$7,000/t (2016 real dollars). The longer supercycle suggests a downwards long-term trend on a decadal scale, with support at the \$4,000/t level (2016 real dollars), quite possibly as supply and technology makes the historically inevitable catch-up with the latest version of a demand surge, before starting the cycle (or cycles) again.

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