RFC Ambrian

The Alchemist

Issue 27:

Copper Price Outlook

Any Sign of a Copper Bottom?

INTRODUCTION

Where we are in the commodity price cycle is one of the most often discussed and relevant questions for the industry. We have thus applied some statistical and mathematical techniques to the analysis of copper price cycles.

So, what's the answer? Well, it depends on what cycle exactly you are looking at. There are cycles within cycles — and then volatility — to consider. To find out more, read on.

This piece outlines a two-pronged approach to copper price analysis: first, we have considered methods in determining price cycle parameters; and second, we've assessed the option value on the copper price for longer-life projects. While there is abundant research in the market based on Chinese supply and demand dynamics, this piece takes an alternative approach to studying the structure of the price cycle through methods in mathematical and statistical analysis. Key takeaways are:

1. Mathematical analysis of long-term historic copper price data suggests that the copper price supercycle is best represented as having a 60-year periodicity, within which there is a weaker 20-year sub-cycle.

2. Analysis suggests that the 60-year supercycle is peaking around now, and the peak of the 20-year sub-cycle was reached in 2011. However, the pace of the decline since this sub-cycle peak has far outstripped what would be expected, which suggests a positive correction may be due.

3. Statistical analysis reminds us of price volatility, and the downward real price trend suggests a baseline copper price of US$4,450/t for 2016, with price support at above US$4,000/t (real) in 2035.

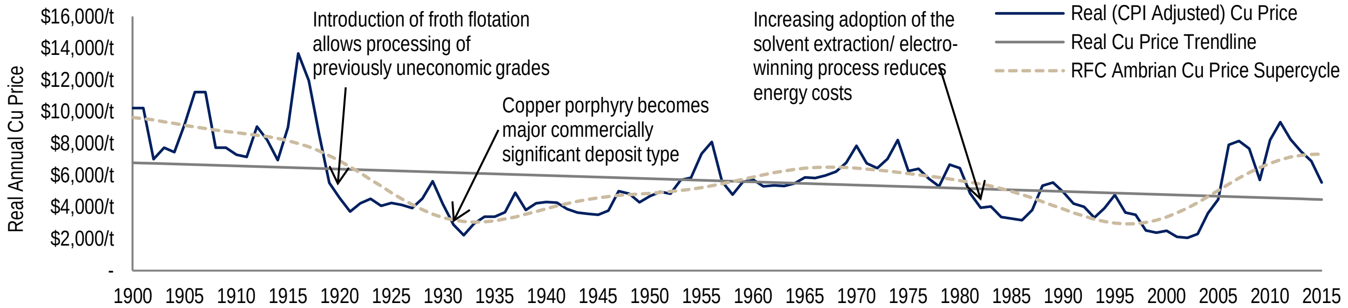
4. Considering volatility, while high levels of price variation are still rare, these occur six times more often than in the normal distribution model.

FOURIER ANALYSIS OF THE PRICE CYCLE

As shown in Figure 1, the copper price has clearly undergone a number of 'life-events': the development of leach/solvent extraction/electro-winning technology in the early 1960s, by which over 2Mt of copper cathode was produced in 2000; the rise of Chile as a major producer, accounting for some 30% of global production (approximately 5.8Mt in 2014); and, most recently and influentially, the advent of China as the dominant consumer, accounting for around half of the global total. Nevertheless, considering the price chart from 1900, it seems clear that that an underlying cyclicity can be observed within the dataset.

We have thus elected to utilise Fourier analysis, which is traditionally used as a method of studying cyclical or periodic functions. By this method, our data series can essentially be decomposed into a number of oscillating signals, or 'harmonics', enabling relationships at different frequencies and the dominant periodicities to be uncovered. The duration of the overriding commodity price cycle should correspond to the period of the highest-amplitude harmonic, while we postulate lower amplitude signals should match with less pronounced sub-cycles.

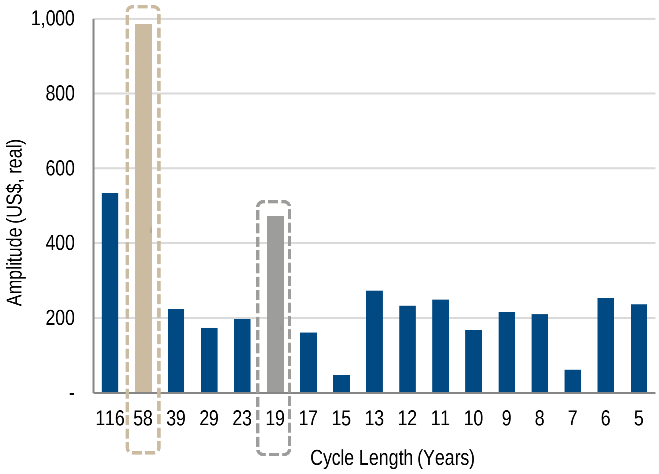
Figure 1: Real Copper Price with Major Events Precipitating Downside Movements



Source: USGS, World Bank, Bloomberg, Other

The Discrete Fourier Transform (DFT) is a powerful tool in revealing the relative strength of periodic components, and can be computed efficiently using the Fast Fourier Transform (FFT) algorithm. Using this method, we have calculated the highest amplitude peaks at cycle lengths of approximately 60 years and 20 years, as shown in Figure 2. The amplitude of the 60-year peak is more than twice that of the 20-year; we therefore suggest that the former represents the length of the commodity price super-cycle, with a weaker 20-year duration sub-cycle.

Figure 2: Fast Fourier Transform (Amplitude)



Source: RFC Ambrian, World Bank, Bloomberg

METHODOLOGY — FOURIER TRANSFORM
Using different terms can approximate to different cycles

We have performed the Fourier Transform based on a copper price data set running from 1900, CPI and trendline adjusted. Trendline adjusting serves to compensate for the long-term downside shift in the real copper price, as seen in the 'Real Cu Price Trendline' in Figure 1, providing a 'cleaner' cyclical signal for our analysis.

Fourier transforming our trendline-adjusted data gives the coefficient and phase information necessary to re-construct the copper price cycle as a Fourier series of the form:

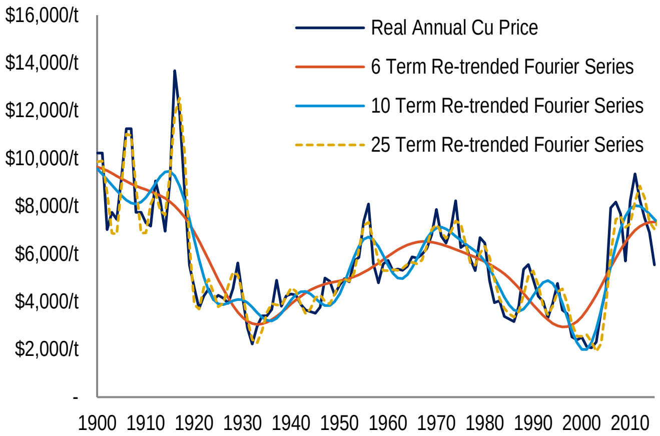
$$p(t) = \frac{C_0}{T} + \sum_{t=1}^{T-1} \frac{2C_t}{T} \cos\left(\theta_t + \frac{2\pi t}{T}\right)$$

Where:

T = number of time samples (years in the data series from 1900)
t = the current year being summed
C_t = the signal amplitude as calculated by the FFT algorithm
θ_t = the signal phase

As shown in Figure 3, where applied to the copper price dataset, the accuracy of the representation increases steadily as the number of terms included rises. While this looks like a moving average chart, the Fourier Transform has the capacity to forecast the future shape of the signal, provided that it continues in the pattern it has in the past.

Figure 3: Increasing the Number of Terms within the Fourier Expansion Increases the Accuracy of the Representations



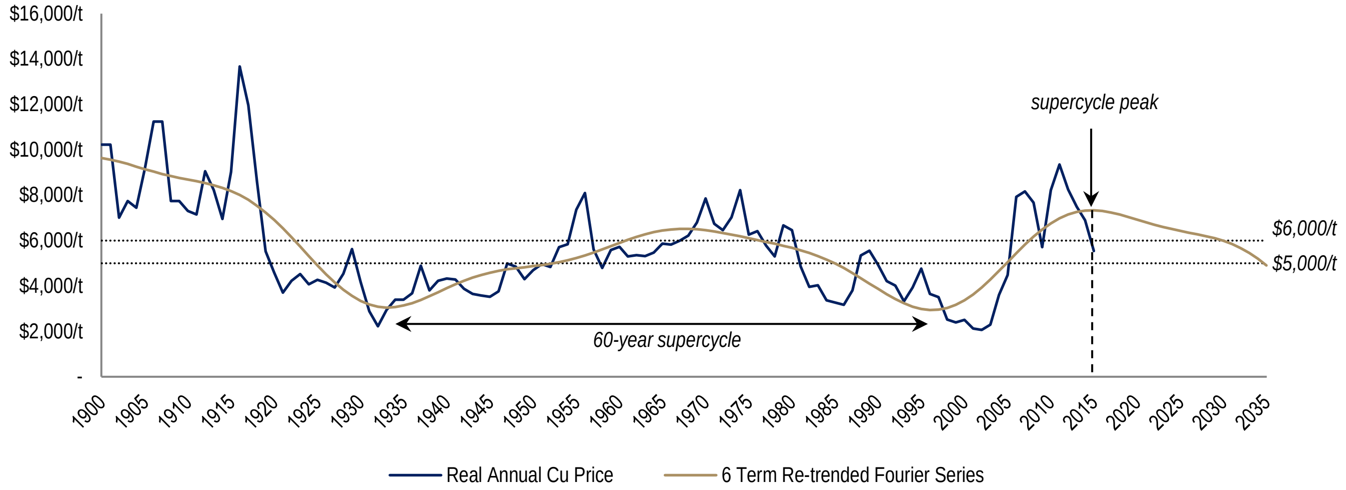
Source: RFC Ambrian, USGS, World Bank, Bloomberg

We can use our Fourier series expansion to project the cyclical price curve forwards, with the number of terms included dependent on our level of confidence that past behaviour will be replicated in the future. Clearly, due to structural shifts in the macroeconomic backdrop, as well as previously mentioned commodity-specific life-events, we must account for a high level of noise. Hence, we build out our Fourier expansion to a relatively low level of granularity, making this method more useful for longer-term forecasting.

We have run our Fourier series expansion forward to 2035, using 6-term and 10-term series. The 6-term series can be seen to act effectively as a proxy for the movement of the 60-year supercycle, whereas in the 10-term series the strongest signature overlying this is the pronounced 20-year sub-cycle.

As can be seen in Figure 4 overleaf, we should currently be passing the peak of the present 60-year supercycle. Thus, we would expect this underlying cyclicity to drive copper price trends downwards from here on a decadal timescale, notwithstanding the impact of short-term market fluctuations.

Figure 4: 6-term Fourier Series Representations of the Historical Copper Price

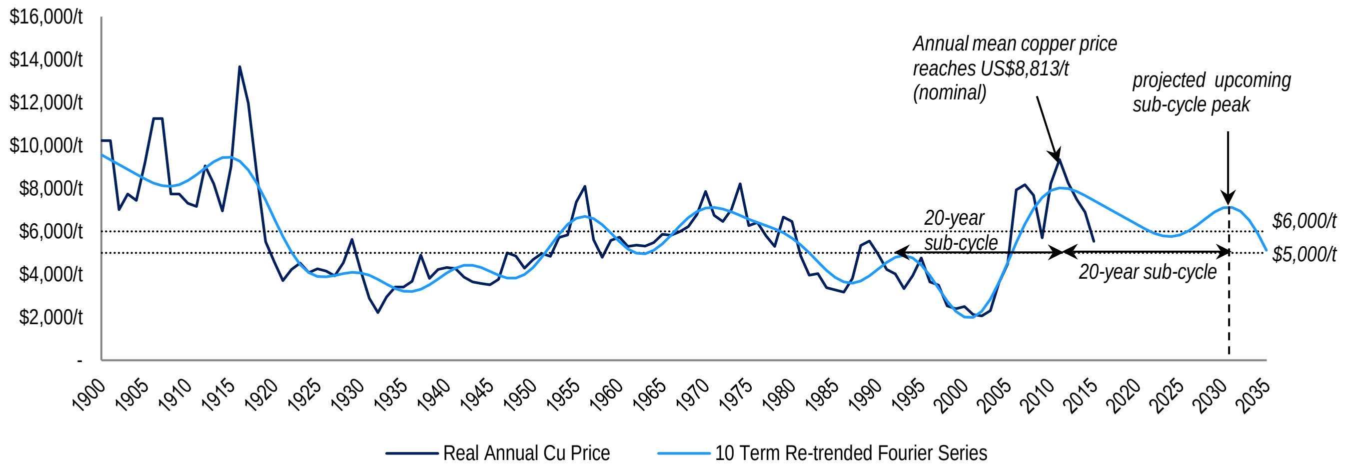


Source: RFC Ambrian, USGS, World Bank, Bloomberg

Figure 5 below shows that, factoring in the 20-year sub-cycle, we see the most recent shorter cycle peak occurring in 2011, coinciding with that year's annual average price spike to over US$9,000/t (real). This represents the highest real annualised value over the last 90 years. We would therefore expect the next 20-year sub-cycle peak to be around 2031.

While our Fourier series representation shows the mean annual copper price being relatively well supported over the entire cycle, we ascribe greater confidence to this method's capacity to project the timing than the quantum of cyclical peaks and troughs.

Figure 5: 10-term Fourier Series Representations of the Historical Copper Price



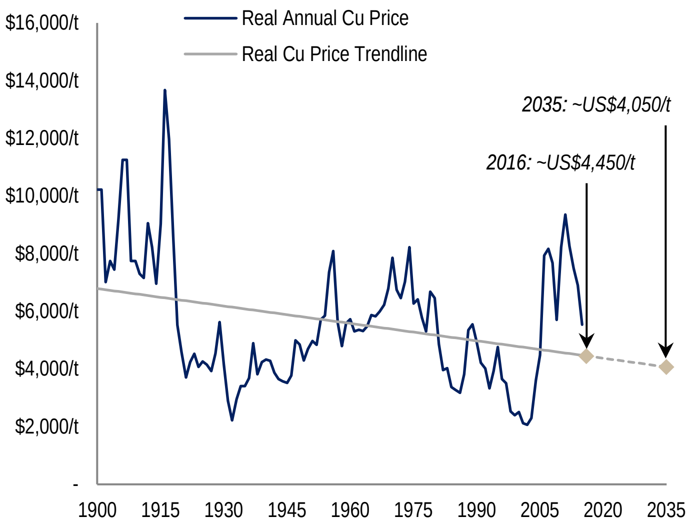
Source: RFC Ambrian, USGS, World Bank, Bloomberg

IMPACT OF VOLATILITY ON VALUE

Now we have defined the two strongest 60- and 20-year cyclicities underlying mid-to-long-term copper price fluctuations, we move to the second prong of our analysis. This involves considering the impact of copper price volatility on prospective value capture from longer-life projects. Consensus and long-term forecasts inherently fail to capture potential volatility, smoothing out the rapid-payback price spikes.

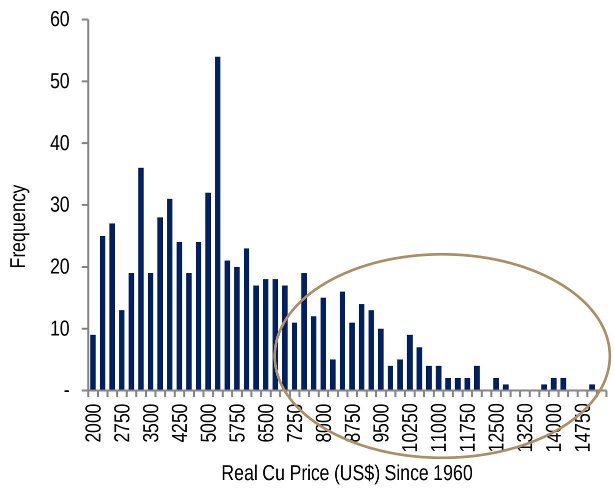
As we saw in Figure 1, the linear real copper price trendline has been downward sloping over the duration of our dataset. This implies that supply side factors (eg, increasing mechanisation and technological advances enabling productivity growth, the economic exploitation of lower-grade resources and a decreased cost base) have on balance outweighed demand growth over the time period under consideration.

Figure 6: Real Copper Price Falling Trendline from 1900



Source: RFC Ambrian, USGS, World Bank, Bloomberg

Figure 8: Real Cu Price Distribution (1960-Present)

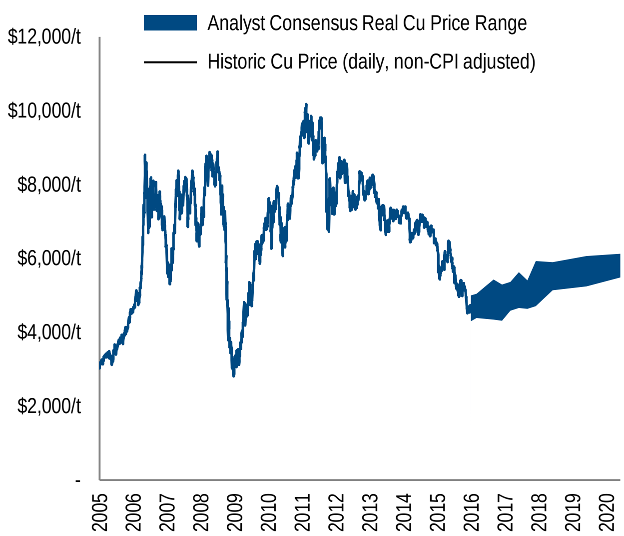


Source: RFC Ambrian, World Bank, Bloomberg

Conversely, analyst consensus shows cautious optimism to the end of the decade for copper pricing, with predictions lying in a relatively narrow band to 2020, as shown in Figure 7. This can be juxtaposed with Figure 8 — a histogram of monthly real copper prices from 1960 — which shows the wide value range actually encompassed by historic prices. This data can be seen to form a right-skewed distribution, with a long positive 'tail' extending to the right. This tail comprises periods of anomalously high pricing, which have clearly had a major short-term impact on project margins, as cannot be forecast by either consensus price projections or the trendline model.

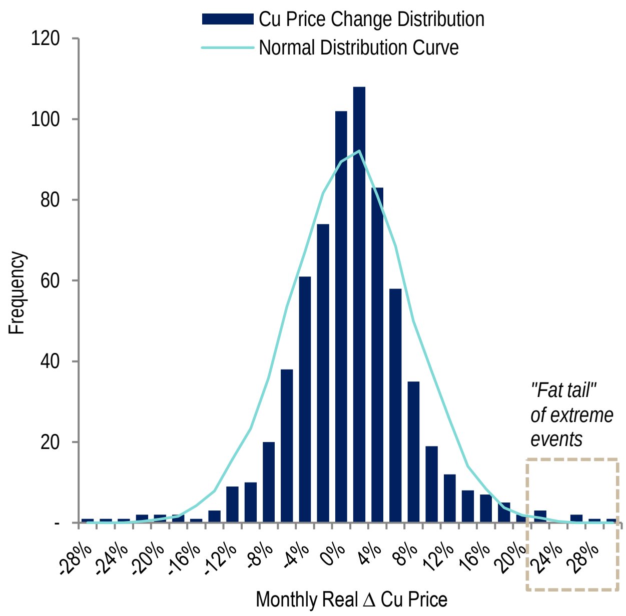
If we now consider month-on-month copper price changes from 1960, we can see that the histogram outlines a more peaked bell curve than the standard normal distribution, with small deviations less probable than in the normal distribution, but, conversely, large price swings more likely to occur. The distribution is therefore said to have 'fat tails' of higher probabilities of extreme events.

Figure 7: Consensus Forecast Real Copper Price Range



Source: RFC Ambrian, Analyst Consensus (10 firms), Bloomberg

Figure 9: Month-on-Month Real Copper Price Change Distribution vs. Normal Bell Curve (1960-Present)



Source: RFC Ambrian, World Bank, Bloomberg

Normal bell curves are traditionally used to make market assumptions, which can underestimate the frequency of 'left tail' downside risk and 'right tail' upside potential.

Table 1: Monthly Copper Price Change Data vs. Modelled Normal Distribution Outputs

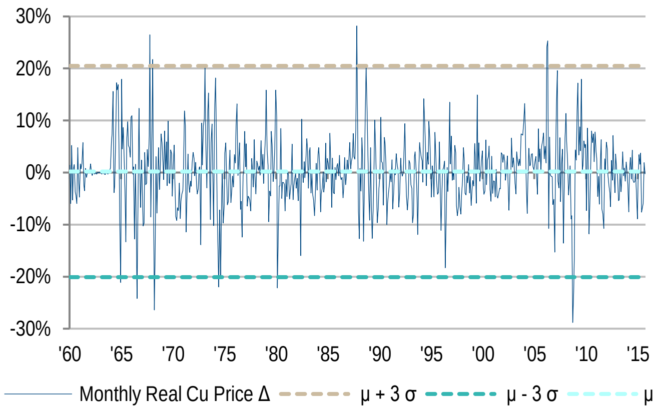
Interval	μ ± 0.5 σ	μ ± σ	μ ± 2 σ	μ ± 3 σ
(Interval Range – Month-on-Month Copper Price Δ)	*(±3%)*	*(±7%)*	*(±14%)*	*(±20%)*
% of Values within Interval – Normal Bell Curve	38.3%	68.3%	95.4%	99.7%
Expected Number of Outliers – Normal Bell Curve	414	213	31	2
Actual Number of Outliers	352	158	37	12

Where: **μ** = average
σ = standard deviation
Nº data points: 671

Source: RFC Ambrian

As Table 1 above demonstrates, 1.2x the number of values lie within half a standard deviation (~3%) of the mean of our distribution than in the normal bell curve. By contrast, the likelihood of an extreme monthly price movement of over three standard deviations (~20%) has been 6x greater historically than would be expected under the characteristic normal distribution.

Figure 10: Month-on-Month Copper Price Movement Time Series



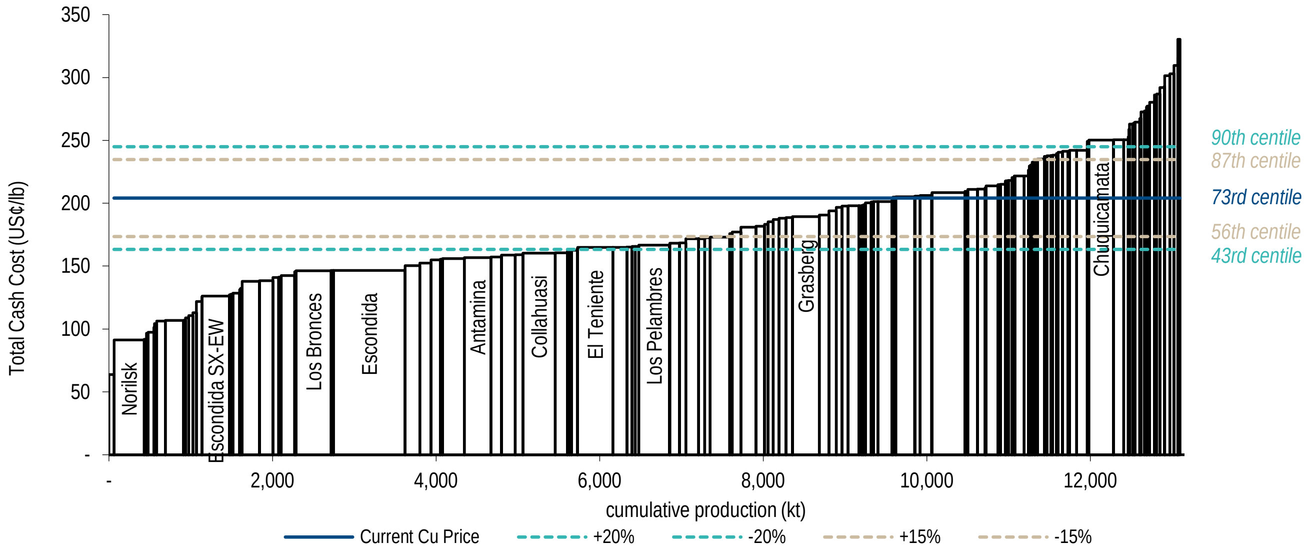
Source: RFC Ambrian, World Bank, Bloomberg

As we would anticipate, such high magnitude swings remain rare, with 2% and 5% probabilities of month-on-month copper price movements exceeding 20% and 15% respectively. Over the mulit-decadal timeframes of long-life projects, however, these translate to material frequencies, with a 25-year life project expected to experience around six extreme events (>20% monthly price swings) and 14 moderate-extreme events (>15% swings).

EFFECT ON THE COST CURVE

Looking at the dynamics of operating margins across the cost curve, we can see that currently under 75% of players are at least breaking even on an operating basis (inclusive of refining, transport and royalty costs) at the current price of approximately US$4,500/t (US$2.04/lb). At a 20% higher copper price, 90% of players would be at least breaking even, whereas if the price were to drop by 20%, below 45% of the cost curve would be above water on an operating basis. This is shown visually in Figure 11 below.

Figure 11: Copper Cost Curve vs. Commodity Price



Source: RFC Ambrian, SNL; Note: Cash cost includes mining, processing, treatment/refining, transport and royalty costs

CONCLUSION

To summarise, the outputs of the analysis suggest that we are around the peak of the current 60-year copper super-cycle, with a shorter cycle peak having been reached in 2011, driven by approximately 20-year periodicity. While understanding our position on the cyclical curve should facilitate a view of longer-term price trends, the impact of time series volatility on near-term project margins and returns should not be overlooked. It can be seen that the pace of the copper price decline since the sub-cycle peak has significantly exceeded what would be expected, specifically in 2015, indicating a correction may be due towards the cyclical curve.

The analysis sugggests the copper price being supported at above US$4,000/t according to the long-term price trendline, but the trendline direction tends to be significantly outweighted by volatility effects over the short term. For a project in the first quartile of the cost curve, a 20% price rise from the current level of around US$4,500/t averaged over a year of the operation's life has the capacity to boost FCF before finance by around 50% year-on-year; meanwhile, for a project in the middle of the cost curve, the barometer moves by closer to 100%.

Current prospective near-term drivers of copper price volatility could include the carry trade potentially beginning to unwind in China. Falling Chinese interest rates (the sixth interest rate cut in a year occurred at the end of October, with the one-year lending rate falling 0.25% to 4.35%) and a weakening Yuan should point to lower availability of high-yielding Chinese accounts. If the carry trade is no longer profitable, the market risks being flooded, with copper no longer being used as collateral for borrowing. It is estimated that as much as 70% of finished Chinese copper imports may have been tied up in the carry trade, equivalent to a physical mass of 15-25Mt.

This year has also seen aggressive selling of copper by Chinese funds, with investors banned from shorting Chinese equities thought to be going short on the commodity instead as a proxy for China's broader economy. Shorting commodities is believed to have become a widespread strategy to hedge investment in the Chinese stock market. Copper is a favourite due to its strong liquidity and high correlation with macroeconomics. Conversely, a decline in this short selling activity would presumably lead to some stabilisation in the copper price, which fell by close to 20% in 2H15.

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