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EQUITY
RESEARCH:
GLOBAL

Commodities

SectorMapping
A Global View

31 March, 2005

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Global

China - The Engine of a Commodities Super Cycle

Commodity Update

- **We believe a super cycle is underway, driven by materials intensive economic growth in China.**
- **A super cycle is a prolonged (decades) trend rise in real commodity prices, driven by the urbanization and industrialization of a major economy.**
- **There have been two super cycles in the last 150 years: late 1800s-early 1900s, driving economic growth in the USA; 1945-1975, prompted by post-war reconstruction in Europe and by Japan's later, massive economic expansion.**
- **High and rising intensity of metals use is the most useful indicator of a super cycle. In China, intensity of use is now three times that of the USA, with demand driven by urbanization, industrialization and fixed capital formation. Importantly, the domestic market drives China's metals demand, not exports.**
- **In past super cycles, supply has increased to meet higher demand growth.**
- **In the present super cycle, increased supply will come at relatively higher costs. Lead times are also increasing, contributing to extended periods of market tightness.**
- **Under these circumstances, higher long-term commodity prices should be used.**
- **Paper presented at the Mineral Economics & Management Society Annual Conference, Washington, April 2005.**

Investment Summary

There have been two super cycles in the past 150 years. We believe a third super cycle is underway, driven by China.

Super cycles are…

A super cycle is a prolonged (decade or more) trend rise in real commodity prices, driven by urbanization and industrialization of a major economy.

There have been two super cycles in the past 150 years: from the late 1800s, driven by the USA; and from 1945 to 1975 as a result of post-war reconstruction in Europe, and subsequently by the Japanese economic renaissance.

Super cycles are demand driven

Highly materials intensive economic activity is the cause of super cycles – intensity of metals use in the expanding economy is high, and global growth is moving to a higher trend.

China – the engine of the present super cycle

China accounts for an increasing share of global economic activity (12% of IP, up from 6% in 1995).

It accounts for around 20% of demand for copper and other commodities, and a much larger proportion of demand growth. Intensity of use is 3 times greater than that of the USA.

The drivers are urbanization, industrialization and fixed capital formation. Greatest metals demand exists in China's domestic market – not its export market.

Supply responses – increased production at higher costs

In past super cycles, expansions in commodity production were not sufficient to offset stronger demand growth.

In the present super cycle, capital and exploration expenditure are increasing but is not expected to result in oversupply.

- costs are increasing, and
- production lead times are extending.

Implications for long-term prices

The higher cost of new supply required to meet demand implies that higher long-term prices are appropriate for project evaluation and discounted cash flow analysis.

Figure 1. Appropriate Long-term (Equilibrium) Commodity Prices - 2005$

Commodity	Unit	Value
Copper	US¢/lb	95
Aluminium	US¢/lb	70
Nickel	US$/t	3.50
Zinc	US¢/lb	50
Lead	US¢/lb	27
Oil	US$/bbl	28
Iron Ore (Lump)	US¢/Fe unit	45
Coking coal	US$/t	62
Thermal coal	US$/t	33

Source: Smith Barney estimates.

In this report we draw mainly on the copper market

The copper market has a number of attractions for this type of long-run historical analysis. It is a mature market. Consumption is relatively evenly distributed across geographical regions and a diversity of end uses, and it is correlated with general macroeconomic trends. Market data is relatively easy to obtain.

Preliminary analysis of other commodities shows similar trends and drivers, although some (such as aluminium and nickel) have shorter market histories.

Super Cycles are

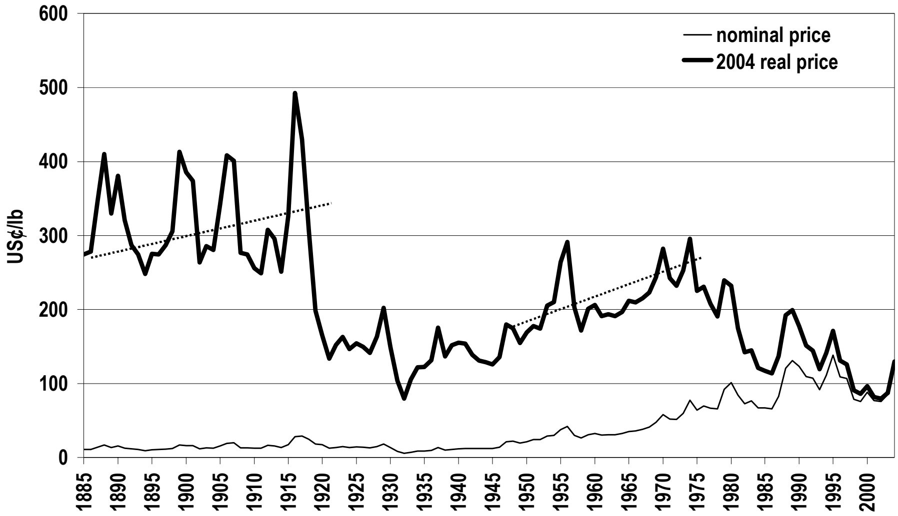
Extended periods (decades) of trend rise in real prices…

For the last 30 years commodity prices have been in trend decline in real terms. But when viewed against a longer time period it is evident that this has not always been the case. In particular, commodity prices rose on a trend basis for two extended periods during the last 150 years: from the late 1800s through to the early 1900s; and from 1945 to 1975.

This pattern can be most clearly seen for copper (Figure 2), but most commodities show similar trends (Figure 3).

Super cycles occurred in the late 1800s–early 1900s (driven by urbanization and industrialization in the USA), and in the late 1940s–early 1970s (driven by post war reconstruction in Europe and Japan, and subsequently the Japanese economic renaissance).

Figure 2. Copper Super Cycles

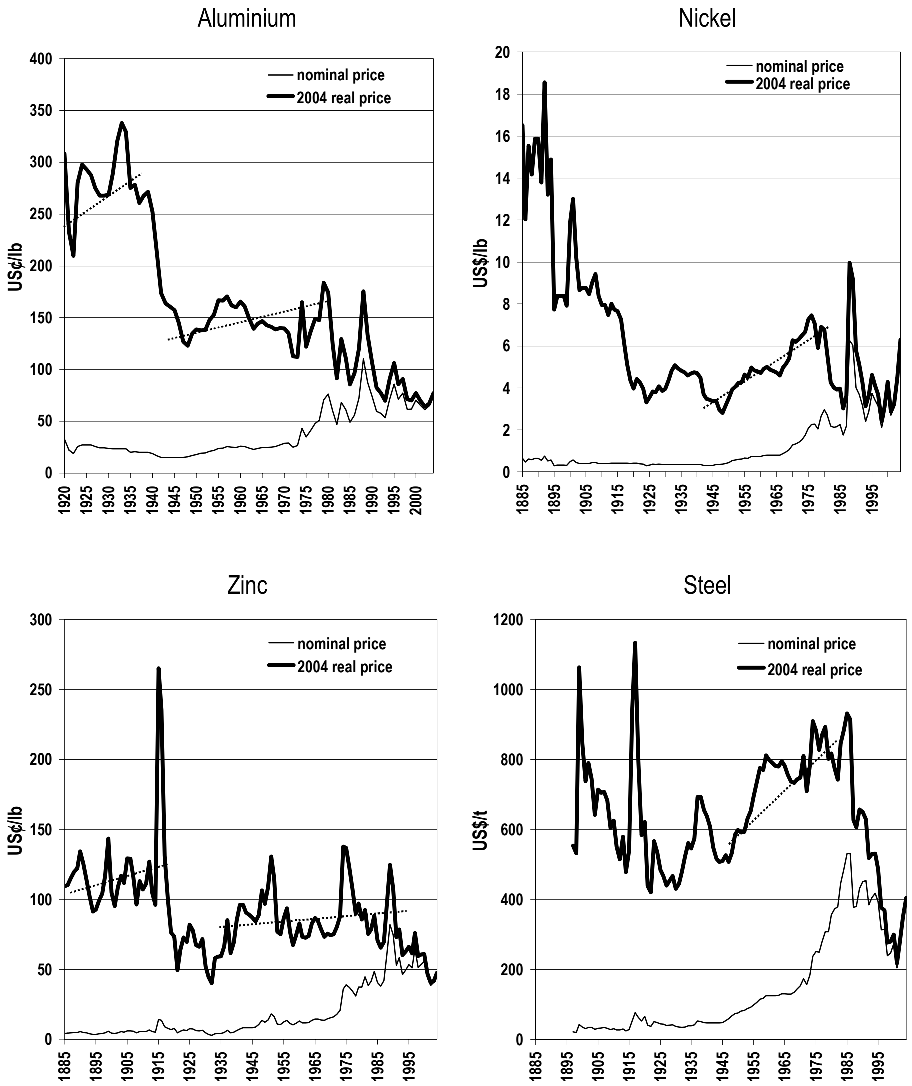


Source: USGS; Platts; US Department of Labor.

Aluminium & nickel are new age metals.

Zinc & steel show similar trends to copper.

Figure 3. Other commodities show similar trends…



Source: USGS; Platts; US Department of Labor.

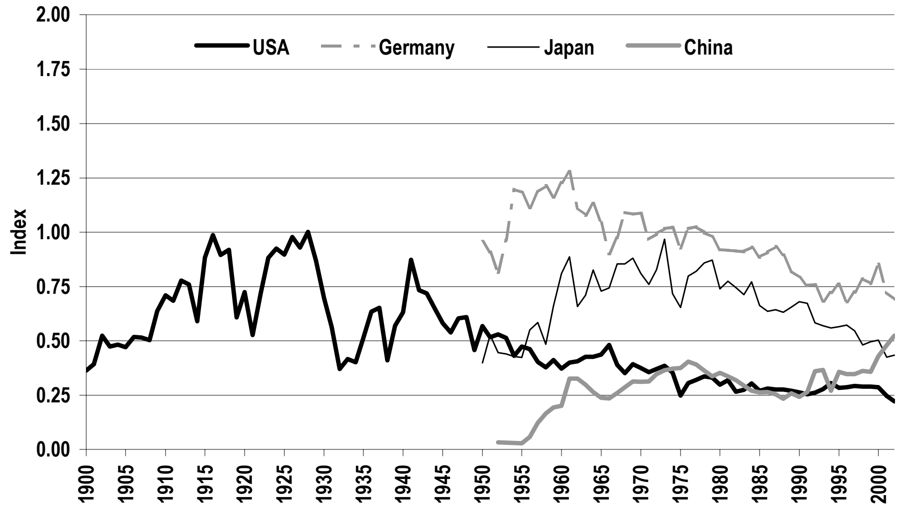
It should be noted that in a super cycle, prices rise on a trend basis. There are still business cycles within a super cycle.

….driven by materials intensive economic growth as major economies urbanize and industrialize.

The key driver of these super cycles is materials intensive economic growth in major economies as they urbanize and industrialize.

This is reflected by high and rising intensity of use (IOU - the amount of copper consumed per unit of economic activity).

Figure 4. Copper - intensity of use



Source: USGS; US Dept of Labor; GGDC; Smith Barney estimates.

Intensity of use peaked in the early 1900's in the USA, in the 1950's in Europe and in the early 70's in Japan.

Figure 4 shows intensity of use based on GDP as the economic denominator.

In China, IOU is only just beginning to rise strongly.

In the USA, intensity rose strongly during the early 1900s, then plateaued and declined from around 1940 as its economy evolved. The highly materials intensive growth phase came to an end, as the economy became increasingly services-based.

In Europe, reconstruction post the 1939-45 war boosted intensity of copper use.

In Japan, intensity rose during the early years of its economic renaissance, but declined from 1980.

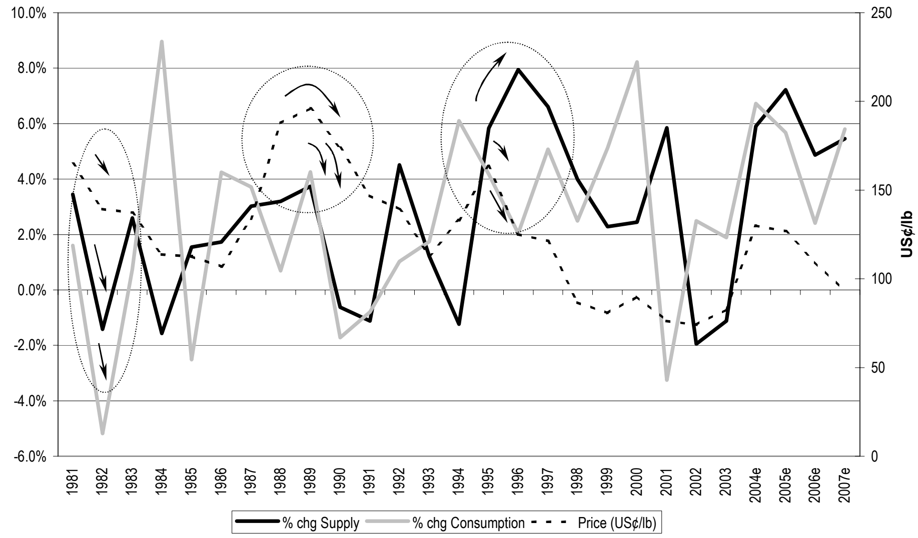
Declining intensity & slowing demand bring cycles to an end

Declining intensity of use brings super cycles to an end as the driving economy evolves from materials intensive infrastructure and manufacturing towards more service based.

We also believe declining demand brings typical business cycles to an end, rather than expanding supply (Figure 5).

Cycles are brought to an end by declining demand. In some cycles (e.g. the mid 1990's) supply continued to increase, contributing to a prolonged downturn.

Figure 5. Cycles in the Copper Market



Source: Smith Barney estimates.

China's Contribution to Global Growth

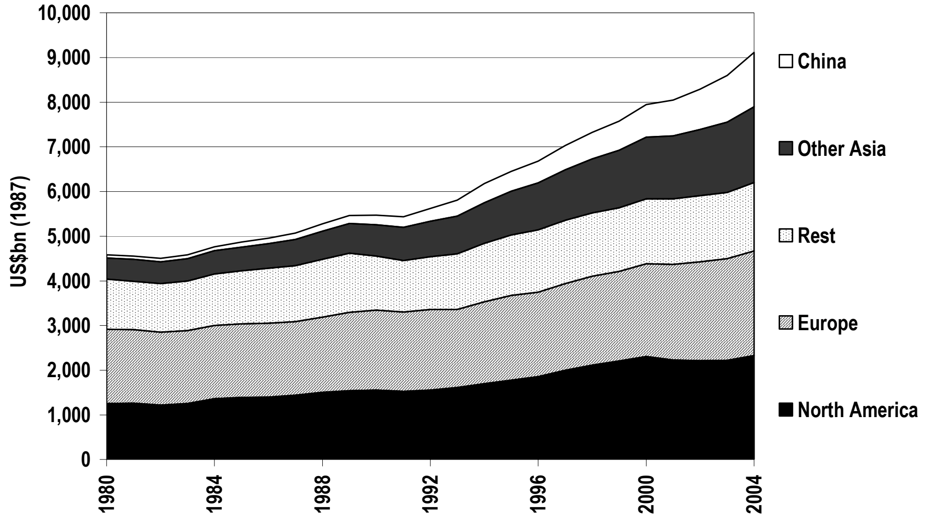
China's contribution to global growth depends on how you measure it.

China accounts for:

- 4% of global GDP on an exchange rate basis.
- 13% on a purchasing power parity basis, up from 9% in 1995.
- 12% of world industrial production, up from 6% in 1995.

China accounts for 12% of world IP, up from 6% in 1995.

Figure 6. Regional Shares of Global Industrial Production

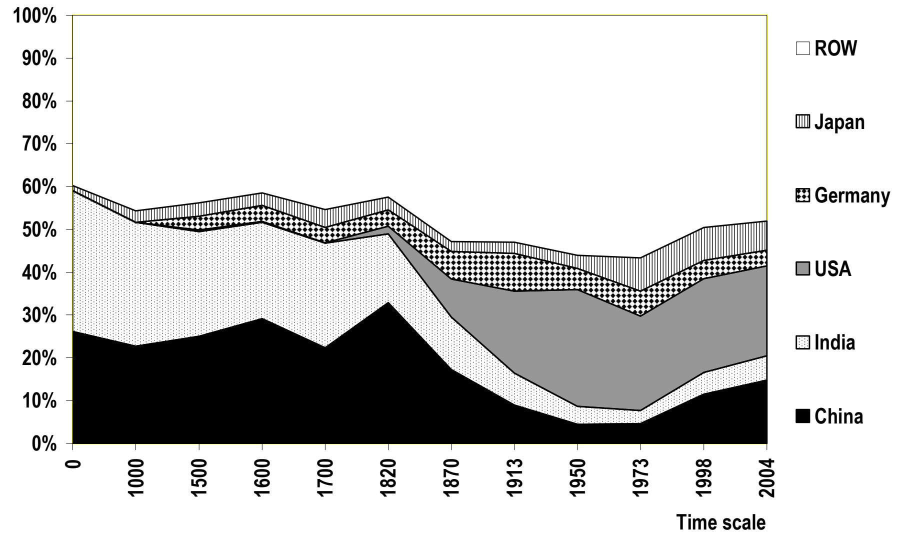


Source: World Bank; Smith Barney.

Interestingly, China accounted for 20-30% of global GDP until the mid 19th century, when it was eclipsed by the USA. Perhaps China is on the way to regaining its past dominance, and perhaps this is the true expression of the super cycle (Figure 7).

China accounted for 20-30% of global GDP until the mid 19th century, when it was eclipsed by the USA.

Figure 7. GDP of Key Nations: 0-2004 A.D.



Source: Maddison (OECD publication); Groningen Growth & Dlpmnt Cent., University of Groningen; Smith Barney estimates.

Super Cycles – Impact on Commodities Demand & the Role of China.

Figure 4 shows that intensity of use in China has begun to lift sharply.

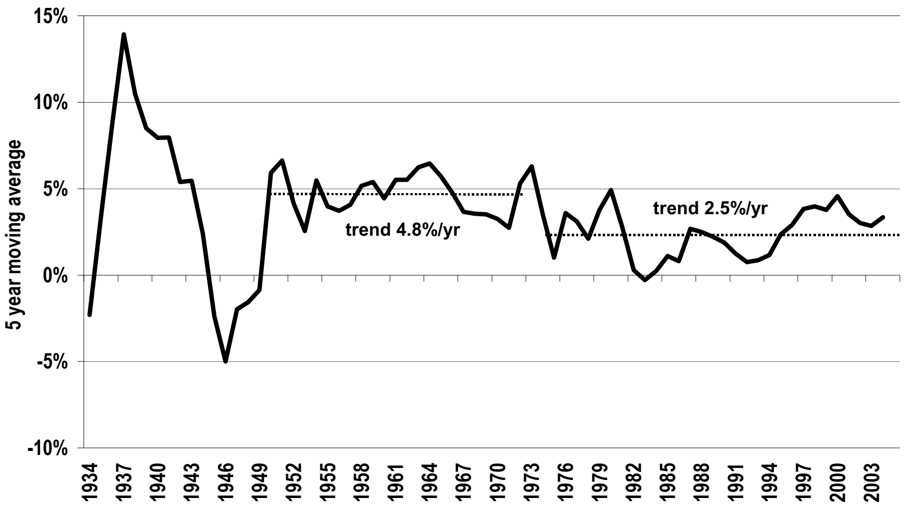
The contention then is that:

Further materials intensive economic activity (as measured by rising intensity of use) in China will drive another super cycle.

Price super cycles are associated with higher levels of trend demand growth. Supply responses are discussed below.

Price super cycles are associated with higher levels of trend demand growth.

Figure 8. Global Copper Consumption Trend Growth

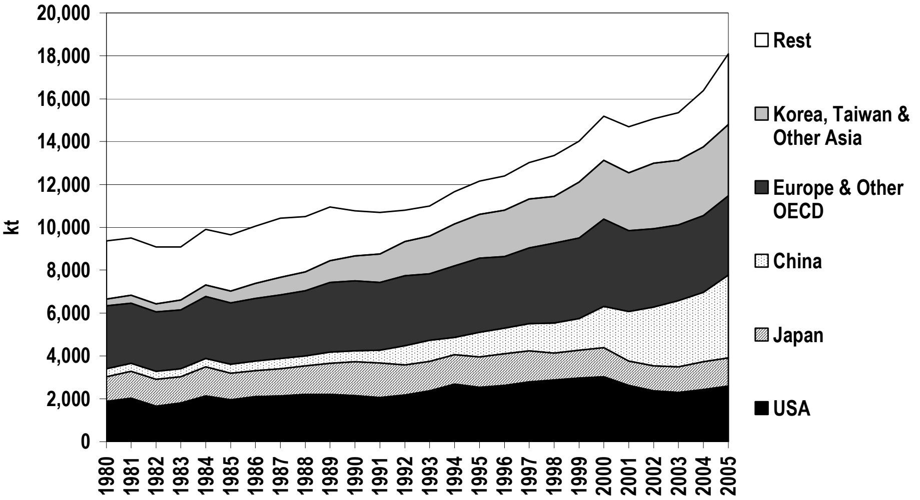


Source: Metallgesellschaft (1929-1980); WBMS (1980-present).

While China's demand for copper (and commodities in general) has been growing for some years, it virtually exploded in 2000.

In 1999 China accounted for 10% of world consumption. In 2004 it reached 20%.

Figure 9. Global Copper Demand



Source: WBMS; Smith Barney estimates.

China now accounts for around 20% of global demand for a broad range of commodities, and an even larger proportion of growth in demand.

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Figure 10. China's Contribution to Commodities Demand

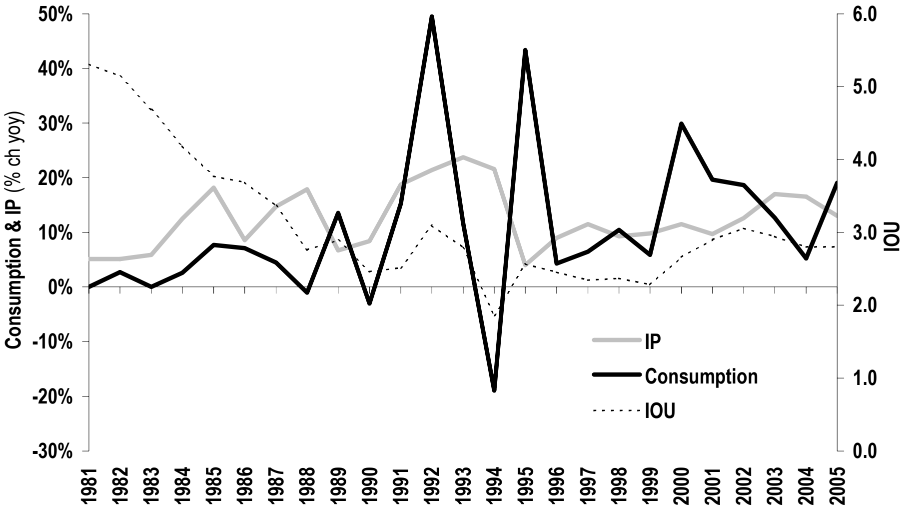
Commodity	China's share of global consumption		China's contribution to y-o-y consumption growth	
	2002	2003	2002	2003
Cement	34%		56%	
Ethylene	6%	6%	23%	5%
Alumina	16%	19%	60%	59%
Aluminium	16%	19%	39%	53%
Copper	18%	20%	112%	78%
Nickel	8%	10%	13%	48%
Zinc	19%	21%	53%	86%
Iron ore	26%	29%	39%	70%
Steel	23%	27%	77%	84%
Gold	6%	7%	3%	-5%
Platinum	23%	18%	75%	-560%
Pulp	18%		27%	18%
Container board	11%		30%	11%
Crude oil	7%	8%	57%	40%
GDP	4%	3%	7%	-16%
Population	21%	21%	11%	11%

Source: Smith Barney estimates.

Intensity in China has increased sharply since 1999…

Some of the dynamics can be seen in Figure 11. (In this data industrial production is the denominator of intensity of use, rather than GDP shown earlier).

Figure 11. China's Copper Demand

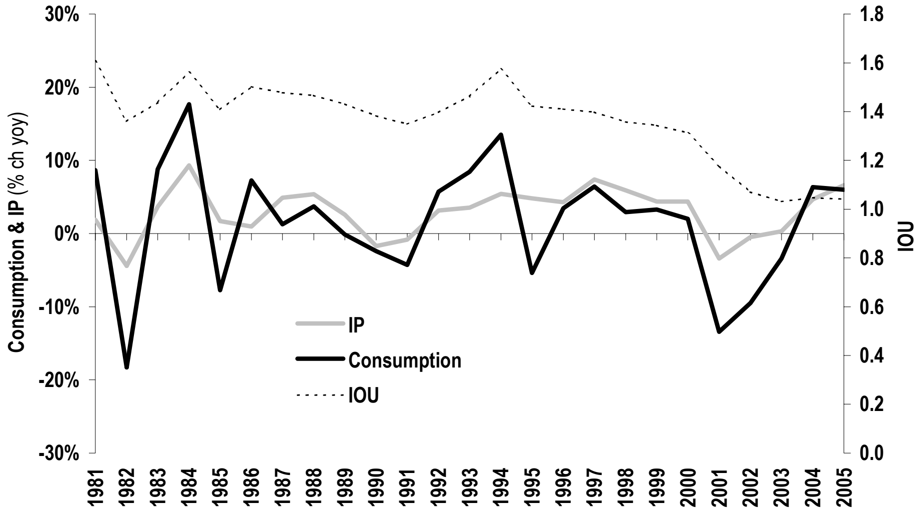


Source: WBMS; Smith Barney estimates.

And can be compared with the USA in Figure 12.

...and it is now 3 times that of the USA, where intensity is declining.

Figure 12. USA's Copper Demand



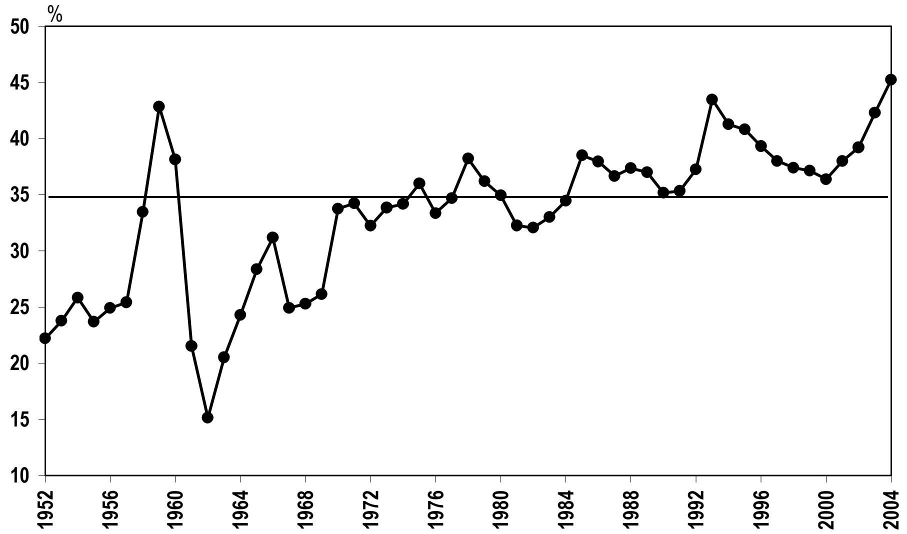
Source: WBMS; Smith Barney estimates.

Drivers of demand –fixed capital formation

Fixed capital formation is an important driver of metals demand in China. Fixed capital formation has increased to around 40% of GDP. Although there is concern that this may prove unsustainable, we expect fixed capital formation to stabilize at around 50% of GDP, but for the growth rate to slow more rapidly than the broader economy.

Fixed capital formation is increasing as a percentage of GDP. It is expected to stabilize at around 50%

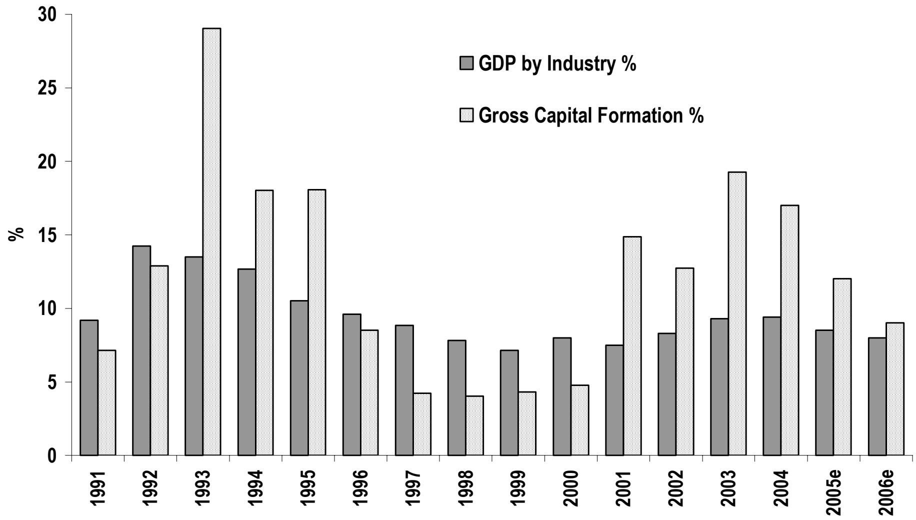
Figure 13. China - Changing Share of Gross Capital Formation in GDP, 1952-2003 (%)



Source: National Statistics Bureau of China; CEIC Data Company; Smith Barney estimates.

Fixed capital formation has been growing at around 20%/yr, but is expected to slow more rapidly than the broader economy.

Figure 14. China's GDP & Gross Capital Formation, 1991-2006



Source: National Statistics Bureau of China; CEIC Data Company; Smith Barney estimates.

Drivers of demand – urbanization

Urban migration is an important driver of fixed capital formation and super cycles. In China, 10 million people per year are moving from the countryside to the cities, according to World Bank estimates, and this may increase four fold as restrictions on the movement of labour are relaxed as required by the WTO.

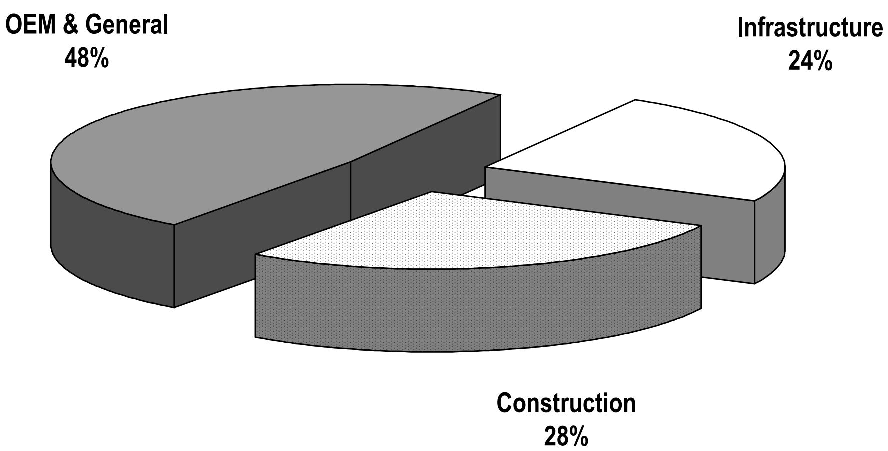
Urban migration was also a driver of past super cycles, but fixed capital formation probably did not reach the proportion of GDP seen in China.

Drivers of demand-domestic consumption

At least 50%, and perhaps 75%, of China's copper demand is for domestic consumption.

At least half of China's copper demand is for domestic consumption.

Figure 15. China's Copper Consumption, by use



Source: Bloomsbury Mineral Economics.

Therefore, China's copper demand is not export driven, nor is a result of a relocation of manufacturing capacity from other countries.

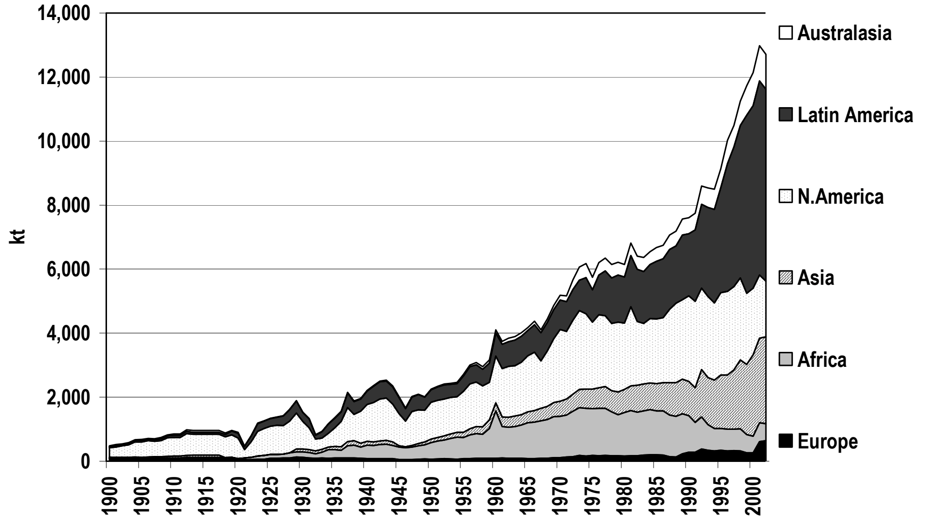
This is also an important characteristic of past super cycles. For example, the super cycle of the 1960s and early 70s faded as Japanese internal development matured, even though exports continued to grow. It is also notable that the boom of the Asian tigers in the early 1990s, which was an essentially export driven phenomenon, did not translate into a super cycle.

Supply Responses in Super Cycles

Copper mine supply from 1900 is shown in Figure 16.

Supply increases in super cycles.

Figure 16. Copper mine production since 1900

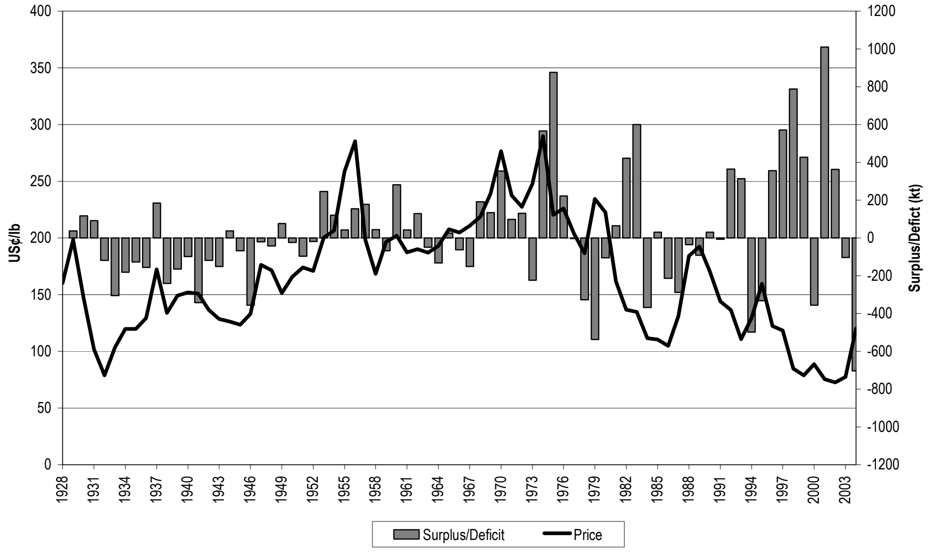


Source: Metallstatistik; WBMS; Smith Barney estimates.

This is combined with demand to show supply-demand balances in Figure 17.

Super cycles are not associated with persisting supply deficits.

Figure 17. Copper Supply-Demand Balance & Price



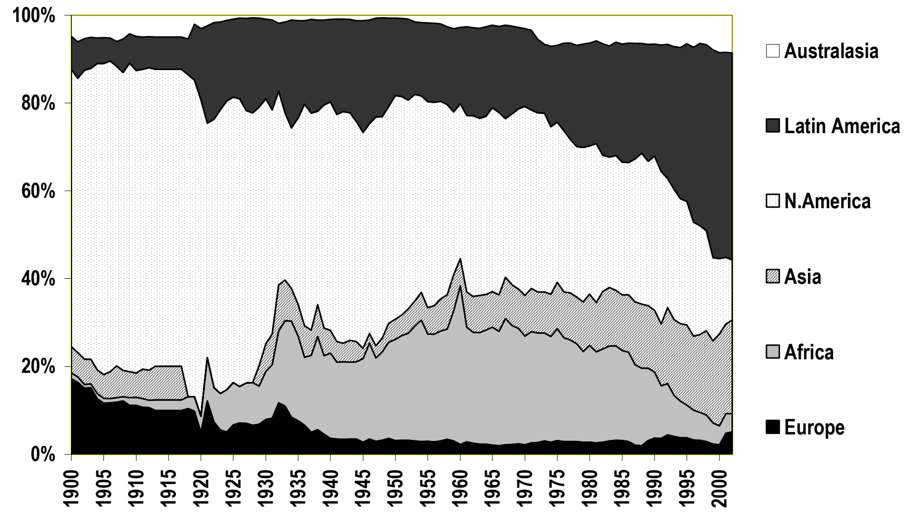
Source: Metallstatistik; WBMS; Smith Barney estimates.

From an analysis of this data, we conclude that super cycles are not associated with persisting supply shortfalls. Supply typically expands in response to growing demand, but production costs also increase. This supports our view that super cycles are demand driven. We believe this is the outlook for the present super cycle, as discussed below.

Changes in the sources of copper supply since 1900 is illustrated in Figure 18.

Figure 18. Copper mine production - regional contributions

The geographical centre of production shifts over time as the resources of each province are depleted.



Source: Metallstatistik; WBMS; Smith Barney estimates.

The chart highlights how the geographical centre of copper production shifts over time as the economically accessible resources of major mining provinces are depleted. North American production dominated global supply in the first half of the 20th century, eventually giving way to Africa – a major producer in the 1950s and 60s. Latin American has been the pre-eminent copper-producing region since the early 1990s

There is no known mineral province comparable to that of Latin America that can be developed over the next 5-10 years to deliver new supply at relatively low cost.

Influence of Technology

The rapid advancement of technology is sometimes cited as a dampening influence on an emerging super cycle. However, on-going technical innovations have been a long-standing feature of the global mining industry – they are not a recent phenomenon.

Technical advances have been a long-standing feature of the global mining industry.

Figure 19. Copper industry developments - a history

1862	Bingham Canyon discovered
1898	Bulk mining introduced at Kennecott using steam-powered shovels
1906	Bingham Canyon start-up
1930	Introduction of open pit mining
1963	Bougainville discovery
1968	SxEw introduced in USA
1972	Ertsberg start-up
1974	Bougainville start-up
1984	Ok Tedi start-up
1990	Escondida; Olympic Dam start-ups
1990	Chilean production expands substantially
1995	La Candelaria start-up
1997	El Abra start-up
1998	Collahuasi start-up

Source: Smith Barney.

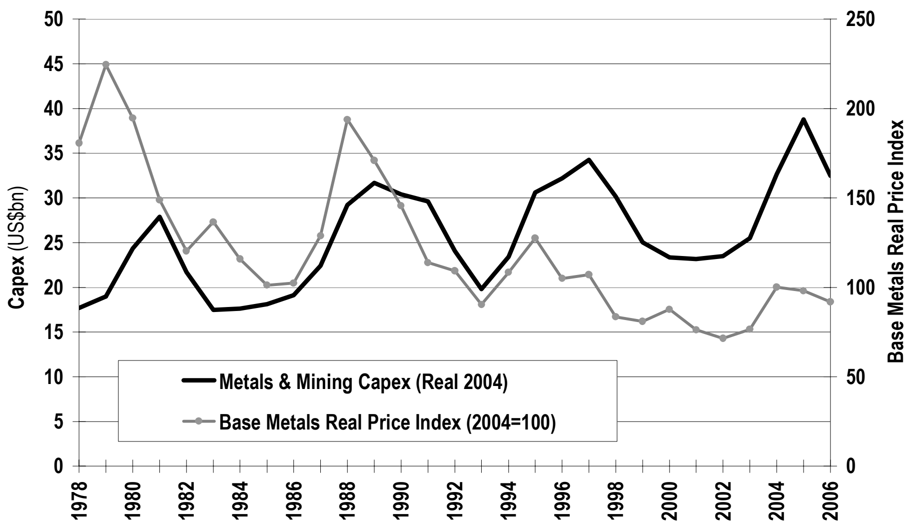
While it is difficult to identify new technologies under development, they are likely to have the same impact on the copper market (increasing supply, lowering costs) as did solvent extraction and electro-winning in the 1990s.

The Capital Cycle

Capital spending typically lags the commodity price cycle (Figure 20).

The capital cycle lags the commodity price cycle.

Figure 20. Metals & Mining Capex



Source: Smith Barney estimates.

The base load of stay-in-business capital spending is around US$15bn per year, although there are indications that this is increasing. Peaks above this base represent spending on new projects.

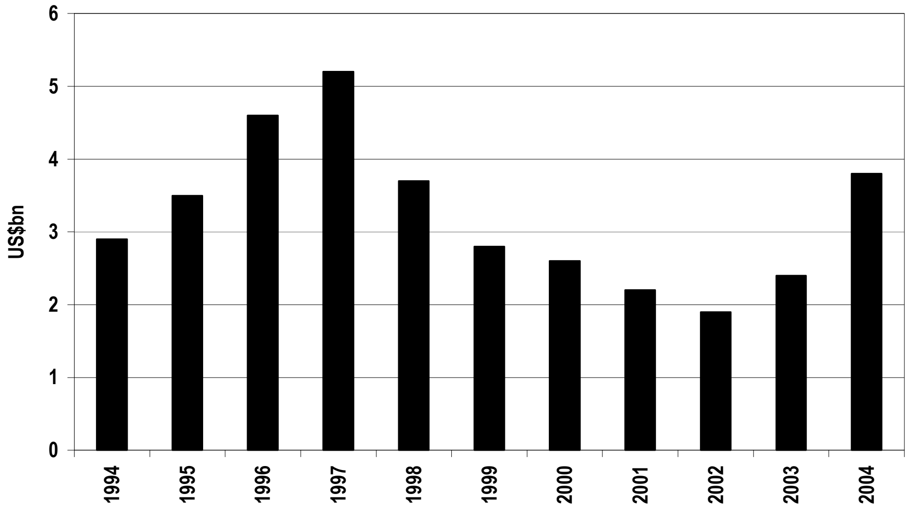
The excess capital expenditure of the late 1990s, combined with a slowdown in demand following the Asian crisis, contributed to the subsequent prolonged recession in commodity markets that extended from the mid 1990s until 2004. This pattern reflects that illustrated in Figure 5.

A capital cycle is underway at present. But, increasing production costs mean that higher capital expenditure is likely to translate into a relatively small expansion in production. Furthermore, increasing lead times due to environmental permitting and more stringent capital budgeting will delay the expansion of current operations.

Exploration expenditure is also increasing. Again though, long lead times threaten to delay the conversion of these projects into new supply sources (Figure 21).

At this stage, we see no sign of oversupply emerging.

Figure 21. Worldwide Non-ferrous Exploration Budgets



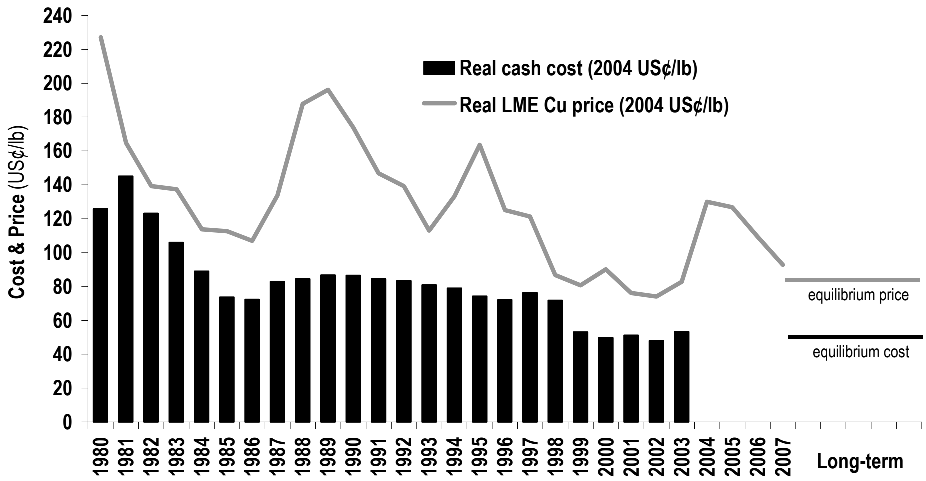
Source: Metals Economics Group.

Production costs and margins

Data on production costs and margins in past super cycles has proved elusive. However, we surmise that cost increased as production rose to meet demand.

Over the last 25 years or so, production costs have been declining on a trend basis, as have prices (Figure 22).

Figure 22. Copper Costs, Prices & Margins



Source: Brook Hunt; CRU; Smith Barney estimates.

Over the last year, costs have increased sharply – although largely from cyclical factors including fuel prices, consumables and labour.

However, we also believe production costs are likely to continue rising on a structural basis. The additional supply required to meet higher trend demand growth will be higher cost.

Margins are expected to remain constant, and prices will be driven higher.

Implications for long-term prices

We believe this environment means that it will be appropriate to adopt higher long-term (equilibrium) prices for project evaluation and discounted cash flow valuations.

Higher trend demand growth will be met by higher cost production. Industry average margins will remain constant. As a consequence, prices will trend higher.

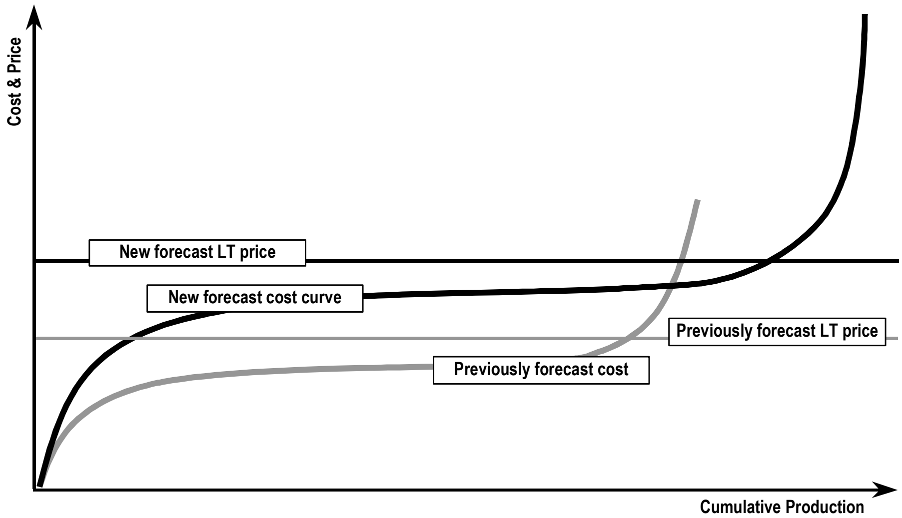
Our approach to deriving long-term prices differs from traditional mineral economics dogma.

Dogma dictates that the equilibrium price is the capital cost of new production, plus a return on the investment. The flaws we see with this are that 1) it ignores the influence of existing production capacity, in which costs are largely depreciated and 2) mining operations rarely return their cost of capital.

Our approach to determining long-term prices is shown schematically in Figure 23.

Figure 23. Cash Costs vs. Prices – a shift in the curves

Long term price will rise with increasing costs.



Source: Smith Barney.

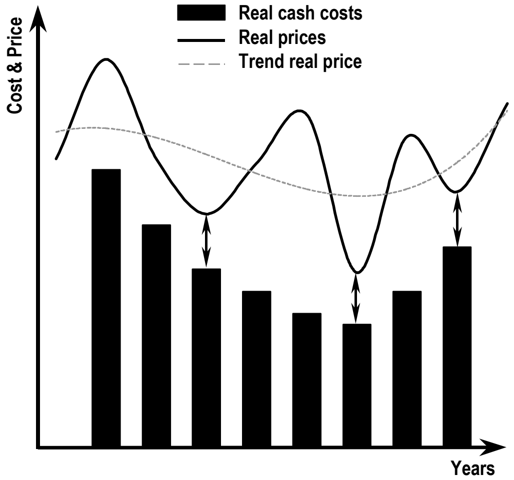
Given higher demand growth, the long-term price is a function of costs and margins. If the average cost increases, and margins remain constant, the long-term price will increase.

Implications for trough prices

A further consequence of the super cycle is that as the current business cycle slows, prices will likely decline to a relative trough level set higher than those reported for recent industry downturns (1993, 2001).

In the next downturn, trough prices will be higher than those of previous cycles.

Figure 24. Cash Costs vs. Prices - parameters

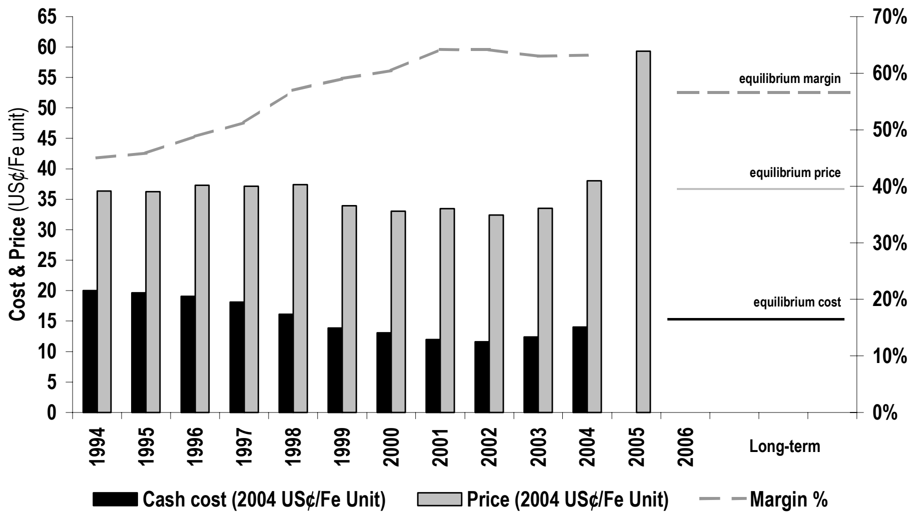


Trough margin	10%
Average margin	39%
Prev. equil price	05 US¢85
New equil price	05 US¢95
Prev. trough price	05 US¢65
New trough price	05 US¢72

Source: Smith Barney estimates.

Iron ore – a different market

Figure 25. Iron ore Costs, Prices & Margins



Source: Brook Hunt; CRU; Smith Barney estimates.

The history of iron ore costs and margins is starkly different from that of copper. Its industry has seen sustained margin expansion. Persisting tight markets mean that margins will probably be sustained.

Figure 26. Appropriate Long-term (Equilibrium) Commodity Prices - 2005$

Commodity	Unit	Value
Copper	US¢/lb	95
Aluminium	US¢/lb	70
Nickel	US$/t	3.50
Zinc	US¢/lb	50
Lead	US¢/lb	27
Oil	US$/bbl	28
Iron Ore (Lump)	US¢/Fe unit	45
Coking coal	US$/t	62
Thermal coal	US$/t	33

Source: Smith Barney estimates.

Appendix 1: References

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Appendix 2: Historical Price Data Details

Copper	1850-96, New York price for Lake copper (99.9%-pure copper), in Loughlin, G.F., Prefatory note on the report on gold, silver, copper, lead, and zinc, Mineral Resources of the United States 1922, Part I, U.S. Geological Survey, 1925, p. 127a. 1897-98, New York price for Lake copper (99.9%-pure copper), in Engineering and Mining Journal. 1899-1908, Electrolytic (99.9%-pure copper) refinery price in New York, in Engineering and Mining Journal. 1909-22, Electrolytic (99.9%-pure copper) domestic f.o.b. refinery, in American Metal Market. 1923-72, Electrolytic (99.9%-pure copper) domestic delivered to Connecticut price, in American Metal Market. 1973-77, U.S. producer electrolytic (99.9%-pure copper) wirebar, in Metals Week. 1978-2004, U.S. producer cathode (99.99%-pure copper), in Metals Week (1978-92) and Platt's Metals Week (1993-2004).
Aluminium	1850-94, in U.S. Geological Survey Minerals Yearbooks and predecessor volumes. 1895-98, 98%-pure aluminum, in American Bureau of Metal Statistics. 1899-1900, 99%-pure aluminum ingot, in American Bureau of Metal Statistics. 1901-04, 99.75%-pure aluminum ingots in 2,000-pound lots, in American Bureau of Metal Statistics. 1905, 99.75%-pure aluminum ingots in 2,000-pound lots, in American Metal Market/Metal Statistics, 1955. 1906-19, 99%-pure No. 1 aluminum ingots, in American Metal Market/Metal Statistics, 1955. 1920-21, 98%- to 99%-pure aluminum, in American Metal Market/Metal Statistics, 1955. 1922-28, 98%-pure aluminum metal, in American Metal Market/Metal Statistics, 1955. 1929-35, 99%-pure aluminum metal, in American Metal Market/Metal Statistics, 1955. 1936-54, 99%-plus pure aluminum virgin ingot, in American Metal Market/ Metal Statistics, 1955. 1955-56, 99%-pure aluminum virgin ingot, in Engineering & Mining Journal. 1957-71, 99.5%-pure unalloyed aluminum ingot, in Engineering & Mining Journal. 1972, 99.5%-pure unalloyed aluminum ingot, in Metals Week. 1973-82, U.S. market spot price, in Metals Week. 1983-92, 99.7%-pure aluminum ingot, U.S. market spot price, in Metals Week. 1993-98, 99.7%-pure aluminum ingot, U.S. market spot price, in Platt's Metals Week. 1999-2004, LME
Zinc	1875-1904, New York price for Prime Western zinc (98% pure), in Ingalls, W.R., Lead and Zinc in the United States, McGraw-Hill, NY, 1980, p. 342. 1905-70, St. Louis/East St. Louis producer price for Prime Western zinc, in American Metal Market/Metal Statistics. 1971-79, U.S. Dealers Prime Western delivered price, in Metals Week. 1980-93, U.S. Dealers High Grade zinc (99.9% pure) delivered price, in Metals Week. 1994-2004, U.S. Dealers Special High Grade zinc (99.99% pure) delivered price, in Platt's Metals Week.
Nickel	1850-1912, Price of refined metal, as supplied by Inco Ltd. 1913-21, Price of refined metal, Historical Statistics of the U.S., Colonial Times to 1970, U.S. Dept of Comm, Census Bureau 1922-45, Price quoted by Inco for electrolytic Ni cathode at NY, in 2-short-ton minimum lots, in US Bureau of Mines Yearbook. 1946-47, Contract price to US buyers of electrolytic Ni cathode in carlots, fob. Port Colborne, Ont, incl. 2.50¢/lb duty, in US Bureau of Mines Yearbook; 1948-61, Contract price to US buyers of electrolytic nickel cathode in carlots, fob. Port Colborne, Ont, incl. 1.25¢/lb duty, in U.S. Bureau of Mines Yearbook. [duty halved on January 1, 1948] 1962-79, Contract price to U.S. buyers of electrolytic nickel in carlots, f.o.b. Port Colborne, Ontario, in American Metal Market. Weighted average for the year. U.S. import duty of 1.25¢/lb was suspended September 27, 1965. 1980-93, LME cash price for primary Ni (min. 99.80%, cut cathodes, pellets, briquets, 6t lots), Metals Week [through June 14, 1993]. 1993-2004, LME cash price for primary primary Ni (min. 99.80%, cut cathodes, pellets, briquets, 6t lots), Platt's Metals Week.
Steel	1897-February 1987, hot-rolled carbon steel bars merchant, Pittsburgh base, dollars per cwt., in American March 1987-1998, hot-rolled carbon SBQ (special bar quality) 1000 series, in American Metal Market. 1998-2004, Metal Bulletin

Source: USGS.

Notes

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ANALYST CERTIFICATION

Appendix A-1

I, Alan Heap, the author of this report, hereby certify that all of the views expressed in this research report accurately reflect my personal views about any and all of the subject issuer(s) or securities. I also certify that no part of my compensation was, is, or will be directly or indirectly related to the specific recommendation(s) or view(s) in this report.

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