



Factors that influence the price of Al, Cd, Co, Cu, Fe, Ni, Pb, Rare Earth Elements, and Zn

By John F. Papp, E. Lee Bray, Daniel L. Edelstein, Michael D. Fenton, David E. Guberman, James B. Hedrick, John D. Jorgenson, Peter H. Kuck, Kim B. Shedd, and Amy C. Tolcin

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Conversion Factors

Mass		
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	megagram (Mg)
ton, long (2,240 lb)	1.016	megagram (Mg)
ton per day (ton/d)	0.9072	metric ton per day
ton per day (ton/d)	0.9072	megagram per day (Mg/d)
ton per day per square mile [(ton/d)/mi ²]	0.3503	megagram per day per square kilometer [(Mg/d)/km ²]
ton per year (ton/yr)	0.9072	megagram per year (Mg/yr)
ton per year (ton/yr)	0.9072	metric ton per year
Mass		
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
megagram (Mg)	1.102	ton, short (2,000 lb)
megagram (Mg)	0.9842	ton, long (2,240 lb)
metric ton per day	1.102	ton per day (ton/d)
megagram per day (Mg/d)	1.102	ton per day (ton/d)
megagram per day per square kilometer [(Mg/d)/km ²]	2.8547	ton per day per square mile [(ton/d)/mi ²]
megagram per year (Mg/yr)	1.102	ton per year (ton/yr)
metric ton per year	1.102	ton per year (ton/yr)

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Summary

This report is based on a presentation delivered at The 12th International Battery Materials Recycling Seminar, March 17-20, 2008, Fort Lauderdale, Fla., about the factors that influence prices for aluminum, cadmium, cobalt, copper, iron, lead, nickel, rare earth elements, and zinc. These are a diverse group of metals that are of interest to the battery recycling industry. Because the U.S. Geological Survey (USGS) closely monitors, yet neither buys nor sells, metal commodities, it is an unbiased source of metal price information and analysis.

The authors used information about these and other metals collected and published by the USGS (U.S. production, trade, stocks, and prices and world production) and internationally (consumption and stocks by country) from industry organizations, because metal markets are influenced by activities and events over the entire globe. Long-term prices in this report, represented by unit values, were adjusted to 1998 constant dollars to remove the effects of inflation. A previous USGS study in this subject area was “Economic Drivers of Mineral Supply” by Lorie A. Wagner, Daniel E. Sullivan, and John L. Sznoppek (USGS Open File Report 02-335).

By seeking a common cause for common behavior of prices among the various metal commodities, the authors found that major factors that influence prices of metal commodities were international events such as wars and recessions, and national events such as the dissolution of the Soviet Union in 1991 and economic growth in China, which started its open door policy in the 1970s

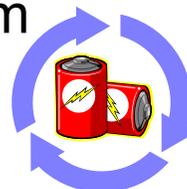
but did not have significant market impact until the 1990s. Metal commodity prices also responded to commodity-specific events such as tariff or usage changes or mine strikes.

It is shown that the prices of aluminum, cadmium, copper, iron, lead, nickel, and zinc are at historic highs, that world stocks are at (or near) historic lows, and that China's consumption of these metals had increased substantially, making it the world's leading consumer of these metals.



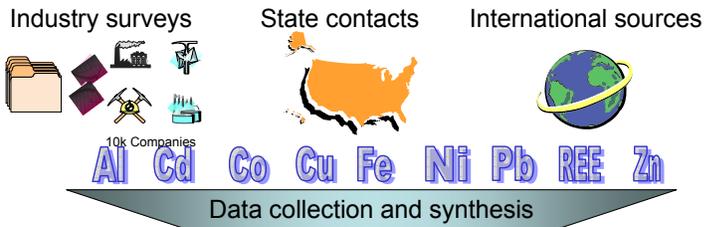
Factors that influence the price of Al, Cd, Co, Cu, Fe, Ni, Pb, Rare Earth Elements, and Zn

U.S. Geological Survey
Minerals Information Team



This presentation is an analysis of factors that influence the price of aluminum (Al), cadmium (Cd), cobalt (Co), copper (Cu), iron (Fe), nickel (Ni), lead (Pb), rare earth elements (REE), and zinc (Zn). The price analysis is based on consumption, production, stocks, and industry events reported by a variety of sources. This is a diverse group of metals significant to the battery recycling industry.

U.S. Geological Survey Minerals Information Team



Data Products

<http://minerals.usgs.gov/minerals/>

The USGS collects domestic minerals information from producers and consumers and international information from a variety of sources. The USGS collects, analyzes, and distributes, primarily on the Internet, the information that it collects.

Information Collected by the USGS

Production	Trade
Consumption	Prices
Stocks	Issues
	Developments

Analysis

Apparent consumption	Price trends
Import reliance	Material flow studies

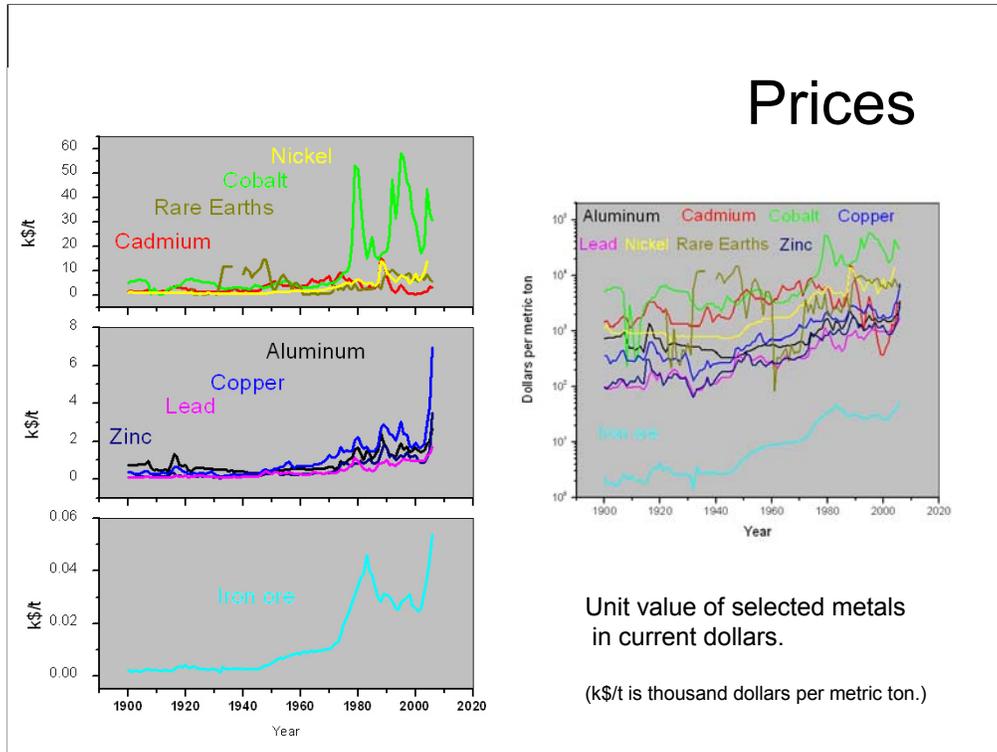
The USGS collects mineral commodity information about production, consumption, stocks, trade, prices, and industry issues such as capacity, cost of production, material use, and environmental issues. The USGS uses the information to quantify U.S. apparent consumption, price trends, material flows, and net import reliance.

[Net import reliance is net imports (imports minus exports) plus adjustments for stock changes. Apparent consumption is mine plus recycle production plus net import reliance. Mine production includes primary product, coproduct, and byproduct materials, including materials recovered during processing or from tailings. Note that apparent consumption and import reliance are material dependent, which means that the quantitative measures depend on which materials are included in the estimation. Because USGS minerals information emphasizes raw materials, the materials included in trade are typically mineral or metal ores and concentrates and intermediate materials, such as ferroalloys or mill products that supply the domestic manufacturing industry. Manufactured products, such as vehicles, electronic equipment, and so forth, typically are excluded.]

Factors that influence the price of Al, Cd, Co, Cu, Fe, Ni, Pb, Rare Earth Elements, and Zn (1900-2006)

Examples of factors that influence raw materials' prices include mining and material processing industry events, such as changes in consumption, production, or stocks that result from mine or plant openings or closings, strikes, or technology changes; however, the raw materials industry does not operate in isolation. It is subject to external influences such as deflation of the U.S. dollar, the breakup of the Soviet Union, economic recessions, rapid growth of the Chinese economy, and trade restrictions. First, look at the prices of these metals together over a long time period (1900-2004) and then individually over a shorter time period (1991-2006). The long-time-period prices are unit values of apparent consumption, so for some of these metals they represent a composite of forms, as reported in U.S. Geological Survey Data Series 140, Historical Statistics of Minerals and Materials in the United States. The short-time-period prices are those reported in the U.S. Geological Survey, Mineral Commodity Summaries.

Prices



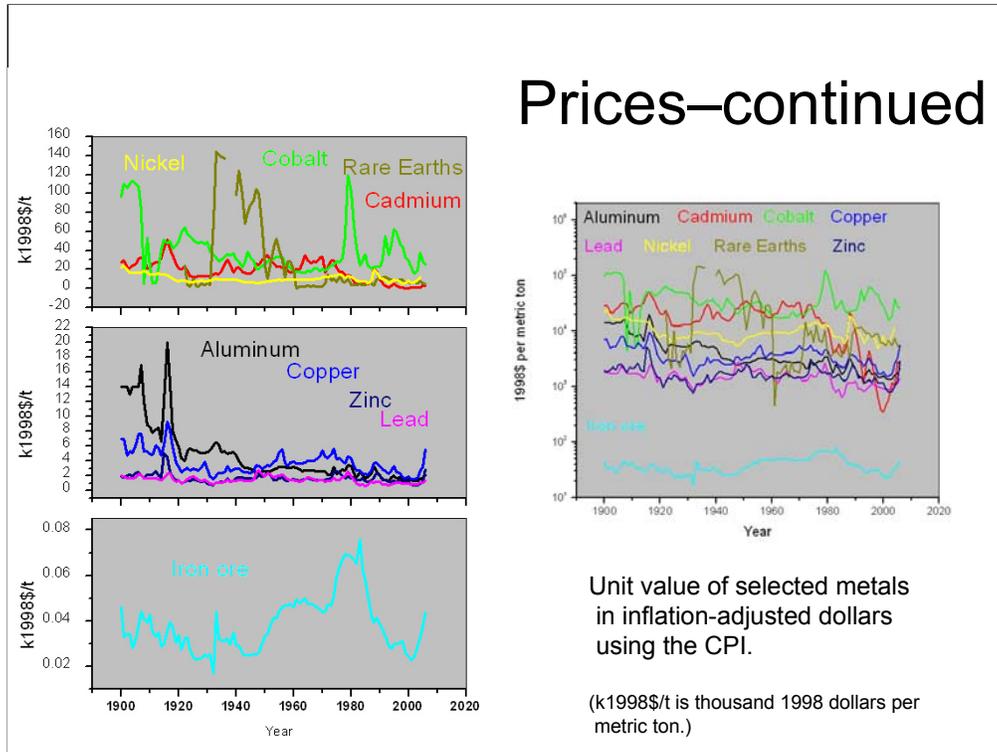
These price histories create a jumble of lines that are difficult to untangle and present in a visually appealing way, not to mention that these prices have a wide range (five orders of magnitude). They are shown together here in three panels and on a logarithmic scale to show historical prices of nine metals on a single graph. They show many peaks and troughs of various sizes. Each price fluctuation cannot be explained but some trends common to them can.

There are three common behaviors: (1) Prices (in nominal terms) start out low and end up high; (2) price fluctuations are smaller in the middle of the time period than they are at the beginning or end; and (3) in 2008, prices are at historical highs for most of these metals. Most metals displayed price peaks just before 1920 (World War I), a stable price through the 1940s (when World War II price controls were in effect), and price peaks just before 1980 (post-Vietnam era).

The quantitatively larger price changes apparent in the recent years are no larger, as a percentage of current price, than price changes in the early part of the time period.

It appears that, from the beginning to the end of the time period, prices went up, and that there was greater price stability in the middle of the time period as implied by the smaller price fluctuations; however, ...

Prices—continued



... when price is adjusted for inflation, the trends are not the same. Measured in inflation-adjusted (constant) dollars; (1) prices are now quite similar to their historical values, marginally higher, or even lower, and (2) price fluctuations are now quite similar to historical fluctuations, and the upward trend disappears.

There is a pattern of fluctuating prices throughout the time period; however, there was relative price stability in the central portion of the time period (about 1940-60) owing to government price controls and allocations during wartime.

The disappearance of the upward current-dollar price trend when deflated to constant dollars (as indicated by the Consumer Price Index used to deflate current to constant dollars) suggests that these long-term metal prices (measured in current dollars) have changed at about the same pace as inflation.

[This is the only place where deflated values are used. All other values in this report are in current U.S. dollars. Note about price range as reported in the U.S. Geological Survey, Mineral Commodity Summaries and Data Series 140: MCS (1991-2006) range from about \$108/t-Mn in 1999 to \$71,000/t-Mo in 2005. Data Series 140 (1900-2006) range \$19/t-Mn in 1921 to \$25,700/t-Mo in 2004.]

Supply and Consumption

The geographic distribution of world metal mine production and consumption.

In addition to supply of and demand for a mineral commodity, money supply is also an important factor in determining price. The geographic distribution of metal mining is influenced by where the economic deposits are located. Consumption of these metals is distributed among several leading consuming countries and many smaller consuming countries that are geographically distributed around the world.

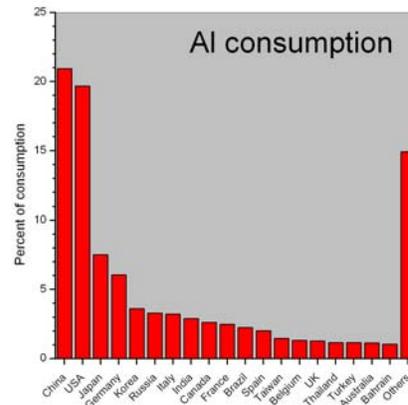
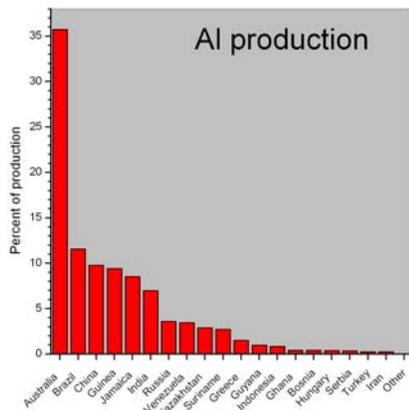
The following bar charts show percent of production (and consumption) by country in descending order of national share of world production (or consumption). The bar to the right labeled “others” represents collective production (or consumption) for the countries not listed separately.

When one country accounts for a large share of production or consumption, it suggests that the country, or events in that country, could have a significant impact on the commodity price.

[Bar charts are based on a 5-year average of the most recently available production (consumption) data reported by the USGS or industry organizations.]

Aluminum Al

22 producers (bauxite)
67 consumers
3 producers and 4 consumers account for 50%

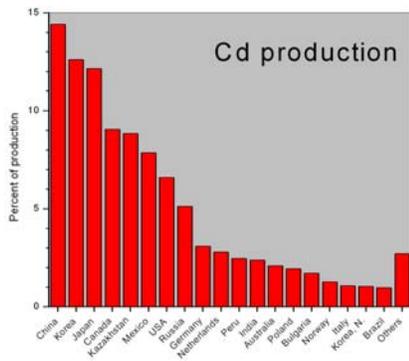


Source: Al production is 2002-06 average bauxite production as reported by the U.S. Geological Survey. Al consumption is 2002-06 average Al refined consumption as reported by the World Bureau of Metal Statistics.

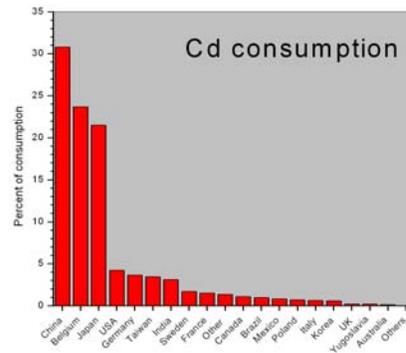
Among 22 aluminum (in the form of bauxite)-producing countries, the leading producer (Australia) accounts for about 36% of production; the leading 3 producers (Australia, Brazil, and China) account for more than 50% of worldwide production.

Among 67 aluminum-consuming countries, the leading 2 consumers (China and the United States) each account for about 20% of consumption; the leading 4 consumers (China, the United States, Japan, and Germany) account for more than 50% of world consumption.

Cadmium Cd



27 producers
21 consumers
4 producers and 2 consumers account for 50%



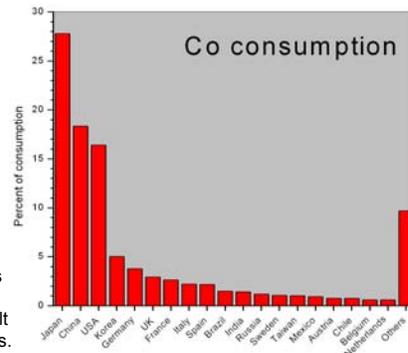
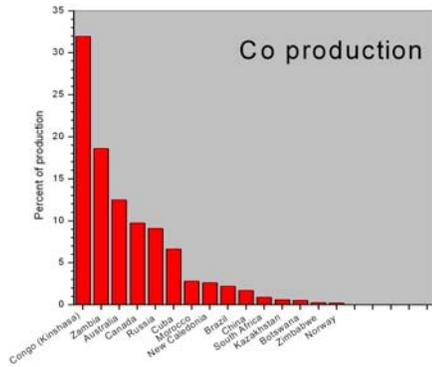
Source: Cd production is 2002-06 average Cd refinery production as reported by the U.S. Geological Survey. Cd consumption is 2002-06 average Cd refined consumption as reported by the World Bureau of Metal Statistics.

Among 27 cadmium-producing countries, the leading 3 producers (China, Korea, and Japan) each account for a similar amount of production and together account for about 39% of world production.

Among 21 cadmium-consuming countries, the leading consumer (China) accounts for about 30% of consumption; the leading 2 consumers (China and Belgium) account for more than 50% of world consumption.

Cobalt Co

15 producers
52 consumers
2 producers and 2 consumers account for 50%



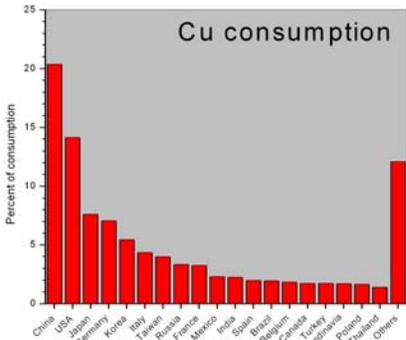
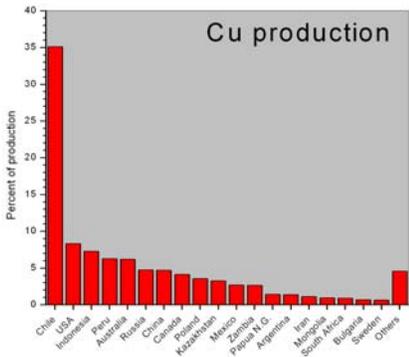
Source: Co production is 2001-05 average mine production as reported by the U.S. Geological Survey. Co consumption is 2002-06 average Co refined demand as reported by the Cobalt Development Institute and the World Bureau of Metal Statistics.

Among 15 cobalt-producing countries, the leading producer [Congo (Kinshasa)] accounts for about 30% of production; the leading 2 producers [Congo (Kinshasa) and Zambia] account for about 50% of world production.

Among 52 cobalt-consuming countries, the leading consumer (Japan) accounts for about 30% of consumption; the leading 2 consumers (Japan and China) account for almost 50% of world consumption.

Copper Cu

49 producers
58 consumers
3 producers and 4 consumers account for 50%

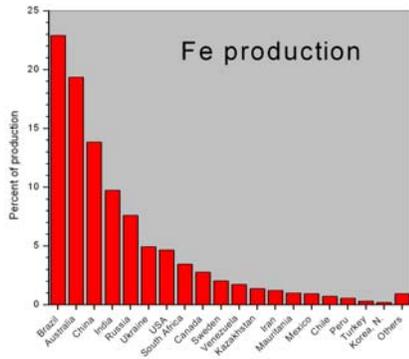


Source: Cu production is 2001-05 average mine production as reported by the U.S. Geological Survey. Cu consumption is 2002-06 average Cu usage as reported by the International Copper Study Group.

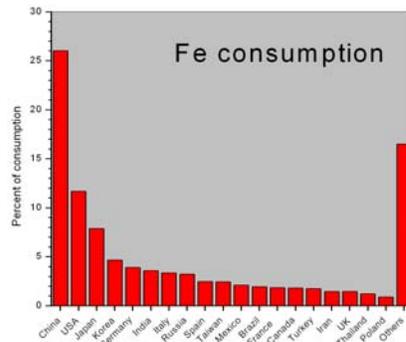
Among 49 copper-producing countries, the leading producer (Chile) accounts for more than 30% of production; the leading 3 producers (Chile, the United States, and Indonesia) account for about 50% of world production.

Among 58 copper-consuming countries, the leading consumer (China) accounts for about 20% of consumption; the leading 4 consumers (China, Japan, Germany, and the United States) account for about 50% of world consumption.

Iron Fe



49 producers
114 consumers
3 producers and 4 consumers account for 50%



Source: Fe production is 2001-05 average Fe ore production as reported by the U.S. Geological Survey. Fe consumption is 2002-06 average apparent crude steel consumption as reported by the International Iron and Steel Institute.

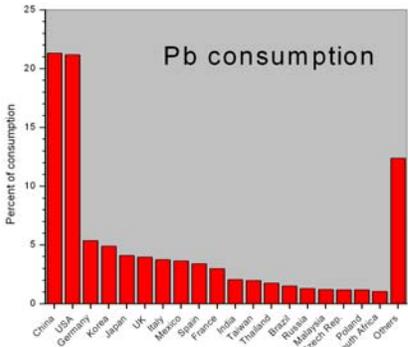
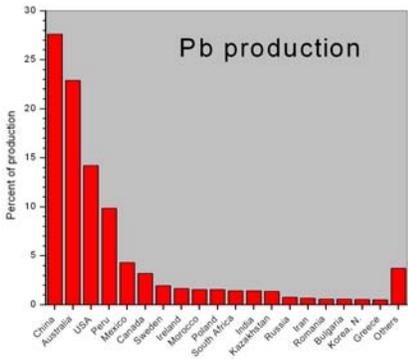
Among 49 iron ore-producing countries, the leading 3 producers (Brazil, Australia, and China) account for more than 50% of production.

Among 114 iron (in the form of steel)-consuming countries, the leading consumer (China) accounts for about 25% of consumption; the leading 3 consumers (China, United States, and Japan) account for about 50% of world consumption.

[Percent of iron production is based on the iron ore production measured in contained iron. Percent of consumption is based on gross weight of steel production; however, 60% of U.S. steel production is by EAF using scrap instead of iron ore.]

Lead Pb

44 producers
69 consumers
2 producers and 3 consumers account for 50%

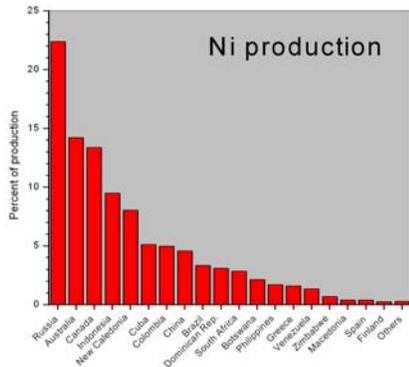


Source: Pb production is 2001-05 average mine production of Pb in concentrate as reported by the U.S. Geological Survey. Pb consumption is 2002-06 average refined Pb metal consumption as reported by the International Lead and Zinc Study Group.

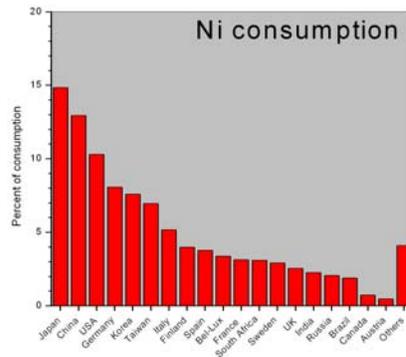
Among 44 lead-producing countries, the leading producer (China) accounts for about 25% of production; the leading 2 producers (China and Australia) accounted for about 50% of world production.

Among 69 lead-consuming countries, the leading 2 consumers (China and the United States) each account for more than 20% of consumption; the leading 3 consumers (China, the United States, and Germany) account for about 50% of world consumption.

Nickel Ni



25 producers
46 consumers
3 producers and 4 consumers account for 50%

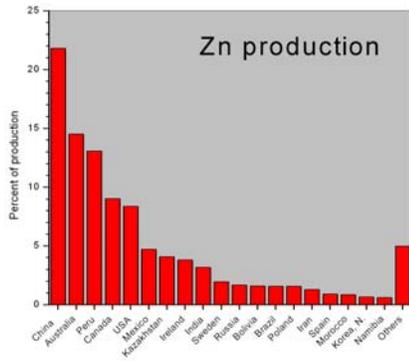


Source: Ni production is 2001-05 average mine production as reported by the U.S. Geological Survey. Ni consumption is 2002-06 average Ni usage as reported by the International Nickel Study Group.

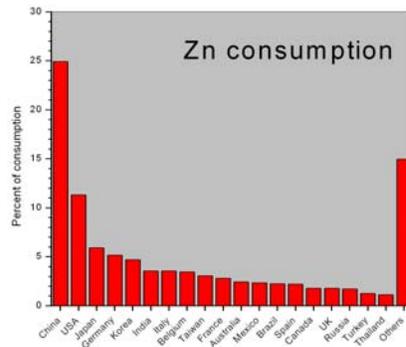
Among 25 nickel-producing countries, the leading producer (Russia) accounts for about 22% of production; the leading 3 (Russia, Australia, and Canada) producers account for about 50% of world production.

Among 46 nickel-consuming countries, the leading 3 consumers (Japan, China, and the United States) account for 37% of consumption; the leading 4 consumers (Japan, China, the United States, and Germany) account for about 50% of world consumption. In 2007, China overtook Japan as the leading consumer of nickel.

Zinc Zn



42 producers
73 consumers
3 producers and 4 consumers account for 50%



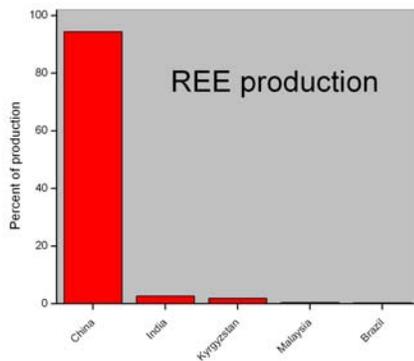
Source: Zn production is 2001-05 average mine production of Zn in concentrate and direct shipping ore as reported by the U.S. Geological Survey. Zn consumption is 2002-06 average refined Zn metal consumption as reported by the International Lead and Zinc Study Group.

Among 42 zinc-producing countries, the leading producer (China) accounts for more than 20% of production; the leading 3 producers (China, Australia, and Peru) account for about 50% of world production.

Among 73 zinc-consuming countries, the leading consumer (China), accounts for about 25% of consumption; the leading 4 consumers (China, the United States, Japan, and Germany), account for about 50% of world consumption.

Rare Earth Elements REE

5 producers
(Unknown) consumers
1 producer accounts for well over 50%



Source: REE production is 2001-05 average mine production as reported by the U.S. Geological Survey.

Among five rare earth-producing countries, the leading producer (China) accounts for more than 90% of production.

(Rare earths consumption data were not available.)

Al, Cd, Co, Cu, Fe, Ni, Pb,
REE, and Zn
Commodity Characteristics

Look at the characteristics and prices of these metals. The price of metals with similar characteristics may have similar influences. For example, the price of a byproduct metal could be influenced by the price of the metal of which it is a byproduct; or, metals that are produced in the same geographic area could be affected by the same environmental event, such as an earthquake or storm, or change in business operating conditions, such as labor relations or taxes.

Metal Production Characteristics

Mining:	
Primary product	Al, Co, Cu, Fe, Pb, Ni, REE, Zn
Byproduct/coproduct	Cd, Co, Pb, Zn, REE
U.S. mine production	Cd, Cu, Fe, Pb, Zn
Ore type:	
Hydroxide	Al
Oxide	Co, Cu, Fe, REE
Sulfide	Cd, Co, Cu, Ni, Pb, Zn
Various	Co, Ni, REE
Recycling:	Al, Cd, Co, Cu, Fe (Steel), Ni, Pb, Zn

Generally, metal ores are mined, beneficiated, and then processed to extract metal. Mining factors affect the production cost, and, therefore, the price of metals. It must be considered whether the metal is mined as primary product, byproduct, or coproduct. If it is a primary product, production can more easily respond to price changes. Byproduct metal production depends on the primary products' market conditions, byproduct market conditions, and fluctuations of byproduct ore grade and recovery rates. (Byproduct may be recovered to remove a detrimental impurity.) For example, cadmium is generally produced as a byproduct of zinc production.

Cadmium, copper, iron, lead, and zinc are produced (mined) domestically; aluminum, cobalt, nickel, and rare earths are not.

Recycling markets contribute a significant amount to the production of Al, Cd, Co, Cu, Fe (steel), Ni, Pb, and Zn. Indeed, industry has integrated these recycled materials into process streams to the degree that they are now essential feed materials and commodities. There are large, active markets for used aluminum, copper, iron (steel), lead, nickel, and zinc for recycling. Cd and Ni are recovered from recycled Ni-Cd batteries.

[Recycling is used here in the sense of post-consumer recovery and reuse. Metal scrap generated in the production process is generally reintegrated into the production process stream.]

Metal Use Characteristics

Base metal	Al, Cd, Co, Cu, Fe, Pb, Ni, Zn
Precious-like metal	Cu, Ni
Nonferrous metals	Al, Cd, Cu, Ni, Pb, REE, Zn
Ferrous metals	Fe
Alloying metal	Co, Ni, REE
Steel (all grades)	Fe (Steel)
Stainless steel	Ni
Reused and recycled	Al, Cd, Cu, Fe, Pb, Ni, and Zn

Al, Cd, Co, Cu, Fe, Pb, Ni, and Zn are base metals; Cu and Ni are precious-like metals in the sense that they have been the object of speculative investment as are gold, silver, and platinum-group metals; Al, Cd, Cu, Ni, Pb, REE, and Zn are nonferrous metals; and Co and Ni are primarily alloying elements.

The leading use of Fe is to make steel. Ni is used in significant amounts as an alloying element in stainless steel. Co and Ni are used as base metals and alloying elements in superalloys. Co and Ni are used in batteries: Co in lithium-ion batteries and Ni in Ni-Cd batteries. REE are used primarily as oxides; however, mischmetal (a natural mixture of REE) is an alloying agent in steel and nickel-hydride battery alloys. Individual REE are added to superalloys. Cd, Ni, and Pb are used to make batteries.

Al, Cd, Co, Cu, Ni, Pb, steel, and Zn have significant recycle production and scrap metal markets.

Factor Classification

All commodities, everywhere
Some commodities, everywhere
All commodities, limited geographic area
Some commodities, limited geographic area

Economic events such as world wars, national industrial growth, the Asian financial crisis (1997-98), recessions, and inflation have affected metal prices. Technologic developments, such as the growth of power and communication industries that require copper wire or the subsequent transition to wireless communication, also affect metal prices.

Commodity-specific events such as the construction of new production facilities or processes, new uses (or the discontinuance of historical uses), unexpected mine or plant closures (natural disaster, supply disruption, accident, strike, and so forth), or industry restructuring all affect metal prices.

Effects are in the present regardless of the event; however, the duration of effects may vary. The duration of a strike is usually substantially shorter than that of a war. A natural disaster may be shorter than a strike. The extent and duration of an event affect price through supply and demand.

Factors Affecting Price

- Scarcity
- Supply-demand balance
- Stocks and rate of use
- Actual or anticipated supply disruption
- Earnings, market performance, expectations
- Investment level

Generally, business analysts say that supply-demand balance determines price; investment analysts say that expectations play an important role in determining price; commodity analysts say that price increases as the number of weeks of supply in stocks diminishes; and financial market analysts say that increased speculative investment in metals causes the price to rise.

Other Factors

- Globalization
- Governments
- Geopolitics
- Growth

Globalization is important because many countries now play a role in metal production and consumption. Events in any of those countries could affect metal price. Events between countries, such as changes in currency exchange rates, play a role.

Governments set trade policy (implementation or suspension of taxes, penalties, and quotas) that affect supply by regulating (restricting or encouraging) material flow. They set the rules for resource extraction. They are a source of demand when they build stockpiles and a source of supply when they dispose of them.

Geopolitical events involving governments or economic paradigms and armed conflict can cause major changes. Historically, there have been two world wars and restructuring of national economies. There is no reason to believe that such events will not happen again. That these events have happened is reason to ask "What will happen and where?" and "Which metals will be affected?"

Businesses grow and reorganize. Despite the best business planning, demand can get ahead of supply when new production facilities come onstream late or do not perform as expected. Supply can get ahead of demand when a capacity increase exceeds the downstream industry's ability to absorb the potential new production.

There is also a national economic growth factor. Societies, as they develop, demand metals in a way that depends on their current economic position. For example, development in a country that is constructing road, rail, public utility, and building infrastructure would make a greater demand on metals use than would the development of a country that has nearly adequate amounts of transportation, housing, and basic services.

Selected Metals:
Al, Cd, Co, Cu, Fe, Ni, Pb,
REE, and Zn
(1991-2007)

Now look at production, consumption, stocks, and price of these selected metals in a more recent time period.

Stocks are a buffer between production and consumption. Stock changes indicate the imbalance between production and consumption.

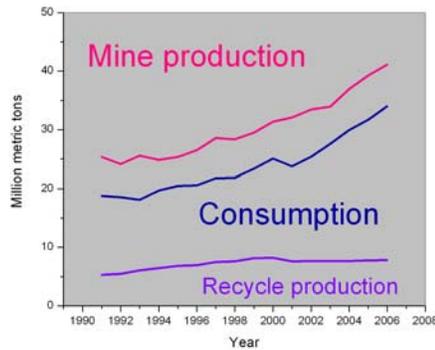
Aluminum

Al

Aluminum is the second leading metal produced after iron. The United States is a major alumina and aluminum producer but does not produce bauxite and is a leading consuming country. [2006 world mine production: Al (in bauxite) was 47 Mt-contained Al (178 Mt-Bauxite ore @ 0.50 Al₂O₃/ore @ 0.529 Al/Al₂O₃); and Fe (in iron ore), 945 Mt-contained Fe (1,800 Mt-ore).]

[Al data sources: Al mine production is Al content of bauxite world mine production as reported in the Bauxite and Alumina chapter of the USGS Minerals Yearbook. Al consumption is Al refined consumption as reported by the WBMS in WMS. Al recycle production is Al secondary production as reported by the WBMS in WMS. Al stocks are metal exchange (LME, COMEX, Shanghai Metal Exchange, and Tokyo Commodity Exchange), country, and U.S. strategic stockpile stocks as reported by the WBMS in WMS. Al price is Al ingot average U.S. market spot price as reported in the Aluminum section of the USGS Mineral Commodity Summaries.]

Aluminum Al



World mine production, consumption, and recycle production

Aluminum stocks and price



Source: See statement of Al data sources.

Aluminum mine production (estimated as world bauxite production times 0.5 units of alumina per unit bauxite times 0.52 units of aluminum per unit of alumina) and consumption (of Al metal) generally have been rising since 1992.

Aluminum price and stocks usually change in opposite directions. Al stocks rose sharply from 1991 through 1993 while price dropped. Since 2002, the aluminum price rose, closing 2007 at a historic high.

Al content of bauxite production exceeds Al metal consumption because about 15% of bauxite production is consumed for uses other than Al metal production; about 5% is directly consumed (for example, for uses such as abrasives, chemicals, cement, proppants, refractories, and in steel mills as a flux additive) and about 10% is used to make alumina that is consumed for uses other than Al metal production (for example, for uses such as abrasives, cement, ceramics, chemicals, and refractories).

[Note: Stocks are London Metal Exchange (LME) plus New York Commodities Exchange (COMEX) plus country plus National Defense Stockpile (NDS) stocks for December of year as reported by World Bureau of Metal Statistics.]

Cadmium

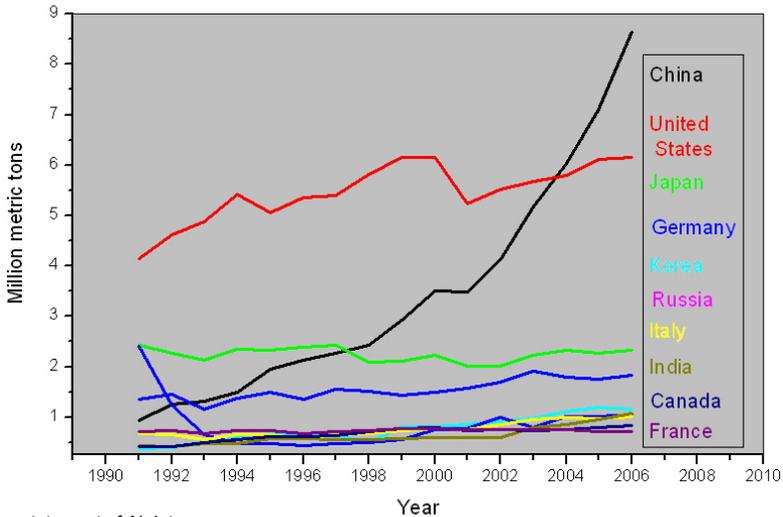
Cd

Cadmium is primarily produced as a byproduct of zinc mining and mostly is used to make batteries, an application that is declining. Its use as a plating metal to protect against corrosion by sacrificial oxidation also has been declining.

[Cd data sources: Cd mine production is Cd world refinery production as reported in the Cadmium chapter of the USGS Minerals Yearbook. Cd consumption is Cd refined consumption as reported by the WBMS in WMS. Cd stocks are country and U.S. strategic stockpile stocks as reported by the WBMS in WMS. Cd price is New York dealer Cd metal average annual price as reported in the Cadmium section of the USGS Mineral Commodity Summaries.]

Aluminum AI

Leading aluminum consumers

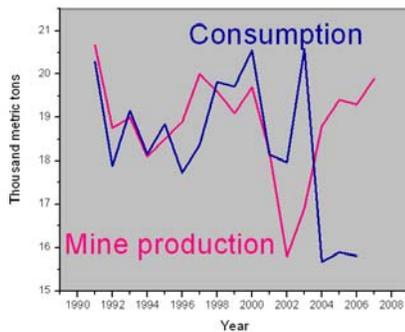


Source: See statement of AI data sources.

Aluminum consumption by most of the leading consumers has been steady during the 1991-2006 period. Among the leading consumers, only China has increased consumption significantly.

Cadmium Cd

World mine production and consumption



Cadmium stocks and price

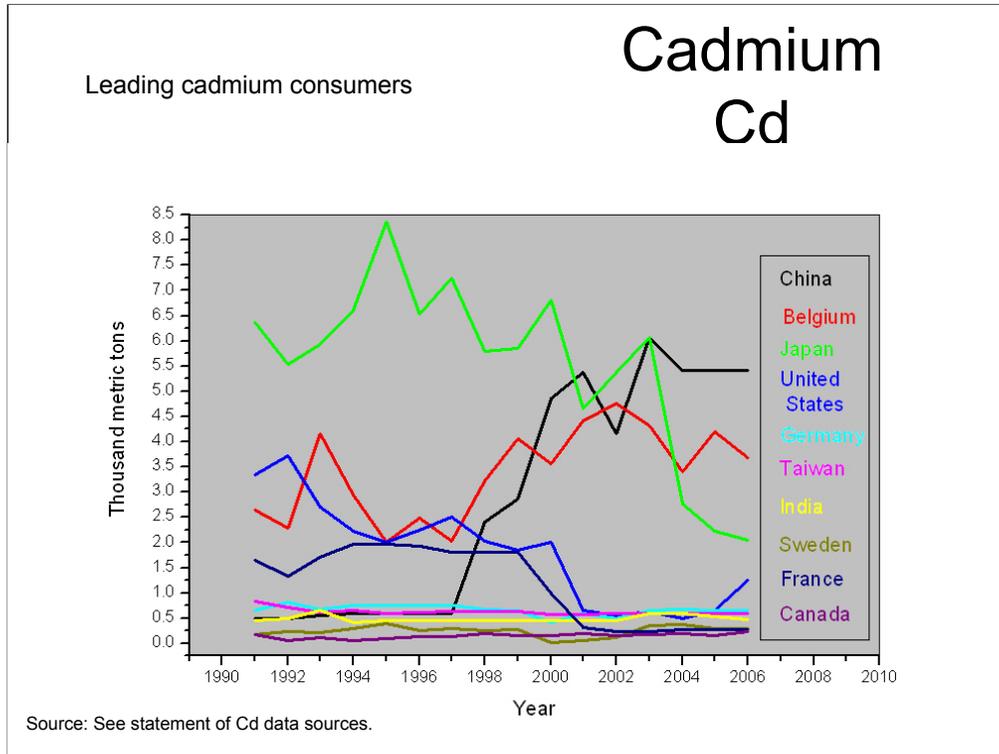


Source: See statement of Cd data sources.

Cadmium mine production, as represented here by cadmium refinery production, was similar to consumption until 2003, when production increased and consumption declined. Cadmium price has been rising since 1999 following a stock decline trend since 1996. Mine production did not respond to change in consumption from 2001-02, which may have resulted from the byproduct status of cadmium. Zn production declined during that time period.

The overall decline in 1991-2003 Cd consumption to 2004-06 Cd consumption may be associated with the substitution of non-Cd-containing batteries for Cd-containing batteries and the European Union Batteries Directive that was expected to reduce portable NiCd battery use in the near future.

[Stocks are country and National Defense Stockpile (NDS) stocks as reported by World Bureau of Metal Statistics for December of year.]



In the early 1990s, Japan was the leading consumer of cadmium; however, Japan's consumption has since declined significantly. U.S. cadmium consumption has declined, too. China and Belgium became the leading cadmium consumers by 2006. The rise in Cd consumption by China and the decline in the United States and Japan are associated with the relocation of battery manufacturers to China.

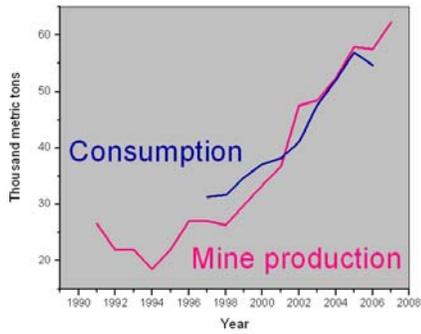
Cobalt Co

Cobalt is mined as a primary product and recovered as a byproduct of copper and nickel production.

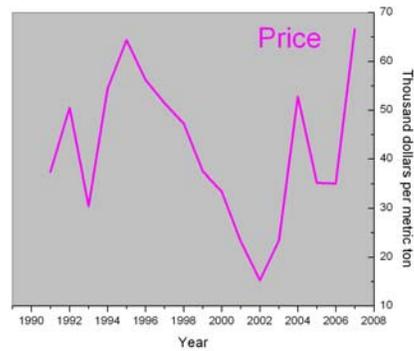
[Co data sources: Co mine production is Co world mine production as reported in the Cobalt chapter of the USGS Minerals Yearbook. Co consumption is refined Co apparent demand as reported by the CDI and the WBMS in Annual Cobalt Statistics. Co price is Co cathode average annual price as reported in the Cobalt section of the USGS Mineral Commodity Summaries.]

Cobalt Co

World mine production and consumption



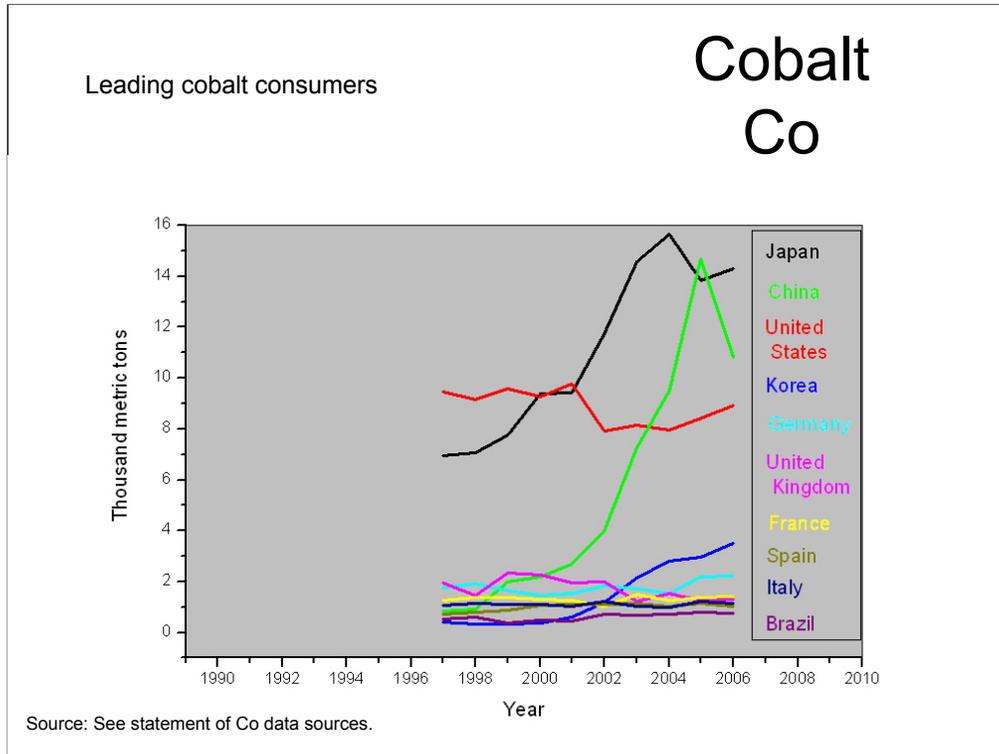
Cobalt price



Source: See statement of Co data sources.

Cobalt production and consumption have increased steadily since 1994.

Despite the steady increase of production and consumption during the time period, cobalt price dropped between 1996 and 2002, indicating that the rate of production was more than adequate to meet the rate of consumption.



Japan and the United States were leading cobalt-consuming countries over the entire time period; however, from 1999 to 2005, China’s consumption grew from that of a leading consumer to the leading consumer.

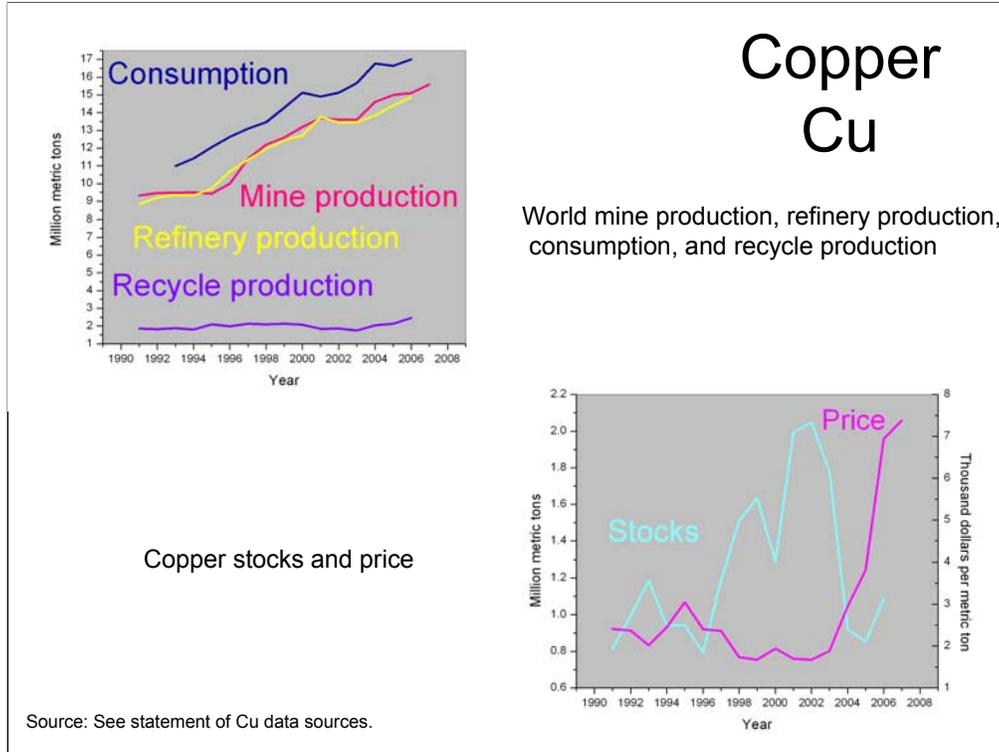
[China’s consumption decline from 2005 to 2006 may have resulted from consumption of stocks, which is not included in consumption shown in the graph.]

Copper

Cu

Copper is produced from an oxide or sulfide ore, which is converted to copper metal. The United States produces a significant amount of copper and is a leading copper consumer.

[Cu data sources: Cu mine production is Cu world mine production as reported in the Copper chapter of the USGS Minerals Yearbook. Cu consumption is Cu world usage reported by the ICSG. Cu recycle production is Cu secondary refinery production as reported by the ICSG. Cu stocks are metal exchange (LME, COMEX, and Shanghai Futures Exchange) and selected merchant stocks as reported by the ICSG. Cu price is average domestic producer Cu cathode price as reported in the Copper section of the USGS Mineral Commodity Summaries.]

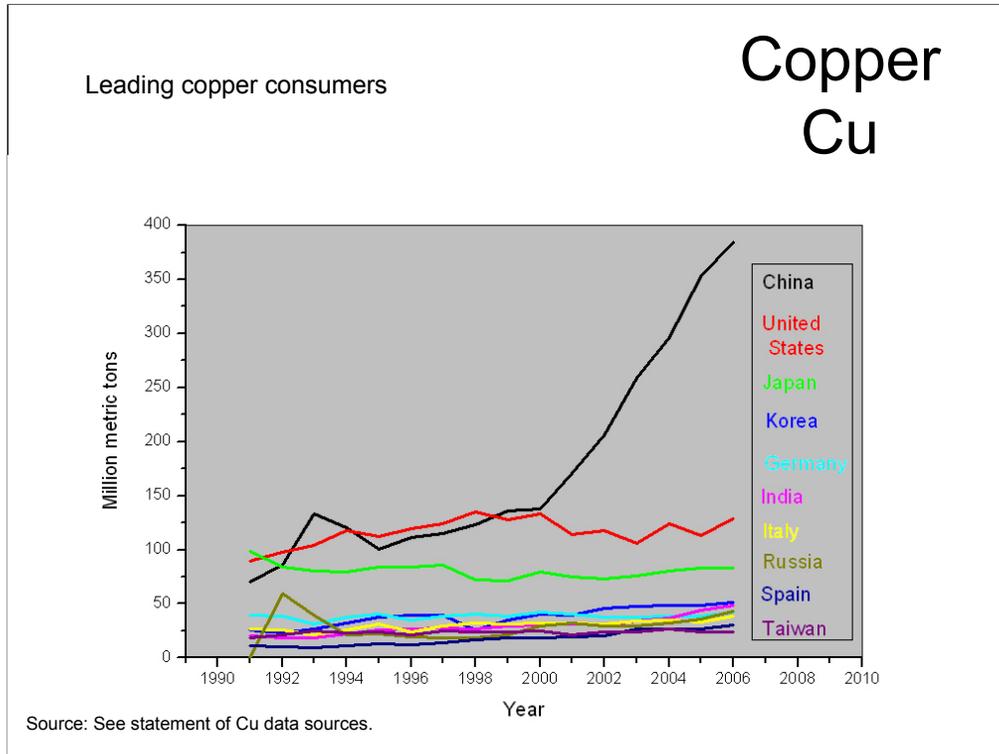


Copper production and consumption have increased steadily since 1991.

On only two occasions during the 1991-2006 period did both annual average price and year-end stocks change in the same direction. These were in 1995-96 and 2005-06 when both stocks and price increased.

The price drop in 1995-96 followed the discovery in 1996 that a rogue trader had used trading company money to maintain the price of copper. Copper is traded internationally on three commodity exchanges, and production, consumption, and stock information is readily available. The copper market is relatively transparent in that a change in supply or demand is reflected in price, while an excess of production over consumption results in higher stock levels, and a deficit of production relative to consumption results in lower stock levels. Recessions result in reduced demand; additional supply can be delayed by long lead times for the construction of new facilities.

Like that of the other metals, world copper mine production and consumption increased while the copper price trend declined between 1991 and 2003. The stocks-price graph suggests that demand exceeded production in 2003 when stocks dropped to near historic low levels and the price rose.



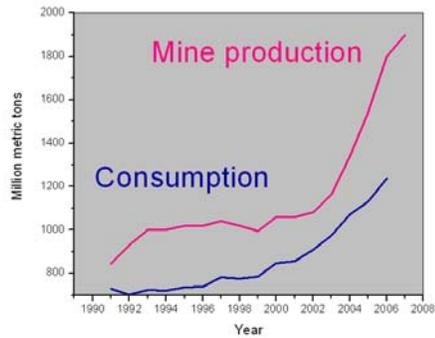
Among the leading copper consumers, China has increased consumption significantly. Consumption by the other leading consumers has changed little during the 1991-2006 period. The 1997-98 decline in Korean copper consumption was associated with the Korean financial crisis.

Iron Fe

As measured by mine production, iron is the leading metal commodity. As measured by production, iron (steel) recycle production and iron slag production are the second and third leading metal commodities.

[Fe data sources: Fe mine production is Fe content of Fe ore world production as reported in the Iron Ore chapter of the USGS Minerals Yearbook. Fe consumption is raw steel world production as reported in the Iron and Steel chapter of the USGS Minerals Yearbook. Fe stocks are mine, dock, and consuming plant Fe ore stocks, excluding byproduct ore as reported in the Iron Ore section of the USGS Mineral Commodity Summaries. Fe price is Fe ore price estimated from the reported value of Fe ore at mines as reported in the Iron Ore section of the USGS Mineral Commodity Summaries. 2001-05 average world production of mined iron was 692 Mt-contained Fe, and steel production was 979.8 Mt, suggesting that the 2001-05 average recycled component of world steel production was 290 Mt (=979.8-692). Slag production in the same time period was 300-400 Mt, based on the Iron and Steel Slag section of Mineral Commodity Summaries 2007 reported production of 200-240 Mt/yr-iron slag, 115-180 Mt/yr-steel slag.]

Iron Fe



World mine production and consumption

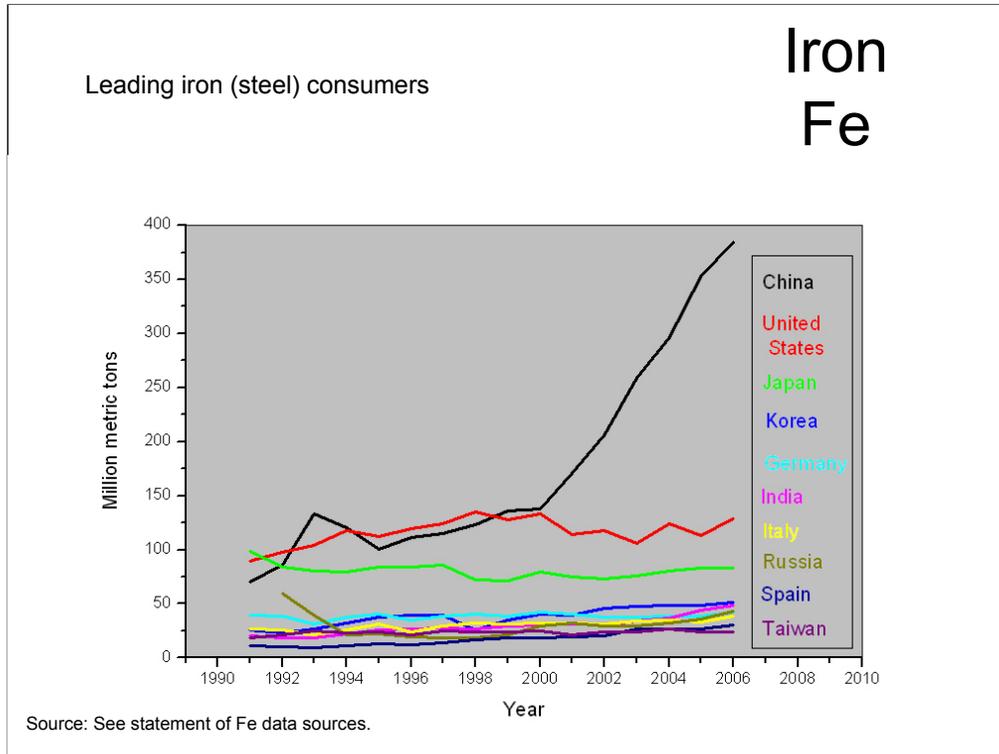
U.S. iron ore stocks and price



Source: See statement of Fe data sources.

Iron mine production and consumption have increased during the 1991-2006 period, strongly since 2002.

The figure shows U.S. stocks and iron ore price. U.S. stocks and price do not appear to change in opposite directions as they do for aluminum and copper until 2001, after which price rose while stocks declined. Possibly, U.S. stocks and price reflected North American (that is, regional) iron ore and steel markets, where a number of iron ore mines reduced production or went out of business, causing the inventory decline before 2001. After 2001, consumption of iron ore by China began to influence the North American market as China's consumption of other metals affected those metals' markets.



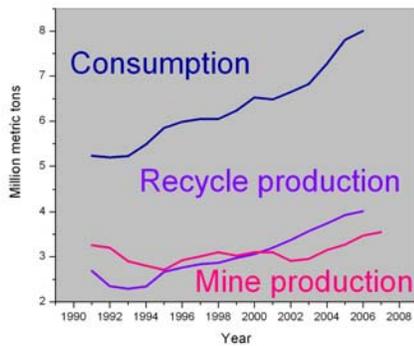
Among the significant consumers of iron (as measured by steel consumption), only China showed significant growth during this 1991-2006 period. The 1997-98 decline in Korean iron consumption was associated with the Korean financial crisis.

Lead Pb

Lead is mined as a primary product. A large fraction of lead production is through recycling.

[Pb data sources: Pb mine production is world mine production of Pb in concentrate as reported in the Lead chapter of the USGS Minerals Yearbook. Pb consumption is refined Pb metal consumption as reported by the ILZSG in Lead and Zinc Statistics. Pb recycle production is secondary world lead refinery production as reported by the USGS in the Lead chapter of the Minerals Yearbook. Pb stocks are LME, commercial (consumer, merchant, and producer), and U.S. strategic stockpile stocks as reported by the ILZSG in Lead and Zinc Statistics. Pb price is North American Pb producer average price as reported in the Lead section of the USGS Mineral Commodity Summaries.]

Lead Pb



World mine production, consumption, and recycle production

Lead stocks and price



Source: See statement of Pb data sources.

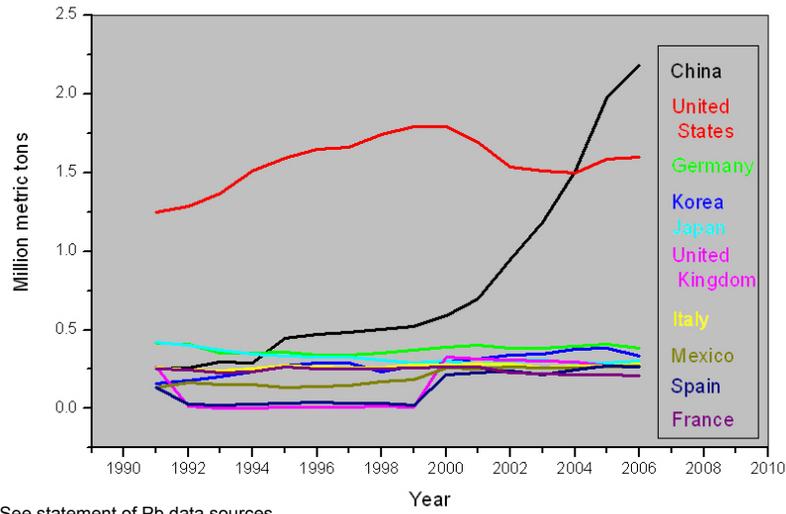
Lead mine production and consumption increased during the 1991-2006 period. Notice that, for lead, recycle production is about the same magnitude as mine production.

After a significant rise in lead stocks from 1991 through 1994, lead stocks declined during the 1994-2006 period. The price increased dramatically from 2003 through 2007.

[Lead stocks are producer, consumer, merchant, and LME stocks for the end of December of year as reported by the ILZSG.]

Leading lead consumers

Lead Pb



Source: See statement of Pb data sources.

During the 1991-2006 period, China moved from being a significant to being the leading consumer of lead. China's growth was strongest from about 2000 to 2006.

Nickel

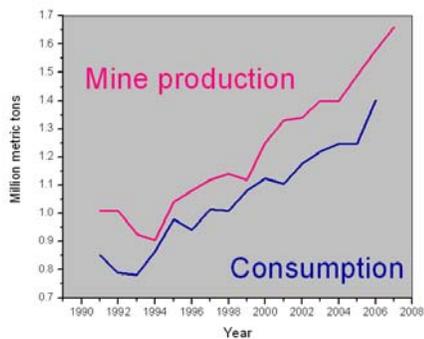
Ni

Nickel is mined in a variety of mineral forms from which nickel extraction is complex and deposit dependent. About one-half of U.S. nickel consumption goes into stainless and alloy steel, and most of the rest goes into nonferrous alloys (copper, brass) and superalloys (nickel-based and nickel-containing, cobalt-based alloys).

[Ni data sources: Ni mine production is Ni world mine production as reported in the Nickel chapter of the USGS Minerals Yearbook. Ni consumption is Ni consumption as reported by the INSG in World Nickel Statistics. Ni stocks are LME stocks as reported by the INSG in World Nickel Statistics. Ni price is average annual LME Ni price as reported in the Nickel section of the USGS Mineral Commodity Summaries.]

Nickel Ni

World mine production and consumption



Nickel stocks and price

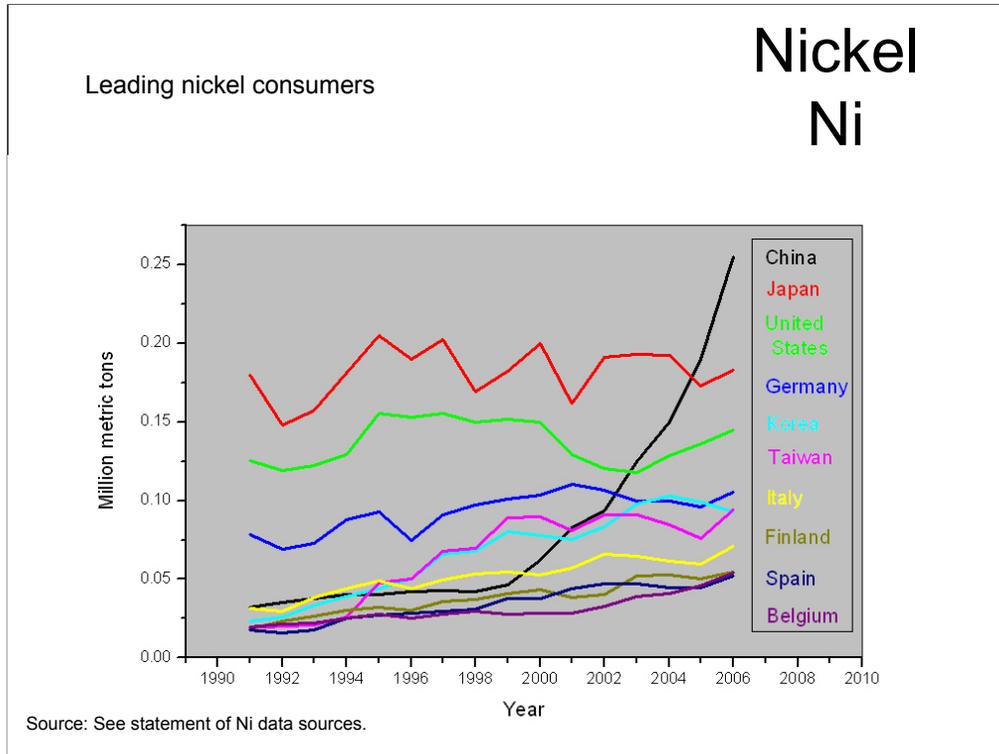


Source: See statement of Ni data sources.

After a brief decline at the beginning of the 1991-2006 period, nickel mine production and consumption have increased.

World nickel stocks increased between 1991 and 1994, after which they have generally declined.

Following the dissolution of the Soviet Union in 1991, Ni stocks were built up until 1994, even as mine production declined. Glenbrook Nickel Company's mine (Nickel Mountain, OR) and smelter (Riddle, OR), the sole remaining primary nickel production operations in the United States, closed following the nickel price decline from 1991 through 1993. From 2001 to 2003, both stocks and price increased, suggesting involvement by investment funds. Several consecutive years of nickel demand growth have drawn down (LME) stocks to historically low levels.



World nickel consumption has been increasing as has that of China and Germany, who are among the leading consumers. During the 1995-2006 period, China moved from being a significant to being the leading consumer of nickel.

Rare Earth Elements

REE

The rare earth elements are a group of 17 elements comprising the 15 lanthanides, scandium, and yttrium—a variety of elements that tend to occur together in minerals.

The large number of elements represented by the REE moniker indicates an even greater variety of diverse uses. Ce, Gd, La, Nd, Pr, and Sm are used in glasses—Ce and Nd to absorb ultraviolet and Gd, La, and Sm to absorb infrared. Eu is used in the red phosphor in television tubes. Nd is used in magnets.

[REE data sources: REE estimated world mine production Rare Earths chapter of the USGS Minerals Yearbook. REE price is price of metal content of mischmetal as reported in the Rare Earths section of the USGS Mineral Commodity Summaries.]

Zinc

Zn

Zinc is produced as a primary product, byproduct, and also has a significant secondary component to production.

[Zn data sources: Zn mine production is Zn content of Zn concentrate and direct shipping ore world production as reported in the Zinc chapter of the USGS Minerals Yearbook. Zn consumption is Zn refined metal consumption as reported by the ILZSG in Lead and Zinc Statistics. Zn recycle production is Zn Western world recovery of Zn as reported by the ILZSG in Lead and Zinc Statistics. Zn stocks are LME, commercial (producers, consumers, and merchants), and U.S. strategic stockpile stocks as reported by the ILZSG in Lead and Zinc Statistics. Zn price is aluminum average LME cash price as reported in the Zn section of the USGS Mineral Commodity Summaries.]

Rare Earth Elements REE



World rare earth element mine production

Rare earth element price

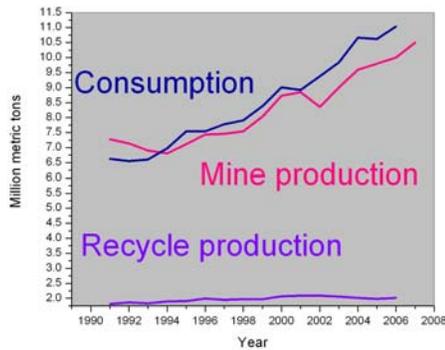


Source: See statement of REE data sources.

Rare earth element production, like that of other metals described before, has been increasing during the 1991-2007 period; however, unlike the other metals, price has been declining. Owing to its strong economic impact, the materials and items that China consumes have been getting more expensive while the price of materials and items that China produces has been getting cheaper. Generally, that translates into the cost of raw materials going up and the cost of consumer products going down; however, in this case, China is by far the leading producer of this raw material, so its price is not rising at the end of the time period as are the prices of other metals. The price of most REE in 2007 rose significantly (not shown in figure) as a result of increased Chinese consumption and China's enactment of export controls. In response to the rising price, Mountain Pass Mine, CA, restarted processing stocks of REE concentrate.

Consumption and stocks data for rare earths are not available. Rare earth production has shifted to China from the United States. China now produces over 90% of world supply.

Zinc Zn



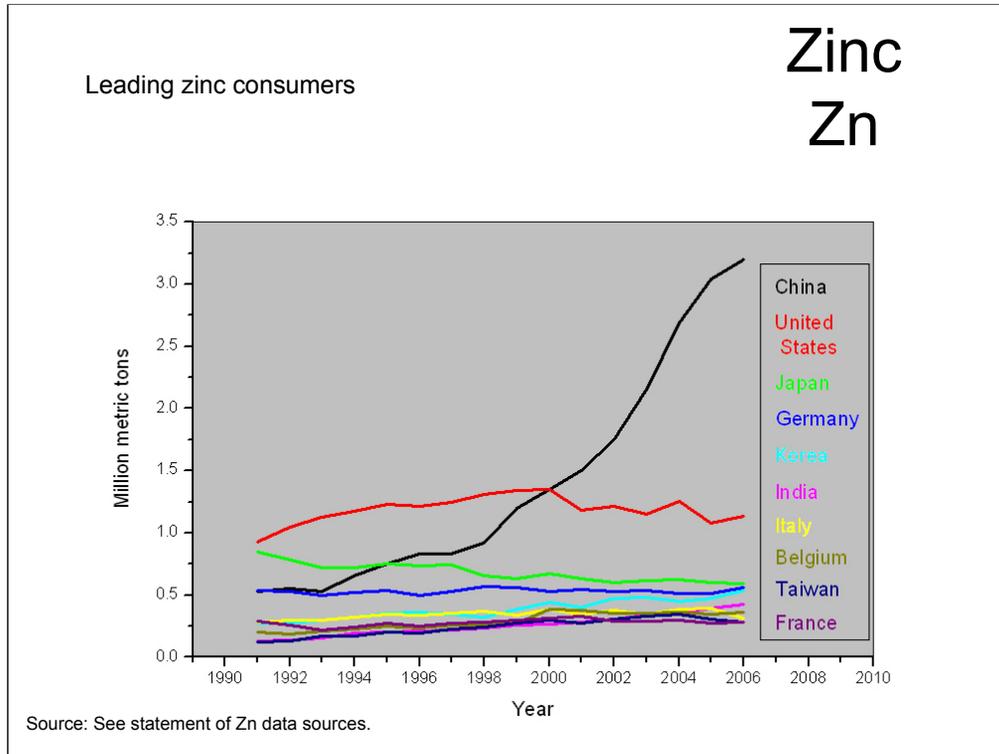
World mine production, consumption, and recycle production

Zinc stocks and price



Source: See statement of Zn data sources.

Zinc consumption has risen after a brief decline from 1991 through 1994, a period during which stocks increased. Zinc mine production and consumption generally increased during the 1991-2006 period. The stock changes before 2003 were associated with small price changes compared to the rapid stock decline and price rise that started in the 2003-04 period.



China moved from being a significant consumer to being the leading consumer of zinc during the 1991-2006 period.

During 2001 in the United States, there was a general downturn in the economy and a 20% decline in automobile sales. These events affected the steel industry, where nearly 60% of U.S. zinc is consumed to make galvanized steel. Reduced consumption in the United States contributed to increased stocks in that year shown on p. 48.

Conclusions and Observations

Conclusions/observations

- Dissolution of the USSR in 1991 depressed the price of metals.
- Growth of China's economy starting in about 1998 coincided with rising metals prices.
- Commodity-specific events, such as mine closure or low stocks, caused variations on the larger trends.

Two major events that affected metal prices during the 1991 to 2007 period—dissolution of the Soviet Union in 1991 and consumption growth in China starting in about 1998—may be associated with the following trends common to many metals: production declines followed by declining prices in the early part of the period that were coincident with dissolution of the Soviet Union, and rising production and dramatically increasing prices at the end of the period that were coincident with economic growth in China. Dissolution of the Soviet Union reduced demand and added to supply. Sustained demand growth in China exceeded world growth in supply and support infrastructure (electrical power, transportation), causing stock depletion and rising prices.

For those metals for which world consumption data are available (Al, Cd, Co, Cu, Fe, Ni, Pb, and Zn), China is a major, growing consumer. For those metals for which world stocks data are available (Al, Cd, Cu, Ni, Pb, and Zn), stocks are at or near historic low levels. Since China's growth is that of its general economy, one would expect the stocks of other mineral commodities (Co and REE) to be affected in the same way.

It appears that dissolution of the Soviet Union in 1991 resulted in the integration of Eastern and Western stocks into a world market, where they caused prices to drop. Lower prices may have caused marginal producers to stop production, leaving the metal production industry less able to meet Chinese demand. In addition, the leading consumer at the time (United States) was in recession from July 1990 through March 1991.

In 2005, copper stocks reached the lowest level since 1996; in 2006, nickel stocks reached the lowest level over the entire 1991-2006 period.

**China-United States Share of Selected Metals Markets
(5-year average)**

Metal	<u>China Share</u>	<u>China Rank</u>	<u>U.S. Share</u>	<u>U.S. Rank</u>	<u>Comment</u>
Aluminum					
Ore production	10%	3	--	--	Australia, #1 (36%) Brazil, #2 (12%)
Alumina	11%	2	8%	3	Australia, #1 (29%)
Smelter production	20%	1	9%	4	Russia, #2 (12%), Canada #3 (10%)
Consumption	21%	1	20%	2	Japan, #3 (8%)
Cadmium					
Ore production	14%	1	7%	7	Korea, #2 (13%)
Consumption	31%	1	4%	4	Belgium, #2 (13%)
Cobalt					
Ore production	2%	10	--	--	Congo, #1 (32%)
Consumption	18%	2	16%	3	Japan, #1 (28%)
Copper					
Ore production	5%	7	8%	2	Chile, #1 (35%)
Smelter production	14%	1	5%	5	Chile, Japan #2, 3 (12%)
Refinery production	12%	2	9%	3	Chile, #1 (18%)
Consumption	20%	1	14%	2	Japan, #3 (8%)

Today, China has the second largest economy after that of the United States. China's impact on the mineral and metals markets is greater than its proportional economic size might indicate because China, unlike developed countries, is building infrastructure, a process that is mineral and metal intensive.

Notice that in this list of China's and the United States' share of and rank in the production and consumption of these metals, China ranks mostly number 1; the United States ranks number 2 or lower for all of these metals.

**China-United States Share of Selected Metals Markets—continued
(5-year average)**

Metal	<u>China Share</u>	<u>China Rank</u>	<u>U.S. Share</u>	<u>U.S. Rank</u>	<u>Comment</u>
Nickel					
Ore production	5%	8	--	--	Russia, #1 (22%)
Plant production	5%	6	--	--	Russia, #1 (21%)
Consumption	13%	2	10%	3	Japan, #1 (15%)
Zinc					
Production	22%	1	8%	5	Australia, #2 (15%)
Consumption	25%	1	11%	2	Japan, #3 (6%)
Steel (all grades)					
Production	24%	1	10%	3	Japan, #2 (11%)
Consumption	23%	1	13%	2	Japan, #3 (8%)
Stainless steel					
Production	13%	2	9%	3	Japan, #1 (16%)
Consumption	22%	1	11%	3	Japan, #2 (11%)

China became the leading stainless steel producer in 2006.

Observations

- Prices are rising over the long term.
- Prices are fluctuating over the short term.
- Short-term price changes exceed long-term price trends.
- Price fluctuations (measured in percentage change) are about the same during most of the time period; however, they are greater in magnitude in recent years.

Historically, nominal metal prices have trended upward, whereas constant dollar prices have not changed significantly. These trends may not be apparent over short time periods because of the amplitude and duration of price fluctuations. Looking at frequently quoted prices (such as those in the trade journals that report prices daily or weekly or commodity exchanges that quote prices even more frequently) obscures long-term trends.

Cost of production sets the lower limit for sustainable prices. Supply-demand considerations, such as plant openings and closings or unexpected events such as industrial accidents or natural disasters, influence short-term price variations. Global events such as wars, recessions, inflation, or economic growth influence longer term trends.

Conclusions and Observations

- The U.S. once dominated the market but no longer.
- China's GDP growth was 11% in Q1 2007.

In terms of the consumer market, the time when the U.S. economy was the predominant influence on price has changed to one in which consumption is shared. China, in particular, is a growing participant (that is, processor and consumer) in the world market. China reported 11% GDP growth in the first quarter of 2007, which some economists interpret as an overheating economy. To determine what effect this will have on metal prices, we must answer the question "Is this the China miracle or the China bubble?" Or "For how long will this be the China miracle and when will it turn into the China bubble?" Sustained growth in China means sustained demand for these metals and high prices until suppliers and infrastructure expand to accommodate the new level of demand.

China's demand for metal results partly from infrastructure expansion in China. At first, infrastructure expansion is metal and material intensive, because China starts with little infrastructure. After roads, bridges, tunnels, and buildings are built, China's expansion will likely turn to less material-intensive development such as in entertainment, health care, and communications. As India grows, its greater GDP will make it more influential in the world market. As China moves away from material-intensive development, India may be moving into material-intensive development. Thus, India may replace China as the material-intensive developing country in the near future.

Current Events with Potential Price Impacts

- Moderation of China's economic growth
- Increase in India's economic growth
- Steel industry consolidation
- Global warming and carbon sequestration
- Rising energy costs
- Value of the U.S. dollar

Metal prices are affected by factors external to the metals industry. The metals industry is a part of the world and national economies, so changes in those economies can affect metals' prices.

Some situations that could affect prices in the near future include possible export limitations on chromite ore from India and South Africa, changes in China's economic growth, and continued Indian economic growth.

Global warming is becoming an issue. High fuel prices raise transportation and production costs. Independent of any metal industry factors, the price of metals changes with the changing value of the U.S. dollar, which has been generally declining. As a result of these factors, the price of metals has been trending upward.

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Appendix 1. List of Abbreviations

Al	aluminum
Cd	cadmium
Ce	cerium
CDI	Cobalt Development Institute
Co	cobalt
COMEX	New York Commodity Exchange
Cu	copper
EAF	electric-arc furnace
Eu	europium
Fe	iron
GDP	Gross domestic product
Gd	gadolinium
ICSG	International Copper Study Group
ILZSG	International Lead and Zinc Study Group
INSG	International Nickel Study Group
k	kilo (10^3)
Korea	Republic of Korea
k\$/t	thousand (current, nominal, not-inflation-adjusted) dollars per metric ton
k1998\$/t	thousand (constant, deflated, inflation-adjusted) dollars per metric ton
La	lanthanum
LME	London Metal Exchange
M	mega (10^6)
MCS	Mineral Commodity Summaries
Mn	manganese
Mo	molybdenum
Nd	neodymium
Ni	nickel
Pb	lead
Pr	praseodymium
REE	rare earth elements
Sm	samarium
t	metric ton
U.S.	United States
USGS	U.S. Geological Survey
WBMS	World Bureau of Metal Statistics
WMS	World Metal Statistics
yr	year
Zn	zinc
\$	U.S. dollar