COCHILCO
COMISIÓN CHILENA DEL COBRE

LONG-TERM COPPER PRICE PROJECTION
DE/11/2008

Intellectual Property Registration No. 171817

COCHILCO

COMISIÓN CHILENA DEL COBRE

CONTENTS

COCHILCO
COMISIÓN CHILENA DEL COBRE

1. Summary

Long-term price estimations are obtained by two different methodologies. First, a methodology based on market information and on the projection of market-relevant long-term variables is used, commonly referred to as “incentive price analysis”. Second, a statistical approach is used that models the long-term copper price as an unobserved component of the spot price.

The industry incentive price is the price point that encourages the entry of the new projects needed to meet future estimated demand. Industry incentive price may be interpreted as a rough approximation to the copper market long-term equilibrium price.

The statistical approach is designed to break down the price trajectory into a cyclical component whose effects decline in the absence of new shocks, and a trend component whose permanent impacts determine the long-term projection. The trend component can also be equated to the long-term equilibrium price.

There is, however, a tradeoff involved in both approaches. While using incentive prices analysis provides a better understanding of the causes underlying the changes in long-term price projections, whether related to the cost structure, demand pressures, or investment costs, this, however, requires knowledge of a range of variables that are not necessarily easier to project than the copper price itself. It also requires the determination of parameters and the use of assumptions ultimately based on expert judgment. The statistical or econometric method, on the other hand, delivers no information on the underlying causes of changes in projections, but doesn’t require judgment-based assumptions and the forecast of numerous variables. Theoretically, it also allows the estimation of the uncertainty associated with projections and, within the bounds of the rather short history of copper prices, allows the assessment of forecast errors.

Hence, an important objective of the study is a critical examination of both methodologies. In the case of the incentive price method this is relevant since it is a common approach taken by the industry and its critical analysis could shed light on the analyst’s role in estimations and on the likely sources of projection error and uncertainty. A critical discussion of the statistical model presented could, on the other hand, be useful in finding new paths of research in this area.

The study has four parts. Part 1 presents the study objectives, a market overview, and a precise economic definition of the variable concerned (long-term price). Part 2 estimates long-term price based on the incentive price method, describes the key variables and parameters involved, and provides related sensitivities. Part 3 presents an econometric model for long-term price estimation and evaluates (as data permits) its precision in terms of off-sample error by comparing its performance to simple projection alternatives. Part 4 briefly discusses the results obtained.

2. Objectives and Overview

2.1 Objectives

This study is primarily concerned with estimating long-term copper prices for use in evaluating copper mining projects. These prices are used to estimate project cash flows and determine net present value for comparison with other projects or the determination of the viability of a project at a given discount rate.

To achieve this, two different methods are used: “incentive price analysis” and a statistical approach. First, the incentive price for all projects in the global portfolio is determined, that is, the price that makes the project viable, given its particular characteristics. Then, in combination with an estimate of the new production required to satisfy estimated future demand, the industry incentive price (i.e., a price ensuring implementation of new projects designed to meet consumption needs) is determined. This may be considered an approximation to the copper market long-term equilibrium price. Second, an econometric approach is used to disaggregate copper prices into a cyclical or autoregressive component and a permanent or trend component which can also be considered an approximation to the long-term equilibrium price of copper.

The incentive price method is widely used by the industry and analysts, while the selected econometric method (generally referred to as the unobserved components model) is especially suitable for explicit trend modelling. The statistical approach used lends itself to the problem at hand, that is, the determination of a best long term forecast. These are the reasons why these particular methodologies were selected in this study.

An additional objective is to review these methods critically. Since testing for long-term price projection accuracy isn't easy or even possible (although the econometric model tries to), clearly laying out the assumptions involved and possible method weaknesses and shortcomings is called for.

Proving the accuracy of long-term price projections is a tough undertaking when data is scant. If average prices over a long period of time (say, 20 years) are considered a suitable approximation to the long-term prices prevailing at any given point in time, there will only be five independent data points in a century of copper prices. In addition, actual long-term prices may not necessarily match the long-term average. The difference lies in the fact that the optimal long-term price will be equal to the best projection based on the data available at a given point. While there is a limit to how well a random variable can be projected, the better our method, the closer to that limit we will be.

Each of these methods has tradeoffs that must be factored in. Since the incentive price method uses large amounts of data, it helps ascribe changes in long-term price projections to changes in those variables. However, it also requires assumptions and parameters based on independent projections and the analyst's best judgment, and does not directly provide an indication of projection uncertainty. The econometric procedure requires only the copper price series, which makes results uninformative about long-term price drivers. In turn, the estimated model is relatively transparent and parsimonious, and gives an idea of uncertainty associated with projections.

Project life, cost, production, and investment data were obtained from Brook Hunt.[1] For copper prices, we used Cochilco price series and USGS data[2] deflated per the U.S. Producer Price Index.[3] As such, copper prices used are real prices.

2.2 Overview

Prior to presenting our estimates, an overview of relevant market data and conceptual definitions are in order.

Copper and other metals and commodity markets are noted for both strong swings and persistent trends. The latter suggest that market equilibrium levels change over time.

---

[1] Copper Mine Cost Study, 2007 Edition" version 3.0 2008.
[2] See www.usgs.gov.
[3] See www.bls.gov. PPI has grown faster than CPI due to high inflation in the period.

For example, a review of 20-year copper price moving averages for the period 1920-2008 shows a low of about 125 ¢/lb. and a high of about 250 ¢/lb. This is clear indication that market equilibrium is not constant, and additionally advices against estimating future prices on the basis of historical averages.

Other market variables behave just as irregularly, with trends that persist over long periods of time.

Copper production costs, determinants of the long-term supply structure, have also evolved in distinctive ways (see next section). From 1980 to 2007, the average net cathode cost[4] ranged from 71.2 ¢/lb. to 184.8 ¢/lb.

In addition, consumption growth has been highly volatile from one year to the next and has exhibited dissimilar levels over different periods. A review of annual growth in 20-year periods from 1946 to 2007 shows a low of about 1.2 percent and a high of 5.4 percent.

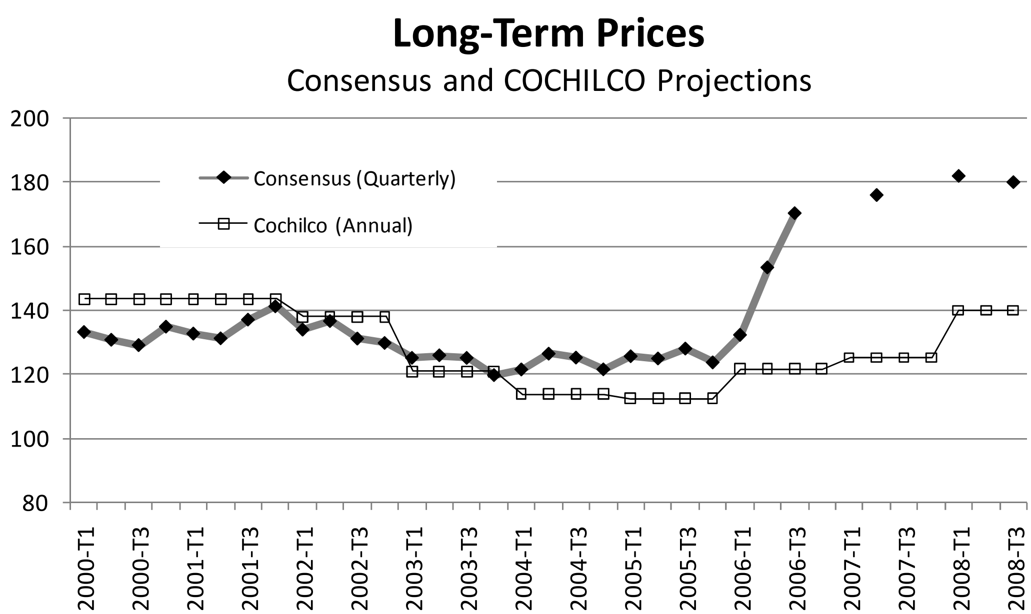
In short, both copper prices and its determinants exhibit marked swings and different persistent levels over time.

As noted below, long-term price estimates have also varied over time. Fig. 1 shows Cochilco's annual estimates, together with quarterly "consensus" values obtained by averaging several projections through Q1 2007, and Brook Hunt's projections at the end of the period.

Projections exhibit a decreasing trend through 2006, and then rise abruptly. Copper spot prices hit bottom in 2001, suggesting that due to persistently high prices, what was first construed as cyclical variations was subsequently interpreted as a permanent change of level.

[4] A measurement of unit cost per lb. of copper produced, it includes operating and overhead costs and interest (total cost) plus discounts accounting for byproducts such as gold and molybdenum.

Figure 1: Recent Long-Term Copper Price Estimates



A definition of the variable we seek to estimate and its significance from an economic standpoint is provided below.

A long-term equilibrium price is a price point providing no incentive for companies to either leave or enter the business. In mining, this means that while the factors of production are paid and returns earned are sufficient for mines in production and projects in development, returns for projects not in production would be insufficient in the long run.

When prices are not in equilibrium, and there are no shocks to demand or supply, copper prices converge toward this long-term equilibrium through the entry and exit of producers from the business. This process, however, is not immediate and leads to persistent price series.

The distinction between short- and long-term impacts is key. A transient rise in the price of oil, for example, will not immediately force companies out of the business. But if the long-term prospects for the price of oil rise substantially, some companies will cease to be profitable and will leave the market, which reduces the supply and impacts the equilibrium price.

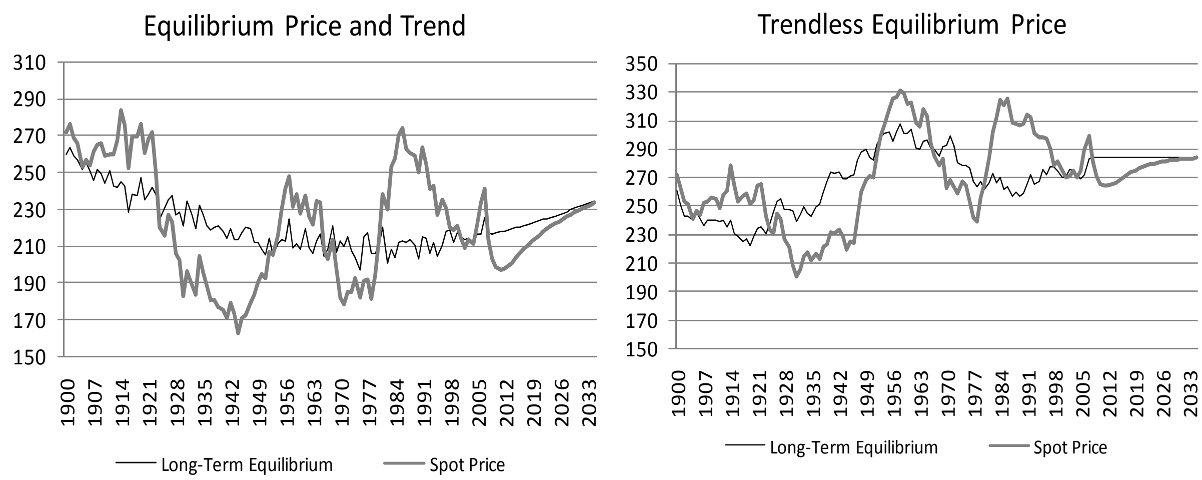
It then follows that the equilibrium price is not static and that many factors can swing it in one direction or another, including the spread of new technologies, changes in deposit reserves or quality, and long-term changes in demand growth.

A long-term price is a summary of the projected long-term market equilibrium price trajectory. When the equilibrium price projection is stable, it can be summarized in a single figure: the long-term price. This is what is implicitly done when evaluating projects on a fixed-price basis. If the equilibrium price follows a certain trajectory, a single long-term price would represent an average, determined by the timeframe used.

Figure 2 illustrates these concepts (note that these are not estimates, only examples). The graph on the left shows an equilibrium price with a clear (quadratic) trend projected into the future. In the case of metals, a quadratic trend has some economic support. The prevailing factors in an earlier stage would be reserve increases and technology improvements, while scarcity would be more important in later stages. The graph on the right shows a long-term equilibrium price variable without a clear trend, making the projection a horizontal line. This equilibrium price model matches the statistical model estimated model below.

In both cases, observed prices fluctuate around the long-term equilibrium price. The cyclical nature of these swings is a reflection of the persistence noted above. The long-term equilibrium price is not directly observed and must be estimated.

Figure 2: Long-Term Equilibrium Price



An additional factor seen from these illustrations is that the longer the forecast horizon, the closer the long-term equilibrium price projection is to the spot price projection. The forecast of the spot price converges rapidly toward long-term equilibrium. Since in mining project assessment the initial stage often involves construction, using the equilibrium price is pertinent. If the project is to go into production within a short timeframe, a spot price projection may be used for the initial years.

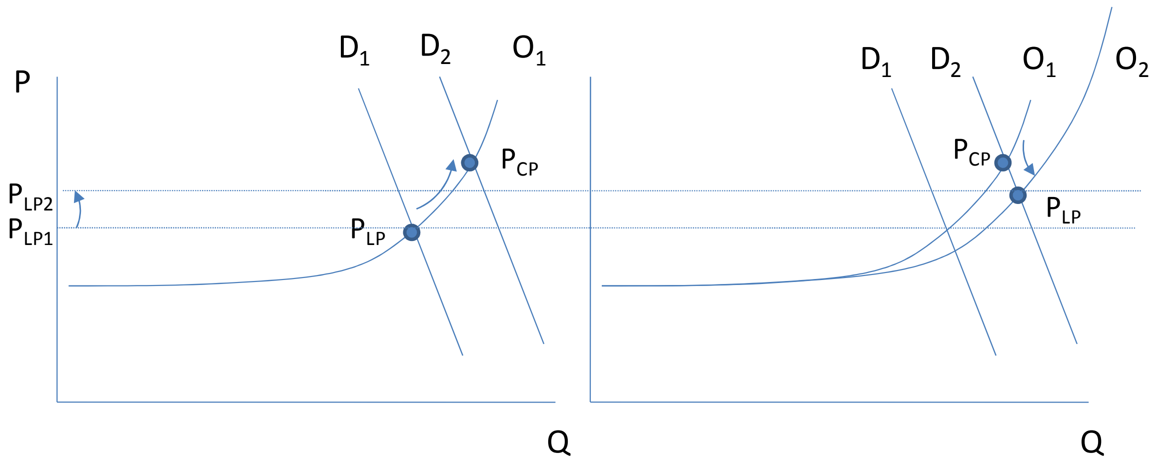
One last conceptual issue to consider is the influence of demand growth on the long-term equilibrium price.

A horizontal long-term supply implies that demand levels have no long-term effects. In copper production, however, differences in deposit quality lead to a rising rather than a horizontal supply curve. In other words, even if the same technology and factor prices are used, marginal costs will vary across mines depending on factors such as reserves, ore grades and type, the waste-ore ratio, and other deposit features.

Fig. 3 illustrates changes in long-term prices driven by changes in demand. For the purposes of incentive price calculation, since demand is considered highly inelastic relative to price, the terms *consumption* and *demand* will be used interchangeably. On the other hand, since demand is relatively elastic with regard to income, demand projections are driven by economic or industrial output growth. In Fig. 3, an impact shifts the demand curve right, generating a short-term equilibrium, but as new production flows in, prices converge toward long-term equilibrium. This, however, is a different type of equilibrium, since new production is added at the far end of the supply curve, changing its structure. This is liable to occur when new projects face, for example, declining grades or smaller scales (rendering them unable to leverage economies of scale). On the other hand, if new projects are identical to existing production, long-term prices remain unchanged, since the supply grows proportionally.

Figure 3: Structure of Supply and Demand

Changes in Cost Structure and Long-Term Prices



3. Incentive Price

3.1 Method

Long-term copper prices are projected on the basis of the incentive price approach widely used in the industry. This approach involves identifying the price point that encourages the new production required to meet future demand, based on minimum project profitability. To this extent, this method can be considered as an estimation of the long-term equilibrium price.

As noted, assumptions in this method include highly inelastic demand. In other industries, increased demand does not imply higher long-term prices, since capacity can be increased at the same prevailing cost using the same technology. In mining, the long-term supply curve is assumed not to be perfectly elastic.

Other incentive price determinants are the long-term project production costs and investments, both of which seek to approximate the long-term supply. Implicit in cost estimates are projected cost determinants, including technical (ore grades, technology, etc.), inputs (labor, steel, oil and derivatives, parts and accessories, etc.), byproducts (molybdenum, gold, cobalt, etc.), and economic conditions (exchange rate, inflation). As this is a non-cyclical cost projection, determinants are set at their long-term levels. For molybdenum –an important byproduct of copper mining– for example, long-term rather than prevailing prices are used.

Changes in cost impacting the industry in a roughly proportional manner may be regarded as upward and downward shifts across the entire supply curve. A key difficulty in these shifts is determining whether they are permanent or likely to revert. To a large extent, this depends on long-term expectations for cost determinants. For example, a permanent rise in oil prices will translate into higher long-term costs for the industry as a whole.

The net present value formula can help determine the price point at which investment becomes profitable:

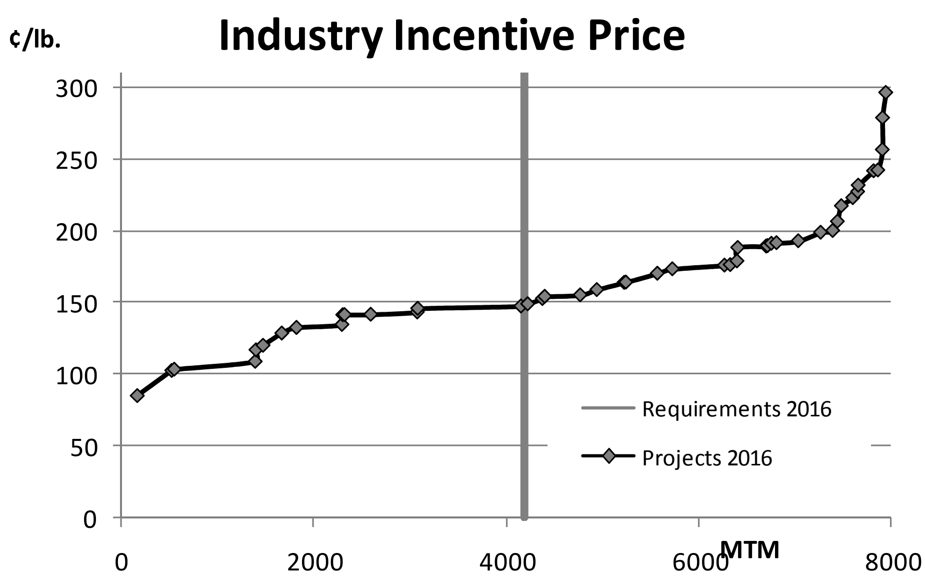
$$0 = -I + \sum_{t=1}^{n} \frac{(PI - C_t)Q_t}{(1+TD)^t}$$

The formula uses the following data: project production information (Q) adjusted for byproduct output (i.e., equivalent production); operating production cost (C), including the maintenance capital required to ensure annual production; the initial investment amount (I); the expected life of the project (n), and the discount rate (TIR). This results in the incentive price (PI) for the particular project.

If incentive prices for an entire project portfolio are combined with a projection of new production requirements, the result is an estimation of the long-term equilibrium price, shown on Fig. 4 as the intersection between the incentive price curve (with aggregate project production) and production requirements for a specific year (2016).

This particular estimation assumes 3.2 percent annual demand growth. Along with assumptions about output decline at existing mines, scrap production, and metallurgical losses, this puts requirements at slightly above four million tons of copper (refined rather than equivalent). The portfolio includes both highly probable and probable projects. As the information required to determine incentive prices is not available for the entire portfolio, total output was estimated based on a factor of production expansion for projects for which information does exist. Finally, a 15 percent discount rate was applied in all projects. The result is an equilibrium price of about 149 ¢/lb.

Figure 4: Incentive Price for 2016: Highly Probable and Probable Projects (Expanded), Based on 3.2% Consumption Growth



As shown, an important number of parameters are involved in this approach. These must be substantiated and, in case of uncertainty, different scenarios must be used. This exercise is carried out below to estimate consumption growth, new production requirements, operating and investment costs, and year of equilibrium price estimation. Some assumptions and parameters are exempted from the test. Demand, for example, is assumed to be highly inelastic, while a 15 percent discount rate is used uniformly[5].

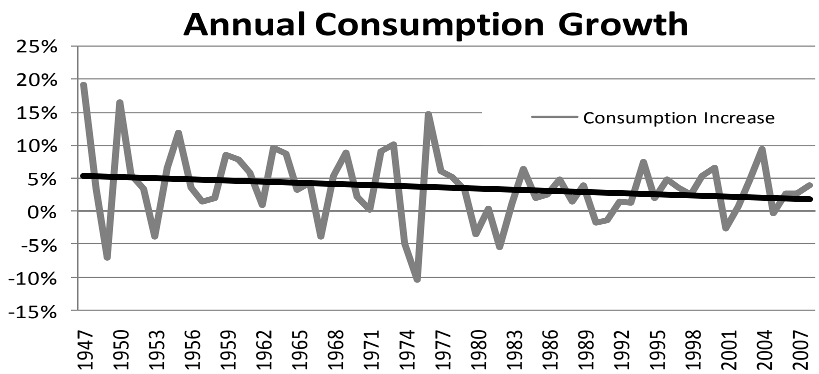
[5] Different scenarios can be constructed using different discount rates. These are not presented in the study but can be requested from the author. Some comments received from industry representatives appear to indicate that 15% could be too high a figure, and that a 10-12% rate could be more appropriate. A lower discount rate would translate into a slightly lower estimated equilibrium price.

3.2 Consumption

A key factor in ascertaining the industry incentive price is expected long-term consumption. The following calculations are not cyclical projection, which depend on world and producer country business cycles and are therefore highly volatile (see Fig. 5). The most likely annual growth rate over an extended period was estimated instead.

Reflecting a systematic decline in copper intensity of use (GDP to consumption ratio), consumption growth fell in 1946-2008. This trend leveled off after China's recent rise as a dominant consumer, leading to a more upbeat medium- and long-term consumption outlook. As noted in Fig. 6, which shows annual growth rates over a 10-year period (so as to smooth out strong annual fluctuations), Chinese consumption has grown well above the world average. As consumption growth elsewhere has declined, China has partly offset the loss. Despite rapid Chinese expansion, the central scenario to be used is that world consumption grows at a rate of 3.2% a year, the same growth that world consumption has experienced over the last decade. Consumption may level off in countries and regions that have seen their consumption declining in past years, and while observers agree that China will keep growing, its growth will not be as fast as in recent times. BGRIMM[6] estimates Chinese consumption at about 6-7% over the next years, falling to about 5.4% by 2015. This comparatively glum forecast is based on increased use of scrap, sluggish growth in the use of copper for consumer products, and moderate growth in other sectors. While in late 2007 Brook Hunt[7] estimated Chinese growth in 2008-2020 at 7.1%, in Q3 2008 it revised this to 6.3%.

Figure 5: Global Copper Consumption Growth



[6] BGRIMM: "The China Factor in Global Copper Usage and its Consequences", 2007.
[7] Brook Hunt: "The Long-Term Outlook for Copper", Q3 2008.

Figure 6: Average Consumption Growth in China and Elsewhere

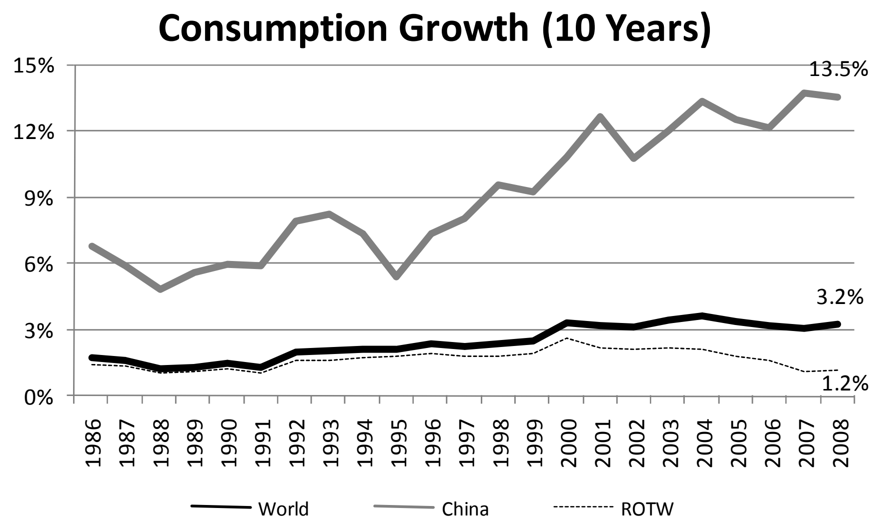


Fig. 7 shows the U.S. leading the consumption decline in this decade, followed by Western Europe and Japan.

The Commonwealth of Independent States (CIS) is a special case. High growth in the current decade came on the heels of an even stronger decline the decade before. This suggests that current growth is, to some extent, a rebound; a recovery of industrial capacity after the fall of communism. While countries such as India and Brazil are shown as having high growth potential, current consumption levels suggest that their impact on world consumption will take a few more decades.

Figure 7: Trends in Refined Copper Consumption Growth

Annual %	USA	Japan	W. Europe	CIS	China	World
1960-1969	5.3	11.5	2.3	3.8	3.5	4.7
1970-1979	1.7	5.3	1.5	4.0	8.0	3.4
1980-1989	1.8	1.7	0.9	-0.9	5.9	1.8
1990-1999	3.6	-2.2	2.5	-16	9.6	3.0
2000-2008	-4.6	-0.9	-1.5	16.4	13.8	2.5

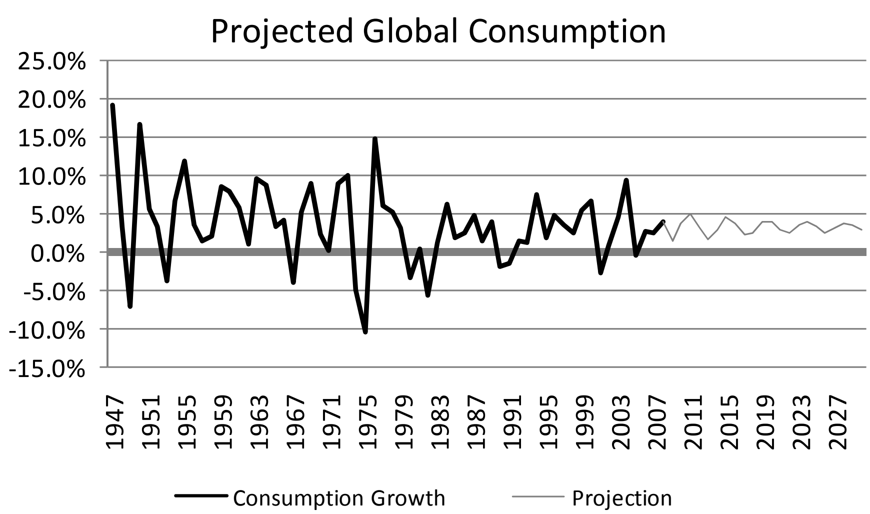
The long-term 3.2 percent annual consumption growth scenario used is based on these factors. Higher projections[8] have been recently revised

[8] CRU estimates consumption growth in 2007-2030 at 3.6% (based on summary presentations delivered at ICSG meetings; the long-term price report is not publicly available). In "The Long-Term Outlook for Copper", Brook Hunt revised projected consumption from 3.7% in late 2007 to 3.4% in Q3 2008, the most recent period available. Most optimistic projections are generally based on the

downward. For sensitivity purposes, two alternative scenarios were used: a pessimistic scenario which basically projects the historic downtrend with 2.8 percent of annual growth, and an optimistic 3.6 percent annual growth scenario based on China's ability to grow at high rates independently of global growth rates.

Complementing this approximate review, it could be noted that a simple univariate estimation of consumption yields a similar result reinforcing the basic scenario. In the ARIMA family of models, the best fit is provided by an ARIMA(2,1,2) model. Coefficients are significant and residuals behave adequately, although the R^2 is only 0.36. This yields a 3.2% annual consumption growth rate (below the 3.6% average for the entire sample), with a broad 2% to 4.4% range. Fig. 8 shows the consumption growth trajectory and projection.

Figure 8: Copper Consumption Growth Projection Using a Simple ARIMA(2,1,2) Model



3.3 New Production Required

Projections distinguish between committed mine production (both existing and under construction) and new production from projects that may or may not materialize, depending, among other factors, on expected long-term prices and profitability.

---

similarity between the incentive provided by Chinese industrial development and past cases of fast growth, such as Japan or South Korea. Consumption in the sixties, for example, grew at a rate of 4.7%.

Fig. 9 lists factors involved in determining new production requirements. Column 1 shows existing mine production (not considering expansions) and production from projects under construction. To account for resource depletion in existing mines, current production shows an annual decreasing trend slightly above 2 percent. This is important, since it implies that requirements are larger than suggested by demand growth alone (for example, with 3.2 percent consumption growth, production must grow above 5 percent just to keep up).

Column 2 corrects for metallurgical losses (under 3 percent) and for possible life-of-mine extensions.

Figure 9: New Production Required

	Current & Under Construction	Committed Production	3.2% Consumption	Consumption Minus Scrap	Req. @ 3.2% Consumption Growth	Req. @ 2.8% Consumption Growth	Req. @ 3.6% Consumption Growth
2008	16856	16391	18804	15795	-595	-657	-534
2009	17859	17392	19406	16301	-1091	-1217	-964
2010	18661	18205	20027	16822	-1382	-1577	-1186
2011	18576	18169	20668	17361	-809	-1076	-538
2012	18550	18175	21329	17916	-259	-603	91
2013	18011	17715	22011	18490	774	348	1209
2014	17470	17250	22716	19081	1831	1319	2355
2015	16795	16682	23443	19692	3010	2408	3629
2016	16156	16137	24193	20322	4185	3487	4905
2017	15599	15685	24967	20972	5288	4489	6115
2018	15119	15250	25766	21643	6393	5488	7334
2019	14578	14776	26590	22336	7560	6543	8621
2020	13952	14225	27441	23051	8826	7691	10015

Column 3 shows consumption growth at a constant 3.2 percent rate (therefore, rather than a cyclical projection, this is simply the result of applying long-term growth to the 2008 consumption level).

Column 4 corrects for the fact that consumption requirements are partially met by scrap.[9] It applies a discount equivalent to 16 percent of

[9] Estimated consumption refers to refined copper only and does not include direct scrap use.

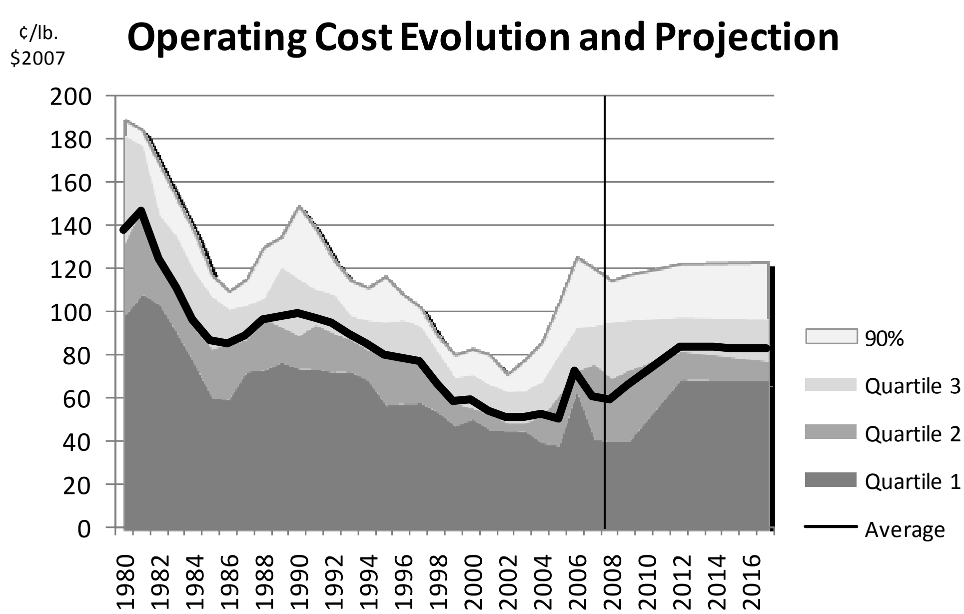
consumption, the most recent available number. While this percentage may be a rough approximation and varies between different data sources, no data to fine-tune the projection was available.

The remaining columns show requirements at various levels of consumption growth. Partly because this is not a cyclical projection, requirements through the first few years appear negative. The projection becomes valid over a longer timeframe, mainly because committed production includes projects under construction. As such, there should be no short-term demand for new projects. Based on this rationale, the above incentive price was calculated for 2016. Although a different year could have been used (see below), a closer horizon was unsuitable.

3.4 Production Costs

Copper mining production costs have exhibited a decreasing trend starting in 1980 (no earlier data is available), and then reverted within the past couple of years. This behavior may account for the changed long-term price prospects noted in Part 1, to the extent that high prices are regarded as the result of a permanent change of level, rather than short-term fluctuations.

Figure 10: Unit Operating Costs in Copper Mining



In addition to the trend, Fig. 10 shows cost distribution across mines. About 25 percent of production comes from mines with costs in the lower tier, while 10 percent comes from mines with costs in the upper tier.

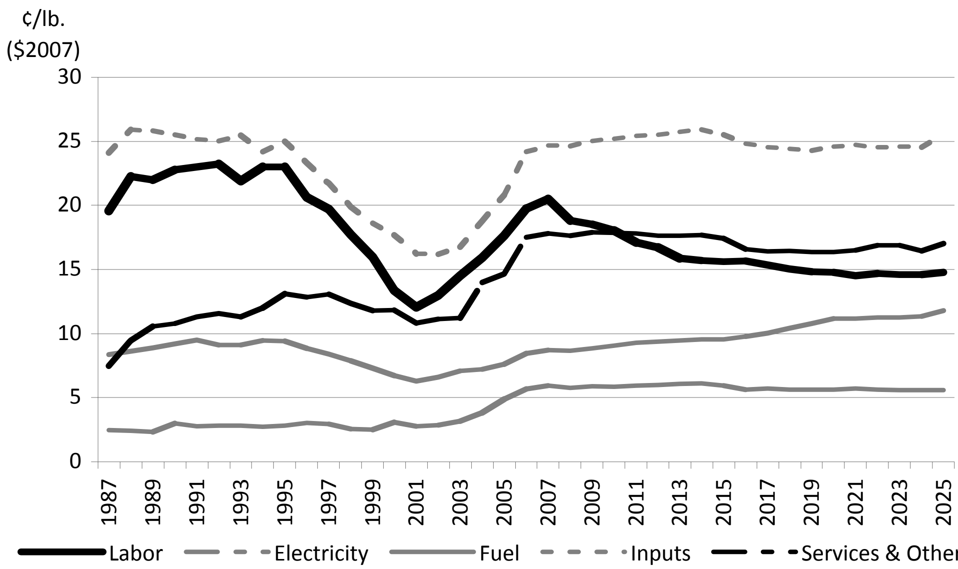
Since such a wide distribution makes it difficult to model project costs based on available information,[10] Brook Hunt's projections, as sensitized below, were used.

For sensitization purposes, the cost share of several key factors and inputs was considered. Labor accounted for about 27 percent of mine costs (concentrate and SX-EW cathode costs, excluding processing, commercialization, and indirect costs), fuels for about 7 percent, electricity for about 12 percent, inputs for about 32 percent, and services and other items for about 22 percent. Unit costs were discounted to account for byproducts, which in recent times refer mostly to molybdenum (about 55 percent) and gold (about 28 percent). While byproduct discounts have been important in recent years, this is less so over the longer term. For molybdenum, for example, expected long-term prices are closer to US$6-7/lb. than to the recent US$30+/lb., while for gold about US$550-650/oz. are expected rather than the recent US$800+/oz.

Fig. 11 shows the evolution and projection of mine cost components (excluding processing, commercialization, and overhead). Interestingly, labor costs contract slowly in the projection (the assumption is that they rise with inflation, as adjusting for nominal salaries is difficult). Inputs, on the other hand, remain high through the long term. Since this conclusion is debatable, it may be kept in mind for sensitization purposes. For example, the high price of steel, a crucial input (about 14 percent of related costs) may well exceed its long-term prospects. The sulfuric acid supply is also exceptionally tight. About 43 percent of inputs are parts and accessories, whose prices may also be considered pro-cyclical. Less debatable is a sustained rise in electricity and fuel costs, even in the slumping price scenario following the crisis of October 2008.

[10] A panel-type operating cost model including economic and technical variables (ore grades, production technology, development type, byproducts, production level) explained about 40 percent of cost variability across mines.

Figure 11: Mine Cost Component Evolution and Projection



3.5 Project information and Year of Evaluation

Since cost information is not available for all projects in the portfolio, this was adjusted for by assuming a more or less similar cost distribution across all projects.

In addition, only a handful of projects (i.e., highly probable and probable) can be considered to be sufficiently far along and pivotal for companies to start production in the medium term. Possible projects are much more vulnerable to deferral or cancellation for reasons other than economic (i.e., other than incentive price). Deposit quality notwithstanding, these are low-priority projects, a broad category that also includes early-stage projects undertaken by smaller companies.

Incentive prices were calculated based solely on highly probable and probable projects. However, since at least some possible projects will have been promoted to probable status by the end of the period under review (2020), they were included in incentive price estimations for the far end of the period.

Fig. 12 shows the structure of the current project portfolio, potential annual production levels, and potential production for projects whose information was used to calculate an incentive price. Also shown is their share of the total from 2012 onwards (as noted, in previous years most needs may be met by projects under construction. In addition, at shorter timeframes, demand projections based on long-term growth can lead to inconsistencies).

Figure 12: Project information

Highly Probable and Probable				Highly Probable, Probable, and Possible			
MTM	Total	Information Available	Percent	MTM	Total	Information Available	Percent
2012	4135	3065	74	2012	6522	3937	60
2013	5795	3603	62	2013	9586	5350	56
2014	7029	3625	52	2014	12504	5804	46
2015	7627	3949	52	2015	14396	6422	45
2016	7939	4546	57	2016	15503	7020	45
2017	8467	4526	53	2017	16413	6987	43
2018	8963	4770	53	2018	17166	7270	42
2019	8871	4732	53	2019	17270	7198	42
2020	9026	4655	52	2020	17722	7026	40

As the timeframe increases and new projects are promoted, the probable project portfolio becomes less representative of real industry options for meeting consumption needs. As such, the lack of comprehensive information will spuriously increase the equilibrium price over longer timeframes. While including all possible projects is a compromise solution, it may lead to underestimating the equilibrium price, since many such projects will be deferred or cancelled altogether. For the same reasons, industry incentive price calculation at nearer terms is also contaminated. All of this entails a significant degree of uncertainty in year selection. Analysts must therefore use their best judgment to determine when the project portfolio is most representative of real industry options. Applicable sensitivities are addressed in the section below.

3.6 Sensitivity of Results

As noted in the costs section, independent production cost projections required for calculating the industry incentive price are not easy to obtain. Fig. 13 shows the sensitivity of equilibrium prices to percent changes in operating and investment costs. Based on the discussion in the costs section, operating cost risks may well be considered to be on the decline. As shown below, the equilibrium price is more sensitive to variations in operating costs than to equivalent percent variations in investment costs.

Figure 13: Sensitivity to Changes in Operating and Investment Costs

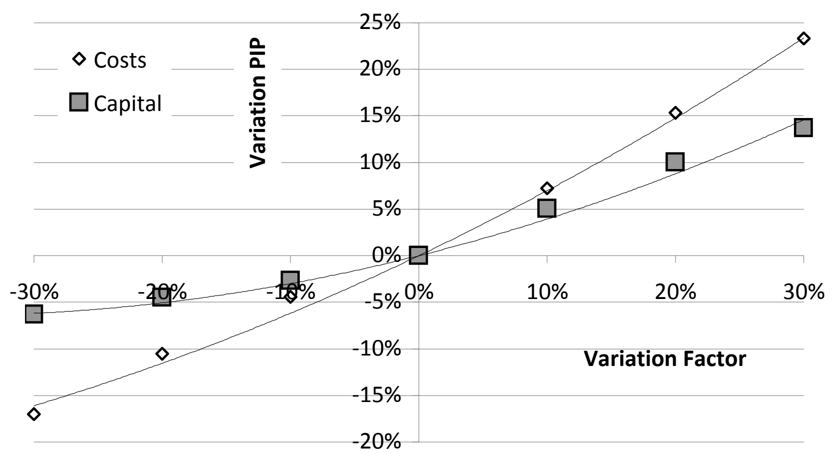


Fig. 14 illustrates the sensitivity of the industry incentive price to a range of consumption growth scenarios across several years. As noted above, new production requirements can be met in the short term by projects under construction. Since this non-cyclical estimation uses a constant rate, these requirements only become valid over a longer timeframe (six years seems enough, considering that business cycles often last as long or less). While the resulting equilibrium price increases over time, this is the result of incomplete data and does not indicate the trajectory of the equilibrium price. To address these difficulties, we selected a range of years in which probable projects can be considered representative of real industry options for meeting consumption needs at a particular point in time. The result was a range of 128.6 ¢/lb. to 175.9 ¢/lb. Since toward the end of the period probable projects will not be very representative of real industry options, possible projects were added as a compromise (right half of table), keeping in mind that these can lead to an underestimation of the equilibrium price. This exercise partially reinforces the idea that the growing trend in long-term equilibrium prices is spurious.

Figure 14: Industry Incentive Price Sensitivity (¢/lb.) to Various Consumption and Year of Evaluation Scenarios

Highly Probable and Probable				Highly Probable, Probable and Possible			
Consumption→	2.8%	3.2%	3.6%	Consumption→	2.8%	3.2%	3.6%
2014	108.8	128.6	134.0	2014		108.8	
2015	134.2	143.0	152.8	2015		118.0	
2016	147.5	148.9	158.7	2016		134.6	
2017	149.1	163.5	175.8	2017	140.2	143.0	146.1
2018	164.0	175.9	193.0	2018	143.1	147.4	147.5
2019	176.1	199.1	235.5	2019	147.4	147.5	152.8
2020		238.7		2020	147.5	152.8	163.9

As to incentive price sensitivity to demand growth, a 3.6 percent growth rate (a recent consensus value) increases the price range to 134 ¢/lb. and 193 ¢/lb. While possible, the pessimistic scenario (2.8 percent annual long-term growth) is considered less probable.

4. Statistical Estimates

4.1 Model

Long-term price estimation is based on an univariate model, which eliminates the need to project the numerous variables impacting copper production costs. The intent is to isolate transient price shifts (which fade away in time) from permanent changes directly impacting long-term projections.

Importantly, long-term prices are not directly observable and are not necessarily equivalent to the average of several years. The difference is best understood by defining long-term prices as the best possible projection over a distant horizon, based on available information. An average of several years, on the other hand, calculates long-term prices on the basis of information that is neither available nor easy to predict at the beginning of the period considered.

From an economic standpoint, the trend component may be equated to a variable yet trendless long-term equilibrium price. The various economic forces impacting long-term equilibrium prices –spread of new technologies, changes in deposit reserves, quality, and other technical issues generally associated with depletion- each tug in different directions over time. If any degree of regression to the average exists in the trend component, available data seems to indicate that this operates very slowly, to the point of being indistinguishable from a non-stationary process. Pindyck [11] substantiates a similar long-term energy price model that builds on Hotelling's model but relaxes restrictive assumptions to show that price levels and trends can be variable over time (instead of the simple exponential trend in a simple Hotelling's model). The same idea of breaking down the price process into two components (a random path and an autoregressive process) is used in a different context by Schwartz and Smith[12] with regard to economic reasons similar to those noted in Section 1 (companies leaving or entering the business versus long-term impacts).

In the model below, the permanent component (i.e., long-term prices) is defined as a random walk. This definition is the result of technology and mining determinants acting continuously and unpredictably to shift the equilibrium price. The transient component fades gradually and can be considered to be the result of shocks temporarily shifting supply or demand from long-term levels. Since a return to equilibrium is not immediate, the transient component can be modelled as an autoregressive component, in this case of the second order. Innovations distribute normally and are not correlated:

$$
\begin{aligned}
&\log(y_t) = \tau_t + \phi_t \\
&\tau_t = \tau_{t-1} + \varepsilon_t && \varepsilon_t \sim N(0, \nu_\varepsilon) \\
&\phi_t = \beta_1 \phi_{t-1} + \beta_2 \phi_{t-2} + e_t && e_t \sim N(0, \nu_e) \\
&\text{cov}(\varepsilon_t, e_t) = 0
\end{aligned}
$$

[11] Pindyck, Robert S.: “The Long-Run Evolution of Energy Prices,” Energy Journal, Volume 20 No. 2, Massachusetts Institute of Technology, 1999.
[12] Schwartz, E. and Smith, J. E.: “Short-Term Variations and Long-Term Dynamics in Commodity Prices,” Manage. Sci. 46, 7 (Jul. 2000), 893-911.

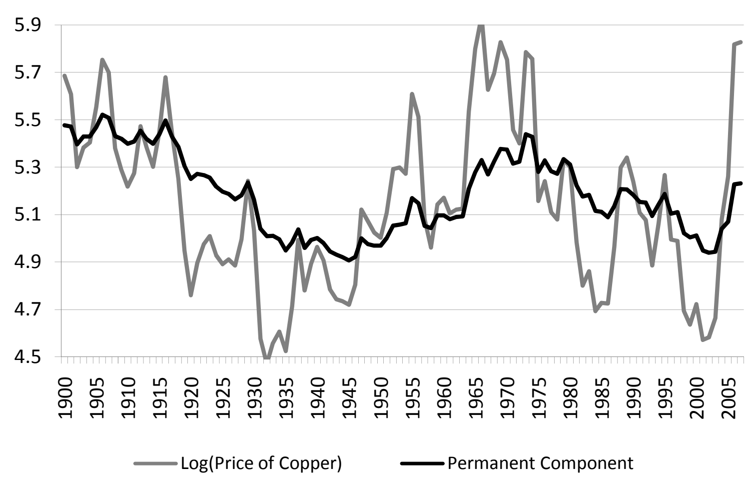
Significantly, this model is related to other procedures used to discriminate between components in a time series. This includes the Beveridge-Nelson approach, in which the permanent component is essentially an ARIMA model projected over an infinite horizon. The Beveridge-Nelson approach is less restrictive because it does not imply null covariance between innovations in the two components. However, in estimates based on this approach, the permanent component appeared too variable, i.e., following price fluctuations too closely.

4.2 Estimation and Results

The model was estimated based on the Kalman filter. This type of estimation requires setting initial-state conditions (long-term prices and cyclical component) as well as variances. The former can be the results of an OLS estimation based on the initial sample data, while the latter can be an arbitrarily large number reflecting the uncertainty of the initial estimation.

Fig. 15 shows the permanent component (which equals, in this approach, the best long-term projection at a given point in time) and the copper price logarithm.

Figure 15: Permanent Copper Price Component



The final state of the permanent component suggests that the best long-term price projection stands at approximately 187 ¢/lb. In 2002, long-term prices attain a minimum of approximately 140 ¢/lb., implying a 6-percent annual rise over the past few years.

Figure 16: Model Results

	Coefficient	Standard Error	z-Statistic	Probability
Beta 1	1.015757	0.083011	12.23645	0.0000
Beta 2	-0.204838	0.094656	-2.164013	0.0305
Trend Variance	0.002488	0.003128	0.795335	0.4264
Cycle Variance	0.027876	0.004179	6.669765	0.0000
	Final State	RECM	z-Statistic	Probability
Trend	5.231275	0.195348	26.7793	0.0000
Cycle	0.484267	0.22809	2.123141	0.0337
Auxiliary Cycle	0.595315	0.188872	3.151946	0.0016

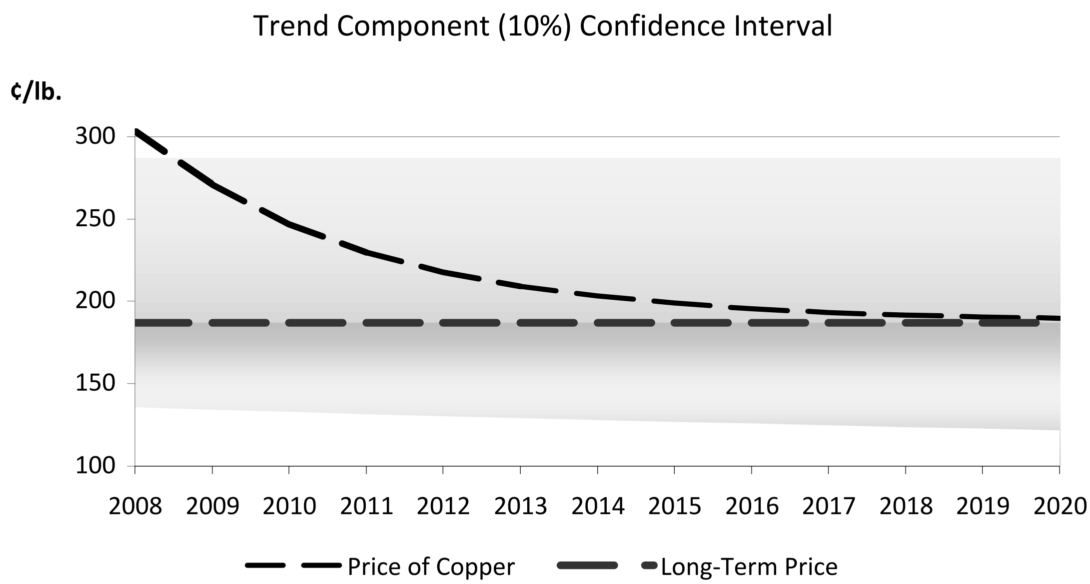
As shown, cyclical component persistence and variance are high, and as a result their impact takes longer to disappear. If an AR(2) does not suffice to capture the cyclical component dynamics, part of the cycle persistence could be incorrectly attributed to the permanent component. In the current high-price scenario, this would entail overestimating long-term prices.

The model does not integrate information on recent price drops. Prices had plunged to under 220 ¢/lb. as of October 2008 and are still falling. In an effort to integrate this information, average 2008 prices prevailing until this writing were added, on the assumption that the most recent price will hold in 2009. The result is a trend component drop to 176 ¢/lb. An effort was also made to expand the model to allow for a trend in the permanent component. That is, it was modeled as a random walk with drift, rather than as a purely random walk. The resulting decreasing trend yields an equilibrium price of some 160 ¢/lb. at the start of the projection period but the drift coefficient turned out to be not significant.

Results in Fig. 16 show that permanent component variance is small (as expected), but not significant. This implies considerable uncertainty in estimating this component (135 ¢/lb. – 257 ¢/lb.), and calls for a better modeling of the cyclical component.

Fig. 17 shows a 10 percent confidence interval and the projected price trajectory. It also shows that because the trend component is a random walk, uncertainty increases with the forecast horizon.

Figure 17: Trend Component Uncertainty



4.3 Evaluation

This section intends to evaluate, to the extent possible, the accuracy of projections provided by the model. Since the equilibrium price is not directly observed, projections are compared with copper price averages over long periods (15, 20, 25 years). Given the rather recent history of copper prices, there are few independent points for comparison (over a period of 100 years, there are a mere five independent 20-year points). Moving windows were used to compare the out of sample model projection and the effective price average using prices from 1930 onwards. This implies testing some 59 projections, but as noted, these are not independent (i.e., a bad projection in a particular year implies a bad projection in adjoining years, and vice versa).

For comparison purposes, other simple models were used to produce alternative projections. The out of sample error shown in Fig. 18 was calculated in all cases.

Figure 18: (Approximate) Evaluation of Model Projection Error

Root Mean Square Error (¢/lb.)			
As compared to average over →	15 years	20 years	25 years
No. of observations (non-independent)	64	59	54
CNO Model	**51.74**	**57.01**	**63.39**
HP Filter	58.01	64.00	70.16
Linear Trend	65.69	67.79	70.05
Quadratic Trend	78.07	86.30	95.08
Average of Last Ten Years	68.76	71.49	71.21

Interestingly, it would appear that using a quadratic trend to project the off-sample, followed by the average of the past few years, seems to be the worst strategy.

The Hodrick-Prescott filter was also calculated, using the last-year trend result as a projection. The choice of this methodology was based on its widespread use in an analogous issue in macroeconomics (estimation of the permanent component of GDP). The filter is defined as trend component (τ) minimizing the following expression:

$$\min \sum_{t=1}^{T} (y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1} \left[(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1}) \right]^2$$

Parameter (λ) determines trend curve smoothness. Rather than estimated, this parameter is set at 100 for annual data. This has proven effective in filtering frequencies associated with the business cycle.

If defined as the difference with a 15-year average, the error resembles the unobserved components model. However, at least for this (small) sample, the error is greater when comparison uses averages over longer timeframes.

While, for the reasons noted, proving the accuracy of long-term copper price projections is not an easy undertaking, at least the proposed model does no worse than the alternatives. Considering the significant magnitude of errors, the difference with the HP filter is negligible in comparisons with 15-year averages but appears to grow in favor of the unobserved component model in comparisons with longer horizons.

5. Discussion and Conclusions

Incentive price method analysis and sensitization illustrate the risks involved in providing a single value for long-term copper prices. Given certain assumptions, providing a range of possible prices seems to be the best course of action. These were determined to be about 129-176 ¢/lb. in a 3.2 percent consumption growth scenario and 134-193 ¢/lb. in a 3.6 percent consumption growth scenario. This at least excludes some overly optimistic forecasts available among analysts, anticipating long-term prices of over US$2/lb. and supports the consensus that long-term prices have in fact increased over the past few years.

In this method, the analyst's best judgment plays a key role. Estimating long-term consumption isn't necessarily easier than projecting copper prices, and the same is true for other parameters involved, such as byproduct and input prices. Some simplifying assumptions, including the high inelasticity of demand and application of a 15 percent discount rate, are not empirically supported but seem reasonable in the context.

In light of these disadvantages, the incentive price model approach gives analysts a comprehensive, intuitive overview of market evolution and trends requiring no complex techniques.

While an econometric approach such as presented here offers little in the way of intuitiveness or explanations as to market evolution and trends, application is transparent and relatively free from hidden assumptions. In theory, availability of a long history of copper prices would make it possible to test for model accuracy and add other refinements. Given the paucity of data, the exercise of evaluating out of sample projections, shortcomings notwithstanding, does indicate that the model presented is a good alternative, at least in this context. The estimated trend level based on data through 2007 (187 ¢/lb.) is even higher than the high range provided by the incentive price method. Adding new information to expand the sample (somewhat unorthodoxly, since a projection is involved), yields a value (176 ¢/lb.) in the upper incentive price range obtained with a 3.2 percent consumption growth rate, and somewhat closer to the midpoint of the incentive price range obtained with a 3.6 percent consumption growth rate.

In addition to obtaining projections, the study intended to cast a critical eye on methods. This process reveals the high degree of uncertainty associated with estimating such an essential mining project assessment parameter, suggesting that assessments ought to account for this uncertainty.

COCHILCO
COMISIÓN CHILENA DEL COBRE

Prepared at the Cochilco Research Department by

Erik Heimlich

Coordinator, Economics and Econometrics

(Translation: Patricio Mason)

November 2008