The Exponentialoid of Resource Consumption

José L. Fernández-Solís

ABSTRACT

This paper analyzes the data of resources at hand, consumption data and projected rates of consumption growth, based on the previously identified drivers of population growth and, more significantly, global increases in affluence (improved standards of living). To the pressing issue of energy consumption, we must add the issues of conspicuous consumption of high-grade metallic ores and the need to find a sustainable solution that will approach stabilization.

The projected growth in resource consumption in response to global population growth (on the short-term horizon) and especially, improving standards of living (on the long-term horizon), points toward an unsustainable future within the next 75 years. The trends are analyzed in the form of so-called “exponentialoids” as introduced by García Bacca (1989). An exponential is an algorithm with limited variables, whereas an exponentialoid is the term coined when multiple complex forces conspire to create a growth with logarithmic properties. Emissions Generation has a logarithmic growth that is caused by complex forces.

This paper contrasts algorithmic interpretations of resource consumption growth based on United States Geological Survey data with an exponentialoid projection of resource consumption. If multiple forces conspire to create an exponential, it can be inferred that the same multiple and complex forces must somehow conspire to tame the exponentialoid. Are current initiatives sufficient to tame a resource consumption exponentialoid?

Keywords: Exponentialoid, Sustainability, Resource Consumption
1.1 INTRODUCTION

The United Nations forum on “Our Common Future” (The World Commission on Environment and Development, 1987) defines sustainability: “Today’s needs should not compromise the ability of future generations to meet their needs”. Pointedly, the Club of Rome publication “The Meadows Report” (Meadows, 1972) observes that technological progress cannot be expected to ensure sustainability, including safeguarding resources and protecting the environment, without some massive global initiatives that are not on the horizon.

“The argument that the world is running out of resources rests on two assumptions. One is that the reserves are not only finite which, of course, is a truism but that they are limited in the sense that resources can only sustain present rates of growth in consumption for a relatively short period of time. The second assumption is that the growth rate of consumption, if left to itself, is not able to respond to the reduction in that of supply. For even if prices rise sharply, the response to this through substitution or raw materials savings, would take too long to prevent ultimate depletion.” Perlman 1974.

Reserves estimation is hazardous since available estimates are generally revised upwards over time due to more extensive exploration and improved extraction techniques. For example,

“...reserves of copper have risen 3.5 times since 1935; of bauxite 7 times since 1950; metals and minerals available data suggest that, in many cases, these are ample for almost every material in the next fifty to a hundred years.” Varon 1975

McHale (1978) adds that the extension of reserves is not only a function of exploration and extraction technology, but also of use rates, functional resource competition, and substitution. At the time of publication, the fear of projected inadequacy due to increased growth rates by major users (mostly the US, the USSR and Europe) seemed unfounded. “1978 population growth rates are declining in these countries and we have earlier shown that increased affluence alone is not necessarily paralleled by a consistent increase in materials’ use.”

Such are the static characteristics of an exponentialoid in the constrained mode. However, at that time, the exponentialoid growth rate in affluence of a major segment of the global population, such as China and India, was not anticipated (see Figure 457.1). This demographic shift has unbounded the socio-political-economic sustainability restraints, allowing the system to become exponentialoid in growth by both population...
numbers, as the latent basis, and by affluence acquisition, the dynamic basis.

For example, natural non-renewable resources (minerals such as iron ore, copper, bauxite, selenium, alumina, zinc, ferro-molybdenum and fossil fuels), relatively unchanged for decades, have doubled in price within the last two years. These price increases are unlike those seen in the 1972 temporary spike, as they appear to be permanent and cross a number of different resources, pointing to a recent exponential growth of construction activity.

However, some economists insist that price is not a surrogate for demand and thus is not a reliable indicator of resource production and consumption. Others argue that price stability is an indicator of resource stability. The argument that price stability indicates that natural resources are stable, even though admittedly exhaustible and un-reproducible, has been quoted by Baumol and Blackman (1993). They point to it as proof that innovation, recycling and waste reduction (Coventry and Guthrie 1999) have increased the productivity of natural resources by the same technological developments that have fueled the extraordinary growth in living standards since the industrial revolution. The argument states that these measures have increased the prospective contribution of the unused stock of resources; thereby the stock of that resource is larger at the end of the year than at the beginning. A group of researchers (Barnett and Morse 1963 and Barnett 1979) found that the real price of extraction of 13 minerals except lead and zinc, declined between 1870 and 1956. Unfortunately this author also quotes the stability of oil prices as indicators.

Steel Consumption in China and the United States, 1990-2003

![Steel Consumption in China and the United States, 1990-2003](image)

*Figure 457.1 Steel Consumption in China and the United States 1990-2003*
1.2 METHOD OF ANALYSIS OF THE CHALLENGES

The issues behind resource consumption are analyzed using:

- Historical literature search
- Multiple sources of evidence
- Multiple explanatory applications
- Theoretical propositions, rival explanations

2.1 RESOURCE AND TECHNOLOGY

The environmental-sustainability challenge deals with both of the following natural questions: (1) where do all the inputs in the form of raw materials and energy for production originate, and (2) where do all the waste outputs go (McDonough 1992; Alarcón 1997; Stallworth 1997)?

2.1.1 Resources

The first question can be examined in this way: Are we living on the interest from the endowment of natural resources or have we begun to consume the endowment itself (Brown 1981)? Regarding inputs, for example, the cement, lime, glass, paper, ferrous and non-ferrous metals, aluminum and steel ‘industries’ are major energy intensive construction resources.

Warning voices from the 1900’s highlighted the case of unrestrained consumption of non-renewable natural resources, especially fossil fuels. Hickerson (1997) quotes biologist Ivie (1948), stating that “we cannot plan to operate for long on fossil fuel¹ as our major energy source.”

Instead, we must adopt a system of energy use (Schafer 2005) which will obtain a maximum amount of energy from renewable sources and a minimum amount from non-renewable sources. The Price System (General Economy), on the other hand, refuses to face the problem, but seeks to deplete our limited fossil fuels (and mineral resources) at the maximum rate that will yield a fair return in the way of profits. Even earlier, Scott (1933) wrote “the history of the human race may well be stated in terms of the ability of man to consume ever-increasing amounts of extraneous (non-human) energy. The limitation and stabilization of that rate of increase is the scientific problem of the not far distant future.” The present study adds to Scott’s issue of energy, the issues of conspicuous consumption of high-grade metallic ores and the need to find sustainable solutions that will approach stabilization. However, these statements will elicit a Neo-Malthusian label.

¹ Other industries, such as agriculture, will be adversely affected. Hickerson (1997) quotes Albert Bartlett of the University of Colorado stating that “Modern Agriculture is the use of land to convert petroleum into food.” However, this subject is beyond the scope of this study.

2.1.2 Emissions

Regarding outputs, petrochemical products are prevalent throughout the construction industry, with buildings as the finished product. Construction consumes 33% of the total global energy production (Energy Information Administration, Department of Energy, U.S. Gov.), with the cement industry being the worst emissions offender.

2.1.3 Technology, the argument

During the last two hundred years, change has been characterized by technical progress. Technical progress is composed of scientific discovery, invention, innovation (Pries and Janssen 1995; Slaughter 1991, 1993, 1998, 2000; Tatum 1996), improvements, and research (Seaden, 1996, 2000a, et al, 2000b; Wortmann, 1992a, b, et al 1997; Koskela 1992; 2000). This technical progress was part of the Industrial Revolution fuelled mainly by a fossil fuel based economy. However, according to the Olduvai Theory proposed by Duncan (1993) and 12 other experts including Bertrand Russell, J. W. Forrester (1968, 1971), Donella Meadows (1972), Richard Leaksy and others, the remaining life expectancy of the Industrial Civilization, as of 1993, was one hundred (100) years.

This places the demise of the Industrial Civilization based on fossil fuels at 2093, which coincides with Hubbert’s (1982) estimates of the year 2100. Although these projections have been the subjects of controversy (O’Neill and Desai 2005) and sometimes ridicule, we take a wait and see attitude. After all, the concept of light as corpuscles was also ridiculed as wave theory predominated, only to be ascertained by Einstein’s later findings that light is particle (corpuscle) and wave, a paradox that not only applies to the micro and macro worlds but also to our real worlds.

Other voices, such as Baumol and Blackman 1993, propose that our exhaustible and un-reproducible natural resources, if measured in terms of their prospective contribution to human welfare, can actually increase year after year, perhaps never coming anywhere near exhaustion.
Table 457.1 World Reserves and Cumulative Production of Selected Minerals: 1950-1980 (millions of metric tons of metal content)

<table>
<thead>
<tr>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>1,400</td>
<td>1,346</td>
<td>5,200</td>
</tr>
<tr>
<td>Copper</td>
<td>100</td>
<td>156</td>
<td>494</td>
</tr>
<tr>
<td>Iron</td>
<td>19,000</td>
<td>11,040</td>
<td>93,466</td>
</tr>
<tr>
<td>Lead</td>
<td>40</td>
<td>85</td>
<td>127</td>
</tr>
</tbody>
</table>


The answer to this proposition, according to these authors, lies in viewing the effective stocks of natural resources as being expanded by the same technological developments that have fuelled the extraordinary growth in living standards since the industrial revolution (see Table 457.1).

The argument is three-fold:

First, innovation has increased the productivity of natural resources (higher gasoline mileage of cars) or the reduction of lost minerals in the extraction or smelting processes (by using economies and techniques that decrease waste);

Second, partial substitutability within the economy of virtually all resources for others has increased resource supplies (even though at close analysis, one mineral in scarcity is substituted by another on the way to scarcity);

Third, recycling (for lead, iron, copper and aluminium) requires less energy in the process. These authors concluded, in 1993, “These three means can all increase the effective supplies of exhaustible resources and can augment the prospective economic contribution of the current inventory of resources, perhaps more than enough to offset the consumption of resources during the same period.” Stumm and Davis (1991) show that recycling copper from chemical compounds and scattered materials, even in the case of infinite consumption of energy, will only reach a share of about 70%. “Therefore recycling is not the solution of the shortage of stocks. Only with a not realistic recycling potential of 100% recycling could guarantee sustainability with not reproducible materials.”

More recently, Baumol et al. (1989) calculated the prices of 15 minerals from 1900 to 1986 that until the energy crisis of the 1970’s experiences a negligible upward trend in prices. However, 2004 has seen an increase in prices in cement, copper, iron-steel, lead and aluminium for diverse
reasons that will be analyzed below (see Figure 457.2). For example, The Wall Street Journal, Thursday, August 18, 2005, stated that regarding mining companies, “on Tuesday (Aug. 16, 2006), copper hit a new high on the London Metal Exchange of more than $3,600 a ton. Nickel, though down a bit from two months ago is selling for about three times its 2001 price. A widely followed measure, the Reuters Jefferies CRB Index, which tracks a broad range of commodities, is more than 50% higher than it was four years ago”.

Carassus' (1998, 1999, 2004) international work regarding a worldview of the construction industry as a construction sector system (at the mesoeconomic\textsuperscript{2} level) provides the logic for a counter argument: It appears that developed economies, in regard to construction in general and building construction in particular, do reach a level when capital assets development slows down while management of existing facilities increases. However, the vast number of the global population is 'underdeveloped' and thus represents a potential for increasing demand for construction as they move in large numbers into a ‘developed’ level of consumption.

\textsuperscript{2}‘Meso’ is a Greek word denoting the state between the Micro and the Macro levels (Holland 1987 cited in Carassus 2004).
2.2 CONSTRUCTION RESOURCES

China’s and India’s increased demands for construction related commodities are worth mentioning (Brown 2005a, b, Kynge 2006). Four years does not constitute a trend; however the query, as posed in this paper, is whether we continue to be in a sustainable portion of a growth curve where the slope is moderate or are we at a point where forces of demographics have unleashed the growth into an exponentialoid. We now investigate in detail some of the basic commodities used regularly in building construction regarding recent trends.

2.2.1 Cement:

In the U.S., strong residential construction spurred by very low interest rates offset stagnant private non-residential construction. Cement companies were not able to build clinker stockpiles ahead of kiln maintenance shutdowns and instead delayed shutdowns in expectation of a relaxation in cement demand that never came. In 2004, US cement production of 96.5 Million metric tons (Mmt) was up 2.2 Mmt from 2003 levels of 94.3 Mmt and compares to China’s 2004 level of 850.0 Mmt, up 37 Mmt from 2003’s production of 813 Mmt. Ninety-eight percent of cement is used in one form or another for construction. The Financial Times (FT) in 2006 reports that, in 2005, China consumed 42% of all the cement consumed in the world.

World Resources: According to the United States Geological Survey (USGS), although individual companies’ reserves are subject to exhaustion, cement raw materials, especially limestone, are geologically widespread and abundant.

Substitutes: Concrete is substituted by aluminium, asphalt, clay brick, rammed earth, fibreglass, glass, steel, stone and wood. Pozzolans and similar materials such as fly ash and ground granulated blast furnace slag, are increasingly being used as partial substitutes for Portland cement in some applications.

2.2.2 Iron-Steel:

Construction uses approximately 14% of the US iron-steel production. Recycled iron and steel scrap is a vital raw material for the production of new steel and cast iron products. The US has recycled steel scraps for more than 200 years and the automotive industry alone recycled about 14 million vehicles in 2004. The recycling rates for construction steel scraps are expected to increase in the US and emerging industrial countries such as China.
Scrap prices increased substantially from $108 per ton in 2003 to $190 in 2004. According to the USGS “the tremendous increase in iron ore consumption in China in 2003 of 261 Mmt to 2004 280 Mmt (19Mmt) compares to the US 2003 of 46 Mmt and 2004 of 54Mmt (8Mmt) affected the US iron ore production for the first time in history. A major Chinese steel company purchased minority interest in a bankrupt iron ore producer in Minnesota and accepted for their portion of the production from the majority partner’s Canadian affiliate.” China has become the dominant source of iron ore demand growth.

In 1992, China surpassed Japan as the leader in producing pig iron (98% of ore iron and thus a good indicator) at 76 Mmt and in 2003 it produced 200 Mmt and continues to grow at a 9% rate per annum since 1992. “China’s astonishing growth affected the large global iron ore producers in Brazil and Australia who continue to invest large sums of money to increase production to satisfy Chinese demand (an estimated 33% increase from the 2004 global production is expected from these two sources by 2009) (FT 2006).

China, in 2004, was the world’s largest producer and consumer of steel. China’s production increased from 272 M tons in 2003 to 336 M tons in 2004 (approximately 25%). In 2004 China imported 13 M tons but this situation is likely to change with its over-production. The overcapacity (from 2 to 30 M tons in 2005 and possibly 50 M tons in 2006) in the world’s largest producer and consumer of steel could damage world price stability.

World resources: Crude iron ore world resources are estimated to exceed 800 Billion metric tons (Bmt) containing more than 230 Bmt of iron; however, total global mine production in 2004 was 1.25 Bmt.

Substitutes: Iron is the least expensive (to date) and most widely used metal, competing with lighter materials such as aluminum and plastics in motor vehicles, aluminum, concrete and wood in construction and aluminum, glass, paper and plastics in containers.

2.2.3 Copper:

Eighteen percent of copper and copper alloys are used in construction. Old scraps provide 225,000 metric tons of copper or 9% of apparent consumption in the US (1.16 Mmt). World mine production of copper rose by .9 Mmt or 6.6% in 2004 but there was a .375 Mmt deficit in 2003 that grew to .7 Mmt in 2004 from demand outstripping supply. Copper use in China in 1995 was 1.19 Mmt. By 2005 it more than trebled to 3.61 Mmt accounting for 22% of the global demand. In 2003 China surpassed the US to become the world’s largest consumer of copper and by 2004 it consumed 46% more than the US in the areas of construction, power generation and electricity networks.

Global inventories continue to decline and prices have doubled from 2005 to 2006, that is, in one year. The FT (10/13/06) reports that “strategic
inventories of refined copper are expected to be depleted by the end of 2007 with little opportunity for rebuilding before the next global recession." The reason for this depletion is a combination of weak mine production and increased global demand. Strikes in La Caridad and Cananea in Mexico and Escondida in Chile conspired to have a yearly production of 14.87m tons, down from 15.22m tons in the previous year. The forecast for 2007 is now at 15.86 when it should have been 16.16m tons. The deficit in 2006 is of 300,000 tons and in 2007 expected to be at 100,000 tons with a tiny surplus in 2008.

The electrification of China’s rural areas, the countryside (more than 400M people in conservative estimates, roughly double the US population) is just getting started, reports Geoff Dyer of the FT (May 2006). China, in this report, is adding 60,000MW of new generation capacity each year until 2010; this is the equivalent of adding more than Spain’s entire energy system each year. China’s expressed capacity need at this time is of 750,000 MW and they have already reached 500,000 MW. India, with an equally large population, is lagging behind its needs so there is another potential for continual growth in this commodity. Western European copper consumption is also increasing at a rate of 9.5% instead of the previously estimated 7.5% (FT 10/13/06).

World resources: A recent assessment indicates 550 Mmt of copper but land based resources are expected to be much higher at 1.6 Bmt with an additional .7 Bmt in deep sea nodules; however, total global mine production in 2004 was 14.5 Mmt.

Substitutes: Aluminum substitutes for copper in various products. In some applications titanium and steel are copper substitutes and optical fiber substitutes in telecommunications. Plastic is a substitute in water pipes and plumbing fixtures.

2.2.4 Lead:

Lead use in construction is decreasing in the US. Its primary use is in batteries. Approximately 1.14 Mmt of lead is recovered in the US annually. Lead prices increased in 2004 by 20% in the US and 66% in world markets. According to the USGS the “main driver for this growth was higher use in China for vehicle fleet expansion, telecommunications and information technology.” Despite a 6% increase in global mine production, refined lead production was stagnant in 2004; thus, a significant production deficit for refined lead was experienced in 2004 and is forecasted to continue in 2005.

World resources: Lead resources are estimated at 1.5 Bmt and mine production in 2004 was at 3.15 Mmt.

Substitutes: Plastics have reduced the use of lead in building construction, electrical cable covering, cans and containers, and water has done the same in paints. Tin has replaced lead in solder for new potable water systems in the US.
2.2.5 Aluminum:

US aluminum consumption is 30% for transportation (airplanes, and all types of ground transportation), 13% in buildings and 6% in electrical. Recovered aluminum in 2004 was 3 Mmt which is 19% of apparent consumption. Canada, Mexico and China received more than 80% of total US exports. World production continues to increase.

World reserve: The world reserve for bauxite is estimated at 75 Bmt while mine production was 156 Mmt. However, USGS estimates that there is essentially an inexhaustible sub-economic resource of aluminum in materials other than bauxite such as clays, anorthosite, alunite, coal wastes and oil shales.

Substitutes: Copper can replace aluminum in electrical applications; magnesium, titanium and steel can substitute for aluminum in structural and ground transportation.
2.3 EXAMPLE OF THEORETICAL SCENARIOS

For discussion purposes and to push the envelope a bit, we assume that current mineral reserves in iron ore, copper, lead and aluminum, in this hypothetical scenario, are:

- Fixed with current estimates (that is no new significant discoveries, a highly unlikely scenario)
- Moderately increasing in the global recycling of some minerals (a likely scenario) and
- Increasing annually by 10% in global demand (translated as mining demand, also a likely scenario)

The question posed on this speculative problem is: when will the current amount of resources are depleted? The scenario may be construed as the worst case scenario, with the understanding that the best case may add additional decades to the results. All estimates are taken from the US Geological Survey (USGS) 2004 data. In greater detail, the problem posed to the Students in Paris 2005 SAP\(^3\) (and also to the Paris 2006 SAP with almost identical results) is as follows:

2.3.1 Iron-steel

a. Crude iron ore world resources are estimated to exceed 800 Billion metric tons (Bmt) containing more than 230 Bmt of iron, and
b. The total global mine production in 2004 was 1.25 Bmt.
c. If world consumption of iron (global mine production) increases 10% each year, how many years will it take to deplete current estimates of crude iron? (see Figure 457.3)

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\(^3\) Some of the students participating in the program that contributed to this analysis are: Thomas Callahan BC05, Michael Delashmit BC07, Rachel Heim BC06, Brett Haynie BC07, Jason Kiefer BC06, Erin Looney BC06, Greg Munna BC06, Ashley Ryan BC06, Viktoria Sazonova BC06, Jacquelyn Schneider BC06
2.3.2 Copper

a. A recent assessment indicates 550 Million metric tons (Mmt) of copper but land based resources are expected to be much higher at 1.6 Bmt with an additional 0.7 Bmt in deep sea nodules, and recycling of copper at this time is estimated to be negligible.

b. However, total global mine production in 2004 was 14.5 Mmt.

c. If world consumption of copper (global mine production) increases 10% each year, how many years will it take to deplete current estimates of all land and sea based copper? (see Figure 457.4)
In the case of copper, several factors reportedly account for the present condition: the cost of improving and adding resources to increase production; the increased cost of energy; the need for large quantities of water to treat the mineral; current mining deposits have a smaller yield and thus are not as profitable; social (demand for more wages and fewer hands for employment) and governmental (taxes or even confiscation of natural resources) issues: economic strategy to reduce production to keep prices high; copper and molybdenum are found together and right now molybdenum, needed for the stainless steel industry, commands higher market prices and thus is more profitable (shifting mining resources towards this commodity.)

All this has created a situation where demand is greater than supply and will be for the foreseeable future, especially with demand increasing and absorbing any new productivity. (FT special editions on copper, 5/10/2006 & 5/26/2006).

2.3.3 Lead

a. Lead resources are estimated at 1.5 Bmt and
b. Mine production in 2004 was 3.15 Mmt.

Approximately 1.14 Mmt of lead is recovered in the US annually (automobile batteries)

c. If world consumption of lead (global mine production) increases 10% each year, and the amount of recovered lead each year increases by 5%, how many years will it take to deplete current estimates of lead? (see Figure 457.5)

![Figure 457.5 Consumption and Depletion of Lead](Figure 457.5 Consumption and Depletion of Lead)
2.3.4 Aluminum

a. The world reserve for bauxite is estimated at 75 Bmt while mine production is 156 Mmt. Other sources of aluminum such as clays are prohibitive at the present time.

b. Recovered aluminum in 2004 was 3 Mmt which is 19% of apparent consumption.

c. If world consumption of aluminum (global mine production) increases 10% each year, and the amount of recovered aluminum each year increases by 5%, how many years will it take to deplete current estimates of aluminum? (see Figure 457.6)

![Aluminum Consumption and Depletion](image)

**Figure 457.6 Consumption and Depletion of Aluminum**

2.4 EXPERTS ON RESOURCE DEPLETION

On the other hand, experts claimed in 1999 that these resources cannot be physically depleted (ST/ESA/1999/DP. 5 DESA Discussion Paper No. 5, Trends in Consumption and Production: Selected Minerals Prepared by Oleg Dzioubinski, Ralph Chipman, March 1999, United Nations).

The question of resource depletion is one of the hottest topics among economists who discuss resource issues and sustainable use of them. As previously mentioned, most economists are not accepting the concept that resources are finite and can be depleted. According to Norton (2005),
"There have been celebrated studies that show there are no downward trends in the percentage of prices devoted to natural resource inputs. This goes back to the famous 100-year study of commodity prices by Barnett and Morse 1963. They found that, in most cases, the percentage of retail commodity prices devoted to resource inputs fell significantly. Follow-up studies in top economic journals have tended to support this, and there is the famous bet where Julian Simon destroyed Paul Ehrlich 1969 in the famous wager. If current trends of resource depletion go exponential, prices would be headed for higher and higher. It looks like the paper has to show that trends that are 150 years old will have to reverse and then grow at an exponential rate."

Precisely as stated, unexpected and inordinate price increases in commodities related to construction have taken place in the last couple of years, although we acknowledge that this is not considered a 'trend.' See Table 457.2. This predictability, based on economic historical trends, forms the core issues. Can we look to the past to predict the future? (FT 10/17/06 has lead up to $1549; nickel at $33640; tin at $10095 and zinc at $3880).

<table>
<thead>
<tr>
<th>Commodities</th>
<th>FT 10/9/05</th>
<th>FT 10/9/04</th>
<th>FT 9/28/06</th>
<th>Year 05/06</th>
<th>High/yr ago %</th>
<th>High/2 Yrs ago %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum HG</td>
<td>2031</td>
<td>1664</td>
<td>2501</td>
<td>470</td>
<td>23.1</td>
<td>50.3</td>
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<tr>
<td>Copper GR A</td>
<td>4356</td>
<td>2841</td>
<td>7706</td>
<td>3350</td>
<td>76.9</td>
<td>171.3</td>
</tr>
<tr>
<td>Lead</td>
<td>1011</td>
<td>926</td>
<td>1400</td>
<td>389</td>
<td>38.5</td>
<td>51.2</td>
</tr>
<tr>
<td>Nickel</td>
<td>28725</td>
<td>12278</td>
<td>31150</td>
<td>2425</td>
<td>8.5</td>
<td>153.7</td>
</tr>
<tr>
<td>Tin</td>
<td>8952</td>
<td>9205</td>
<td>-883</td>
<td>-8.8</td>
<td>-5.6</td>
<td>258.0</td>
</tr>
<tr>
<td>Zinc SGH</td>
<td>7705</td>
<td>955</td>
<td>3419</td>
<td>-4286</td>
<td>-55.6</td>
<td></td>
</tr>
</tbody>
</table>

Table 457.2 Commodities Price Increases

However, Philosophers of technology and invention (Mitcham 1994) agree with Garcia Bacca (1989) that no invention of the past is a predictor of the next, directly or indirectly. Each invention stands alone in coming out, although it may be based on previous models. If this is the case then it could be interpreted that the economy may be moving into a new mode that is not anticipated by previous trends, just like technology and inventions are no predictors of future technology and inventions. According to McHale
(1978) all these (technology, inventions, economy) move exponentialoid, do not move in isolation, and are not deterministic one of the other.

The economic issues are not resolved and are hotly debated. Kuhn’s (1976) dictum applies here, “nothing about the rationality of the outcome of the current evaluation depends upon their, in fact, being true or false. They are simply in place, part of the historical situation within which this evaluation is made.” Thus for the last 150 years prices have receded. Right now they are increasing and some are becoming dynamic and even increasing exponentially. Kuhn (2000) adds the proverb: “As in individual development, so in the scientific group, maturity comes most surely to those who know how to wait.”

3. OTHER OBSERVATIONS

New technologies in finding resources, mining, recycling and innovations in the use of these resources may extend the effective life of mineral deposits, but current indication is that the rate of consumption of all the minerals as well as fossil fuels is currently relatively flat at the bottom of the “J” curve with demand rising exponentially. This consideration will have major economic, social and political implications for the countries where these natural resources reside as well as for the economies consuming the resources.

Furthermore, the theory of substitutions, unless new materials are created, appears to lose strength when all (including current substitutions) are experiencing the same pressures in consumption and depletion. This raises the possibility of a scenario where most resources approach extinction within a relatively short period of time (75 to 100 years), all within that same period of time.

Current approach to demand is to increase capacity in mining and processing; however, logic indicates that the trend cannot continue into an infinite future, some even say it has a rather short time horizon. Along with the pressing need for finding processes in resource creation that are environmentally friendly, we may look to first time technologies such as nano to provide new high-tech materials with logarithmically increasing properties in relation to current material performance criteria.

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