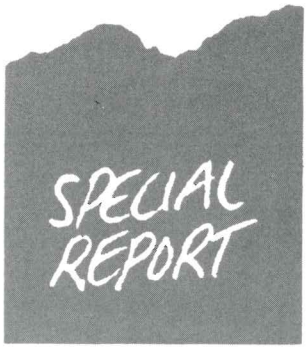

Minor metals or the economic role of by-products within the non-ferrous industry

By Osires Carvalho and Nicos Terezopoulos

Introduction

In recent years a great deal of scientific knowledge has been produced about the chemical and physical properties of minor metals, contributing to broaden their already extensive utilisation in engineering. Otherwise, far less has been published about economics of them as a group of industrial commodities, produced and marketed on a continuing basis. The economic relationship among minor metals and their links with other groups of mineral commodities - the non-ferrous metals, for instance - do not seem to have been entirely analysed, at least in the light of standard economic theory.

Minor metals as a group of independent mineral commodities do not seem to have received the necessary attention in terms of economic analysis. Their importance is undisputable in today's industrial environment, simply because they are crucial inputs for virtually all components utilised in assembling high tech capital and consumer goods.

An economic problem may normally be approached either by means of qualitative or quantitative analytical tools, or through both. This work, however, can be considered as a qualitative study of the production and market structure for minor metals, observing their close geological and economic ties with the non-ferrous industry.

The metals here considered as minor are a quite diverse group of metallic elements. Notwithstanding this, minor metals have one very important point in common: They are either nonferrous metals or derive from them in joint production as by-products and co-products. The observation and analysis of this fact from an economic standpoint constitutes the core of the present study.

Background on Minor Metals

First and foremost, minor metals are termed minor due to their relatively small output in relation to the traditional large tonnage mineral industry. Interest in them is not recent and some of today's minor metals - arsenic, mercury, cobalt have been known and used for centuries. In the course of the Industrial Revolution attention was called to a few others but their real importance emerged at the turn of this century. On the whole, the nascent demand and incipient supply coupled with the lack of knowledge about their properties, kept minor metals out of the flow of technological changes and economic development until the Second World War.

Minor metals, classified as such, seem to be a collection of metallic elements with very little in common. Indeed, they are quite different. Their properties, for instance, are quite diverse: thallium and bismuth are among the heaviest natural elements and while mercury is liquid at near room temperature, tungsten shows one of the highest melting points. Also, in terms of output, their production present a wide variation. While antimony production can be measured in terms of thousands of tons per year, scandium output, by contrast, amounts to a few kilos per year.

Differences seem to outweigh similarities among minor metals. Some of them - mercury and tungsten - are individually mined and others - germanium and gallium - to be produced, require the accumulation of large quantities of residual material in smelters and refineries, since they occur only as a tiny fraction of major metals. Some other minerals such as the *Rare Earth metal group* (RE) are produced from placers deposits which are also the source for the winning of titanium and zirconium. Yet, while some minor metals are traditional and widely used mineral commodities, others find application only in a few sectors of the high technology industry.

The scope of the present study encompasses minor metals within the framework of the non-ferrous industry. In selecting them, the following criterion was

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observed: either the element itself was a non-ferrous metal, or it was derived from non-ferrous minerals, in joint production. Lithium and hafnium are good examples of non-ferrous metals used as steel improvers and alloying elements. Beryllium, cadmium, *Platinum Group Metals* (PGM), tellurium and thallium are a good sample of minor metals derived from the latter processing stages of heavy non-ferrous metal concentrates. In this regard it is worth noting that from the smelting and refining processes of only three non-ferrous concentrates - copper, lead and zinc - more than twenty endproducts are recouped, most of them minor metals.[1]

The extraction of ores from mineral deposits is the first step in producing metals. Some, like iron ores, possess only one mineral worth recovering and their exploitation results in a single individual product. On the other hand, it is common to find ores containing several valuable metals. From copper ores, for example, nickel, PGMs, gold, silver, cobalt, molybdenum and rhenium are recouped from different copper deposits. Also, lead and zinc are commonly found and mined together, and just to highlight the mineralogical complexity of some mineral deposits, copper is also produced from some lead-zinc ores, as well as tin and tungsten from some other nickel deposits.[2]

The elements considered as minor in this study are presented in Table 1 along with their chemical symbols. In linking minor metals to the non-ferrous industry, the six elements composing the platinum group were treated as a single one, for they occur together, in variable proportions, generally associated to large sulphide deposits of nickel and copper. Also, the fifteen elements named as Lanthanides in the periodic table of elements were also considered as a single group, for they are commonly known as Rare Earth Metals. Gold and silver, despite their recovery as byproducts and co-products from non-ferrous minerals were excluded from the list. Actually they are more conveniently classified as major metals, for a large and diversified industry is directed to their recovery and marketing.

Nowadays, the widespread use of minor metals in high technology sectors has frequently brought these elements into evidence, namely by terming them as critical or strategic metals due to their increasing importance to the civil and defence industries.

Excluding the criticality question there are some aspects worth highlighting about minor metals. They are elements with a particular set of properties that make them important in current and potential uses. However, the physical properties themselves do not define which element will be primarily used. Behind all this is the fact that minor metals are economic goods, with costs of production and utilisation, and supply and demand environment playing the major roles.

This is the subject of this study: the economics of minor metals within the non-ferrous industry.

Table 1
Minor Metals within the non-ferrous industry

Antimony (Sb)	Radium (Ra)
Arsenic (As)	Rare-Earth Metals - RE [3]
Beryllium (Be)	Rhenium (Re)
Bismuth (Bi)	Scandium (Sc)
Cadmium (Cd)	Selenium (Se)
Cobalt (Co)	Silicon (Si)
Columbium (Cb) [1]	Tantalum (Ta)
Gallium (Ga)	Tellurium (Te)
Germanium (Ge)	Thallium (Tl)
Hafnium (Hf)	Thorium (Th)
Indium (In)	Titanium (Ti)
Lithium (Li)	Tungsten (W)
Mercury (Hg)	Vanadium (V)
Molybdenum (Mo)	Yttrium (Y)
Platinum Group Metals - PGM [2]	Zirconium (Zr)

Notes:
[1] This element is also known as Niobium (Nb) in technical literature
[2] The group includes six elements: platinum and palladium, the most well known, and iridium, osmium, rhodium and ruthenium.
[3] Comprises the following fifteen elements: lanthanum, cerium and neodymium, the most common ones and, praseodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium.

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Scope and nature of economic analysis

The analysis of natural resources in general and mineral resources in particular involves both, the knowledge of physical sciences and economic theory. The main purpose at this stage is to draw a general framework for much of the analysis to follow. Therefore, an attempt will be made to set up the basic economic background required to analyse the production and market structures for minor metals.

Mineral Economics, despite its interdisciplinary nature, falls within the context of economic science. In general, the study of economics is often divided into microeconomics and macroeconomics, the former looking at the interaction of producers and consumers in individual markets - germanium, for instance -and the relationship among different markets - say the overall market for minor metals. The latter studies the behaviour of overall economic figures, such as the *Gross National Product* (GNP), as well as categories that cut across different markets, such as the gross mineral production or the net mineral exports.

Markets are at the centre of economic activity, and a large number of interesting questions and issues in economics are concerned with how markets behave. In a broad operational sense a market can either be competitive or non-competitive. A perfectly competitive market is characterised by a large number of buyers and sellers but none of them have any impact on price formation. Excluding government intervention, the markets for agricultural products are quite close to this model.

The world market for copper, lead and zinc, for instance, is composed of a few dozen major producers. Thus, the impact on price in case one producer shuts down, tends to be reduced or quite negligible. These markets are competitive enough to be treated as if they were perfectly competitive. The same is true for many other mineral and natural resource markets. On the other hand, some markets may have many producers but are not perfectly competitive, for one producer can affect the price of the product. The world oil market is quite illustrative in this regard.

The principles of supply and demand are the most important tools of microeconomics, for they help to explain price and output in individual markets and how price and output in different markets are related. Through microeconomics the costs of production and the degree of sensitivity of supply and demand in relation to price, in different periods of time, can also be explained. Also, within the realm of microeconomics is the study of the industrial organisation, translated in terms of business strategies such as integration, diversification and concentration, pursued by each producing firm. The study of market arrangements - monopoly, oligopoly and competition - is also within the scope of microeconomics.

The boundary between micro and macroeconomics has become less and less distinct in recent years. This is explained by the fact that macroeconomics also involves the analysis of markets the aggregate markets for inputs, final goods and services. To analyse the way aggregate markets behave, it is vital to understand the way they operate individually. This aspect highlights the increasing importance of the foundations of microeconomics in helping to address a wide range of aggregate market issues.

The concept of industry is quite simple and comprises the set of individual firms producing equivalent or similar range of inputs or final products. For instance, in periods when the electronic industry is drawing down its silicon inventories, production can be considered below demand. Production can either be less than demand when producers are selling their stocks or, more than demand when they are building them up. Likewise, whenever consumers, speculators or other private stockholders are reducing their inventories, consumption is above demand. On the other hand, in periods of inventory accumulation, consumption is placed below the demand level.

An economic decision may produce different results, this being dependent on the time scale during which it is observed. Relating to this point it is worth noting that the long-term concept in economics has nothing to do with calendar time. Keynes's boundary between the long and the short-term was defined in terms of the dual role of investment.[3] In the short-term the decision to order new capital goods, or to build new plants is based on an increase in demand. The limit of the short-term is the point at which the new capital begins to be used in production and the rate of output increases. This macroeconomics approach corresponds to the way the short-term is defined by the theory of the firm, a very basic concept in microeconomics.

Prices, in general, are not fixed. Hence, the short-term variations in prices can be classified into two broad groups: those mainly determined by changes in production costs and those mainly explained by changes in demand. In general terms, changes in the prices of final goods are cost-determined while changes in the price of raw materials, including mineral commodities, are demand-determined. There is no doubt that the prices of final goods are affected by change in the prices of raw materials, but it is through the cost structure that this influence is transmitted.

It is clear that these two types of price formation are a result of different supply conditions. As a result of existing idle capacity, the production of finished goods is elastic. Whenever demand increases it is met mainly by expansion on the production side while prices tend to remain stable. Price changes which may occur are mostly explained through the structure of production costs.

Mineral commodities are quite different in this respect since to increase their

supply a large time span is required. It takes time to develop a new mine, build or enlarge processing facilities. On average, five to seven years are required for a new mine venture to be fully developed. Supply being inelastic in the short-term, increase in demand leads to reduction in inventories and a rise in prices, generally magnified by the action of speculators or other private stockholders. A primary rise in demand which cause prices to soar is generally followed by a secondary wave of speculative demand. Therefore, it becomes even more difficult for output to cope with demand in the short-run.

By-products, co-products and their cost frontiers

The majority of minor metals are originally found in joint sources with other valuable minerals and do not become independent mineral commodities until they are submitted to subsequent stages of processing.

Mining, in the sense of physical removal of matalliferous rock from the earth crust, is the starting point in metal production. In the next stage, milling, the various constituents of the ore are separated, the valuable metal-bearing minerals concentrated and the waste materials transported to a dumping area. All minor metals pass through the stages of mining and milling, but for most of them the final stage of metallurgical reduction and refining is required to produce independent economic goods.

The conditions just commented upon are common in the production of virtually all minor metals, though presenting technological variations in order to obtain a particular metal or group of metals. Just a few minor metals are mined for their own production and mercury is the most noticeable example. Ore is a term universally accepted to define mineral deposits that can be exploited on a profitable basis using current technology and existing market conditions [4]

Moreover this term can be used with the name of a metal, such as tungsten ore, this meaning a mineral deposit that can be economically developed by exploiting a single element, hereafter defined as major metal.

For the majority of minor metals, such as those produced as by-products and co-products of major metals, there is no ore under its own name. Since the majority of them are joint products, either originated at the milling, metallurgical reduction or refining stages of production, in each case, their physical existence may have little influence on the mining of the major metals they are derived from.

As noted, it is usual that more than one mineral can be economically recovered from he same deposit. Nickel and cadmium, for instance, are found in copper ores. On the other hand, the copper metal itself can also be recovered from some zinc ores. It is common for lead and zinc to be exploited as co-products while enhancing the recovery of some more elements as by-products bismuth, germanium and gallium. Therefore, the primary source materials for most minor metals are generally slimes, slags, residual tailing and other waste materials left after the recovery or major metals.

Differences between major and minor metals are quite large. Observing them from an economic standpoint, however, show that they differ clearly at the point where they are separated as joint products. In other words, the process of becoming independent economic goods originates at the production stage in which a minor metal or its source material is initially separated as a single product. At this stage the specific costs arising from the potential final product are specifically accounted for it. This point can either occur at the mining, milling, metallurgical reduction or refining stages, but the flow of costs is the frontier line separating the main product from by-products and coproducts.

To produce metals according to the ever increasing market specifications quite often results in higher production costs. The mining industry, as other industrial sectors do, has frequently to pay more for labour, equipment, power, transport plus the financial costs of capital investments. Moreover, the mineral deposits now being worked are in general lower grade and sometimes located in remote areas, which means higher costs in treating more ore to obtain less concentrate. This typical cost scenario in the metals industry is virtually the same in minor metal production.

Frequently the idea of a by-product as a free economic good is incorrectly used. Conversely, they are generally quite expensive to produce. The production of any by-product resulting from joint-production can be classified according to whether the byproduct separation is necessary to produce a marketable main product and whether the separation process is in itself sufficient to produce a marketable by-product commodity. [5] Separation of by-products is an ordinary technical procedure in the metallurgical industry, though the reasons lie more on the economic side which means that the market value of the main product is greatly reduced if the separation process is not performed. Specification is fundamental in trading metals and so it is required the elimination of most existing impurities. For instance, the tantalite concentrates produced from pegmatites in Northeastern Brazil is quoted in terms of percentage of metal content. Lower grade concentrates, in general, are less valuable for the removal of impurities leads to additional processing costs.

Usually, the most common type of by-product is the one for which the separation from the main product is necessary but not sufficient to produce a marketable final product. There are a few exceptions. Whenever the existing impurity has no effect on the value of the main product, the potential by-product need not be removed. The existence of molybdenum in tungsten concentrated from tektites and that of columbium in tanta-

lum concentrated from pegmatites are quite illustrative examples of this nature.

If the condition of a minor metal is a by-product of a major metal it does not mean, as noted, that they are free economic goods. Actually, they are very expensive commodities. The further processing required to make them compatible with today's metal specifications results in a cost structure that must be covered by the market price so that the metal can be recouped and supplied on a profitable basis. Rhenium provides a quite clear example in this respect. This obscure minor metal is used in almost 90 of cases as a catalyst in the production of low-lead, high-octane petrol. Otherwise rhenium's production is a good example of the high processing existing behind its final supply on the marketplace. Actually it is obtained as a by-product of molybdenum, but almost solely from the molybdenum which is itself a by-product of copper. In other words, rhenium can be said to be a typical example of a by-product of a by-product.

As noted, minor metal impurities may or may not be removed from the main product, this being dependent on whether their presence enhances or reduces the market value of the main product. Antimony can either be extracted from lead ores as a metal or it can be left on the concentrate and reduced to a primary antimonial-lead alloy. [6] Thus, by-products resulting from joint production can, in general, be divided into four possible alternatives, based on whether their separation is necessary to produce a marketable product, and on whether the separation process is in itself sufficient to produce an independent marketable by-product. So, the four possible economic alternatives for obtaining a by-product, are:

1. Necessary and sufficient
2. Necessary but not sufficient
3. Unnecessary and sufficient
4. Unnecessary but not sufficient

The supply curve for the first alternative is simply a vertical line parallel to the Y-axis. Since there is no cost involved, the short-term supply is equal to the long-term supply, this being limited only by the output of the main product the minor metal is actually derived from.

The separation of unnecessary or insufficient by-products, i.e., the winning of an elemental metal which is not required for the marketing of the main product, can be considered as an independent operation. In other words, it constitutes an autonomous technical decision for the management staff of a producing company.

Economic rationale seems to recommend the extraction of an unnecessary but sufficient by-product, alternative 3, when the net revenue from extraction is greater than without it. In case of a by-product separation that is unnecessary and also insufficient, alternative 4, the market price must cover both the cost of separation and the cost of further processing of the byproduct, minus any positive or negative variation in the value of the main product that may be derived from the separation. It is worth saying these are theoretical considerations on by-product recovery; since they normally produce only a small fraction of the major metal revenues, such an accounting refinement is not justified.

Alternative 2 is the most general in by-product production. The supply curve for the second alternative and also the co product curve which will be further discussed are mostly based on *Braz.* [7] It is shown in Figure 1 that there is a cost that must be covered for the by-product be adequately supplied. At the price P_1 the short term supply matches the existing demand D_1. However, if the demand increases to D_2, there will be a shortage at the previous price and the market will only be balanced at the price P_2. The supply curve in the long term is also limited by the output of the main product. As there is a cost structure to be covered, only at a compatible demand level will the overall available source material be converted into a final by-product metal. In other words, part of the minor metal bearing material can be left for later processing under more favourable market conditions.

The economic approach of a co-product is slightly different, for one of the two products can be of more importance, as shown in Figure 2. Provided the production costs of producing the by-product C_1, represented by P_1 is covered, its production is justified and it will be supplied on the market. The quantity q_1 however, is tied to the co-product C_2, which determines the production scale up to the price P_1- It is worth noting that for prices above P_1, co-product C_1 covers more than its own production costs, so that its production is no longer completely dependent on the output of co-product C_2. So, the supply curve of C_1 approaches that one of C_2, which is the leading co-product. Whenever the price of C_2 increases, the supply curve of C_1 moves rightward.

As noted, a by-product has virtually no influence on the mine output, otherwise it would not be a by-product. Co-products on the other hand do so and, sometimes in such a dynamic way that, at least in the short-term, a co-product can rival the leading element in terms of revenue.

Industry and Markets

As noted, microeconomics theory defines industry as the set of individual firms devoted to producing a specific intermediate or final good. In this sense, the production of minor metals cannot be considered as a separate industry, composed of firms concentrating on the mining and recovery of minor metals. Otherwise, this sector is characterised by the existence of firms producing minor metals, but only as a small part of their overall activities. For instance, the policy guidelines and capacity dimension of a producing firm cannot be measured through the production of minor metals, for their participa-

Figure 1
Supply curve for a by-product whose separation is necessary but not sufficient

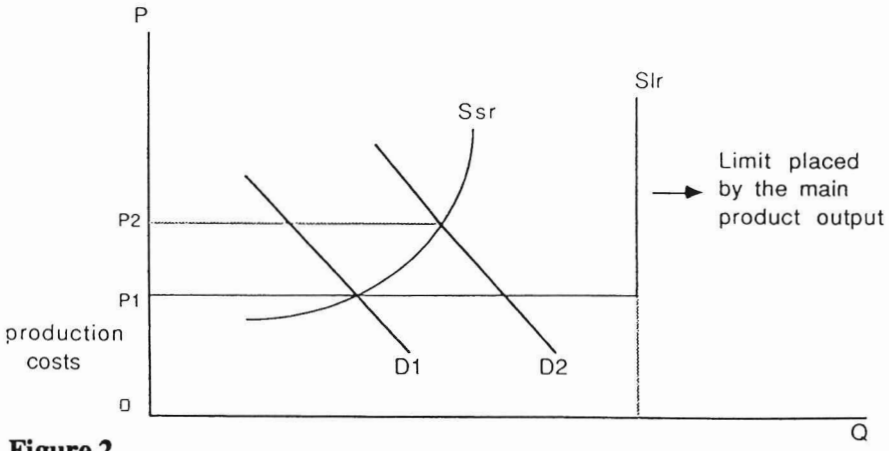
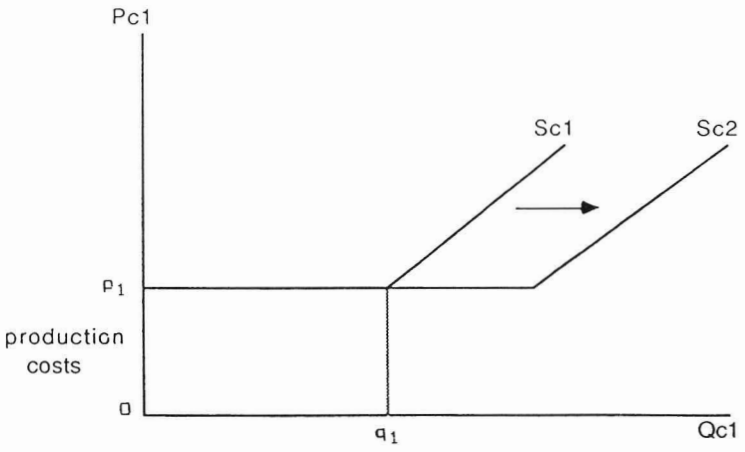


Figure 2
Short-term supply curve for a co-product



tion is generally small within the context of a non-ferrous company.

The production of minor metals by large firms is a common feature within the non-ferrous industry. Besides possessing the source materials, these companies also benefit from being integrated producers, for they can enjoy whatever economies of scale exist. Furthermore, by forward integrating into minor metals production they raise a barrier to new entrants, simply because it is not feasible to purchase major metal concentrates to recover the small amount of minor metals they contain.

The non-ferrous industry is composed of a homogeneous group of large companies transnationally integrated from mining to metallurgy. After the major metal upgrading and reduction, the material left over is the base material for obtaining minormetals. At this stage, the bulk of metal production is frequently concentrated on a small number of large firms. These companies may collect source material from different mining operations and either produce a uniform primary minor metal product or several different products. Going further into the processing chain, there is a substantial increase in the forms a minor metal or its chemical compounds can be recouped and traded.

Silicon, a vital material for the state-of-the-art electronics, provides a fairly illustrative example in this respect.[8] Semiconductor grade silicon is obtained as the final product of a sequence of valuable intermediate silicon-based products, such as metallurgical-grade silicon and silicone chemical products. This implies, a priori, that production of semiconductor grade silicon should not be isolated from that of producing the intermediate material, and vice-versa. So, it is quite evident that metallurgical reduction and further processing stages are responsible for the rise of minor metals and their compounds as individual mineral commodities.

Different agents and institutions interact within the marketplace to complete the complex set of transactions required to transform different inputs into final products. For commodities that have their prices set by producers, virtually all purchasers can be taken to be consumers. By contrast, when these commodities are sold at metal exchanges, new actors and market arrangements are introduced, such as merchants, dealers, speculators and direct contracts between producers and consumers.

To analyse the role played by each agent and its contribution to market stability does not seems to be relevant to the scope of the present work. However, it is worth highlighting the main features observed in the minor metal trading environment.

The market for minor metals, to a large extent, behaves quite similarly to that of major metals, in the sense they can be traded in competitive markets, producer markets, by merchants, dealers, or on the basis of contracts between producers and consumers. Table 2 summa-

rises the way a great deal of minor metals are traded.

The price set by agents within each market is always different, for differences in motives among agents can lead to differences in price behaviour. The minor metal clearing price, depending upon the market feature, are even more difficult to settle.

It is not irrelevant to recall minor metals' joint-production condition of by-products and co-products. The production of two metals of equivalent importance is called coproduction and the joint costs are often accounted to the two in proportion to their price weighted volumes. By contrast, by-product output is considered of only secondary importance and the joint costs are allocated to the main product they are derived from. Therefore, for metals produced as both main product and by-product, the latter represent a low cost source of supply which make their supply quite inelastic to prices during periods of depressed markets.

In the case of the molybdenum industry for instance, by-product molybdenum is a cheaper source of supply and so quite insensitive to price fluctuations, for most of its costs are supported by the main product - copper. Therefore, molybdenum primary producers have to play a major role in reducing production to balance the market price during periods of depressed markets.

Competitive and producer markets are the main types of market arrangement in metal trading and each one presents its own supply curve. As noted, severe fluctuation in metal prices is a typical short-term phenomenon. So, it is important to analyse the nature of metal supply for both competitive and producer markets in the short-term.

Microeconomic theory makes a clear distinction between production fixed and variable costs. Under the profit maximising assumption, firms operating in competitive markets will carry on production so long as price exceeds the marginal additions to variable costs. This being the case the firm will be better off producing the extra unit of output, for it will cost less than the market price. Beyond the point where marginal variable cost exceeds market price, production ceases, for it will mean losses per unit of output. A great deal of minor metals are produced by competitive firms and traded in competitive markets, meaning that market clearing price is set with a minimal influence of major producing firms. So, the prices are allowed to change to any level required to balance the market. Terminal prices at commodity exchanges like LME and COMEX are examples of

Table 2
Minor Metals trade and market arrangements

Product	Producer	Competitive	Merchant	Dealer	Contract
Antimony	•	•	•		•
Arsenic		•	•		
Beryllium	•				
Bismuth	•		•		
Cadmium	•		•	•	
Cobalt	•	•			
Columbium	•				
Gallium	•		•		
Germanium				•	
Hafnium				•	
Indium	•		•		
Lithium	•				
Mercury		•			
Molybdenum	•		•	•	
PGM	•	•		•	
RE		•			•
Rhenium		•			
Selenium		•			•
Silicon		•			•
Tantalum		•			
Tellurium	•	•	•		
Titanium	•	•			
Tungsten	•	•			
Vanadium	•	•	•		
Zirconium		•			

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Tarring, T. & Robbins, P. (1983). *Trading in Metals.* Metal Bulletin Books Limited pp. 143-173.

Hargreaves, D. & Fromson, S. (1983). *World Index of Strategic Minerals.* Gower Publishing and David Hargreaves, pp. 37-169.

Indium, germanium and selenium are minor metals used in new rapidly expanding sectors, eg electronics and optics. Photo below. Left to right.

this model. Producer prices are those set by a leading firm or by agreement among major producers within the industry. Since producer prices are set on a more stable long-term view of the market, they are less volatile than exchange prices and tend to change at discrete intervals.

Exchange and producer pricing systems both have their virtues and faults. However, it is worth underlining the fact that choice of pricing system is mostly determined by existing structural conditions within each industry. There is no single system that works efficiently for all industries and metal commodities.

High price volatility may induce consumers to substitute metals sold on exchanges, for relatively stable prices are preferable for planning purposes. However, a significant advantage of exchange-determined prices is their transparency. The LME and COMEX prices which are continuously published, have worldwide visibility. Different from producer prices, terminal prices emerge from real transactions and quotations are uniform across customers.

From the cost standpoint, the exchange pricing system does not prevent prices that are persistently above marginal costs, which means short-term losses for producing firms. On the other hand, producer prices, normally based on production costs for the industry as a whole, are relatively more stable and consumers tend to opt for the security provided by price stability.

From the points observed so far it can be noticed that each pricing system presents it own advantages and disadvantages. This fact may help to explain the many different features observed within metal markets.

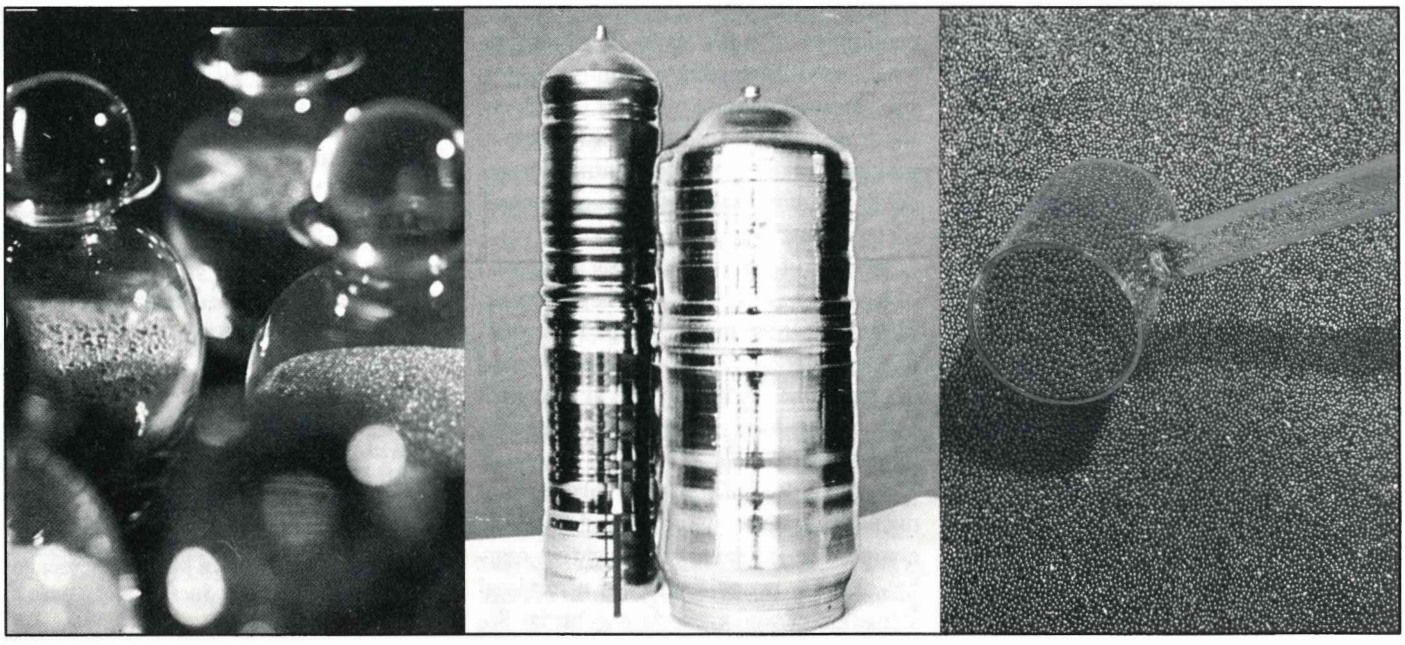
Concluding remarks

Minor metals are a special group of mineral commodities in both geological and economic terms. In terms of mineralogy, they can either be non-ferrous metals themselves or be derived from them, in joint production, as by-products and co-products. These particular features are analysed here within the framework of the metal industry in general, and in relation to the non-ferrous environment in particular. The main conclusions achieved throughout this work are now presented as follows.

The boundary between micro and macroeconomics has become less and less distinct in recent years. This is explained by the fact that macroeconomics also involves the analysis of markets the aggregate markets for inputs, final goods and services. To analyse the way aggregate markets behave, it is vital to understand the way they operate individually.

Prices, in general, are not fixed. Hence, the short-term variations in prices can be classified into two broad groups: those mainly determined by changes in production costs and those mainly explained by changes in demand. In general terms, changes in the prices of final goods are cost-determined while changes in the price of raw materials, including mineral commodities, are demand-determined. There is no doubt that the prices of final goods are affected by change in the prices of raw materials, but it is through the cost structure that this influence is transmitted.

Mineral commodities are quite different in this respect since to increase their supply a large time span is required. It takes time to develop a new mine, build or enlarge processing facilities. On aver-



age, five to seven years are required for a new mine venture to be fully developed. Supply being inelastic in the short-term, increase in demand leads to reduction in inventories and a rise in prices, generally magnified by the action of speculators or other private stockholders. A primary rise in demand which cause prices to soar is generally followed by a secondary wave of speculative demand. Therefore, it becomes even more difficult for output to cope with demand in the short-run.

Differences between major and minor metals are quite large. Observing them from an economic standpoint, however, show that they differ clearly at the point where they are separated as joint products. In other words, the process of becoming independent economic goods originates at the production stage in which a minor metal or its source material is initially separated as a single product. At this stage the specific costs arising from the potential final product are specifically accounted for it. This point can either occur at the mining, milling, metallurgical reduction or reining stages, but the flow of costs is the frontier line separating the main product from by-products and coproducts.

To produce metals according to the ever increasing market specifications quite often results in higher production costs. The mining industry, as other industrial sectors do, has frequently to pay more for labour, equipment, power, transport plus the financial costs of capital investments. Moreover, the mineral deposits now being worked are in general lower grade and sometimes located in remote areas, which means higher costs in treating more ore to obtain less concentrate. This typical cost scenario in the metals industry is virtually the same in minor metal production.

Frequently the idea of a by-product as a free economic good is incorrectly used. Conversely, they are generally quite expensive to produce. The production of any by-product resulting from joint-production can be classified according to whether the byproduct separation is necessary to produce a marketable main product and whether the separation process is in itself sufficient to produce a marketable by-product commodity.

Usually, the most common type of by-product is the one for which the separation from the main product is necessary but not sufficient to produce a marketable final product. There are a few exceptions. Whenever the existing impurity has no effect on the value of the main product, the potential by-product need not be removed.

If the condition of a minor metal is a by-product of a major metal it does not mean, as noted, that they are free economic goods. Actually, they are very expensive commodities. The further processing required to make them compatible with today's metal specifications results in a cost structure that must be covered by the market price so that the metal can be recouped and supplied on a profitable basis.

The production of minor metals by large firms is a common feature within the non-ferrous industry. Besides possessing the source materials, these companies also benefit from being integrated producers, for they can enjoy whatever economies of scale exist. Furthermore, by forward integrating into minor metals production they raise a barrier to new entrants, simply because it is not feasible to purchase major metal concentrates to recover the small amount of minor metals they contain.

The non-ferrous industry is composed of a homogeneous group of large companies transnationally integrated from mining to metallurgy. After the major metal upgrading and reduction, the material left over is the base material for obtaining minor metals.

A great deal of minor metals are produced by competitive firms and traded in competitive markets, meaning that market clearing price is set with a minimal influence of major producing firms. So, the prices are allowed to change to any level required to balance the market. Terminal prices at commodity exchanges like LME and COMEX are examples of this model.

Exchange and producer pricing systems both have their virtues and faults. However, it is worth underlining the fact that choice of pricing system is mostly determined by existing structural conditions within each industry. There is no single system that works efficiently for all industries and metal commodities.

From the cost standpoint, the exchange pricing system does not prevent prices that are persistently above marginal costs, which means short-term losses for producing firms. On the other hand, producer prices, normally based on production costs for the industry as a whole, are relatively more stable and consumers tend to opt for the security provided by price stability.

Notes:

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