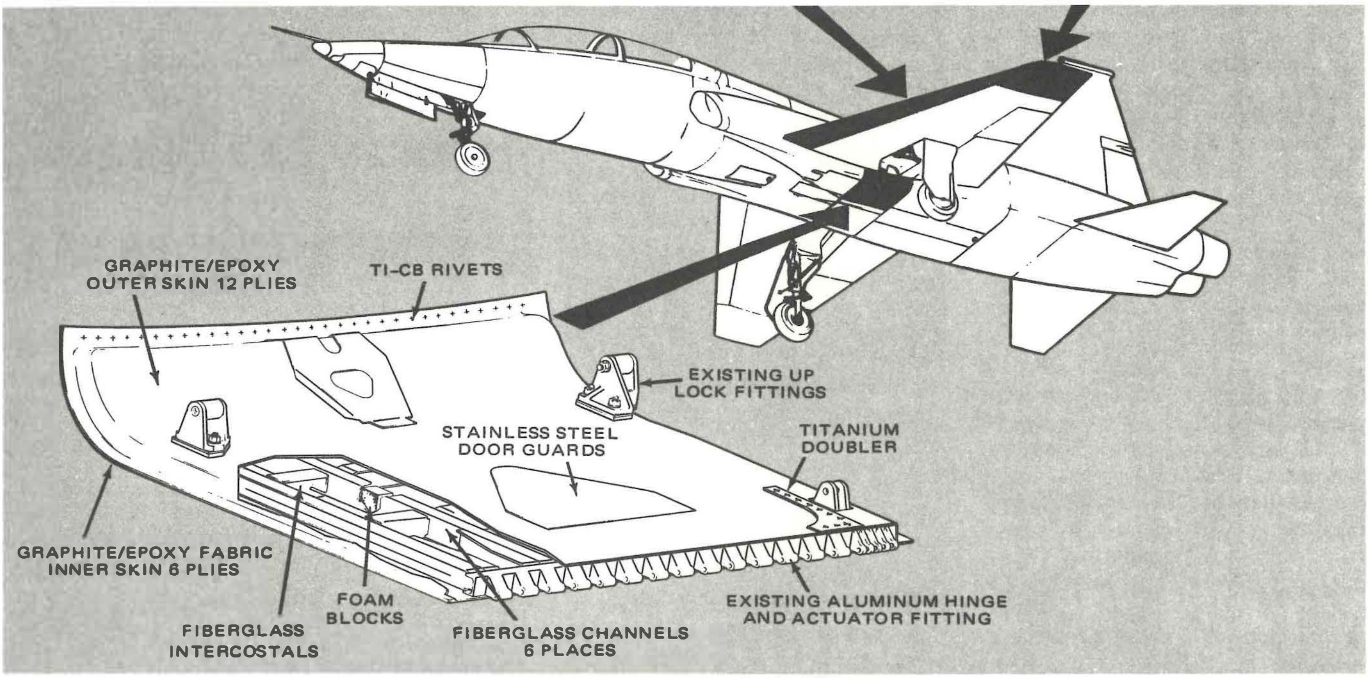
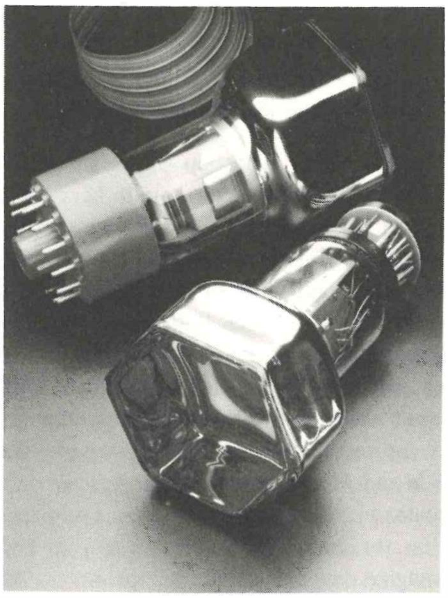
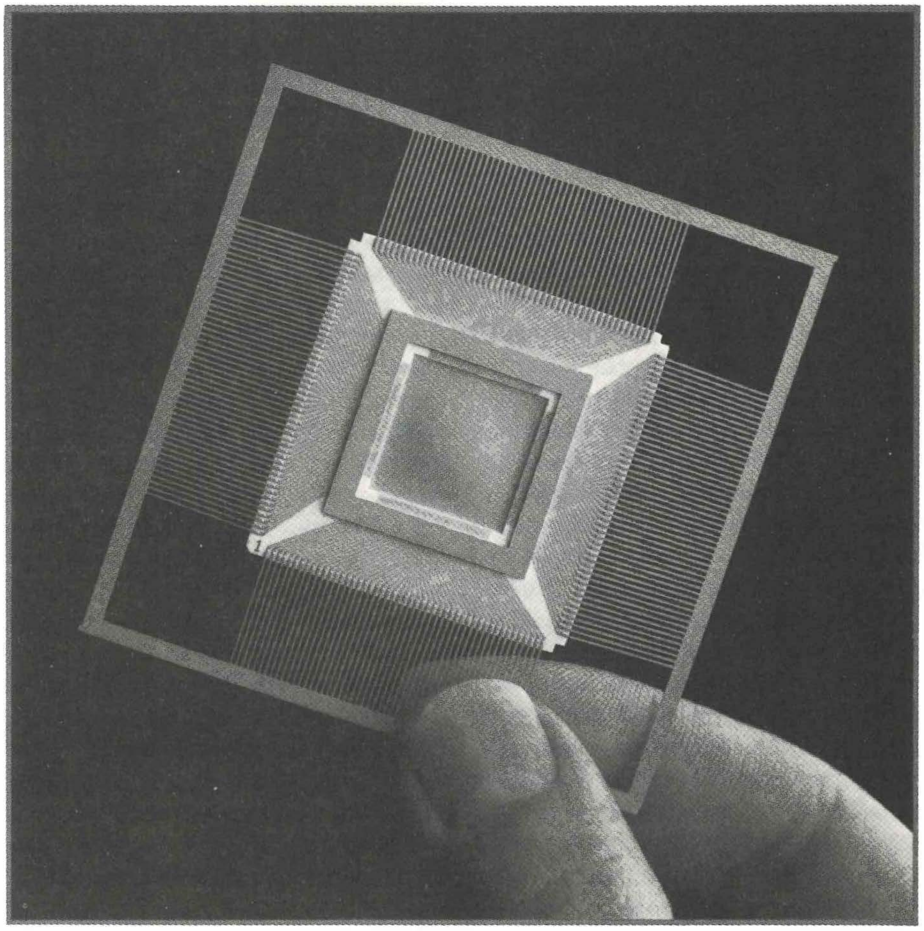
New materials play a key role in the development of military aircraft. Figure shows the use of composites, graphite/ epoxy fabric, fiberglass in the Northrop T 38 (below).



Beryllium is a strategic metal vital to the production of electronic components such as this 196 lead Very High Speed Integrated Circuit (VHSIC), fabricated by the US-based TNC Brush Wellman, a world leader in the production of metallic beryllium (right).

Photomultiplier tubes for medical CAT and other advanced applications include precision parts of beryllium copper.





SPECIAL REPORT

New technologies, industrial restructuring and changing patterns of metal comsumption

By Fernando Gonzalez-Vigil

The following pages offer an exploratory, preliminary analysis of some of the main factors influencing the long term patterns of metals consumtion, and the way these patterns are transformed by recent structural changes and technical innovations.

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From tight supplies and mounting or high current prices during the seventies, most of the metal industries moved in the early 1980s to depressed prices, low demand and investments, over-capacity and excess supply with strong competition among producers for outlets in the industrialized markets. The overall recovery of some developed economies since 1983 has not prevented 1984 from being the fourth consecutive disappointing year for almost the entire metal industry. When asked for an explanation to the present difficulties, many mineral analysts usually underline the role of supply, trade or financial-related factors, such as;

- supply rigidities arising from the increased share of production controlled by governments or state firms, and their failure to respond to market signals as quickly and efficiently as private firms;
- the growing import threat some developed country domestic mining industries are facing from foreign producers more competitive or eager to sell at any price due to balance of payments problems;
- the downward pressures on prices exerted by the strong dollar and high interest rates, and the enhanced unpredictability of price movements, which are now relatively more influenced by traders, exchange markets and non-integrated producers.

Structural changes in metals and materials consumptions

The role of demand-related factors is being, however, increasingly recognized and, what is more significant, the low levels of metals consumption in recent time do not seem to conform to an explanation exclusively based on short-term or even business-cycle terms – e g, the 1980–82 recession-linked downfall, or the weak capital investment in plant and machinery since 1983.

More lasting forces appear to be in play tending towards a long term decline in main industrial societies' demand for several major metals, and towards structural changes in the composition of their metals and materials consumption. These forces are apparently accentuated by the on-going industrial restructuring and technological changes affecting the productive apparatus of developed economies. But, as John Tilton correctly points out, there is a relative lack of thorough studies on factors governing metals demand by comparison to what we know about supply, trade or pricing.[1]

The following pages offer, therefore, only an exploratory, preliminary analysis of some of the main factors influencing the long term patterns of metals consumption, and the way these patterns are transformed by recent industrial structural changes and technical innovations. These transformations carry on very crucial implications for the whole metal industry, including TNCs and, particularly, many developing country producers that are anxiously waiting for an upsurge in metal markets and prices and rely heavily on mineral development for their future industrialization process. If demand prospects for major metals that conform the bulk of their exports are not so bright, TNCs and other international sources of capital will probably maintain a cautious attitude concerning new undertakings, and developing countries will presumably be confronted by hard choices concerning the allocation of their own and scarce capital resources to mineral projects, their multiplying effects in terms of processing and overall national development, and their market destination.

The declining demand for some major metals

The long cycle in the world economy activity is without doubt an important explanatory factor of overall trends in the pace of metals consumption. As Table 1 shows, the crisis that started in the early 1970s put an end to the high rates of demand growth known by most major metals (with tin as the only exception) during the expansionary period of the fifties and sixties, and the slowdown has been further deepened by the recession in the early

1980s. The significance of this fall is paramount indeed, as the seven metals listed in Table 1 represent around three quarters or more of the value of all metals minerals in the world economy and, in particular, they accounted for three quarters of developing countries' exports of all non-fuel minerals in the mid-seventies and, toghether with manganese ore, for 53 per cent of the total non-fuel mineral export earnings received by developing countries in 1980.[2]

But patterns of metals consumption growth differ markedly across national economies or regional economic groupings. Even during the expansionary period after the Second World War, metals demand growth in the US and other "mature" developed market economies of Western Europe was generally below the world's average growth (Table 2). The inverse being true for the USSR and, especially, for the conspicuous cases of Japan and developing countries. In this second group of countries the slowdown since the 1970s crisis has been also very pronounced, yet keeping above-the-average rates of demand growth or negative rates less widespread across metals. In relative terms, therefore, low consumption growth in major metals is a distinctive characteristic of "mature" developed market economies. The US in particular, wherein that long-term trend stands for all the metals listed in Table 2, while the ferrous and alloy metals show a relatively better performance among the Western European economies. Aluminium and, to a lesser extent, nickel deserving to be singled out as the major metals with highest past demand growth, in all country groupings.

Table 1

Declining trend in world consumption of some major metals[1], 1951–83 (percentage)

	1951–69	1964–74	1974–79	1979–83
Iron Ore	6.2	4.5	0.1	–1.4[2]
Aluminium	9.2	8.4	3.0	–1.1
Copper	4.7	2.9	3.5	–1.9
Lead	4.1	2.8	4.4	–1.9
Zinc	4.9	3.8	1.1	–0.8
Tin	1.0	1.2	–0.8	–2.0
Nickel	6.2	5.7	1.9	–2.3

Sources:
For 1951–79: Metallgesellschaft AG, *Metal Statistics,* various issues; as presented in United Nations Economic and Social Council, Committee on Natural Resources, *Mineral Resources: Trends and Salient Issues* (E/C.7/115, New York, 6 April 1981), Table 4.
For 1979–83: World bureau of Metal Statistics, *World Metal Statistics,* (London, August 1984).

Notes:
[1] Data and analysis in this and following sections refer mainly to *primary apparent consumption* (primary production minus exports plus imports plus changes in stocks), except when indicated otherwise.
[2] 1975–82, according to data in UNCTAD, *Marketing, Distribution and Transportation of Iron Ore: Areas for International Cooperation* (TD/B/C.1/PSC/41, 18 July 1984), Table 6.

Similar or complementary results can be drawn out from the analysis of the long run metals' intensity-of-use (I-U) patterns. For most of the selected metals, the US I-U peaks are to be found in the fifties or even before, those of Western Europe in the sixties, and those of Japan in the late 1960s or during the seventies. While the USSR has very recently reached its I-U peaks in some metals or in others will reach them sometime in the future, and the developing countries are still in the very upward slope of the I-U curve in all but one metal (tin). The interesting opposites are provided by, at one side, crude steel and the old non-ferrous metals (copper, zinc, tin) wherein the "mature" developed market economies generally reached their I-U peaks before the Second World War, sometimes approached again after the European reconstruction period (copper) and, at the other side, nickel which I-U peaks have been reached quite recently (after the mid-sixties) by the main developed market areas, and aluminium which has still a growing I-U projected in all the country groupings. Tin being an extreme example of a metal apparently in the last stage of its product-cycle, with an already lasting decline in its I-U throughout the world.

In other words, in order to explain the long-term trends in metals consumption we must take into account, besides the rate of overall economic growth and its long run cycles, at least two other aggregate factors, namely:

- the level of income (as a rough approximation to the level of economic development)
- the type or pattern of industrialization followed by each specific economy or country groupings.

As income per capita grows, at low levels of gross output there is in the first place a rapid increase in major metals intensity-of-use, and then as higher levels of real output are reached the intensity-of-use of major metals tends to decrease steadily.[3] The long run downward pressure on

Table 2

Patterns of metals consumption growth by main countries or country groupings, selected periods (percentage)

Country groups	Aluminium	Copper	Lead[3]	Zinc[4]	Tin	Iron ore[5]	Steel	Manganese ore	Chrome ore	Nickel	Tungsten	Cobalt
	Non-Ferrous						Ferrous and Alloys					
1971–75												
World	8.6	4.4	3.3	4.6	2.0	5.5	5.4	4.2	4.8	6.3	4.2	4.9
US	6.6	1.9	2.0	1.5	–0.4	1.8	2.0	0.4	0.1	4.3	2.9	2.5
Western Europa	8.0	3.8	1.4	3.8	1.2	4.4	5.5	4.7	4.9	6.0	4.1	4.6
Japan	19.1	12.0	5.0	11.0	9.2	16.0	12.9	8.3	14.4	16.7	9.0	14.5
Other developed[1]	9.0	3.8		4.9	1.8	7.5	5.5	4.9	5.9	8.5	9.1	5.8
USSR	8.6	5.4	4.7	6.6	1.8	6.4	6.9	3.5	4.4	7.0	3.1	8.0
Developing[2]	17.0	8.9		11.3	4.6	10.7	10.4	9.6	11.3	19.8	4.6	6.1
1970–1980												
World	4.7	2.7	1.8	2.3	–0.4	1.0	0.9			3.4	1.1	
US	2.8	0.6	0.6	–2.4	–1.6	–1.9	–3.4	–6.0	0.5	1.8	1.6	3.7
European community	4.2	1.3	0.2	0.8	–1.7	–0.1	–1.7	–0.2	6.5	3.4	–6.0	0.2
Japan	7.1	4.9	3.4	2.2	1.9	7.0	–0.9	1.5	4.1	4.3	–4.9	0.7
1980–83												
World	0.0	–1.0	–0.8	–0.1	–2.9	–1.4	–8.8	–11.1		–1.5	–6.5	
US	–1.8	–1.7	1.2	–1.7	–6.9		–14.6	–27.3	–30.7	–6.5	–10.7	–9.6
Western Europe	–0.4	–2.8	–2.5	–1.5	–4.5	4.7	–4.9	–7.9		–3.2		
Japan	3.2	1.6	–2.9	0.8	–0.5		–6.8	–6.7		–2.0		
Other developed[1]	–1.8	–3.6	–6.5	–1.7	–4.3		1.9	–19.3		–9.3		
Centrally planned	0.5	0.8	–0.1	1.4	0.8	1.8				0.9		
Developing	2.3	–1.2	1.1	1.4	–1.1	4.0				–2.2		
1975–2000 (Projection)												
World	4.1	2.8	2.8	2.9	1.9	2.8	2.6	3.1	3.0	2.8	3.1	3.3
US	4.0	1.9	1.8	2.0	0.9	1.6	1.7	1.2	0.5	2.0	2.3	2.9
Western Europe	3.7	2.8		2.6	1.8	2.6	2.2	2.6	3.2	2.6	2.8	2.6
Japan	4.9	3.2		2.8	2.3	3.3	3.4	3.5	3.9	3.4	3.5	3.7
Other developed[1]	4.0	2.6		3.0	2.3	2.6	2.5	2.9	3.4	2.7	2.9	3.0
USSR	3.5	2.4		3.1	1.9	2.8	2.6	3.1	1.3	3.0	2.9	3.1
Developing[2]	4.6	4.3		3.9	2.9	4.2	3.5	4.2	4.2	4.5	3.9	5.6

Sources:
Periods 1951–75 and 1975–2000: W Malenbaum, *World Demand for Raw Materials in 1985 and 2000* (New York, McGraw Hill, 1979) Chapter V; Period 1970–1980: P C Crowson, *Minerals Handbook 1982–83* (New York, Van Nostrand Reinhold Co, 1982); Period 1980–83: World Bureau of Metal Statistics, *World Metal Statistics* (London, August 1984).

Notes:
1 Includes Canada, South Africa, Australia and New Zealand.
2 Includes both market and centrally planned economies.
3 For 1960–75, according to L Fischman, *World Mineral Trends and US Supply Problems* (Washington, DC Resources of the Future R-20, 1981) Part I.
4 Refined zinc for 1951–75 and Slab zinc for 1980–83.
5 The periods are: 1951–75, 1970–80 and 1975–82.

prices resulting from this income-effect (assuming no significant constraints or disruptions from the supply side), is not in turn matched by the price-effect, as most major metals are price-inelastic, in the sense that demand increases by a smaller percentage than the percentage decrease in price.[4]

The significant weight of consumer goods and services activities in the US industrialization pattern is reflected in its relatively vigorous demand growth for a "light" metal such as aluminium, which intensity-of-use is still projected to further increase in that country. Whereas the importance traditionally accorded to heavy-industries by the USSR, Japan (until the early 1970s) and many developing countries (as a result of their import-substituting policies), is reflected in their relatively high intensity-of-use of iron and steel products and some related alloys (manganese ore, tungsten). Military production also explains these consumption trends of ferrous metals and alloys in the case of the USSR, as well as the rapid growth of demand in the US for other speciality metals of high-technology civilian and military applications, as we shall see later on.

At a first level of aggregation then, GDP growth and its long cycles, levels of income and industrialization patterns are three general factors of discernible impact on the long term trends in metals consumption, and their expected joint influence in the upcoming future provides a large part of the basis for projected rates of major metals consumption growth lower in general than those achieved during the expansionary period after the Second World War, as well as for a persistant differentiation by country groupings with relative low rates in the US and other main "mature" developed market economies in front of relative high rates in developing countries (see Table 2 again). In fact, developing countries are expected to be – as a group – the faster growing market for the major metal raw materials produced by themselves, with a resulting increase in their shares in world consumption (Table 3).

Table 3

Shares of developing countries in the world consumption of selected major metals: 1961–80 and projection to 1995

	1961	1970	1975	1980	1995
Aluminium	5.0	10.2	15.2	16.1	20.2
Copper	8.6	9.9	14.1	16.3	19.5
Lead	11.2	13.7	18.2	19.6	29.8
Zinc	11.5	13.7	17.9	20.4	28.4
Tin	14.0	17.1	20.0	19.5	27.6
Iron ore	13.5	12.0	16.7	19.4	28.9
Manganese ore	11.1	19.6	23.4	26.8	36.8
Nickel	0.3	1.1	4.9	5.8	9.7

Source:
The World Bank, *The Outlook for Primary Commodities* (Commodities Staff Working Paper 9, Washington, D C, 1983) Tables 20 and 21.

Even though there is almost a consensus about the continuing differentiation of levels of major metals consumption growth between developed market and developing countries, at least two important observations deserve to be mentioned here regarding the upcoming future.

The first one deals with the forecasted slowdown even in developing countries' demand growth for major metals, during the next fifteen years or so and by comparison to the expansionary period after the Second World War. This has to do not only with estimations of less favourable conditions for rapid economic growth in many Third World countries (especially during the 1980s), but, and more to the point, it reflects also the expected influence over those countries major metals-consuming intensity of the technological changes and substitutions among materials spread from the industrialized world, resulting in a major metals-consuming intensity relatively lower than that achieved by developed market economies in the past at comparable levels of income.

The second remark refers to the expected net impact of technical innovations and changes in the composition of output or aggregate demand, on future patterns of metals consumption. While most analysts and projections available so far seem to agree in forecasting lower rates of demand growth or intensity-of-use as a result of these factors,[5] a recent study directed by Leontieff comes out with projected demand growth rates for the US and world economy that in many cases are at similar or not significant lower levels than those of the past expansionary period, bringing thus a different perspective on the metals intensity-of-use implications of probable changes in technology and in the main components of the final, aggregate demand.[6]

It appears, therefore, that the technological innovations and the changes in the sectoral composition of output (and trade, we might add) are another two important factors to be considered for a more complete understanding of patterns of metals consumption. They will be discussed in the following pages, included in a broad and useful distinction suggested by Tilton, between factors related to changes in the product composition of income, and those related to changes in the material composition of products.[7]

Composition of output and trade

During the past two decades, manufacturing and construction, two sectors that are important end-users of metals, increased their shares in the GDP of developing countries but decreased them in the case of developed countries in the seventies (Table 4), and this is of course a reason behind the already seen differentiated trends of metals consumption between both economy groupings. The most striking sectoral evolution has been, however, the persistent growth of the services sector in developed and developing market economies, accelerated in both cases during the last decade. Yet services is actually a very heterogeneous sector. In developing countries it is usually more significant the weight of traditional and personal services activities, while in developed countries it is generally higher the relevance of modern services complementary to the industrial and other business activities. The metals-consuming intensity of services in industrialized societies is then certainly higher than in most Third World countries.[8]

When compared to manufacturing, the metals-consuming intensity of services has been traditionally considered as low, and the opposite directions showed in recent times by both sectors shares in the developed market economies GDP have provided an additional explanation for those countries' declining demand growth for major metals as well as for the forecasted continuation of this tendency in the upcoming future. Nevertheless, the slackening manufacturing productivity growth since the late 1960s plus the rapid flourishing in several industrialized countries of very modern, financial, trade, communications and high-technology related services, have brought to some analysts to suggest that many services may be more metals-intensive than various manufacturing branches per unit value of output.[9]

In fact, one important reason for the

Table 4

Structure of GDP and manufacturing output (1975 prices) in developed and developing market economies, selected years (percentage)

	Developed market economies			Developing countries		
	1960	**1973**	**1981**	**1960**	**1973**	**1981**
GDP composition						
Agriculture	6.6	4.7	4.2	31.1	20.1	18.0
Total industry	38.8	41.7	38.3	30.1	39.4	35.7
Manufacturing	25.8	29.5	27.6	14.2	17.5	18.8
Construction	8.3	7.6	6.1	5.1	5.3	6.3
Services	54.6	53.7	57.5	38.8	40.5	46.3
	1963	**1973**	**1979**	**1963**	**1973**	**1979**
Manufacturing structure by end-use						
Consumer non-durables (ISIC: 32 less 321, 332, 342, 352, 361, 390)	17.9	16.2	16.4	16.9	15.4	14.9
Intermediate goods (ISIC: 321, 331, 35 less 352, 362, 369)	21.9	23.4	23.2	27.0	26.6	25.9
Capital and consumer durable (ISIC 38)	36.7	39.3	40.2	15.0	21.9	24.0
Others, mainly resourcebased (ISIC: 31, 353, 37)	23.4	21.1	20.2	41.0	36.1	35.2
by mineral and energy resource-consuming intensity						
Very low (ISIC: 361, 331, 31, 323, 234, 342)	22.8	18.9	18.7	32.3	25.4	24.6
Low (ISIC: 321, 322, 332, 385, 355)	14.1	12.8	12.1	20.0	16.0	14.3
Medium (ISIC: 384, 382, 390)	22.9	23.2	23.4	9.5	14.0	13.9
High (ISIC: 341, 383, 381, 351, 352, 256)	25.4	30.6	32.5	17.2	22.5	25.3
Very high (ISIC: 362, 369, 37, 353, 354)	14.7	14.4	13.2	20.8	22.1	21.9

Sources:
GDP data from United Nations – DIESA, *Handbook of World Development Statistics 1983* (New York, PPS/QIR/5, April 1984) Tables 1, 2 and 10; and *Compendium of World Development Indicators 1983* (New York, PPS/QIR/3, June 1984) Tables 37, 38 and 46. Manufacturing output data from United Nations Statistical Office and UNIDO data base, as presented in UNIDO, *Industry in a Changing World* (E.83.II.B.6) Tables III.6 and III.7.

relative high rates of demand growth projected by the already quoted study conducted by Leontieff, lies precisely in the high metals-intensity of military or defense-related spending therein estimated.[10] As will be seen later on, the roles played by the defense and high-technology (industries and services) related components of final demand are crucial for the understanding of the recent and projected differentiated patterns of consumption regarding major metals and other non-fuel minerals of special applications.

Turning now to the composition of manufacturing output, the inter-industrial changes observed during the past two decades seem to indicate that developing countries are, all in all, effectively moving in a more mineral-and-energy intensity direction. This is at least what is suggested by the upward trend in the joint share of branches with medium, high and very high resource-consuming intensity (see Table 4 again). The classification by end-use also reflects this trend through the increased share of capital and consumer durable goods branches, especially in the case of the small though very dynamic sub-group conformed by the NICs and other major developing exporters of manufactured goods. And the intermediate and resource-based goods branches, despite their decreasing shares, still account for the bulk of most developing countries' manufacturing output. In the case of developed market economies, however, the picture offered by the inter-industrial changes standpoint is less conclusive since, on the one hand, the very high resources-intensity branches have lost ground but, on the other, there has been an increase in the shares of medium or high resources-intensity branches. At the same time the branches with lower resource-intensity have not decreased as much as in developing countries in the seventies.

What seems to be an established fact is that many capital and consumer durable branches, together with some intermediate goods branches (i e chemicals), will continue to play as "leading" industries in the world economy, with expected increasing shares in developed market economies as well as in some faster growing developing countries. These have been and will continue to be manufacturing branches with a relatively strong materials-consuming intensity. The key question to be answered refers therefore to the forces responsible for the specific metals-intensity component within that overall materials-consuming propensity. To this end, it is of primal relevance to discuss the sense of the changes in materials consumption patterns brought up by the on-going industrial restructuring and technological innovations, and this will be subject to the following section.

But the trade composition also matters a lot, evidently, as exports and imports structures help to identify the actual or potential metals-intensity of any economy, beyond its own domestic industrial structure. Recent information issued by UNCTAD and UNIDO[11] shows that as much as 57 per cent of most developing countries' industrially processed exports was composed by resource-based goods during the seventies, at the same time that exports of labour-intensive industries were the faster growing in the case of the major developing exporters of manufactures. As the degree of local processing increased in many of those countries during the same period, they now consume more of their own metal resources in ores or intermediate forms (such as copper blister, alumina and various concentrates), but they do still continue to "export" to developed countries the bulk of the consumption of metals in final forms. On the other hand, some developed economies (Japan being the clearest example) consistently "export" their consumption of some ores or intermediate forms, through the reallocation of processing plants towards other countries, both developed and developing. This reallocating process, together with the industrialization drive observed in Third World areas until the late seventies, account for the higher role now played by imports in the actual metals-consuming intensity of both developed and developing market economies.

In looking forward for assessing the metals-consumption impact of current technological changes and industrial restructuring process, it is important therefore to derive their implications on the international division of labour, and particularly on prospects for further local processing in developing areas.

New technologies and changing patterns of materials consumption

The developed market economies diminished markedly their consumption growth of ores and metals during the seventies (from an annual average of 4.1 per cent in 1963–73 to 0.2 per cent in 1973–80), as well as the growth of their imports of ores and metals from developing countries (down from 4.1 per cent to 2.0 per cent between the same two periods). According to UNCTAD, the explanation for these downward trends lies – besides the general economic slow-down which has accompanied the crisis during the past decade – in two important factors.

- The first is the displacement of natural by synthetic materials. It is a real long-term trend observed even along the expansionary decade of the sixties. It was further accentuated by the following crisis in spite of the rising energy costs involved in the fabrication of such synthetic materials.[12] Plastics, in particular, have been and still are replacing various metals in many important applications.
- A second factor, less influential than the previous one consists in the import substitution among natural raw materials, a long term process also, that in the seventies affected especially the non-ferrous metals and ores supplied by the developing countries.

The already lasting march of industrialized nations away from natural raw materials is not only the reflection of the market economies' intrinsic drive towards increasing efficiency and productivity in the use of materials and other factors of production, but it translates also those nations' efforts to progressively reduce their dependency on primary commodities imported – notably – from developing countries, where risks related to supply or price disruptions are usually perceived as high. In the case of metals and other non-fuel minerals, considerations of that sort have given grounds for a sustained search for synthetic substitutes; for the past three decades' concentration of major mining TNCs investments in "safe" locations within the industrialized world (US, Canada, Australia, South Africa) or in some developing areas of East Asia; and for changes in the consumption-mix among metals and other non-fuel minerals themselves, very often in detriment of many major metals crucial for developing mining exporters.

This twofold process of changes in materials consumption affecting metals – i e the gradual displacement of natural by synthetic materials, plus substitutions among metals or other non-fuel minerals – is apparently being enhanced and rendered more complex in the midst of the current industrial restructuring, spurred by the progressive generalization of new technologies (micro-electronics, telecommunications, automation, robotics, integrated computer systems) applications across the economic apparatus of main industrialized countries, which are shaping up the new leading industries of the immediate future.

In the US, while the total fixed investments stagnated, those in high-technology and communications equipment grew very fast since the early 1970s until reaching the first share of fixed investments in producers' durable goods, with 27.5 per cent in 1974–1979, 40.9 per cent in 1980–1982 and 47.5 per cent as an average in the first year of recovery, 1983.[13] Since the late 1960s Japan has implemented an industrial restructuring programme favouring the domestic location and building up of high-technology, clean industries, in response to that country's constraints on labour and land availability, to rising oil prices and to its high import-dependency of many essential natural raw materials.[14] And the major Western European economies are now trying by all means to reduce their relative lag in high-technology, a fundamental field for international competitiveness[15].

Besides the continous progress made in the field of communications and transport, some of the outstanding characteristics of micro-electronics and automation are:

- a great increase in the continuity and integration of the production and circulation processes (through the unification in a single command unit of the before separate functions of conception-design, production and marketing; through the reduction or almost elimination of "dead-time" or "porosity" in the working process; etc);
- bigger and yet more flexible scales of production, with increases in the absolute amount of output and in its diversification by lines of products as well, both more than proportional to the related increases in plant-size and in capital "captive" in the whole operation;
- considerable savings in factors of production, including labour, energy costs, as well as in the volume and value costs of raw materials and other feedstocks, per unit of output.

All of this implying a lesser growth of productive "heaviness", a much faster velocity of capital turnover and mobility, and significant cost-reduction at the process and product levels, thereby improving productivity, profitability and the freedom of capital to circulate along different industrial, trade or financial activities.[16]

Another outstanding characteristic of high-technology being the crucial role played in their promotion by developed countries' governments, and more specifically by military or defence-related spending in countries such as the US.[17] And this by virtue of the high technologies' double strategic value: as a key for the international economic competitiveness, as well as for the global military supremacy.

The metal industries are being thoroughly affected by the race for high-technology, a fundamental part of the general cost-reduction efforts deployed by many industrialized countries since the seventies which, together with the macro anti-inflationary policies pursued later on during the early 1980s recession, were aimed to reconstitute productivity and profitability in the leading capital and consumer durable industries, so providing the basic rationale for the currently depressed prices of metals and other primary commodities. The general drive towards economizing oil-sourced energy and replacing it by other sources of energy, has drawn an imported increase in electricity used by developed countries' mining and metallurgy industries.[18] The search for lower labour costs has gone through jobs elimination or lay-offs, new labour contracts with less wages and labour benefits, and the creation of new firms or plants non-unionized; the US and other developed country steel and copper industries providing many examples to the point.

The development of new technologies and the related industrial restructuring with the progressive emergence of new high-technology leading activities within the capital and consumer durable industries or services, appears then as an important set of factors contributing to the use of less amounts of metal feedstock per unit of output, at the least in the major industrialized economies in the short term and – probably – also in other (including developing) countries in the long run. This set of factors should be added to the others previously discussed in this paper (i e GDP growth and long cycles, level of development, industrialization strategies, composition of output and trade), for the explanation of long term trends in metal consumption patterns and, in particular, for understanding the recent and projected behaviour of the demand for those major metals that are crucial for many mining developed producers.

In this respect, it is worth noticing the differentiated impact the new technologies and recent industrial restructuring apparently have on demand trends by categories of metals. Table 5 shows the seventies' rates of demand growth in the two developed market countries more advanced in high-technology (US and Japan), as well as several available forecasts for the US and world economy. During the past decade, the performance of demand for major metals of general uses has been impressively low or bad (particularly in the US) when compared to that of high-technology metals, and this is also true when compared to that of most special steels and alloy metals, though to a lesser extent and with the only exception of aluminium in this case. Furthermore, while the consumption growth of major general use metals slackened in the second half of the seventies, the one of many high-technology or special alloy metals accelerated in contrast,

Table 5

Patterns of metals consumption by main end-use categories of metals: historical and alternative projected rates of growth (percentage)

				Projections up to the year 2000[2]										
End-use		**1970–80[1]**		**United States of America**					**World**					
Categories	**Metals**	**US**	**Japan**	**USBM**	**R&W**	**WM**	**LF**	**IEA**	**USBM**	**R&W**	**WM**	**LF**	**WB**	**IEA**
General uses														
Basic steel industry	Iron ore	–1.9	7.0	1.0	1.9	1.6		2.2	2.3	2.1	2.8		2.3	4.0
	Steel a)	–3.4	–0.9	1.8		1.7			2.7		2.6			
	Manganese b)	–6.0	1.5	1.4	2.1	1.2	–0.1	2.9	2.7	0.6	3.1	2.6	2.6	4.9
Older non-ferrous	Copper	0.6	4.9	3.0	2.3	1.9	2.2	3.1	3.9	2.7	2.8	2.6	2.7	4.4
	Lead	0.6	3.4	1.8	4.4		1.9	4.8	2.8	3.3		2.0	3.1	4.5
	Zinc	–2.4	2.2	1.7	2.6	2.0	1.5	1.5	2.1	2.6	2.9	2.5	2.9	3.5
	Tin	–1.6	1.9	0.9	2.2	0.9		0.8	0.9	2.9	1.9		0.7	4.0
Light	Aluminium	2.8	7.1	4.6	4.3	4.0	2.3	2.3	4.7	5.1	4.1	3.7	3.7	3.7
Special uses														
Special steels and alloys	Chromium c)	0.5	4.1	3.4	2.4	0.5	–1.3	3.1	3.3	–0.5	3.0	2.2		4.6
	Nickel	1.8	4.3	4.0	4.1	2.0		2.7	4.3	3.2	2.8		2.3	2.7
	Tungsten d)	1.6	–4.9	4.6	2.1	2.3		3.0	3.5	2.1	3.1			4.5
	Cobalt e)	3.7	0.7	2.9		2.9	1.6		3.0		3.3	1.7		
	Molybdenum	3.1	4.4	4.2	2.4			2.6	4.5	2.4				4.2
	Vanadium	–0.3	8.7	3.8	2.5			3.0	3.6	4.3				4.7
	Columbium	4.1	12.1	5.1					5.1					
High technology	Beryllium a)	11.9		0.5					0.5					
	Tantalum e)	19.5	13.6	3.1					3.2					
	Silicon f)	6.9	10.3	3.2				2.9	3.7					4.5
	Zirconium f)	8.0	8.4	4.5					3.3					
	Titanium f)	6.2	12.9	5.0	2.3			2.4	5.4	2.1				3.5
	Lithium	5.2	11.7	5.7					5.9					
Other	Antimony	–3.2	–6.9	2.1					2.3					
	Cadmium	–2.1	–3.8	1.8					2.0					
Precious metals	Platinum group	6.3	10.1	2.5		2.6		3.2	2.6		3.5			4.6
	Silver	0.8	3.9	2.2				3.3	2.5					4.3
	Gold	–2.6	2.2	2.2				3.3	1.4					4.5

Sources:

[1] Data from P C Crowson, *Minerals Handbook 1982–83, op cit* except when indicated; [2] USBM: US Bureau of Mines, 1978–2000 forecast period for most metals, according to *Mineral Facts and Problems* (1980 edition – Bulletin 671). For iron ore, steel, aluminium, lead, columbium, tantalum, titanium and silver the forecast period is 1981–2000, according to *Mineral Commodity Profiles,* 1983; R&W: R G Ridker and W D Watson, *To Choose a Future* (John Hopkins Univ. Press, 1980). Forecast period: 1970–2000; WM: Wilfred Malenbaum, *op cit,* Tables 5–2.1 to 5–2.12. Forecast period: 1975–2000; LF: L Fischman, *op cit,* Part I. Forecast period: 1980–2000; WB: The World Bank (1983), *op cit,* Table 21. Forecast period: 1980–1995; IEA: Wassily Leontieff *et al, op cit,* Tables 7–66 and 7–68. Forecast period: 1970–2000.

Notes:

a) Historical data for 1973–80 (instead of 1970–80), according to OECD (1981), *op cit,* Table 1, p 23. WM forecast refers to crude steel only; b) Historical data and WM, FL and WB projections refer to manganese ore; c) WM and LF projections refer to chrome ore (chromite) only; d) Historical data for concentrates only; e) Historical data for the US correspond to the 1975–80 period, according to US Bureau of Mines, *Minerals Yearbook* (various issues); f) Historical data refers to silicon metal, zirconium metal in US and concentrates in Japan, and Titanium sponge.

accompanying the ascendent investments in high-technology equipment during that period.[19]

Available forecasts seem to predict the persistence of this differentiated trend, with comparative high rates of demand growth projected for the cases of high-technology metals, the "light" aluminium and most special steels or alloy metals. Moreover, whereas in these three cases the projected rates of US demand growth are generally very closed to – and sometimes even higher than – those estimated for the world economy, the estimated future growth of US demand for basic ferrous and older non-ferrous (the "major") metals appears as consistently and significantly below the estimated growth in the world economy (see Table 5 again).

The cost-reduction efforts being deployed since a decade or so in order to come out with final industrial products with low weight, oil-sourced energy savings and improved efficiency, certainly account for the comparatively better (in respect to other major general use metals) demand performance of light metals such as aluminium, in the recent past and in the upcoming projected future as well. The general tendency towards higher automated and continuous production processes steps up the demand for most metals classified within the high-technology and special steels and alloys categories, because their suitable properties for high strength/low weight alloys and superalloys, or for high-speed/hot-work special tools and machinery, or for special corrosion-inhibiting applications. High-technology applications are accounting for growing shares in the US patterns of metals end-use demand, e g:

- electronic components (silicon metal, beryllium, tantalum)
- industrial ceramics (titanium, zirconium, antimony)
- special chemical uses (cobalt, nickel, molybdenum, vanadium, titanium, zirconium)
- special machinery and tools (chromium, tungsten, vanadium, titanium, zirconium), including nuclear reactors in the cases of beryllium and zirconium.

The already mentioned role of defense or military-related factors regarding high-technology, is expressed in the importance of such applications within the transportation end-uses of metals such as cobalt, molybdenum, columbium, vanadium, beryllium, tantalum and titanium.

In short, the rise of high-technology and the current industrial restructuring are transforming the materials composition of products in the main developed market economies (with the eventual dissemination – more or less complete – of these changes to other countries of the world system), in a way that tends to intensify the consumption of synthetic materials vis-à-vis the natural ones and, concerning specifically the non-fuel minerals, tends to intensify the consumption of speciality metals or other industrial minerals vis-à-vis the major (basic ferrous and older non-ferrous) metals.[20]

If the tendencies continue to prevail or are even enhanced in the course of time (as many seem to expect it), logic implications (which are, in fact, working hypotheses to be explored through further research) would be that the emerging leading industries and services related to high-technology capital and consumer durable activities would exhibit a total materials-intensity generally higher than their metals-intensity, and would experiment changes in the composition of their consumption of metals that would generally work in detriment of the major metals-intensity, *caeteris paribus.* A derived hypothesis being that even though many developing countries may continue to increase their shares in the world output or trade of capital and consumer durables (as they further industrialize and experiment the corresponding changes in composition of output or trade), their future metals demand growth and intensity-of-use, yet higher than those of the developed market economies, would presumably not meet the levels achieved in the past by developed countries at comparable levels of income. The extent of this impact depending on the degree of actual dissemination of the current restructuring and new technologies across industries and throughout the world; and the specific mix of materials and metals consumption depending also on policy options regarding developing countries' industrialization strategies and their access to international flows of capital, goods and services.

The restructuring in the non-fuel minerals industry

The dissemination of new technology applications across industries is still an on-going process and, though very much accelerated in some of the main industrialized nations since the early 1980s, remains at its very beginnings in extent and deepness. Its most visible or immediate impact is being observed so far in crucial capital and durable consumer or chemical industries, but its modernizing influence is gradually spreading also to the so-called "traditional" industries (like textiles–clothing, for instance[21]) and to the non-fuel minerals mining and processing industry as well.

In this respect, a revealing example is provided by a recent assessment of technological innovations projected to be in force in the US copper industry between this decade and 2005.[22] This survey found that advancements in computer software and in increasingly sophisticated analytical techniques offer a great potential for major technological changes in copper exploration over the next 20 years, likely to be concentrated in analysis and interpretation of available deposit data (through improved geogologic-al models, automated integration of multidisciplinary data, and the wide use of multispectral satellite scanning – LANDSAT), rather than in the collection of additional deposit data. A movement toward the greater use of continuous systems as well as of information systems and computer control methods, is predicted as the most likely trend in the extractive stages of the industry – mining and mineral concentration, reflected in the adoption of automated production monitoring and control (APMC) systems, of portable crushing-conveyor systems, of autogenous and semi-autogenous grinding, and of more automated and selective beneficiation process. These technologies generally enable to maximize equipment utilization, to optimize route selection, to economize the use of electric power, and to achieve maximum metal recovery and high grade concentrates. In the processing stages, the experts surveyed felt that flash smelting technology (a relatively energy efficient process) would likely be more widely adopted in the US over the next 20 years, as an alternative to the conventional reverberatory furnace, but a gradual movement toward continuous smelting methods was also forecast; and in refining, the major technological change expected is the gradual automation of a variety of refinery operations.

This gradual movement toward more automated continuous production and control systems may increase considerably the efficiency and competitiveness enjoyed by various developed countries' domestic metallurgies, in face of the higher competitiveness enjoyed by various developing countries at the stages of mineral ores, concentrates and some intermediate forms. The impact of those technological innovations on the metallurgy of developing countries will of course depend on the degree and pace of their dissemination. But in general terms it seems clear that many developing countries will face increased technological barriers-to-entry (particularly) in the high value-added stages of processing, with the consequent uncertainties about the extent of their future prospects for further local consumption of minerals in concentrates and intermediate forms.

Another important aspect of the restructuring that is affecting the non-fuel minerals industry is the research and development of "new materials" such as fine ceramics, polymers, high-performance alloys, and composites materials. Generally speaking, these materials involve very high value added, are developed with the help of sophisticated formulation techniques, possess particularly useful properties and have a cost-performance ratio markedly more favourable than that obtained with conventional materials.[23] The recent trends toward lighter industrial structures and products, high-performance machinery and equipment, miniaturized components and products, and higher energy efficiency or reduced consumption of energy per unit of output, have strongly incentivated the development and commercial applications of these new materials. Although their own fabrication sometimes requires considerable amounts of electric energy (thereby increasing the electricity consumed at the electrometallurgy and non-metallic industrial minerals branches), their final utilization in the demand-end industries brings up substantial economies in energy and metals consumed per unit of output at those productive stages, as indicated in Table 6.

The fabrication of these new materials, which are synthetic directly or indirectly through very sophisticated combinations of various natural materials, is a field wherein the main industrialized societies enjoyed significant advantages *vis-à-vis* most developing countries. Moreover, within this new generation of materials have been the recent more dynamic substitutes for natural materials – metals included, and they have the most promising perspectives for further replacing metals of general use and of speciality uses as well. So far, however, the major, older non-ferrous metals have been relatively the most affected by this kind of substitutions.

Turning to the substitutions that take place among metals, in this case also the older non-ferrous metals (copper, lead, zinc and tin) have lost ground in various main applications in favour of light metals (aluminium) and speciality alloys and high-technology metals, a substitution process that has contributed to their declining demand in main industrialized economies and that it is not so recent in fact, but that is being accentuated by the current restructuring and new technologies. In contrast, in the case of speciality alloys most substitutions of this sort happen among themselves, or in favour of some high-technology and platinum-group metals, though potential substitutes are often limited by estimated lower performance and/or cost effectiveness. A similar remark is generally valid for the high-technology metals. For these the substitution threat comes from either non-metallic industrial minerals or – especially – the aforementioned "new materials". Composite materials, in particular, that possess mechanical properties comparable or higher than high-resistance steels and light alloys, with substantially lower density.

In short, all kinds of metals are – in different degrees – threatened of substitution by synthetic materials, some non-metallic minerals and the "new materials". So far the older non-ferrous have been affected to a greater extent and this category of metals has also been the most affected by substitutions among metals, in favour of light and speciality metals. Important substitutions among metals in favour of the older non-ferrous ones have been less frequent, as light and speciality metals usually find metal substitutes within their own category. Trends of that sort are certainly behind the differentiated patterns of consumption by category of metals previously discussed and showed in Table 5.

Furthermore, the actual consumption growth of metals in their primary form (i e what really matters from the mining producers' view point) is also influenced by the relative importance of secondary (scrap and waste metal) consumption. Recent data indicate high shares of old and scrap consumption in the total consumption of non-ferrous metals: the 1981–82 averages were 48.1 per cent in lead, 37.9 per cent in copper, 27.2 per cent in aluminium, 24.2 per cent in zinc,

Table 6

Selected list of new materials and range of applications

Material	Properties	Major applications	Economic and social implications
Fine ceramics	Highly heat-resistant, very hard and high-precision	Thermal or heat engines; aircraft and spacecraft; electronics; fibers	Conservation of energy and metal resources
Polymers	New plastics with very high performance		
High effective bio-separaters	Highly selective permeability and separative function of mixture close to that of living organisms	Separation, refining and desalination	Emergence of non-polluting energy- and -space efficient industries Solution to water shortage problems
Electrically conductive	Electrical conductivity comparable to metals, or even superconductivity in some cases	Wiring of electric equipment; electronics Power generation and transmission lines	Conservation of copper and aluminium Conservation of energy
Others	High-strength materials; high elasticity materials; bio-compatible materials	Structures; mechanical engineering Medical	Conservation of natural resources Improved medical treatment
Metallic Super conductive alloys	Highly workable, anticorrosive; superconductivity at normal temperatures	Power generation and transmission Nuclear fusion reactor Magnetically levitated transportation system	Conservation of energy; sweeping solution of energy constraints
Alloys with controlled crystallization	Mechanical strength substantially improved	Aircraft, space and energy industries	Conservation of metal resources and energy
Composites	Combination of different materials (metals, plastics, ceramics, fibers)	Structures; aeronautics; space	Conservation of metal resources and energy (less weight)

Source:
Japan External Trade Organization (JETRO), *White Paper on International Trade – Japan 1982* (Tokyo, 1982) p 71.

and a relative low 19 per cent in tin.[24] Some other metals do have comparable shares (such as antimony, nickel, gold and silver) though, in general, secondary demand is much less important among special alloys and high-technology metals, and it will continue to be that way according to available forecasts. It is worth mentioning that, in this case, technology changes do not seem to be as much a decisive factor as the relative prices of scrap and primary metal. But, whatever the reason may be, this is for sure an additional trend contributing to the deteriorating long term prospects of (primary) demand for major non-ferrous metals, including aluminium this time.

The current industrial restructuring and spread of new technologies are, therefore, accelerating past trends related to substitution patterns and the continuity of metal production processes. At the same time they are transforming them qualitatively by opening new dimensions and a potentiality almost unconceivable not long ago, and by pushing the non-fuel minerals industry itself toward a whole internal restructuring. The general impact of these in-process changes (together with the role of secondary demand) on metal consumption patters do not preclude at all the fact that each metal industry is obviously experimenting them in a singular way, and has its own particular constellation of problems to face it.

In the case of *copper* the survey quoted above, predicting more automated, continuous and computer-aided methods, implies a probable acceleration of a tendency visible many years ago with the introduction of the continuous-casting. It has already signified, among other effects: the partial substitution of cathodes for wirebars (thereby affecting wirebar prices and productive capacity, located mainly in developing countries); reduced markets for low quality blister copper; and the strengthening of comparative advantages for the location of electric wire and cable manufacturing plants in developed coun-

Optical fibers are rapidly replacing pair cables (above) and coaxial cables (below), thus depriving the copper industry of a vital market.

tries.[25] Besides, copper has been considerably replaced by synthetic materials (optic fibers, plastics) or light metals (aluminium) in some of its important traditional markets: machinery, communications, construction and electric industries. In the last two copper has, however, good prospects in the future, though an intense effort of research and development of new applications (such as new copper–nickel-based alloys suitable for shipbuilding or ocean oil-drilling; as additive for fertilizers; through lighter components for motor cars; etc) will be required anyway in order for this metal to keep the pace in the time coming.[26] The copper industry is then facing problems and challenges much more general and far-reaching than its current depressed price and crisis in some developed countries may suggest.[27]

Aluminium, as seen before, has had and will very probably continue to have the best demand and intensity-of-use prospects among all major non-ferrous metals, and is also less threatened by substitutes than them; even though most experts do forecast lower rates of demand growth for this non-ferrous metal too. But its properties and strategic civil and military applications (it is one of the "controlled materials" in the US Department of Commerce's Defense Materials System), together with the increasing reliance of main industrialized nations on foreign sources of bauxite and alumina, have incentivated since long ago very sustained and intense (by comparison to other non-ferrous metals) research efforts sponsored by transnational corporations and/or developed country governments. The main technological developments are related to a chloride electrolyte or direct smelting process using non-bauxite material (calcined kaolinitic clay), and to improvements in alumina reduction methods (electrolyte additives, new electrode materials, more heat-and-power efficient cells).[28] The latter are stimulated by the high weight of energy costs in alumina reduction, that may bring more competitive plants in other (mainly developing) countries. But, on the other hand, there is now a huge surplus of alumina capacity at the world level, and this may counteract a further location of processing plants in developing countries in the immediate future.[29]

As for the case of the *iron and steel* industry, its basic components (iron ore, steel and manganese) still do not have substitutes in their main applications, but depending on relative price changes steel may be more replaced in the future by aluminium and plastics in transportation, and by concrete in construction. In spite of the already very old and lasting declining trends in demand growth and intensity-of-use, projected to continue in the upcoming future, the current restructuring and new technologies have, on one side, increased the requirements for speciality steels of higher strength, lower weight, higher performance and lower costs; a field wherein Japan and some Asian developing countries have become very competitive.[30] On the other side, those recent developments have accentuated the need for full modernization programmes in the United States and Western European iron and steel industries, in order to overcome problems of aging facilities, high labour costs, competitive challenge from other country producers, and excess capacity worldwide.[31] It is so that, besides strong protectionist pressures, those countries are moving now toward more continuous operations, aided by computer and automated systems, that offer advantages such as higher labour productivity, better product quality, high yields of finished products and lower energy consumption. The US steel industry, for instance, reduced the amount of energy required per ton of raw steel by 11 per cent between 1972–81, and shifted its energy consumption away from coal and fuel oil toward natural gas and electricity; moreover, wage worker productivity improved at an average rate of 1.9 per cent/year during that period.[32] The outcome of these modernizing efforts will obviously be very influential in determining whether or not it will finally prevail the particular kind of division of labour that appeared to emerge in the last decades: most developing countries producing and/or supplying ordinary steels, and some of them (basically among the Latinamerican and Asian NICs) together with the main industrialized nations competing among themselves for the speciality steels market.

The role of the transnational corporation and other institutional or market organization factors

The reviewed trends in metal consumption patterns and their main related set of factors (economic growth and long cycles; level of development; industrialization strategies; changing composition of output and trade; and the role of current industrial restructuring and new technologies in the changing materials composition of products) are all very macroeconomic in scope and have worldwide implications. Large segments of the metal industry are in a crisis that unavoidably affects or involves firms of all kinds, big or small, private or public. Nevertheless, the specific influence of institutional and market organization factors must not be underestimated. Not all the firms or economic agents involved have an even capacity to resist the crisis and survive it, or to prevail at the end after successfully overcoming the challenges posed by the current restructuring.

Considerations of this kind are pertinent when it comes to single out the particular role played by transnational corporations (TNCs) in the on-going industrial and technological changes that are affecting the patterns of metal consumption, in the way previously discussed. At first glance, that role may appear as a very important one, in the case of TNCs operating in the main metals' end-using industries, given the well-known and documented key positions they enjoy in leading capital or consumer durable industries and related services,[33] and given also the crucial relevance of technology for the building-up of their ownership-specific advantages at the international level.[34] But this says little about whether TNCs are engaged in those changes as a part of their own offensive or active strategies or rather as a consequence of defensive or passive reactions, or both ways. Restraint for drawing easy conclusions in this respect is strongly advisable because, as seen before, the role of other institutional factors – such as developed country governments – in high-technology development is very important too, and the overall share of state involvement has been increasing together with the internationalization of the world economy.[35]

Furthermore, most of the available data from the growing number of studies or surveys on new technologies application or cost-reduction efforts and related changes in materials consumption is at the industry or branch level. Table 7 provides an example of the so far scattered information available at the firm level. In accordance to the general trends already analyzed, changing production methods in Ford Motor Co seem to be using more of light and speciality metals (aluminium, high-strength steels) or synthetic materials (plastics), and less of other general-use metals (copper, lead, zinc and ordinary iron and steel products). But conclusive judgements on TNCs' particular role must wait for more comprehensive firm-to-firm data, suitable for identifying those changes' comparative intensities by firms of different size and ownership structure.

Table 7

Average materials consumption for cars manufactured by the Ford Motor Company, 1977, 1982 and 1985

	1977	1982		1985[1]	
Material	**Kilogrammes**	**Kilogrammes**	**Percentage change**	**Kilogrammes**	**Percentage change**
Hot and cold rolled steel	1 016	623	–38.6	567	–9.0
Cast iron	281	160	–43.2	143	–10.5
High-strength steel	48	114	+140.0	122	+7.1
Plastics	75	102	+35.8	102	+0.4
Aluminium	50	60	+20.9	61	+1.5
Rubber	82	59	–28.3	54	–7.0
Copper and brass	16	15	–8.6	11	–21.9
Lead	13	13	–3.4	11	–10.7
Zinc die-casting	15	5	–70.6	5	0
Other	164	75	–54.3	73	–2.7
Total weight	**1 760**	**1 226**	**–30.3**	**1 149**	**–6.3**

Sources:

Forbes, 1982-11-22, pp 161–167; and United Nations, *Mineral Resources – Trends and salient issues, with particular reference to rare metals* (New York, E/C.7/1983/8), p 13. The percentages were calculated on the basis of the original figures in pounds (dry weight).

Note:

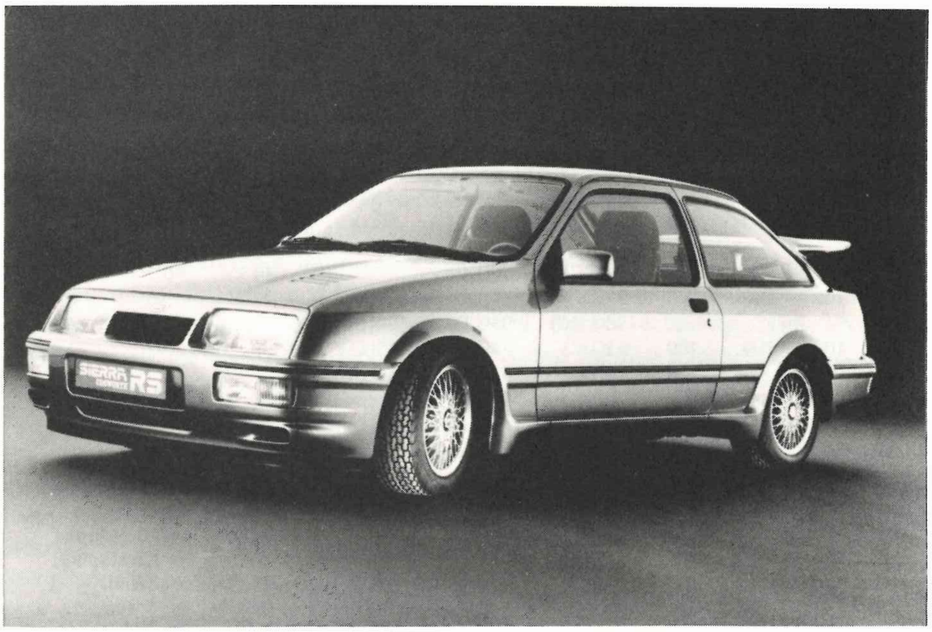
[1] Projected.

In the case of mining TNCs, the picture is even more mixed. Many of them have been strongly hurt by low demand, depressed prices, high idle capacity and sharp fluctuations in exchange markets.[36] With the exception of the gold market and firms, most mining and primary processing ventures have experienced financial troubles since the late seventies and negative profits during the early eighties recession, and even though their economic position improved slightly later on they still scored as big losers in terms of inflation-adjusted profits in 1983.[37] Diversification, either into other minerals or into other industries, has helped some mining TNCs (such as Amax, Anglo-American, Newmont Mining, Inco, Noranda, Falconbridge, Western Mining Corp, and some Japanese and Australian firms) to do better in these hard times. In fact, it is not by chance that those mining TNCs taken over by oil-TNCs were extremely concentrated on one or a few older non-ferrous metals (copper, mainly). Some of these mergers do not seem, however, to have been a success for the acquirer in financial terms, in the short-term at least, as the copper and minerals branches of Standard Oil of Ohio-Kennecott and of Atlantic Richfield-Anaconda ended 1983 with substantial losses.[38]

But diversification alone is not enough to meet the challenges confronting mining TNCs. Modernization and technological excellence is the main way out, and TNCs know it very well though not all of them can cope with it rapidly because the high indebtedness accumulated during years of declining or depressed markets. Emphasis in recent times has been on cost-reduction and some expenditures in new equipment rather than on investment in new plants.[39] Capital spending programmes have been either deferred or cancelled, and operating costs reduced through decreasing overmanning, shut down of facilities, elimination of workers' and office staff's jobs, and new wages and benefits contracts.[40]

All in all, in spite of the fact that technological research is being generally inten-

Ford Tanus 1980 and Ford Sierra RS Cosworth 1985 illustrate the rapidly increasing use of new materials in the car industry.



sified in metal industries and some corporations have been able to continue long standing efforts devoted to new equipment or production method innovations,[41] the overall picture that emerges from the recent event shows most of the mining TNCs badly hurt by the crisis and just initiating the adjustments that may prepare them to cope better with the general trends in high-technology and materials consumption patterns. Only a few among them took the right initiatives at due time and seem to have played an active, aggressive role amidst the on-going restructuring.

Turning now to the influence exerted by other institutional and market structure factors on the changing patterns of metal consumption, here again, it must be said that their influence is important, yet not at all undirectional or uniform, nor can unequivocal causal links be easily established. It is quite clear that the metals most negatively affected by changing patterns of metal consumption in industrialized societies (i e the general-use metals, the older non-ferrous in particular) are precisely those that account for the bulk of developing countries' mineral exports. Moreover, in most of those metals developing countries have significant shares in world exports and primary production (mining and first stages of processing), and their governments have significant equity participation, while the degree of market concentration is less pronounced than in speciality metals (Table 8). To the extent that present developing countries' position in processing and state ownership is in part the consequence of their exercising of permanent sovereignty over natural resources during the past two decades, one may be tempted to conclude that the declining consumption of general-use metals in developed market economies is also an answer or reaction to a new market organization and political environment.

Nevertheless, it has been already demonstrated that the declining intensity-of-use of general-use metals (aluminium excepted) is a very long term trend indeed, which in some cases started even before the Second World War. Besides, the share of developing countries in world exports and production of some speciality metals is important too, and the same is true regarding government ownership (in molybdenum and cobalt, for the information available in Table 8, and presumably in columbium and tantalum as well). In other words, if the changes in ownership and political environment had any explanatory influence it must be restricted to the *accelerated* decline in major general-use metals during the seventies, and even in that case the explanatory value should be shared with the overall economic slowdown and with the other factors related to changes in the composition of output, trade and materials con-

Table 8

Production, trade and ownership structures in metal industries (per cent)

	World reserves (share 1980)		World primary production (share 1979–1980)		World exports (LDC share 1981–1982	Import dependence[1]			Main source of DC's net imports (1979–80)			Government ownership[2]		Degree of concentration[3]	
	DC	LDC	DC	LDC		EC	Japan	US	EC	Japan	US	WW	LDC	I	II
Iron ore	35	31	39	27	46	87	89	25	52(LDC)	53(DC)	68(DC)	40	62	37	62
Steel			56	9	9	12	2	16	66(DC)	79(LDC)	87(DC)			21	33
Copper			54	21	58	80	80	20	68(LDC)	68(LDC)	58(LDC)	22	68	30	48
Blister			43	33	85							26	64	30	53
Mining	32	56	35	42	64							32	58	40	56
Lead			64	12	19	44	47	13	77(DC)	81(LDC)	50	20-25		36	55
Smelting			56	13	3										
Mining	63	18	52	20	30				54(LDC)	75(DC)	77(LDC)	15	7.5	36	549
Zinc			64	9	8	57	48	49	64(DC)	60(DC)	80(DC)	18	9	21	38
Mining	62	24	54	19	26							23	11	24	40
Tin	9	66	8	77	86	93	99	94	93(LDC)	99(LDC)	97(LDC)	30	35 min	68	89
Aluminium			69	10	16	45	70	73	78(DC)	59(DC)	81(DC)	18	45	42	70
Alumina			68	17	36				83(LDC)	100(DC)	78(DC)	15	21	52	72
Bauxite	30	67	42	47	71				53(DC)	67(DC)	100(LDC)	28	41	47	67
Nickel			57	13	35	87	100	88	58(DC)	73(LDC)	68(DC)	10	7	54	72
Mining	27	54	41	31								11	8	67	82
Manganese: ferro						99	99	100	95(DC)		88(DC)			77	94
ore	62	11	28	27	43				53(DC)	76(DC)	53(DC)				
Chromium: ferro						97	99	90	71(DC)	85(DC)	79(DC)	17	30	50	72
ore	69	31	42	22	30				50(DC)	56(LDC)	44(DC)				
Tungsten:															
ores and conc	26	9	30	23	30	78	85	48	63(LDC)	56(LDC)	67(LDC)			43	64
Cobalt: metal	13	62	26	62		100	100	100	53(DC)	61(DC)	60(DC)	82	89	77	93
Molybdenum:															
ores and conc	61	30	74	14	25	100	99		74(DC)	79(DC)		14	90	82	89
Vanadium	52	2	60	1		100	100	40	97(DC)	84(DC)	100(DC)				
Columbium: ferro									100(LDC)	93(LDC)	100(LDC)				
ores and conc	5	81	12	88		100	100	100	61(DC)	54(DC)	65(LDC)				
Silicon: ferro			61	10		44	43	20	84(DC)	62(DC)	64(DC)				
metal			80	1					99(DC)	96(DC)	98(DC)				
Titanium: minerals	74	25	83	9	9				97(DC)	55(LDC)	88(DC)				
		ilmenite				100	100	80							
metal	17	81	51	0							57(DC)				
		rutile													
Tantalum: ores															
and conc	19	75	36	59		100	100	100	n/a	77(LDC)	58(DC)				
metal									94(DC)	95(DC)	65(DC)				
Zirconium: ores															
and conc	65	24	85	3		100	100	68	97(DC)	99(DC)	98(DC)				
Lithium	28	64	75	5		100	100		100(DC)	100(DC)	net exp				

Abbreviations:

DC – Developed (market) countries.
LDC – Less developed (or developing) countries.
EC – European Community (ten).
WW – Western World.

Sources:
P C Crowson, *Minerals Handbook 1982–83, op cit,* for data on world reserves, Import Dependence, Maine sources of Imports and World Primary Production, completed in the last case by Metallgesellschaft , *Metal Statistics 1972–82, op cit,* and OECD, *The Iron and Steel Industry in 1982, op cit.* Pierre-Noel Giraud, *Geopolitique des Ressources Minières* (Paris, Economica, 1983) for data on LDC share in World Exports (Table 33) and on Degree of Concentration (Table 45). Marian Radetzki, *State Mineral Enterprises in Developing Countries, op cit,* Table 2.1 and pp 30–33: plus C Stobart, *Role of Government in Mineral Resources Development* (London, Institution of Mining and Metallurgy, 1983) pp 177–180, for Government ownership data.

Notes:

1 Imports as a percentage of domestic consumption (usually in all forms) plus exports.

2 Capacity (or production in some cases) proportional to government equity holding, in the case of Radetzki's estimations, Capacity under state equity (including minority) interest, in the case of Stobart.

3 Part of Production controlled by major firms. Level I: four major firms (five in molybdenum, manganese, chromium and tungsten). Level II: eight major firms (ten for above listed metals).

sumption, which together are contributing to the "maturity" state of many general-use metal's product-cycle in industrialized nations.

It may well be that what matters for any practical purpose is not so much the level of developing countries' shares in production or government ownership but rather the more or less conflicting characteristics of the nationalization processes that brought about them, which are in turn a function of the high importance accorded by developing countries to the general-use metals in their mineral development strategies, as well as of developed market economies and TNCs policies aimed to preserve a stable and cheap flow of mineral supplies. Tenants of the security of supplies factor usually bring as supporting arguments the share of developing countries in world reserves, the minerals import-dependency of developed countries, the main source of industrialized nations' minerals net imports, and the socio-political conditions and attitudes in developing nations.

To start with the latter, recently sophisticated country-risk evaluating techniques have undoubtedly improved and rendered more objective a debate traditionally too emotionally or ideologically charged in all the discussing parties; yet, here again, it should be remembered that the shift away from consuming most general-use metals started long before the climax of socio-political conflicts around them. On the geographical distribution of reserves, the picture is also mixed: developing countries' share is significant not only in some general-use ores but in some speciality ores as well. As for the import-dependency of main developed nations, it is considerably higher or even absolute in most speciality minerals and, by the way, most of the highly conflictive nationalization processes opposed developing countries to TNCs based in the *less* dependent industrialized country: the United States of America. In contrast, the situation appears much clearer if we look at the sources of developed nations net imports: by an overwhelming margin, the main origin sources of developed nations net imports of speciality metals are developed nations themselves.[42] Developing countries are in general more important as import sources for Japan, and this may help to understand better that country's singular policies concerning the Third World mineral development.

In short, the influence of institutional and market organization factors on the changing patterns of metal consumption, though evidently significant, does not seem to be as important or straight as that exerted by the current industrial restructuring and emergence of new technologies, together with the more fundamental, macroeconomic or inter-sectorial processes that account for the long cycles in economic growth, the level of development and industrialization patterns and, in particular, for the changing compositions of output, trade and materials-mix of products. The changes in ownership and localization of processing that favoured developing producers have presumably contributed to accelerate the shift in industrialized nations' consumption of metals away from the old metals of general uses. And the particular concern of developed market economies and TNCs for securing supplies appears as a very singular and long standing one.[43] This is reflected especially in the high level of control by developed countries, as a group, of their import flows in most of the highly strategic and demanded speciality metals.

Concluding remarks: implications for international investments and challenges for developing countries

The long term declining trend in the overall consumption of metals in favour of other materials may have contributed to the well-known lasting decrease in the share of mining within the sectoral composition of the Western world's foreign direct investment. The early 1980s witnessed a further decrease in that share.[44] The special intensity of that trend in the case of the old metals of general uses, may have in turn contributed to the low share of developing countries in the total investments by mining and processing TNCs.[45] Nevertheless, this share went up in the early 1980s, from 33 per cent to 41 per cent in the case of the book value of US mining and smelting investments abroad between 1980–83, from 64 per cent to 72 per cent in the case of Japanese accumulated stock of mining and processing FDI between 1980–82, and from 8 per cent to 38 per cent in the case of the Federal Republic of Germany net annual flows of FDI in mining and smelting between 1979–81.[46]

As this happened during recession years generally characterized by low levels of new mining investments elsewhere, by mines and plants closings, and by large projects being scaled down, postponed or cancelled, one might wonder if a reversal of the trend of previous decades, when foreign direct investment in mining was flowing away from developing countries, is occurring since the early 1980s. However, the period elapsed is yet too short to clearly answer this question. Some short-term factors might have acted on those recent figures, as the impact of the overvalued dollar and related exchange rate changes on operations and income abroad, for instance.

The differentiated patterns of metal consumption by category of metals are, however, clearly influencing the current sectorial distribution of mining investments. Information provided by recent surveys[47] shows that besides gold, which has enjoyed good years in these speculative recent times, the light (aluminium) and speciality metals have been relatively preferred by TNCs and international investors in the early 1980s, and most of these investments have taken place in developed countries. Regarding the old major metals of general uses, the recent preferences of TNCs and international investors seem to have gone to polymetallic deposits, in order to spread risks. In this case investments are located both in developed and developing countries. The intervention by government or state-owned firms is essential for explaining the rest of the recent investment activity in developing countries' old major metal deposits, which basically corresponds to the completion or continuation of projects started in the second half of the seventies.

As for the specific influence of the current restructuring and new technologies on the location of mineral investments, the afore reviewed outstanding characteristics of high-technology and the increasing use of more continuous, integrated or automated production methods, may have as one general implication the modernization of developed countries' metallurgy industries and the reinforcement of their comparative advantages for the location of high value-added stages of processing. Another related general implication being the increased advantages derived from locating processing plants near the consuming, end-using industrial markets. This may work in favour not only of the industrialized countries but of a small group of developing countries (mainly the NICs or semi-industrialized) as well.[48]

Nevertheless, the significant flexibility of production scales and combination of fabrication lines with automated systems of remote control, that the new technologies allow for, make their accommodation to smaller markets feasible. This makes a more widespread location of processing plants in the Third World possible, to serve local and/or regional markets.[49] In this sense, Alcan Aluminium's Annual Report for 1982 says:

> "Developing markets cannot be economically served by the high-volume production facilities used in mature markets. The multiple variety of small orders typical of a developing country must be served by a flexible capacity, capable of adjusting outputs to demands, and of growing by incremental stages."[50]

Another factor that may stimulate the location of processing plants in developing nations is energy costs. Even though the long run tendency of new technology applications is to reduce energy consumption per unit of output, it has been previously seen that, for the moment at least, metal processing is a high energy consuming industry and its use of electricity has been rising in recent years. But developing countries compete in this respect with some minerals-rich developed countries that are also very well-endowed with abundant and cheap energy sources, e g Canada. For this reason, Canada is currently receiving increasing attention from international investors and its energy availability has contributed a lot to the growing competitiveness of some Canadian TNCs, such as Alcan.[51]

In other words, the new technologies and on-going restructuring do not seem to predetermine a rigid pattern of minerals processing location, though there are strong reasons to assume that the location-specific advantages of industrialized countries may be strengthened concerning the high value-added stages of processing. In contrast, in the extractive side of the non-fuel minerals industry, mining, the location-specific advantages of developing countries seem more well established, generally because the high quality of their ores, and particularly for those metals with reserves located in developed countries are almost saturated by the action of extensive exploitation, such as bauxite, cobalt, chromite, manganese, tin and platinum group.[52] In this respect, it is worth noticing the forecasts estimating that 60 per cent of all the required investments in processing during 1981–95 would take place in developed countries, whereas 67 per cent of all required investments in mining would be located in developing nations.[53] The metals industry's international division of labour may therefore continue for quite some time, with the bulk of the developing nations supplying mineral raw materials, sometimes processed up to an intermediate level, and developed market economies concentrating most of the high value-added, final processing.

The new technologies do, however, open some doors or rooms of manoeuver for a more extensive spread of metals processing worldwide. Yet presumably a small group of more advanced developing nations are going to take advantage of those opportunities in an easier and faster way. For most developing metal producers, some very difficult options are on the agenda concerning their mineral development strategies and their relationships with TNCs and consuming nations. In this respect, even though many mining TNCs have been severely affected by recent events in the industry, their ownership-specific advantages will be enhanced in the long run as a result of the pressures for modernization and adoption of new technologies coming from the general restructuring process. The technical and financial barriers-to-entry are thus rising in the metals industry. This is an important change for an industry that in the last two decades suffered from a relative technological stagnation while developing countries progressed in their direct access to mining and processing techniques. And this is happening at the same time that many developing metal producers witness their bargaining position weakened by the impact of the recent crisis.

On the other hand, it is well true that many metal producers in developing countries now possess new assets in their favour:

- their national production and management capabilities are substantially improved compared to the past.
- their nationally-owned firms are today an established fact in the industry.
- the prior period of sharp conflicts or tensions is apparently leaving the place to an epoch of closer and more stable working relationships between developing state-owned enterprises and TNCs, as expressed in the multifacetic modern forms of association between them.

To these new realities, should be added

the ever present industrial and military need by developed market economies for the Third World's mineral endowments in spite of their declining consumption of metals. And this need will continue to be expressed in different government procurement policies and TNCs strategies, as it has been in the past. Developing metal producers do have, therefore, an array of actual or potential leverages in order to play a prime role in the industry and to participate in the benefits of the current industrial and technological changes.

Perhaps the single most effective leverage in the long run may be the prospects for a faster growing market for metals in the developing area itself. As has been correctly indicated elsewhere,[54] the realization of that prospect exiges important actions at the level of international economic relations and cooperation for development, oriented to facilitate the prompt restoration of economic growth and industrialization in large segments of the developing world. For developing mineral producers this means a challenge of progressively reorienting the destination of their exports towards the fastest growing markets, under the framework of regional programmes of cooperation or integration. Strengthening regional integration or cooperation schemes among developing nations is equally a fundamental step if their goal is to participate in the current technological changes and further develop their metallurgies and metal fabricating industries.

The long term prospects of demand for the old metals of general-uses also imply fundamental decisions by the developing mineral producers about the very definition of their future mineral development strategy. To rely on those metals in order to sustain financially an overall industrialization process may become harder and harder with the course of time, as their historical peaks of consumption intensity may not be reached even by the faster growing markets of the upcoming future. Even assuming that past demand performances will be met again, it is now an assimilated experience that mineral exports-led strategies have been associated with less economic growth and industrialization than other growth strategies in the developing world.[55] And the speciality-use metals with better demand prospects would neither in volume nor in value sustain an overall economic growth in most developing nations. The main challenge is therefore an imaginative redefinition of the role the mineral sector must fulfill in order to serve the aspiration for national and regional development in poor nations.

Notes and references:

[1] See *Structural Change in the Metal Industries: Understanding the Role of Demand – A program of Research* (Pennsylvania State University, Department of Mineral Economics, 1984), p 2. Fortunately, Prof Tilton is currently launching a research programme which is aimed at filling the knowledge gap on such an important subject.

[2] UNIDO, *Mineral Processing in Developing Countries* (Vienna, E, 80, II.B.5), p 2; The World Bank, *Outlook for Primary Commodities* (Washington, DC Commodities Staff Working Paper 9, 1983) Tables 41 and 45, and *Commodity Trade and Price Trends,* 1983–84 edition, Table 7.

[3] See Wilfred Malenbaum, *World Demand for Raw Materials in 1985 and 2000* (New York, McGraw Hill, 1979) Chapter IV.

[4] World Bank, *op cit,* p 69.

[5] See the sources in Table 5, below.

[6] Wassily Leontieff, James C M Koo, Sylvia Naser and Ira Soh, *The Future of Nonfuel Minerals in the US and World Economy* (Lexington, Mass, Lexington books, DC Health and Co, 1983), Chapter 6, Tables 6.10 and 6.11, and Appendix G.

[7] *Op cit,* p 5–7.

[8] A pertinant digression here is for pointing-out the little knowledge available about the metals-consuming intensity of the so-called "informal economy", which importance in developing countries is estimated to be rising very rapidly. Given the spread of very business-oriented workshops or small factories within that kind of economy, not uncommonly connected to formal plants and businesses through quite tied yet clandestine linkages, it would not be too surprising that the "informal economy" might have an actual metals-consuming intensity higher than what can be imagined at first glance.

[9] See, for instance, H H Landsberg, "Materials: Some Recent Trends and Issues", in P Abelson and A L Hammond (eds), *Materials: Renewable and Nonrenewable Resources* (Washington, DC, American Association for the Advancement of Science, 1976), and W A Vogeley, *Non-Fuel Resources,* A Report to Resources for the Future (Washington, DC, 1976).

[10] W Leontieff *et al, op cit,* Chapter 8 and Appendix G.

[11] UNCTAD, *Trade and Development Report 1982* (Geneva, E.82.II.D.12) Table 31; UNIDO, *Industry in a Changing World* (Vienna, E.83, II.B.6) Chapter 7, and Tables VII–6, VII–7 and p 213.

[12] UNCTAD, *op cit,* Chapter 3, Tables 20 through 22.

[13] Garri J, Schinasi, "Business Fixed Investment: recent developments and outlook", *Federal Reserve Bulletin,* January 1983, *Survey of Current Business,* January 1984, Table 6.

[14] Felicity Marsh, *Japanese Overseas Investment: the new challenge* (London, The Economist Intelligence Unit – Special Report No 142, April 1983), p 2.

[15] A recent survey on British manufacturing firms shows that in 1983 almost half of them (30 per cent in 1981) were already using or have actual programmes to use high-technology equipment. The Federal Republic of Germany announced last year an ambitious programme to foster its fabrication of high-technology electronic equipment, through the combination of public procurement policies and decentralized linkages between firms and research centers. And the promotion of small-or-medium sized firms in high-technology activities is a key component of

the present economic policy in France. See Jim Northcott and Petra Rogers, *Microelectronics in British Industry: the pattern of change* (London, Policy Studies Institute, 1984); *Business Week,* 1984-04-09, pp 41–42; Shawn Tully, "Mitterrand's Risky New Right Turn", *Fortune,* 1984-04-30, pp 164 and 170.

[16] For valuable industry case studies supporting these findings see, for instance, Rafael Kaplinsky, *The impact of electronics on the international economic setting: the use of computer-aided design* (Vienna, UNIDO/15.257, 1982); United Nations Centre on Transnational Corporations, *Transnational corporations in the international semiconductor industry* New York, ST/CTC/39, 1982); Frederick Williams, *The Communications Revolution* (California, Sage, 1982); and Olivier Pastré and Joelle Toledano, *Généralisation de l'Automation et Effects sur l'Emploi* (Paris, Université de Paris-Nord, Centre de Recherches en Economie Industrielle, October 1978).

[17] Military spending in research and development represented around one third of the total US spending in R&D in 1984. The Pentagon contracts and procurement programmes have considerably attenuated the early 1980s recession impact on the aerospatial, computer, scientific instruments and communications industries. And US military spending in durable goods projected until 1987 may account for almost half the forecasted growth in the aerospatial industry, as well as for around 20 per cent of estimated growth in the cases of the electronic, refining and metals fabrication industries. See, Bruce Steinberg, "The Military boost to Industry", *Fortune,* 1984-04-30, pp 44–45.

[18] Between 1967 and 1982, the US mining industry increased the amount of electricity used to produce each dollar of GNP by 0.6 kwh. The increasing use of processes requiring electricity in benefication and smelting, the need for more electricity use as the quality of ore decreases, and the preference for smaller plants in lieu of large plant, being among the specific factors contributing to such a trend. See US Bureau of Mines, *Minerals and Materials,* April/May 1983, Tab 4 and p 5.

[19] Nevertheless, it is worth mentioning that most special use metals have demand movements even more cyclically pronounced than those of major non-ferrous metals. In 1980–83, for instance, in spite of the fact that US investment in high-technology equipment continued to rise relatively fast, the demand in that country for high-technology or special alloy metals declined significantly more (in a range of between –6.4 per cent annual rate for beryllium to –22.8 per cent annual rate for molybdenum) than for non-ferrous metals (ranging form –6.9 per cent for tin to a positive 1.2 per cent for lead). See corresponding data in US Bureau of Mines, *Minerals Yearbook,* 1981, 1982 and 1983 issues.

[20] Not incidentally, a recent analysis of inter-industrial structural changes in the United States economy between 1972 and 1979 concludes that industrial minerals have been far less impacted than non-ferrous metal ores mining and primary manufacturing industries, as well as than primary iron and steel manufacturing. See United States Bureau of Mines, *Minerals and Materials,* April/May 1983, Table 3 and p 3.

[21] K Hoffman and R Ruch, *Microelectronics and clothing: the impact of technical change on global industry* (Geneva, ILO, 1984).

[22] Louis J Sousa, "A Summary assessment of projected technological innovation in the United States copper industry", *Minerals and Materials* (US Bureau of Mines, April–May 1983), pp 36–48.

[23] Francis Lecroisey, "New Materials and Energy", *TOTAL Information,* No 96, 1983, p 31.

[24] Metallgesellschaft A G, *Metal Statistics 1972–1982* (Frankfurt, 1983), p V, Table 2.

[25] Examples are two plants located in the Federal Republic of Germany and in France, respectively, through joint ventures concerted by the Chilean firm CODELCO; as well as the joint venture between Zambia Copper Corp, and the French firm Thompson Brandt. See Juan Carlos Bossio, *El Cobre, la Restructuración Industrial y las Nuevas Tecnologías* (Lima, Conference paper submitted to the Consejo Nacional de Ciencia y Tecnología, July 1984) pp 3–4.

[26] Comisión Chilena del Cobre, *Boletin Informativo Internacional,* Vol 5, No 4 (Santiago, December 1983), pp 1–3.

[27] In respect to the present crisis in the United States copper industry, a lot has been said about the responsibility of imports from state-owned, subsided developing country' producers. Nevertheless, according to a recent study the major factor behind that present crisis may rather be the dollar over-valuation and the resulting impact on exchange rates, that have rendered the copper of many developing countries more competitive internationally and have made the full capacity utilization a rational policy through depression for both private and state-owned producers in those countries. See Marian Radetzki, *State mineral enterprises in Developing Countries: their impact on international mineral markets* (Stockholm, Institute ofr International Economic Studies, February 1983) pp 210–212.

[28] Luke H Baumgardner and Frank X McCawley, *Aluminium* (US Bureau of Mines, Commodity Profiles, 1983) pp 1 and 19.

[29] Eric A Trigg, "Key Developments and trends in the world's bauxite and alumina industry", *Minerals and Materials* (US Bureau of Mines, February–March 1984) p 35 and Figure 1.

[30] Christian Gillen, *Analysis of the Crisis in the Iron and Steel Industry* (Consultancy report to UNIDO – Negotiations Branch, Vienna, March 1984), pp 5–6 and 15.

[31] US Bureau of Mines, "Declining domestic capacity to produce and process materials: steel and ferroalloys", *Minerals and Materials,* October–November 1983, pp 34–35.

[32] Frederick J Schottman, *Iron and Steel* (US of Mines, Commodity Profiles 1983) pp 3 and 11.

[33] See, for instance, the data presented by John M, Stopford and John H Dunning, *Multinationals – Company Performance and Global Trends* (London, Macmillan, 1983); and by the UNCTC, *Trans-*

national corporations in world development – third survey (New York, E.83.II. A.14).

[34] On the concept of ownership-specific advantages and multinationality as resulting from a firm's capacity to internalize them, see John H Dunning, *International Production and the Multinational Enterprise* (London, George Allen and Unwin, 1981) pp 25 and 27.

[35] The share of state-owned firms in the total sales of the 500 largest western world firms increased from 2.4 per cent in 1962 to 7.8 per cent in 1979, and 40 among them operated virtually as transnational firms in 1981 with sales of G USD of more each. (UNCTC, *op cit,* E.83.II.A. 14, pp 50–51). The share of public expenditures in the GDP of developed market economies increased persistently during the last two decades, and especially in the seventies: 29.3 per cent in 1961, 33.3 per cent in 1971 and 40.9 per cent in 1981 (The World Bank, *World Development Report – 1984,* Table 2.3).

[36] Stocks of main mining and processing TNCs registered record lows (second after construction firms) at the New York Stock Exhange between 1981–1982. 1983 was a booming year for the New York and London metal markets, but the wave of high-risk speculative investments or operations resulted in unexpected unfavourable price movements in 1984. See, *The New York Times,* 1982-08-08, p F2; *Financial Times,* 1983-10-11, p 24 and 1984-10-09, p 13.

[37] See US Bureau of Mines, *Minerals and Materials,* October–November 1983, Table 1, p 1; *Survey of Current Business,* April 1984, Table 6.20 and *Business Week,* 4/30/84, p 74.

[38] Anne B Fisher, "The Decade's Worst Mergers", *Fortune,* 1984-04-30, p 266.

[39] See Eugene P Seskin and J Steven Landefeld, "Plant and Equipment Expenditures 1984", *Survey of Current Business,* January 1984, Tables 1 and 2.

[40] For instance, Phelps Dodge negotiated new wages and benefits that cut labour costs by about 10 per cent. *Business Week,* 1983-09-26, p 39.

[41] Examples of recent Japanese mining firms innovations regarding the use of microprocessors (Komatsu Ltd), continuous flotation system (Dowa), new hydraulic drifters and jumbos (Furakawa) and continuous copper smelting and converting process (Mitsubishi), are given in Robert J M Wyllie, "Japan: equipment and know-how in the world of mining", *World Mining,* October 1983, pp 71–89. For the Australian case, see R Lane White Michael P Sassos and C Brian Gomez, "Australian Mining: innovating to stay competitive", *Engineering and Mining Journal,* November 1983, pp 38–43.

[42] Developed country' governments and TNCs are nonetheless concerned by the extreme concentration of some speciality metal's supplies from one or few countries. This is the case of cobalt, for instance, which substitution by other metals has been stimulated by supply disruptions and sharp price increases in 1978–1980, due to political and economic problems in Zaire, the biggest supplier. And in the cases of vanadium, chromium, manganese and platine, the problem is the very strong concentration of reserves and production in the USSR and South Africa.

[43] In a previous work, we have already discussed the role of concern over security of supply in explaining the shift of US and some European direct investments abroad away from developing countries and toward "safe" industrialized countries (such as Canada, Australia, South Africa, and the US itself), that occurred since the 1950s. See UNCTC, *International Investments in the Non-fuel Minerals Industry: main trends and recent developments* (New York, November 1984), pp 5 and 10.

[44] From 6.0 per cent to 5.8 per cent in the case of US investment abroad during 1980–82. From 28.3 per cent to 26.2 per cent in the case of Japanese foreign investments in the same period. And from 19.7 per cent to 12 per cent in the case of the Federal Republic of Germany, between 1979–81. UNCTC, *idem,* Table I-5.

[45] 15.7 per cent during 1966–75 and 13.5 per cent in 1976–80. Developing countries' share in US book value of direct investment in mining and smelting decrease from 53 per cent in 1960 to 33 per cent in 1980, and oscillated between 15–30 per cent of total mining expenditures made by major European TNCs during 1966–80. Japan being the exception, as developing countries increased their share in that country total mining investments, from 50 per cent before 1973 to 64 per cent in 1980. UNCTC, *idem,* Table I-2 and p 12.

[46] UNCTC, *idem,* Tables I-3 and I-5.

[47] See *Mining Magazine,* January 1984, pp 58 and passim; and UNCTC, *idem,* pp 19–20.

[48] An example is the Nippon Kokan technical license agreement with ASEA AB, to manufacture in the ASEAN area hot and cold isostatic presses, used in fabricating new materials such as fine ceramics and sintered alloys. *Industrial Minerals,* March 1984, p 75.

[49] For a discussion of this and other counteracting factors to the general tendency in favour of locating high value-added mineral processing in industrialized nations, see Fernando González-Vigil, "Restructuración Internacional e Industrialisación Periférica", *Economía de América Latina* No 12 (Mexico City–Buenos Aires, CIDE-IPAL, Second semester 1984), pp 43, 45–46.

[50] As quoted in *Mining Magazine,* July 1983, p 3.

[51] Andrew C Brown, "Alcan Shakes the Aluminium Market", *Fortune,* 1983-02-21, pp 124s; *Business Week,* 1984-01-23, p 54.

[52] Raymond F Mikesell, *New Patterns of World Mineral Development* (London–Washington, DC, British–North American Committee, 1979), pp 10–11.

[53] The World Bank, *op cit,* Tables 38 and 40.

[54] Herbert H Kellog, "Metal Production: a time to reflect", *Journal of Metals,* May 1983.

[55] For a comparison of the relative economic performances of mineral and non-mineral developing economies, see Pierre-Noel Giraud, *Géopolitique des Ressources Minières* (Paris, Economica, 1983) pp 652–655. ■