The Materials Revolution and Economic Development[1]

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1. Introduction: The Significance of Advanced Materials[2]

The revolutionary transformation in Materials Science and Engineering (MSE) in the 1970s and especially in the 1980s, and the consequent spawning of new advanced materials, is of fundamental importance to the world economy. It is of equal significance to the arrival and diffusion of information technologies in industrialised and industrialising economies alike. For many developing economies still dependent on the primary commodity export sector, it threatens to have serious implications in the years to come.

Throughout the 1980s, much attention has focused on the impact of information technologies on the Industrialised Advanced Economies (IACs) and the consequent implications for industrialisation and economic development. Much attention has already been paid to the impact of the microelectronics revolution on the trend towards systemic Computer Integrated Manufacturing (CIM), the prime importance of organisational change if maximum gain is to be derived from the new technology, and the rising importance of multiskilling, responsible autonomy and quality control on the shop floor.[3] An understanding of such changes is vital for industrial and trade strategy in developing economies.

The materials revolution has been little analysed and understood within the economics profession and even less so in relation to economic development. The quantum leap in the scientific and technological capabilities of the materials sector will have wide repercussions in an expanding array of mineral, metal, agricultural and tropical commodities of importance to developing economies, and will alter the parameters within which industrialisation strategies can be devised and operate successfully.

In the 1990s it is likely that the world economy and industry will be shaped by three major technology families: advanced materials, microelectronics and biotechnology. It is the materials producing sector which conditions, constrains and facilitates innovation in high-technology sectors and is a central part of the move towards more flexible manufacturing technologies and organisation of production.

2. The Tendencies and Consequences of the Materials Revolution

2.1 The origins and characteristics of the revolution in materials science and engineering (MSE)

The revolutionary advance in quantum physics during the period 1895-1930s greatly expanded our ability for scientific study and understanding of the structure of solids, both crystalline and amorphous, and of the connections between the structure and properties of matter. Nevertheless, these advances could only be taken full advantage of relatively recently.

By the late 1980s, materials science and applied research achieved such greatly enhanced capabilities for manipulating and building materials inconceivable at the beginning of the decade. For example, at the atomic level:

> . . . instruments such as the scanning tunnelling microscope and the atomic resolution transmission electron microscope can reveal, with atom-by-atom resolution, the structures of materials. Ion Beam, Molecular Beam, and other types of equipment can build structures atom layer by atom layer. Instruments can monitor processes in materials on time scales so short that the various stages in atomic rearrangements and chemical reactions can be distinguished. Computers are becoming powerful enough to allow predictions of structures and of time-dependent processes,

[1] My thanks to David Evans for comments and suggestions on an earlier draft.

[2] This article is based on chapter one of Kaounides (1990b). For a more comprehensive coverage of the subject matter and greater elaboration of the arguments, the reader is referred also to Kaounides (1989a, 1989b and 1990a). It should be pointed out that the arguments in this paper mainly concern agricultural and mineral raw materials, rather than food production which, of course, is coming increasingly under the influence of biotechnology. Nevertheless, there exist significant overlap and cross-sectoral linkages in the pure science base, industrial sectors, materials and processes.

[3] We examine in detail the interconnections between advanced materials and information technologies in Ch. 2, and the role of materials in the new manufacturing and market circumstances associated with the emerging post-Fordist industrial paradigm in Ch. 3 of Kaounides (1990b). For an elaboration of the JIT organisation of production and its relation to new flexible automation technologies currently diffusing in industry, see: Kaplinsky (1985, 1988 and 1989) and Schonberger (1982, 1986).

starting with nothing more than the atomic numbers of the constituents

[US National Research Council 1989:74][4]

For centuries materials synthesis and processing relied on empirical observation. More recently, enhanced theoretical insights offered *qualitative* guidelines to modelling and prediction. Materials scientists are now able to provide *quantitative* theoretical modelling guidelines in the design and processing path of materials. They can now improve the processing and properties of *existing* materials. Entirely *new* materials with predictable properties can be designed at the atomic or molecular level and processed so as to acquire the characteristics or combination of properties required in a specific application. It is the ability of material scientists to intervene at the atomic or higher levels that lies at the core of the materials revolution.

[4] The arguments herein owe much to this excellent and authoritative report.

New Advanced Materials[5]

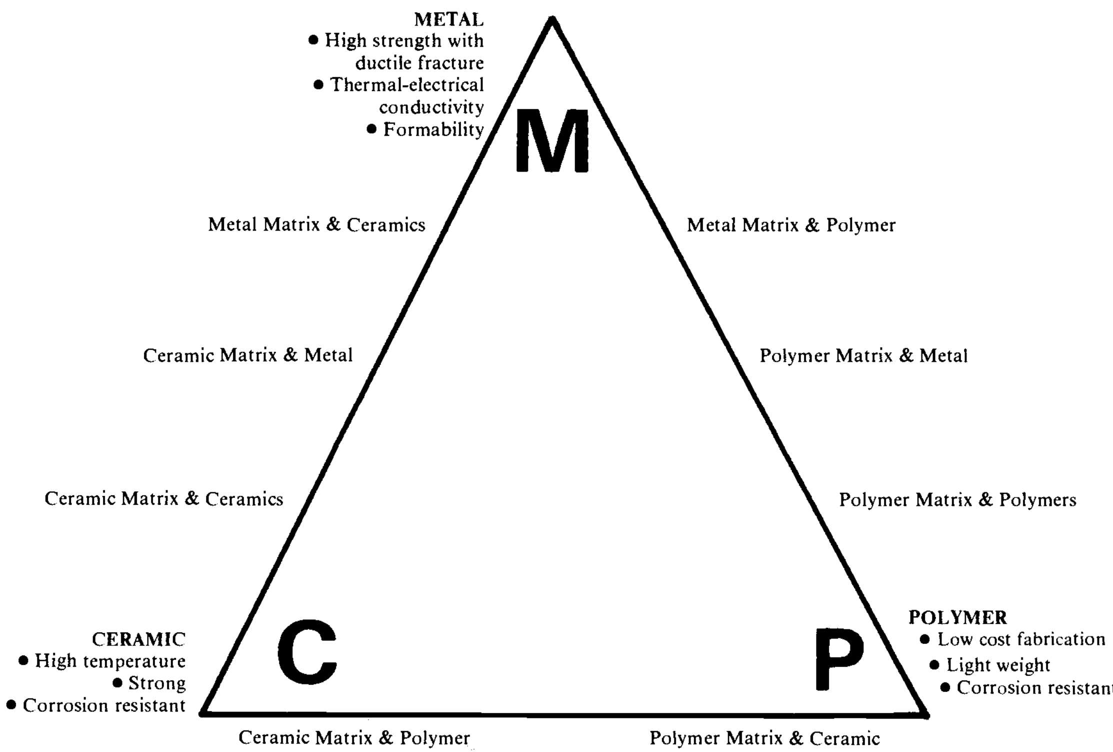
A consequence of these enhanced powers has been the proliferation of new interconnected clusters of knowledge-intensive, high-performance materials such as advanced metals, advanced ceramics, engineering plastics and advanced composite systems, as shown in Figure 1 below.

The arrival of advanced material capabilities is leading to an acceleration in the rate of materials and product invention and innovation. With the more rapid obsolescence of products and processes, it is likely that no one material will dominate the market place for long periods, as has been the case until now. Nevertheless, advanced composite systems with a synergistic combination of materials families and properties meeting demanding performance criteria may become the preferred materials in many applications in the first decades of the next century.

[5] For careful attempts to define and classify new advanced materials, see US Bureau of Mines (1987).

Figure 1

Advanced Material Systems

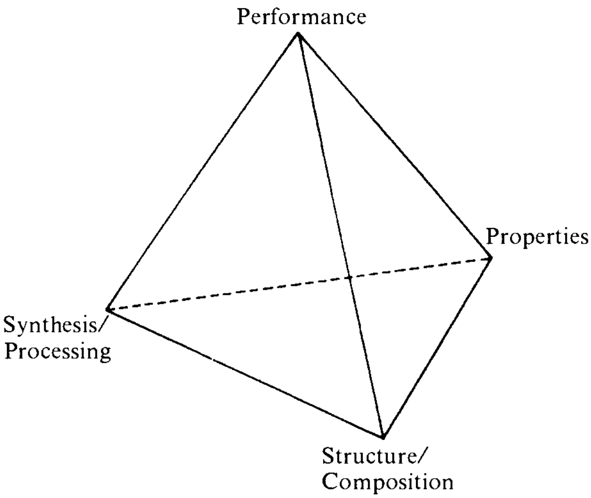


Source: Alcoa, Position Paper from the 10th Biennial Conference on National Materials Policy, 1986.

Characteristics of Modern MSE

Modern MSE has emerged from diverse fields. The four main elements comprising MSE, namely structure and composition, properties, synthesis and processing, and performance, in the form of a tetrahedron are shown in Figure 2.

Figure 2 **The Four Elements of Materials Science and Engineering**



Source: Materials Science and Engineering for the 1990s, National Research Council, Committee on Materials Science and Engineering, 1989, p.29.

Materials research and development now requires that materials scientists become closely involved in the processing and fabrication stages of production. The structure of materials consists of the arrangement of atoms into crystalline arrays or disordered structures which determines properties and performance. The controlled *processing* path a material follows will affect microstructure and thereby properties and performance in use.

Underlying:

(a) the discovery of new materials with new properties (e.g. the high temperature super-conductors in 1987),

(b) improvements in the control of structure and composition, and, hence, properties, of known materials, and,

(c) progress in the development of materials processing and manufacturing technologies, lies *synthesis*. Synthetic capabilities in the chemical and physical combination of atoms and molecules to form materials is integrally connected to the processing and manufacture of solid materials. Materials synthesis, processing, fabrication and manufacture are merging.

The nature and complexity of the problems in materials synthesis and processing is such that a team effort across many disciplines and previously separate research teams is now required. MSE is a *multi-disciplinary* science requiring inputs from solid-state physics, chemistry, metallurgy, ceramics, composites, surface and inter-face sciences, mathematics, computer science, metrology and engineering. These multi-disciplinary aspects are crucial elements of the new materials era.

2.2 Some consequences of the emerging materials scientific and engineering base

The modern MSE approach is becoming both necessary and applicable to *all classes of materials*. It involves a deep understanding of *both* pure science, across many disciplines, and of the fundamentals of processing and fabrication technology. Synthesis is emerging as a crucial determinant of progress in pure materials research. Moreover, competence in materials *synthesis and processing* is the critical component in international competitiveness of national industrial structures and industrial branches engaged in both traditional and high technology activities. Increasingly, the synthesis, design and processing of a material must be integrated with the design and manufacturing path of the end-user. Materials design and Computer-Aided-Design and Manufacture of the end product require close integration and iterative interaction. MSE and the emerging methods of organising production are forging links between producers and users of materials and components with serious repercussions on the organisation, location and global sourcing strategies of industry. As we enter the 1990s, the enhanced science or knowledge content of materials and associated processing technologies implies that empirical and craft-related approaches are becoming inadequate and obsolete across the materials spectrum.

The new MSE will have far-reaching effects. The mechanisms of incorporating scientific insight in the productive sphere and the educational, infrastructural and industrial organisation requirements of the new materials age, the global restructuring of basic industries and the opportunities open to developing economies to enter, or remain, at particular stages in the transformation of materials into useful structural and functional components and final products are all affected.

3. The Materials Revolution and Economic Development

3.1 The primary commodity sector

A central organising idea in development in the post-

Table 1	**Share of Primary Commodities and Manufactures in Total Exports, 1970, 1980, and 1984**

	Exports, fob, (billion current US dollars)			*Percentage of total exports*		
	1970	*1980*	*1984*	*1970*	*1980*	*1984*
Developing Countries						
Primary Commodities						
America	11.2	45.1	43.1	65.9	43.3	38.2
Africa	8.3	23.2	18.3	70.3	23.8	30.4
Asia	9.3	47.4	44.2	43.1	21.1	18.7
Others[2]	1.9	7.3	7.9	44.2	27.9	28.1
Total	30.6	23.0	113.5	55.9	27.2	25.9
Petroleum[3]						
America	4.1	41.5	43.8	24.1	39.9	38.8
Africa	1.8	50.2	33.8	15.3	51.6	56.1
Asia	4.5	88.5	69.9	20.8	39.4	29.6
Others[2]	—	1.4	1.1	—	5.3	3.9
Total	10.5	181.6	148.6	19.2	40.2	34.0
Manufactures[4]						
America	1.7	17.5	26.1	10.0	16.8	23.1
Africa	1.7	23.9	8.1	14.4	24.6	13.5
Asia	7.8	88.6	122.2	36.1	39.5	51.7
Others[2]	2.4	17.5	19.0	55.8	66.8	68.0
Total	13.6	147.5	175.4	24.9	32.6	40.1
Total Exports						
America	17.0	104.1	112.9	100.0	100.0	100.0
Africa	11.8	97.3	60.3	100.0	100.0	100.0
Asia	21.6	224.5	236.3	100.0	100.0	100.0
Others[2]	4.3	26.2	28.0	100.0	100.0	100.0
Total	54.7	452.1	437.5	100.0	100.0	100.0
Industrial Market Economies						
Primary Commodities[1]	49.0	241.9	210.9	22.4	19.9	17.6
Petroleum[3]	7.6	90.3	95.4	3.5	7.4	7.9
Manufactures[4]	162.1	884.8	894.0	74.1	72.7	74.5
Total Exports	218.7	1,217.0	1,200.3	100.0	100.0	100.0

[1] SITC 0 plus 4 and 68 (includes non-ferrous metals).

[2] United Nations data for other developing countries is obtained as a residual figure and does not necessarily reflect the actual export performance of the countries/areas involved.

[3] SITC 3.

[4] SITC 5 to 19 excluding 68 (excludes non-ferrous metals).

Source: Commodity Trade and Price Trends, World Bank, 1987-88 edition, Table 1.

war period has been the leading role assigned to the primary export sector as an 'engine of growth'.[6] Primary producers participating in the international division of labour on the basis of comparative advantage would obtain both static efficiency and dynamic gains through higher income, savings and investment, creating the potential for a diversified industrial structure and sustained growth.

However, manufacturing exports have turned out to be a more reliable 'engine of growth'.[7]

The value of non-fuel primary commodity exports as a percentage of total developing country exports has fallen from 55.9 per cent in 1970 to 25.9 per cent in 1984, while manufactures have risen from 24.9 per cent to 40.1 per cent and petroleum from 19.2 per cent to 34 per cent, as shown in Table 1. Since 1984, the share of petroleum exports has fallen dramatically with the collapse of oil prices after 1985/86. Clearly, rising importance of manufacturing and fuel exports bears a large part of the responsibility for the declining dependence of developing countries as a whole on non-oil commodity exports. Factors operating on the supply, demand and prices of commodities have also contributed. But these figures mask considerable variation between countries. It is a sobering fact that despite progress on manufacturing exports in a handful of developing countries, most developing economies still remain dependent on primary commodity production and exports for their foreign exchange earnings. The primary commodity export sector, with its varying but generally low degree of downstream processing, has remained for most developing countries the backbone of economic activity and of their development prospects.

Recent UNCTAD calculations [1987a:83] indicate that agricultural and mining production is the single most important component of GDP for all developing countries except the handful of fast growing manufacturing exporters, and that for most, the share in GDP is more than 30 per cent as compared to less than 10 per cent for 95 per cent of all developed market economies. Moreover, for more than 80 developing countries the share of primary commodities in total export earnings is above 50 per cent. In many cases, and especially for low income countries, it is also accompanied by a high degree of export concentration on a limited number of primary products. In 1986, the share of non-oil primary commodity exports in total exports of the 42 least developed countries was 65 per cent.[8] In the period 1982-85, the majority of Asian economies derived 40 per cent of their export earnings from non-fuel primary commodities, whereas the figure was over 70 per cent for the majority of Latin American countries, and more than 80 per cent for a majority of African countries [UNCTAD 1988b:12].

Following the relatively strong market position of commodities in the 1970s accompanied by a large expansion of capacity, the 1980s have until recently witnessed oversupply in many commodity markets, coupled with a slump in prices. The worst hit region was sub-Saharan Africa, where the combination of falling prices and stagnation in primary export volumes led to a sharp decline in real purchasing power. In Latin America and South Asia purchasing power also declined due to insufficient growth in the volume of primary export in the 1980s. In contrast, the volume of primary commodity exports increased in East Asia, counteracting the falling prices and maintaining purchasing power.

Declining total commodity export earnings until 1987 have meant a worsening overall trade performance, despite the rise in manufactured exports in 1985 and 1986 for developing countries. Falling commodity prices and export earnings have led to increasing need for external borrowing.

The outstanding debt of these countries nearly doubled between 1980 and 1985 so that whereas 75 per cent of non-fuel primary export earnings were required to service debt in 1980, by 1985 this had risen to 130 per cent. By 1986 debt service payments accounted for 33 per cent and 44 per cent of the total export earnings of Africa and Latin America respectively.

Another aspect of the disappointing performance of commodity exporters often cited concerns the long-run deterioration in the real prices of their commodities. In the first half of the 1980s, the net barter terms of trade of primary commodity exports by developing countries declined by an annual average rate of 3.9 per cent, such that by 1986 they were less than half the highs attained in 1950. UNCTAD's index of prices of commodities of export interest to developing countries deflated by the price index of manufactured goods declined dramatically from 1985 to 1987, and despite the small rise in the first eight months of 1988, the index was still only two thirds of its value in the base period of 1979-81. Thus the experience of the 1980s simply reinforced the long-run deterioration in the real purchasing power of primary exports by developing countries, evident[9] since the 1950s, despite some intermittent gains. The onset of new materials technologies and the diffusion of advanced materials could in the 1990s exacerbate the

[6] See Lewis (1980). For the debate between trade as an 'engine of growth' vs. trade as a 'handmaiden of growth', the reader is referred to the admirably clear discussion in Evans (1989) Ch. 9.

[7] For an overview of performance, see Chenery and Syrquin (1986).

[8] UNCTAD (1989b) pp.146-7. For 23 of the 42 least developed countries, the Hirschman index of export concentration was over 0.5 in the mid-1980s and for 14 of the 19 for which 1970 data were available, the index had risen by the mid 1980s, indicating greater export concentration. In addition, the top ten exporters in this group of 42, accounted for 67 per cent of total least developing country exports in 1986, whereas the bottom ten accounted for only 2 per cent.

long-run deterioration of many primary commodity net barrier terms of trade.

Commodity Policy

It was in order to address problems such as these that the calls[10] for the establishment of a New International Economic Order (NIEO) were made by UNCTAD in Nairobi in 1976, in order to restructure, amongst other things, international trade in commodities. A set of measures was proposed that would act on export prices and export volumes so as to increase stability in commodity trade and improve growth in real export earnings. The Integrated Programme for Commodities (IPC) was and continues [see UNCTAD 1987a:110-21 and 1987b:23-9] to be seen as central to this process, consisting of five major, mutually supporting elements: a series of international stocks, a common fund to finance them, long-term multilateral commitments on trade and bulk-supply contracts, compensatory financing and increased processing of raw materials.

Substantial emphasis has been placed in recent years on compensatory financing of commodity related shortfalls in export earnings, but no more has been achieved apart from some improvements in the existing International Monetary Fund (IMF), STABEX and European Community (EC) SYSMIN schemes. Another area receiving attention is the *individual* International Commodity Agreements (ICAs), which are an integral part of the IPC and the Common Fund, in order to enhance producer-consumer cooperation and to achieve price stabilisation and greater predictability in commodity markets. Despite the meagre and disappointing results in this area, UNCTAD VII in 1987 reaffirmed its commitment towards improving and expanding the coverage of ICAs.

[9] For evidence of long-run trends, disaggregated by commodity group, see Evans (1989), Tables A9.2.3, A9.2.4 and A9.2.5. For a succinct discussion of the theoretical and empirical issues associated with the terms of trade between primary commodities and manufactures, see Evans (1989), pp.283-291. Although the decline of prices was widespread in the 80s, except coffee, tea and rice, the most affected were minerals and metals and food products. However, the recorded upward movements in the price indices of agriculture and mineral raw materials in 1987 and 1988 do not appear to be the result of an increase in the rate of growth of GDP and industrial production in IACs, but rather of speculation, short-term shortages and lower inventories held by industry.

[10] The cornerstone of international policy formation for primary commodities remains the UNCTAD Conference Resolution 93(IV) in May 1976 at Nairobi, which adopted the Integrated Programme for Commodities (IPC). This was further complemented by conference resolution 124 (V), 1979, and resolutions 153 (VI), 155 (VI), 156 (VI), 1983. More recently, UNCTAD VII reaffirmed the validity of resolution 93 (IV) [see UNCTAD 1987b] and called for the implementation of measures springing from it but also reflecting the current world community situation and the situation of individual commodities. For an overview of the world commodity situation see UNCTAD (1988a, 1988b, 1987a, Ch. III, and 1986), North-South Institute (1988), and Maizels (1987).

Together with a recent emphasis on horizontal and vertical diversification, the objective of greater LDC participation in the processing, marketing, distribution and transportation of their primary commodities, *remains* an important IPC-related aim of UNCTAD.[11] Conference resolution 124(V) in 1979, agreed:

> . . . to establish a framework of international cooperation for expanding in developing countries the processing of primary products and the export of processed goods and to establish a framework of international cooperation with a view to increasing the participation of developing countries in the marketing and distribution of their commodity exports and their earnings from such activities.

This objective is still considered valid, but little progress has been achieved in this, as in the other cross-commodity areas, at least in a multilateral framework. Moreover, the important question of market access and trade liberalisation, again integral to IPC aims, is linked to the areas of processing and increased diversification of commodity production for export. The obstacles to primary and processed commodity trade, which have in fact worsened in the last two decades, [see Introduction of this volume, Table 2], have not even begun to be addressed by governments in the above context, and although such considerations have been present in multilateral negotiations within GATT and the Uruguay Round, they have not been resolved.

Despite little or no headway in virtually all aspects of intergovernmental activities on commodities springing from the IPC, UNCTAD argues that this does not place in doubt the soundness of the IPC objectives. Rather the latter have become more relevant in recent years, and thus constitute ends that must be achieved with 'certain shifts of emphasis in tactics'. Hence, further action is underway to expand and stabilise commodity export earnings and to strengthen commodity markets and prices. Given the conditions and prospects faced by commodity-based economies, *greater* emphasis is now to be placed on action to further diversify commodity production and to increase processing, with due regard to the development of new uses, threats of substitution, assimilation of new technology and increasing productivity, as well as the need to improve their position in marketing,

[11] See UNCTAD (1987a) pp.26-27 and UNCTAD (1987b) p.11 and 114. For an overview of the recent emphasis and action on commodities by UNCTAD in the areas of the Common Fund, the processing, marketing and distribution of commodities, market access, compensatory financing, and the conclusion of individual international commodity agreements, see UNCTAD (1987a) pp.110-121. For developments, since UNCTAD VII, see UNCTAD (1988c). A commodity by commodity case approach seems to be emerging, while diversification is given a greater emphasis than processing. There is also an emphasis on such aspects as market access, transparency, marketing, distribution and transportation for the successful implementation of processing, where it is undertaken.

distribution and transportation. Greater degrees of processing of domestic raw materials is also an objective of developing economies themselves, and was in fact the central area of discussion between the Africa-Caribbean-Pacific Group of States and the EC in the recent negotiations for the conclusion of the Lomé IV Convention.

It is not evident that improved commodity metal or chemical production for the world market is either feasible or desirable as a universal aim of commodity policy and national development plans in the 1990s. Apart from trends in specific markets which may necessitate that LDCs abandon commodity production in the long-run, remaining or entering in even the first stage of downstream processing must address the new materials science and engineering base identified in 2.0 above, and the restructuring process in basic industries described in 3.2 below.

In terms of the NIEO[12] proposals, and the centrality still accorded to IPC, it is clear that they do not address the need to devise productive strategies. The overall emphasis remains on prices, on short-run stabilisation and on redistribution rather than the necessary restructuring and scientific and technological upgrading of the productive base in the context of long-run capital accumulation.

3.2 Restructuring in the 1970s and 1980s and the position of developing economies

A number of LDCs have increased the degree of domestic processing of raw materials before export during the last two decades [UNCTAD 1987a:92-3]. The expansion of domestic processing capacity in LDCs, together with the redeployment of labour intensive production in traditional sectors, such as clothing, and in segments of electronic goods assembly, was viewed as broadly in line with changing global patterns of comparative advantage in the context of the internationalisation of production. UNIDO saw global restructuring of industry as manifesting convergence of the interests of LDCs, MNCs and IACs, and, moreover, as a mechanism for meeting the Lima target of LDCs' share of global manufacturing reaching 25 per cent by 2000. But overcapacity appeared in several sectors by the early 1980s, and concern about import penetration by the NICs soon led to the erection of protective barriers by IACs facing severe structural difficulties. The 1980s have since witnessed a major rationalisation and reorganisation of industrial branches and increasing diffusion of microelectronics-based automation technologies across the whole of the manufacturing base of IACs, thus beginning to erode traditional sources of comparative advantage for manufacturing production in developing regions.

[12] See Evans (1989), section 9.7, for a critique of NIEO proposals, and the IPC, in terms of the inefficiency, inequity and impracticality associated with the latter.

The Restructuring of Basic Industries in the IACs in the 1980s

Here a number of interesting tendencies can be identified:

(1) Large segments of inefficient productive capacity have been shut down, while remaining capacity has been modernised and technologically upgraded. The shedding of labour has been accompanied by new contracts for more flexible work practices and multiskilling;

(2) Smaller but high-productivity modern productive capacity has been retained within IACs in traditional smelting and processing activities, exemplified by the current healthy state of the US copper and aluminium industries;

(3) It is generally accepted that economic and political forces are making for an inexorable redeployment of ever larger portions of commodity metal and petrochemical production to developing regions, and Australia and Canada, from which the requirements of IACs are to be met on the principle of least cost sourcing;

(4) Firms in these industries have begun a discernible strategic move downstream into high-valued added processing and fabrication of specialty metals and chemicals aimed at specific niche markets;

(5) A related feature is the forging of close relationships between the producers of metals, chemicals, ceramics and glass with their customers in industry, with the aims of meeting the latter's more stringent specifications and quality requirements in specific applications;

(6) Together with the move to downstream vertical integration, firms in Japan, the USA and Europe, have begun to diversify into related business and into advanced materials;

(7) The tendency towards the in-house acquisition of multi-disciplinary scientific and engineering capabilities for multi-materials competence in conditions in which barriers between traditional materials markets are eroding and marked by significant interpenetration of materials in end-users is a discernible trend in some companies, and will acquire greater prominence in the years to come;

(8) Accompanying diversification and entry into new materials competences is the necessary tendency for joint ventures and technology licensing agreements, together with mergers and acquisitions, as a means to combine synergistically specific strengths across materials technologies and national markets;

(9) The availability and properties of existing natural materials have ceased to determine the characteristics of final products. New advanced materials are being developed to eliminate import dependence on

strategic and critical metals, and the processing and fabrication of materials, such as fine ceramic and metallic powders, ultra pure glass, carbon fibres and components, is becoming the critical stage in strategic import dependence of national economies.

Advanced and Traditional Materials

The restructuring process of IACs entails a twin impact on the resource base and on the interplay between the use of (improved) traditional and advanced materials in industry. Although the adverse impact of substitution and technical change is not a new phenomenon for industrial raw materials, the observed marked declines in intensity of use since the early 1970s may signal the onset of a complex set of structural factors acting on the demand side [see, for example, Tilton 1988; UNCTAD 1989a]. Sectoral shifts in the product composition of national output away from materials intensive sectors, and declining material use per unit of final output, resulting from substitution and technological and organisational change in manufacturing, have combined to reduce intensity of use.

This process may continue in the 1990s and indeed accelerate as a wide range of natural fibres, sugar and metals such as aluminium, copper and steel, face greater substitution from the diffusion of advanced materials. Classification and data availability limitations place insuperable obstacles at present in the way of attempts to quantify the impact of advanced materials on specific classes of materials in the 1970s and 1980s. The problem is compounded when it comes to projections on the diffusion of advanced materials and the figures available are making no more than informed guesses, which vary widely among sources. Some indication of the relative importance of advanced materials in comparison to traditional materials is provided in Table 2 for the case of Japan.

Advanced materials are projected to constitute a mere 4 per cent of the value of conventional materials in 1990. If the 1983-90 growth rates of 18 per cent for advanced materials and 3 per cent for conventional materials are projected to the year 2000, then the share of advanced materials rises to 14 per cent, and by 2100 this rises to 39 per cent of the value of conventional materials. This is, of course, only a very rough indication of the potential impact of advanced materials on market shares.

Trends in intensity of use and demand for specific raw and semi-processed commodities in the 1990s and

Table 2 **Advanced and Conventional Material Production in Japan**

	1983 $ mn	*1990 Forecasts $ mn*	*Growth 1983-90 (%)*
Advanced Materials			
Fine Ceramics	1,670	6,315	19
New Polymers	1,800	4,210	13
(Engineering Plastics)	1,100	2,736	14
New Metals	710	2,315	18
(Amorphous Metals)	12	147	42
Composites	105	631	29
(Carbon Fibres)	63	160	14
Total	4,285	13,471	18
Conventional Materials			
Steel	67,676	80,000	2
Non-ferrous	29,200	35,790	3
Ceramics	36,324	44,210	3
Chemicals	80,955	101,052	3
Textiles	33,945	40,000	2
Pulp and Paper	29,730	34,526	2
Total	277,830	335,578	3
Advanced Materials as % of conventional materials	1.5	4.0	

Source: Dubarle (1989): 'Advanced Materials: The Silent Revolution', OECD *Observer*, 158, June-July, p.9.

beyond depend on a complex set of factors, such as the growth in GDP and fixed capital formation in developed and developing regions; consumer tastes and environmental concerns; technical change and potential for further economisation in material use; and defensive R & D and marketing strategies in traditional materials utilising the insights offered by MSE and strategic integration with end-users. The diffusion of advanced materials is at present severely constrained by processing difficulties, especially in ceramics and composites, the lack of awareness in industry, the lack of commonly accepted standards and the sunk capital in existing production facilities. What is clear is that traditional materials such as natural rubber, wool, aluminium, steel, lead and zinc are mounting a spirited defence, and the outcome will not be clear for some time to come. Nevertheless, given the large research effort in all areas of advanced materials design and processing, in many cases with considerable state support in IACs [see National Institute of Standards and Technology 1989], and the cumulative gains of early entry and of learning by using and producing new materials, there is no room for complacency or resignation in developing regions.

3.3 Implications and opportunities for developing economies

The Materials Revolution and LDCs

It must be stressed again that the revolution in MSE has an impact right across the industrial materials spectrum.[13] The implications of this proposition can be summarised as follows.

1. The insights and methods of MSE as set out in 2.1 can and *must* be used to improve the *properties and processing technologies of existing materials*. Given the pressures of the world market and user industries for higher quality, durability and reliability and for new designs commanding a marketing premium in niche segments of the market, no economy or industry can afford to ignore this in the years to come, at any stage of the materials cycle. This applies to a broad range of user manufacturing activities, from designer dominated, small-scale, flexibly-specialised industry,[14] to flexible mass- and batch-production in engineering sectors.

2. The more efficient use and upgrading of domestically or regionally available natural resources can contribute significantly to meeting the basic needs of developing countries in housing, transportation, water and energy distribution, health care and food packaging [Rohatgi 1989]. MSE offers considerable scope for developing economies to make fuller use of domestic materials while minimising energy requirements and pressures on the environment.

3. MSE research can also, and *ought* to, be directed to produce advanced materials directly relevant to the needs and resources available for development.

4. LDCs possess materials, such as rare earths, niobium and zirconium, and/or technology skills that are required in the production and use of advanced materials entering domestic industry and the world market. Hence, the evolving materials era also affords opportunities for developing economies, where appropriate, to gradually enter new materials production, use and trade, at several stages of the transformation of the raw material into semi-processed and processed forms and components entering final end-use.

LDCs must acquaint themselves fully with the new MSE potentials and requirements and begin, where necessary, to build the institutions and basic techno-economic, experimental, testing and standards capabilities which can be used to fully utilise and upgrade local resources to meet domestic and world market imperatives. A critical aspect of this will be the institutional capability to assess, assimilate and use the proliferating information and data on new materials.

Acquired Dynamic Comparative Advantage

For each LDC economy, the central concerns will be (a) the *point of entry*, and (b) *selectivity* in building up scientific and materials *processing and engineering technology skills*, utilising existing strengths while entering into joint ventures and technology licensing agreements, in the context of a coherent and dynamically integrated step-by-step acquisition of skills, productive assets and competitive advantages. It is clear that there is an important role for the *state* in providing the umbrella institutions within which such decisions can be made, and in setting priorities and reforming the educational, training, banking, legal and institutional framework and trade regime.

Looking at East Asia, the last few years have witnessed a dynamic process whereby the move towards high-value added manufacturing by the rapidly industrialising NICs has created 'opportunities' for other lower wage economies in the region, such as Malaysia, Thailand, the Philippines and Indonesia, and more recently Vietnam, to enter into relatively labour-intensive industries and segments of the

[13] It should be noted that UNIDO is currently exploring the possibility of establishing regional networks of centres of excellence and institutes for testing and standards, and is also in the process of establishing a new centre for research in new materials in Trieste, Italy, concentrating on semiconductors, super conductors and composites. In addition, the first phase of the establishment of a new international centre on materials in Brazil has just been completed. The centre would assist LDCs to meet their needs in materials information, standards, education, training and techno-economic analysis in the 90s. See Kaounides (1989c).

[14] For a useful discussion of the concept of flexible specialisation see Schmitz (1989).

production process. This cannot, of course, be an end in itself, but the latter group of countries can expand their industrial base and expertise by building on existing strengths without neglecting the need to build their educational, scientific and technology skills, and, importantly, improve their maintenance and support industries, and infrastructure, especially in transport, telecommunications and reliable energy generation and distribution. On the other hand, the attractiveness of the relatively higher wage first tier NICs in the region lies now in terms of larger internal markets, and the availability of skills and infrastructure enabling sophisticated products manufacture and the production of advanced materials components for domestic use or export to regional markets.

South-South Trade

In this process of shifting and acquired comparative advantage, there is clearly an important role for South-South trade as production capacity and infrastructural requirements expand in countries at different levels of development. In this connection, it is interesting to note the changing direction of developing country primary commodity exports in recent years, as Table 3 shows:

Table 3 **Changing Destination of Exports of Primary Commodities from Developing Countries**
(Percentage share of intra-developing country exports in total developing country exports)

	1973	*1980*	*1986*
Food	17.9	23.5	19.9
Raw materials	22.7	26.1	27.7
Ores and minerals	6.7	11.5	18.2
Non-ferrous metals	11.0	15.7	22.7
Fuel	18.6	22.2	27.9
Total primary products	18.0	22.1	24.9
Excluding food and fuel	16.0	19.3	23.6

Source: World Economic Survey, 1989, UN, ST/ESQ/211.

As industry has been growing in the more industrialised LDCs, this has provided expanding markets for primary exports from other LDCs. Most of the increase has been due to imports by Asian LDCs [UNCTAD 1987a]. In fact, exports of primary non-fuel commodities from Asian economies to other Asian economies as a percentage of their total exports went up from 22.5 per cent during 1966-70 to 34 per cent during 1983-85, while exports from African and Latin American LDCs to other LDCs also registered large increases in the same period. There may well be further scope for South-South primary trade, especially if trade barriers come down. But it must be remembered that the industrialisation process, especially in the first tier NICs, will also be accompanied by the application of sophisticated manufacturing technologies, and this will have repercussions on the type and quality of materials, including advanced materials, required.

4. Conclusions

A primary objective of international commodity and economic policy in the 1990s must be the avoidance of the further marginalisation of that large number of LDCs which can least afford to be cut off from the fruits of the materials, information and biotechnology revolutions. Given the high vulnerability of the least developed economies to their external environment, reduced export earnings and government revenues have meant unacceptable curtailments of expenditures on education, health and the maintenance of productive capacity and infrastructure in the 1980s, with possibly disastrous consequences if allowed to continue in the 1990s. Consequently, urgent action is required in, amongst other areas, tariff reform, improved market access, debt relief and external financial flows.

Such measures, together with other mechanisms for strengthening the position of primary producers in sub-Saharan Africa, the least developed economies, lower-middle income LDCs and second tier NICs in existing commodity markets can only be viewed as first steps or prerequisites in the process whereby these economies begin to build and acquire the necessary competences to assimilate and adapt the MSE revolution and the parallel educational, engineering, testing and standard, quality control, and institutional skills and structures that will enable them to use domestic resources to meet basic needs and participate more fully in a more dynamic and open world economy. Hence, commodity policy must begin to move away from a preoccupation with redistribution. It needs to focus instead on long run productive strategies appropriate to the emerging materials and manufacturing best-practice technologies and to the circumstances of LDCs at different levels of development of the productive forces and availability of resources and skills. South-South trade and regional collaboration in R & D, training, information and data gathering and exchange, testing and standards institutes networking, collaboration of professional societies and universities, would play an important role in the effort to target and selectively acquire dynamic comparative advantage, especially for the least developed economies.

Moreover, insistence on structural adjustment measures aimed at improving domestic supply responses and the workings of the market mechanism could prove a dangerous irrelevancy in the 1990s if accompanied by a neglect of the new materials and manufacturing circumstances, and hence the necessary national and international forms of action to meet the challenge posed to many LDCs.

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