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DRAFT WORLD-WIDE STUDY OF THE IRON AND STEEL INDUSTRY: 1975–2000

PREPARED BY THE

INTERNATIONAL CENTRE FOR INDUSTRIAL STUDIES

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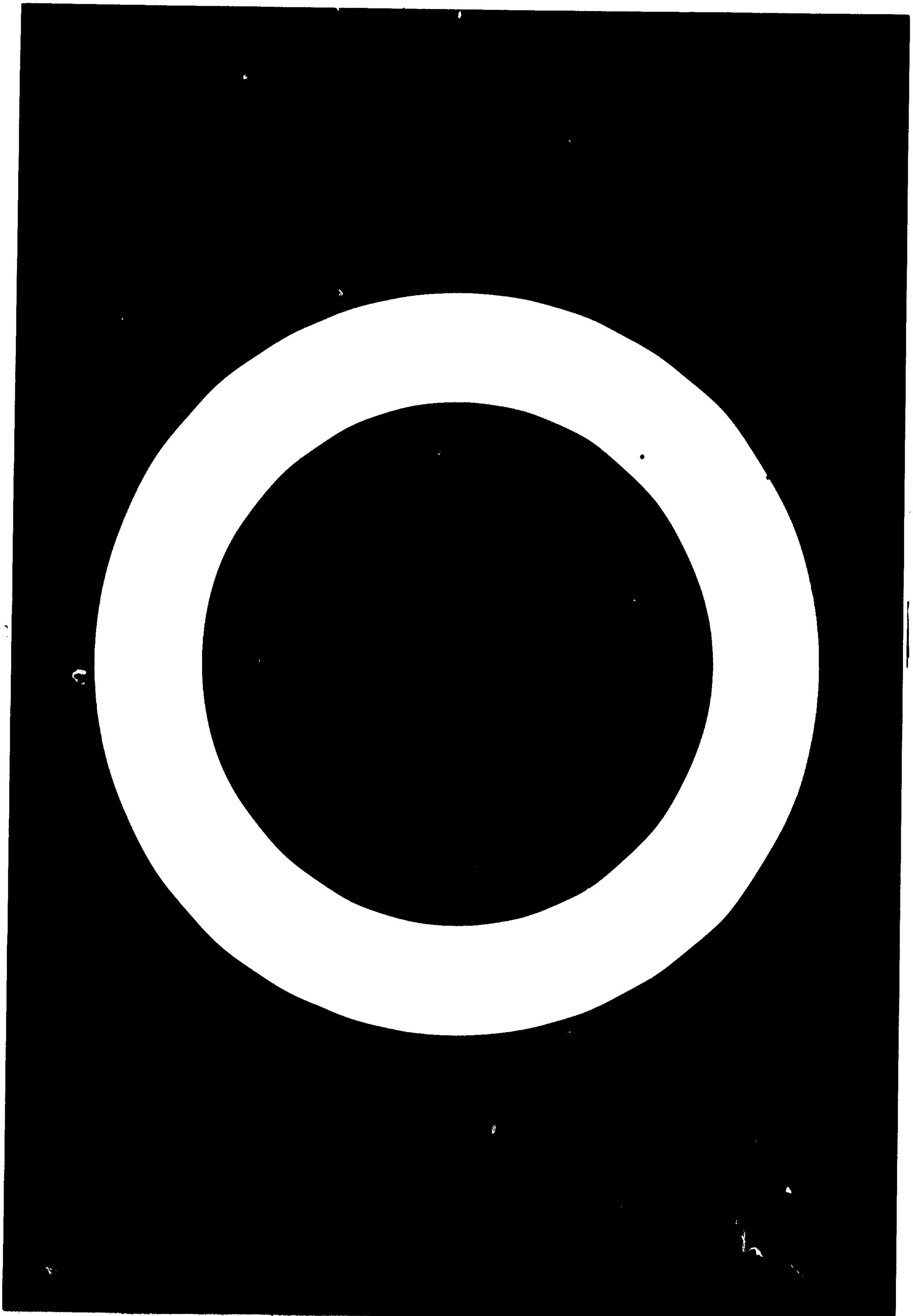
CONTENTS



INTRODUCTION

The Lima Declaration and Plan of Action on Industrial Development and Co-operation, which was adopted at the Second General Conference of UNIDO in March 1975 (and subsequently endorsed by the General Assembly at its seventh special session) re-asserted that industry was a dynamic instrument essential to the rapid economic and social growth of the developing countries, and called for a 25 per cent share for the developing countries in total world industrial production by the year 2000. (Their present level is 7 per cent.)

The Lima Declaration and Plan of Action instructed UNIDO that "in order to give concrete content to the process of industrialization in the developing countries, studies must be undertaken and specific measures formulated in different sectors of industry, special attention being given to priority sectors". One of the priority sectors identified for study was the iron and steel industry, the development and extent of which are generally accepted to be prime indicators of the level and maturity of a country's industrialization.

The present draft study represents a concerted attempt to provide an overview of the opportunities for, and constraints upon, the development of the iron and steel industry, which is closely linked with such other sectors as construction, transportation, agriculture and resource extraction. Through this study, the newly established International Centre for Industrial Studies in UNIDO seeks to contribute to an understanding of the issues involved: projections provide an indication of the magnitude of growth in the sector, and extend to the year 2000.

The opportunities open to developing countries in their endeavour to increase their share in world industrial production in this field are considered, as are implications in terms of the relative positions of various iron and steel production capacities in the world. Despite the amount of data collected, however, the study is not intended as a mere compendium of statistics: rather, it is intended as a decision-making tool for persons involved in investing in the iron and steel industry. Its component chapters treat the factors that must be considered in any meaningful discussion of the iron and steel industry and its significance for the future of the developing countries. The data have been gathered, sometimes with difficulty, to serve as illustrative background material essential to the clarification of the issues discussed and to an understanding of the multifarious factors involved.

The study attempts to identify the main opportunities for the advancement of the iron and steel industry and to assess the potential contribution this sector could made to the attainment of the over-all industrial production target set in the Lima Declaration.

Following a summary, the second chapter provides a survey of past and present iron and steel consumption and production, with future projections through 1985 and extensions to the year 2000 in variant form denoting low and high estimates of possible consumption. On a global basis, the production patterns are assumed to shift in such a manner that the share of the developing countries will increase at a rate higher than that of the developed countries. In the following chapter, estimates are given which indicate that the developing countries' share of steel exports may also increase. Together, the two chapters lend substantiation to the hope expressed in the Lima Declaration concerning the attainment by the developing countries of the 25 per cent share in world industrial production by the year 2000. According to the growth scenarios, a total of some 1.7 - 1.9 billion tons of steel may be produced world-wide by the year 2000. Of this, the developing countries may be expected to produce [illegible] to 25 per cent, a substantial increase over the 5.1 per cent produced in 1974. This expansion may include numerous small plants for the manufacture of such products as reinforcing rods and large plants.

The subsequent three chapters are devoted to technological considerations, resources, and capital requirements in order to provide decision-makers with information concerning choice of processes, optimum utilization of resources and financial orders of magnitude. Consideration is also given to environmental problems, direct reduction of ore and the use of charcoal as a source of energy.

An initial attempt on the part of UNIDO to point up the implications of the Lima Declaration and Plan of Action for the iron and steel industry, this study is also oriented towards the system of continuing consultations called for in the Lima Declaration with a view to facilitating the creation of new industrial facilities in developing countries.

It must be borne in mind that the strict time schedule established for the initiation of the consultations allowed only eight months for the completion of this study, whereas at least 18 months would have been more commensurate with the task. The work was facilitated to some degree, however, by the use of studies carried out in this field by UNIDO in years past, and the experience accumulated in the course of technical assistance activities.

In view of the dynamics of change that are constantly occurring in the technology, trade patterns, geographical location and financing of the iron and steel industry, it is essential that policy- and decision-makers recognize that the situation presented in this study may change when the time arrives for decisions regarding investment and implementation. Furthermore, regardless of the possible progress set forth in this study as attainable by developing countries, careful consideration should be given before implementing decisions to possible gaps between planned and actual production so as to assure appropriate utilization of capacities.

From the foregoing, it will be obvious that the present draft will need to be revised and updated on a regular basis. Thus, as a first step, copies of this draft study are being submitted to Governments and selected individuals in order to solicit their criticism and comments which will be incorporated in the revision.

The International Centre for Industrial Studies is indebted to the following persons for their co-operation in the preparation of this draft study: John Elliott, Bay Estes, Janos Fath, William Hogan, R. Krishnan, and Nelson L. Nimerow, and to the International Iron and Steel Institute, VÖEST-Alpine, IIASA and UNCTAD for having supplied information.

Chapter I

SUMMARY

World steel production and consumption to the year 2000

In this study, global estimates of steel production in 1985 and alternative growth scenarios to the year 2000 are presented. The 1985 estimate was obtained by elaborating upon projections made by the International Iron and Steel Institute at Brussels. 1/ In the course of this elaboration, past trends in production and consumption were anal; ed, as were subjective judgements with regard to future rates of substitution for steel and competitive products, the severity of the 1975-1976 recession and country plans for future development of the industry.

Estimates for 1985, together with high and low growth scenarios for the year 2000, are shown overleaf. World steel production is expected to reach almost 1.1 billion tons by 1985. The share of the developing countries in this production should rise from the 1974 figure of 5.1 per cent to 11.7 per cent (125 million tons).

The growth scenarios developed for the year 2000 were based on postulated annual growth rates for world steel production of 3 and 4 per cent respectively. These scenarios should be interpreted strictly as indications of possible future growth. According to Alternative A (3 per cent) some 1.7 billion tons of steel would be produced in 2000, whereas according to Alternative B (4 per cent) this figure would be some 1.9 billion. The estimated share of the developing countries could range from 22 to 25 per cent of world production.

A supplementary investigation of historical changes in the pattern of industrial growth and its implications for steel production and consumption was also carried out. The methodologies applied were quantitative, based on the approaches adopted by other international organizations.

Undoubtedly, these estimates will have to be revised as world economic conditions change. In anticipation thereof, more formal means of forecasting

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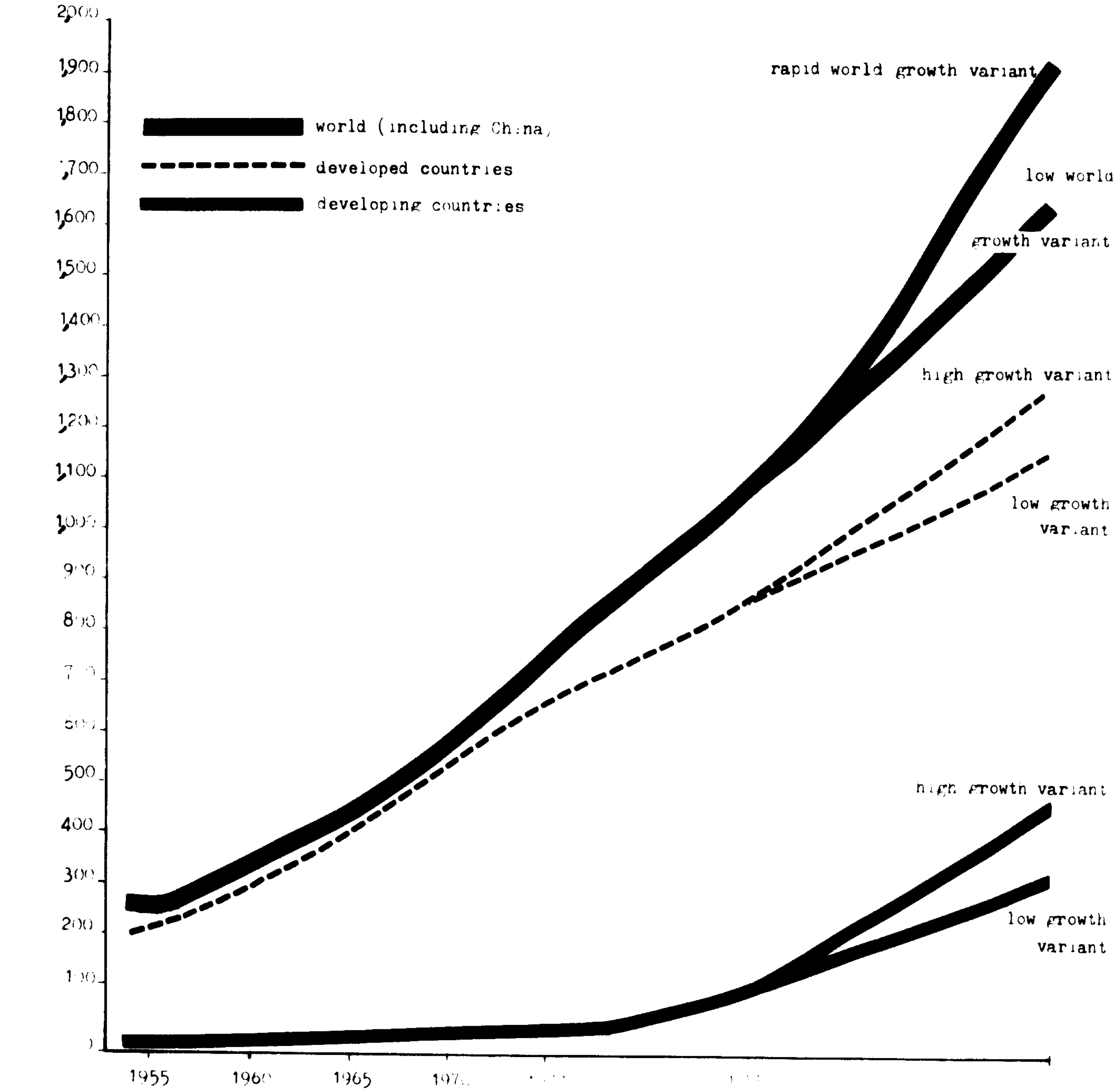
1/ See International Iron and Steel Institute, Projection 85, Brussels, March 1972.

Steel production, 1955-2000



Note: Figures for China are included in the world totals, but are not shown as part of the two economic groupings.

Source: UNIDO estimates.

steel production are being developed in UNIDO. Owing to the strict time schedule that had to be maintained during the conduct of this study, the preliminary results of the more formal forecast could not be explicitly incorporated in the estimates presented. Nevertheless, it is considered useful to present the results of the quantitative investigations carried out since they complement some of the assumptions employed in developing the estimates in this report, and the techniques constitute one element in a more sophisticated forecasting framework.

Production patterns

The work draws heavily on the structuralist approach to sectoral development and adopts traditional structural models to estimate sectoral growth. [2] Multiple regression techniques were applied to the following equational forms:

$$\ln x = a + b \ln y + c \ln N$$

and

$$\ln x = a + b \ln y + c \ln N + d (\ln y)^2$$

where x = per capita value added by iron and steel: [3] y = gross domestic product per capita: and N = population in millions.

Per capita income is traditionally considered the most important determinant since demand for iron and steel is known to increase substantially as income rises. The distribution of total demand among investment, government consumption and private consumption varies with the level of per capita income and thus has a significant impact on demand for iron and steel. With regard to supply, the level of per capita income tends to be closely related to the relative costs of labour and capital: it is thus indicative of the probable extension of industrial production into capital-intensive and complex industrial sub-sectors such as iron and steel.

2/ This is a method frequently employed to approximate the growth paths of manufacturing and or industrial sub-sectors, such as iron and steel. See, for example, H. B. Chenery and M. Syrquin, Patterns of Development, 1950-1970, a World Bank research publication (London: Oxford Univ. Press, 1975), and UNCTAD, "The Dimensions of the Required Restructuring of World Manufacturing Output and Trade in order to reach the Lima Target" (TD/185/Supp.1), presented to UNCTAD IV, Nairobi, May 1976.

3/ Value added is at factor cost. The definition of the iron and steel sector is taken from the UN International Standard Industrial Classification.

The second structural variable incorporated in such an approach is population. Production of iron and steel is dependent, to some extent, upon economies of scale. Together with per capita income, population provides a means of measuring the influence of market size, and thus the importance of economies of scale in iron and steel production.

The percentage change of iron and steel production for a given percentage change in GDP per capita or population can be derived from the regression analysis. The derivations, which conform to the traditional concept of elasticity, are known as growth and size elasticities, respectively. For example, a coefficient of 2.15 (see the table below) implies that iron and steel production increased by about 2 per cent for a 1 per cent increase in GDP per capita. A similar interpretation applies to the population elasticities.

A summary of the growth elasticities for iron and steel production at level of per capita income in selected years is shown below.[4] Comparison of elasticities for large countries (populations of more than 15 million) with those for small countries (populations of less than 15 million) reveals important differences in growth patterns.

	(GDP per capita)					
	$ 225		$ 500		$ 1,000	
	Large countries	Small countries	Large countries	Small countries	Large countries	Small countries
1963	2.15	3.26	1.84	2.73	1.26	1.72
1966	2.21	4.68	1.86	3.69	1.24	1.86
1970	2.25	3.96	1.90	4.18	1.26	1.76
1973	2.15	3.91	1.85	3.18	1.28	1.84

Source: UNIDO, based on data supplied by the UN Statistical Office.

Growth elasticities in small countries are decidedly higher than those in large countries. This serves to demonstrate the rapid response of iron and steel production once the constraining factor of small market size is alleviated.

[4] The elasticities are derived from the regressions for the second equation quoted on page 3.

As indicated in the table, the growth elasticities tend to decline at higher levels of per capita income. However, they exceed unity throughout the income range shown. This fact suggests that iron and steel is an important growth sector, regardless of the level of development. Over the period 1960-1973, each set of elasticities can be seen to have exhibited a similar pattern of behaviour, reaching a maximum in the latter half of the 1960s and declining in more recent years. For large countries, the relationship between iron and steel production and per capita income was remarkably stable over the period investigated. However, annual fluctuations in the figures for small countries were somewhat high. These facts are particularly important when regression results are intended to serve as a guide to the approximation of future growth patterns in iron and steel production.

Size elasticities are not a significant determinate of iron and steel production. Unlike per capita income, small increases in population do not have a substantial impact on production. This characteristic distinguishes the iron and steel industry from consumer goods industries, such as food, textiles or clothing, where minor population increases stimulate production through final demand. In investment goods industries, production is responsive to factors other than consumer demand.

Consumption patterns

As with the production analysis, a cross-section approach to the study of steel consumption was adopted. Unlike a time-series approach, this method enables the researcher to assess the impact of common factors affecting consumption patterns in all countries for given years or groups of years. When the identified relationships between steel consumption and its determining factors remain stable over a period of time, the statistical results provide a guide to future conditions.

The basic hypothesis is that the per capita steel consumption observed at a given time in various countries is subject to the same broad set of factors, such as access to the same types of production technology, similar price ratios between steel and other goods, and comparable patterns of steel utilization. According to a line of reasoning analogous to that described for the production patterns (page 3), GDP per capita is frequently used as the measure best reflecting these factors.

The methodology used in this report to determine consumption patterns was a standard bivariate and multivariate regression analysis applied to data given for 45 countries. The following expressions were selected as an initial attempt to provide a plausible explanation of the relationship between per capita steel consumption (c) and GDP per capita (y):

$$\ln c = a + b \ln y$$
$$c = a + b \ln y$$
$$\ln c = a - {}^{b}/_{y}$$
$$\ln c = a - {}^{b}/_{y} - d \ln y$$
$$\ln c = a + b \ln y - d (\ln y)^2$$

where a, b and d are constants. 5/

These equations were tested for several time periods and sample stratifications. The results confirmed the analytical validity of the approach and revealed a slight superiority in the performance of the multivariate models when applied to the total sample, and a clear superiority in that of the bivariate model where the samples were stratified according to the level of economic development. Hence, the hypothesis of a common pattern of steel consumption among different countries can be accepted. As confirmed by detailed analysis, the level of economic development is an important factor in specifying the relationship between steel consumption and per capita income.

Further investigation served to reveal how consumption patterns change over time. In the case of the developed countries, the pattern exhibits a tendency to rotate clockwise in successive two-year periods from 1950 to 1970. Time instability was also found in the case of developing countries, but no clear trend could be detected.

Income elasticities of steel consumption were derived from the regression equations. Depending upon the functional form considered, these elasticities are constant, or they decrease with either higher levels of per capita steel consumption or higher levels of per capita income.

5/ These forms have been applied in several instances. See, for example, FAO, Agricultural Commodities - Projections for 1975 and 1985, Vol.II, Rome, 1967.

	All countries	Developed countries	Developing countries
1950-52	1.329	1.083	1.234
1959-61	1.[illegible]84	1.062	1.321
1968-70	1.261	0.977	1.068

Source: UNIDO, based on data supplied by the UN Statistical Office

The table above shows examples of income elasticities for steel consumption obtained from regressions of the equation ln c = a + b ln y, by country grouping in selected years. As might be expected, income elasticities for developing countries are generally higher than those for developed countries, i.e. marginal increases in income induce larger increases of steel consumption in developing countries than in developed countries. In the case of developed countries, the time trend was found to reduce income elasticities, a phenomenon that may be interpreted as reflecting a trend towards saving steel.

Methods and results of the 1985 estimate

The Brussels forecast, upon which the present projections were partly based, was carried out in 1971/72 as a medium-range forecast for 1985. Subsequent to the forecasting exercise, unusual cyclical fluctuations occurred. Although the original forecast had been based on a trend line and due account had been taken of past cyclical fluctuations, the extent of the 1974-76 fluctuations necessitated an adjustment.

In effecting this adjustment, future plans for expansion and investment in the iron and steel industry were given serious consideration. This information was compiled on a country-by-country basis, often at the project level. Where demand projections at the national level were available in respect of projects planned, these data were also taken into account as well as any intentions to produce either for export or domestic markets. Major and potential steel producers in all developing countries are included. Owing to divergent assumptions regarding such factors as planned rates of capacity utilization and possible project delays, some degree of judgement was required in determining the weight to be given to each plan when making the projections. On the basis of such exogenous information, the original Brussels forecast of 1,144 million tons of steel to be produced in 1985 was revised to 1,069 million tons.

Estimates for 2000

The alternative growth rates for world steel consumption in the period 1986-2000 cited in this study reflect the fact that, since world production will equal world consumption in the long term, the same growth rates apply to production. Levels of world production and consumption thus calculated for the year 2000 are 1,665 million tons (Alternative A) and 1,925 million tons (Alternative B).

Sub-regional production and consumption growth rates: 1986-2000

Regional and sub-regional totals for production and consumption have been estimated on the basis of the UNIDO forecast for 1985. Growth rates at regional, sub-regional and country levels have been assumed for the period 1974-1985 in order to estimate the pattern of distribution.

Comparable estimates have been made up to the year 2000. Consumption rates of 2 to 2.5 per cent are assumed for the developed countries while those in the developing countries are assumed to be 3-4 times higher.

Whereas production in the developed countries is assumed to grow at approximately 2 to 2.5 per cent up to the year 2000, production rates in the developing countries are expected to increase by 6.7 to 9.4 per cent over the same period.

The iron and steel trade of developing countries: structure, prospects and policies

Implications for developing countries

Global trade patterns in the iron and steel industry are determined by steel consumption trends which in turn are commensurate with the pace of industrialization. As developing countries enter the early phases of industrial development, their imports of steel and steel-intensive products tend to increase rapidly. Over the period 1964-1973 the developing countries' imports of crude steel rose in value from $1.6 billion to 5.1 billion: if the Lima target is to be attained, it has been estimated that the steel imports of these countries must increase to a value of $26.2 billion by the year 2000. Developing country imports of semi-finished steel products from developed countries grew from 986,000 tons in 1964 to over 5 million tons in 1973, and the value of indirect steel imports through capital equipment rose from $9 billion to $30 billion from 1967 to 1973.

Steel exported from the developing to the developed countries between 1964 and 197 increased in value from $10 million to $668 million: three-quarters of these exports were in the form of semi-finished products. Primary and intermediate processing of steel is being located to an increasing degree in the developing countries, and it would appear that this trend will continue since it enjoys wide support among decision-makers in both industrialized and developing countries.

The total trade in raw materials, semi-finished, and finished steel products of the 50 developing countries (from six regions) that supplied statistical information for this study was largely with developed market economies which in 197 provided some 80 per cent of these developing countries' steel imports and absorbed 60 per cent of their exports. Approximately 10 per cent of the steel trade flow of these countries was with the developed countries with centrally planned economies. Whereas their imports from other developing countries were less than 10 per cent of their total, their exports to other developing countries approached 30 per cent.

The intraregional patterns of steel trade at all levels of processing seem to suggest that while the dependence of the developing countries on steel imports from the developed countries will certainly continue and even increase, certain of the more advanced developing countries are emerging as prominent intraregional suppliers, for geographical and pricing reasons.

A significant aspect of trade in the iron and steel industry is that contrary to the pricing behaviour of most commodities, where price stability increases with every stage of processing, costs in the iron and steel industry fluctuate most at the top rather than at the bottom of the processing ladder. Whereas the cost per ton of heavy steel plate increased from $[illegible]88 in 1966 to $40[illegible] in 1974, or some 45 per cent, the prices of iron ore in, for example, India and Brazil rose by only 1[illegible] and 60 per cent respectively over the same period (India: $6.85 to $7.85 per ton; Brazil: $9.30 to $14.90 per ton). The main explanation for this is that iron ore export prices are set in long-term contracts while those of intermediate and finished steel products are subject to the cyclical variations of the world steel market with "on-the-spot" purchases and open bargaining. On the other hand, the f.o.b. price of coal, a resource that is concentrated largely in the developed countries, effectively doubled, from $11.15 to $22.1[illegible] per ton, in the period 1964-197[illegible].

Barriers to trade

Among the chief obstacles to international trade in iron and steel are tariffs, non-tariff barriers and high transport costs. Most developed countries currently levy tariffs of 6-10 per cent on intermediate and finished iron and steel products, the tariffs escalating with the level of processing involved. However, for most developing countries these tariffs are offset by the Generalized System of Preferences, which provides duty-free access for their iron and steel products, but is subject to arbitrary and complex quota restrictions.

In accordance with the Lomé Convention, the European Economic Community grants duty-free privileges to 46 developing countries on all their industrial and primary exports to its member states.

Non-tariff barriers include such ad hoc restrictions as import licenses, exchange controls, customs duties, as well as patents and trademarks. Their impact varies from case to case, but they must be taken into account by developing countries considering the export of steel to developed markets.

Transportation costs present a major obstacle to prospective steel exporters in developing countries since they can reduce or eliminate whatever advantage their exports may enjoy in the markets of the developed world. Escalating ocean freight rates present a strong incentive to intraregional trade among the developing countries.

The international market

The international steel market is based on intergovernmental negotiations and agreements, and the industry is usually arranged in a monopolistic or oligopolistic manner at the national level. These agreements may encompass: voluntary import and export quotas; market-sharing arrangements for quantities and types of products traded; guidelines for investment and specialization policies; and "gentlemen's agreements" concerning pricing policies.

A developing country entering the international steel market, be it as an exporter or importer, must take into account the trade constraints and arrangements already in operation.

Technology of steel-making

The various processes involved in steel-making are described in this study with a view to attempting to assess raw material, energy and capital requirements.

Given that the introduction of a new steel process from conception to wide-scale commercial application often takes as long as a decade, only processes that are currently in commercial use or under development should be included in any assessment of steel production technology up to the year 1985.

Iron-making

Iron blast furnace. In the last two decades, the iron blast furnace - the principal iron production process - has undergone major improvements and grown enormously in size. Although the practical scale for blast furnace use ranges from 0.5 million to approximately 3.5 million tons of hot metal per furnace, large integrated steel plants have furnaces with capacities of 7,000 to 12,000 tons of hot metal per day, i.e. 2.5 million to 4 million tons per year. Blast furnace operations in the coming three decades are expected to follow several major trends:

(a) Reduction of coke rate by fuel injection. Where coke is expensive or supplies are limited, the coke rate can be reduced by injecting fuels into the tuyeres and hot gases into the stack. By 1985, coke consumed during normal operation should be equivalent to the lowest level currently attainable, i.e. perhaps 350 kg per ton of pig iron, with an auxiliary tuyere-injected fuel consumption of 100 kg (equivalent) per ton. Total energy consumption should therefore be about 3.1 G cal per ton of pig iron, diminishing after 1985, with the injection of gases into the stack, to 3.0 G cal per ton; with coke consumption being reduced to possibly 250 kg per ton of pig iron. Where supplies of reasonably good coking coals are available up to the end of the present century, coke rates can be expected of 475 to 525 kg and the equivalent in injected fuels of 25 to 50 kg per ton of pig iron, i.e. a total of 3.7 G cal per ton of pig iron.

(b) Substitution of form coke for metallurgical coke. Where coal not suitable for coking but suitable for conversion to form coke is in adequate supply, it will probably become the principal fuel used in blast furnaces with a corresponding drop in the use of injected fuels. This material will most likely be commercially available within the next five years.

(c) Substitution of charcoal for coke. Provided that it is in abundant supply, charcoal can be used as a blast furnace fuel. Although highly reactive, it is not strong enough to withstand the abrasion of the charge in a standard-height furnace; it can, however, be used most satisfactorily in smaller furnaces. When this form of substitution is made, afforestation programmes should be introduced in the interest of environmental conservation.

Direct reduction. Processes employed to reduce iron ore to solid metallic iron - other than the iron blast furnace - are called "direct reduction" processes. Depending on the processes used, several of which have found industrial application, the end-products are sponge iron, metallized iron ore, reduced pellets, direct reduced iron etc.

Direct reduction processes are generally classified according to the reductant and fuel employed. While gas is used as the fuel and reductant in the shaft furnace, gas retort system and fluidized bed, solid fuels are used in the rotary kiln and in the retort system of the same name. It is to be noted that all direct reduction processes enjoying large-scale commercial application utilize gas, primarily reformed natural gas, as both fuel and reductant.

Processes employing various types of solid fuel have been in use for several years, albeit on a modest scale. The present capacity of direct reduction systems tends to be small, at the most that of a small blast furnace. Where production capacity of more than 0.6 million tons per year is required, several direct reduction units will be necessary. In 1975, only 1.5 per cent of the world's pig iron was produced using direct reduction processes. This notwithstanding, in 1976 no less than 50 new plants were under construction or being planned, 20 of which should be operational by 1980. Most of these new plants are larger than those existing at present. Some 5 per cent (30 million tons) of the world's pig iron in 1980, and possibly 8 per cent by 1985, will be produced by these new capacities.

Steel-making

The principal processes by which common steels, such as carbon and low-alloy, are produced on an industrial scale are: the basic oxygen type of furnace (LD/BOF or OBM/Q-BOP); the Basic Bessemer; the electric arc furnace; and the open-hearth furnace. The principal raw materials from which the steel is made are pig iron (hot or cold), iron and steel scrap, and direct reduced iron.

Basic oxygen furnaces. Current advances in steel-making attributable to these furnaces are: decreased heat times; improved slag control and lining life; improved furnace control; better furnace charging methods; and improved facilities for collecting and utilizing waste gases. Although the OBM/Q-BOP process was developed several years after the LD/BOF process, it offers only limited advantages and is not expected to replace the LD/BOF process to the same extent that the latter process replaced the open-hearth and Basic Bessemer furnaces in the years between 1950 and 1965.

Basic Bessemer process. This is reasonably well suited to the production of many steels of commercial quality. Although it has fallen into disuse, its operation is simple and inexpensive and may still be considered for the refining of hot metal with a high phosphorus content (1.5 - 2 per cent).

Open-hearth furnaces. The principal disadvantages of these are the high cost of the plant and refractories. A further constraint is the high degree of labour required for operating the furnace, which is otherwise very flexible in terms of size, raw materials and fuels.

Electric furnace. The principal electrically powered furnace employed in the production of steel is the arc furnace which operates on a three-phase alternating current. Several methods for melting direct reduced iron have been developed. However, the conventional electric arc furnace is not ideally suited to melting directly reduced materials, especially those containing more than 4 per cent gangue, as this leads to the formation of a large volume of slag.

Casting operations. Two types are now in general use: traditional ingot casting used extensively in large and small steel plants, and continuous casting which is currently used in approximately 10 per cent of all steel produced in the United States and approximately 20 per cent in Japan.

The continuous casting process can be expected to spread further, on account of its savings in energy and its high yield compared with conventional ingot casting.

Changing technological patterns. Despite the difficulty of forecasting the evolution of individual steel-making processes known today, certain trends are identified in this study:

(a) The decline of the Bessemer and Thomas processes, to some 1.5 per cent of world steel production in 1975;

(b) A decrease in open-hearth steel-making, although the process is still used in steel plants in various parts of the world (0.8 per cent of the world steel production in 1975);

(c) The phenomenal spread of basic oxygen furnaces since the mid-1950s, accounting for 50.8 per cent of crude steel production in 1975;

(d) An increase in electric furnace processing, which has more than doubled from 7 per cent in 1950 to 16.9 per cent of steel production in 1975.

Considering all the steel-making projects under construction and in preparation, it can be anticipated that the use of basic oxygen furnaces will increase to nearly 70 per cent of crude by 1985.

In the light of expanding use of direct reduction and the trend towards transforming primary energy (including nuclear energy) into electricity, the electric furnace will be used to an increasing degree in world steel-making (about 20 per cent in 1985, and [illegible]8 per cent in 2000) at the expense of the open-hearth process in particular, which will probably decline to 10 per cent of world steel production in 1985 and to 2 per cent by the year 2000.

Whereas the basic oxygen furnace will have achieved its highest share in world steel production by 1985, it is expected to decline subsequently to 60 per cent of world production in the period 1986-2000.

<u>Levels of integration</u>. In planning the iron and steel industry, the choices to be made are not solely linked to the technology of iron and steel-making processes, since consideration should also be given to the level of integration of the various processing stages.

According to the traditional classification, an integrated plant would carry out all operations from the production of pig iron using iron ores and coal to the production of finished products. Non-integrated steel plants need not have smelting furnaces; they could rely on steel scrap as the principal raw material.

In the past, in a period of growing iron and steel demand with consequent low scrap availability, the construction of integrated steel plants with coking facilities was considered necessary. Today, however, the direct reduction process offers an alternative to total dependence on scrap supplies and, if combined with electric arc furnaces and continuous-casting, offers another possibility of integrating iron- and steel-making in one plant. It is to be expected that, as regards processing, the main cost/price relationships in iron- and steel-making will be determined by the large complexes with 10-20 million tons capacity.

Small and medium-sized units will still be able to work efficiently with supplies of local scrap or reduced ore. Their proximity to markets, raw material and energy sources, as well as their ability to respond flexibly to specific requirements, could overcome the cost advantages enjoyed by large-scale plants.

The design and manufacture of steel plant equipment

Steel plant equipment is manufactured by a large number of enterprises operating as independent firms, or as associates of major steel-making companies. The development of local spare parts manufacturing capacity is a complex process. It can be assumed that the average annual requirement of spare parts ranges from 2,400 tons to 3,200 tons per million tons of production capacity, depending on the age of equipment and standard of maintenance. Local manufacture of spares may help obviate production delays and reduce import bills as well as promote the development of local engineering skill and manufacturing capabilities.

In developing local steel plant engineering and production capabilities, priority should logically be given to light- and medium-weight rolling mills and finishing line equipment. In building up a steel plant manufacturing industry:

(a) A design and engineering company can be formed to specialize in the purchase and development of equipment designs;

(b) Manufacturing companies producing similar equipment could expand and restructure their organization to meet local requirements;

(c) One company could be set up to manufacture equipment and spare parts.

The design and manufacture of steel plant equipment will of necessity lead to a strengthening of the heavy engineering sector. In a sector such as the heavy capital goods industry, the appropriate balance of engineering, production and marketing capability can only be assessed in the long term.

Environmental management

The iron and steel industry is responsible for the production of gaseous, liquid, and solid contaminants. The gaseous contaminants from large plants include sulphur and nitrogen oxides, ammonia, and carbon oxides, as well as particulates such as iron, silica, and limestone. The liquid contaminants include tars, oils, phenols, cyanides, ammonia, heavy metals, low pH, and suspended solids. Solid wastes are largely raw material fines, such as carbon, iron, silica, and limestone.

Most contaminants in the conventional process originate in the preparation of pig iron, i.e. in coke ovens, sintering and pelletizing, and blast furnace operations. The coke ovens contribute most of the chemical contaminants while the other units generate the solid matter. In addition, the finishing operations in hot-forming and cold-rolling give off metals, acids, and oil as well as iron scale, while power plants exude oxides of sulphur and nitrogen.

Gaseous contaminants can be controlled by baghouse filters, cyclone separators, electrostatic precipitators, and both solid and liquid scrubbers. Liquid contaminants can be removed by neutralization, sedimentation and flotation as well as by concentration and re-use. In certain instances, biological treatment is required. Solid wastes are settled in or filtered out of scrubber and process water wastes; they can also be refined from blast furnace and basic oxygen furnace slag. No positive steps have been taken on an international scale to reduce noise levels or prevent aesthetic contamination.

As a plant becomes "environment conscious" it tends to convert more and more of its air and water contaminants into solid wastes which in turn become one of its major concerns. It is very important to the economics of the industry to recover and re-use as much of these solids as possible. The re-use of solids found in mill-scale, blast furnace dust, sinter plant dust, slag, lime dust, scrap and scarfing powder is recommended for reasons of economics as well as pollution abatement. All the particulate solids recovered - with the exception of slag - can be incorporated in sinter mix, pellet-making, coke-making, and powder metallurgicals. The blast furnace slag can be re-used in the production of cement, insulation, building materials, and aggregates for road building. Basic oxygen furnace slag is also valuable for both its iron and relatively high phosphorus content. The iron can be reclaimed for re-use in the plant, while the remaining phosphorus can be used as a fertilizer.

The major process changes which reduce environmental pollution are:

(a) Dry instead of wet quenching of coke;

(b) Hydrochloric acid instead of sulphuric acid pickling;

(c) Direct reduction instead of blast furnace methods.

The environmental consequences of steel production at a given site should be studied and evaluated prior to approval of the project. Environmental quality guidelines should be established during plant design and construction so as to prevent excess environmental contamination. The site of a steel mill must be selected carefully to ensure that there is ample air and water for dilution, and land to serve as a buffer zone and receptacle for residual unusable solids. In iron and steel production some environmental degradation is almost inevitable, but the degree of degradation should not exceed the minimum standards acceptable to the local community and government, nor should it be arbitrarily set by the industrial plant. Furthermore, care should be taken to ensure that the clean air and water at present abundant in many developing oountries are not squandered through indiscriminate use as waste receptors. In general, stricter environmental controls should be exercised in iron and steel plants constructed in the developed countries, since heavy industrialization in these countries no longer permits the use of the natural environment as an effluent receptacle.

Air and water pollution control costs can be expressed either as a percentage of production costs or in dollars per ton of product. In the first instance, the factor will be 1 to 2 per cent, in the second $2 - 5 per ton of steel produced. These costs are sufficiently low to be spent by plants in developing and developed countries alike. They should be absorbed in the price of the steel and passed on to the consumer. These costs may be reduced still further in future by establishing integrated industrial complexes containing steel mills and such auxiliary industries as fertilizer and agro-industrial plants. Though the production of iron and steel results in the discharge of numerous contaminants, it need not be constrained by environmental factors since control technology is known and abatement costs are relatively insignificant in relation to other production costs.

Plants should be located primarily but not solely in developing countries on minimum-cost sites, preferably in integrated industrial complexes so that both production and environmental costs can be minimized through the utilization or re-cycling of wastes. Considerable research and pilot experimentation is necessary in order to optimize these industrial complexes (which may contain a different mix of industries for each site). Wherever possible, steel products should be manufactured using direct reduction, electric arc furnaces and continuous casting sequences, thereby minimizing environmental damage.

Resources

In considering the resources necessary for the development of the iron and steel industry, resource availability and geographical distribution are of paramount importance. These factors are considered here as they relate to energy resources, mineral reserves and scrap availability. An attempt has been made to assess the prospects of an increased share in production for individual countries, in terms of resource availability. It is hoped that the assessment will assist in the decision-making process regarding the establishment of production capability, concomitant with the aims of these countries in terms of their desire for import substitution, export targets and self-sufficiency.

However, availability of resources is not the only factor vital to the development of an iron and steel industry. Some countries have achieved a successful development record in this sector without the advantages of domestic mineral or energy resources; with trained manpower, acquired technological skills and financial creditibility, they have been able to produce and export. Nevertheless, it is considerably easier for a country having its own resources to enter the production field.

Eight major parameters have been identified with respect to energy and mineral resources. Four of them relate to energy - total coal, natural gas, potential oil and hydro-electric energy; and four relate to raw materials or are combined fuel and reductants - coking coal, ferrous ore, charcoal, and manganese ore.

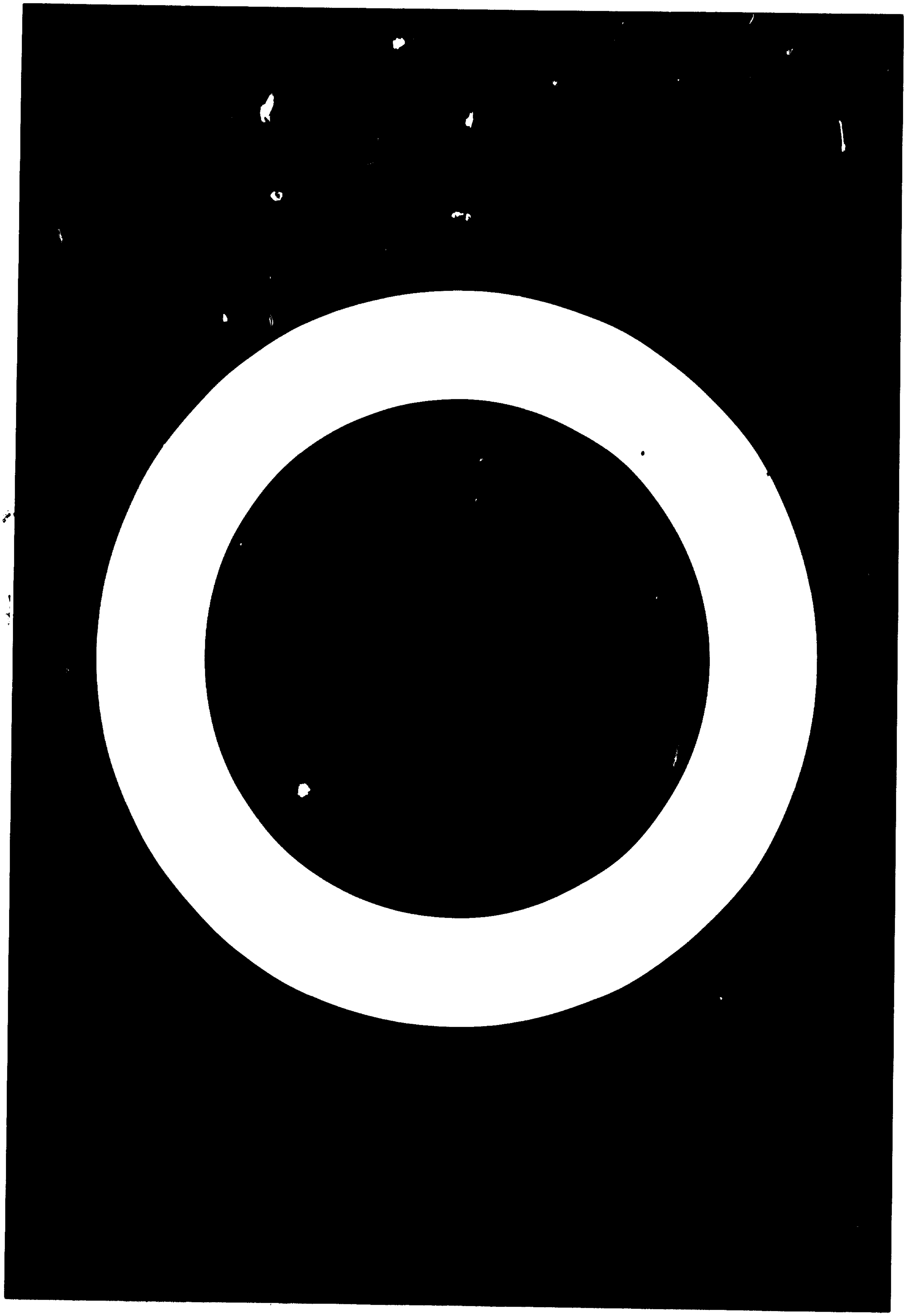
It can be seen that the most significant hindrance to the establishment of steel production facilities in the developing countries is the lack of coking coal. This lack will, to some extent, limit the technologies that can be utilized in the desired over-all expansion pattern, but it will not necessarily preclude development by individual countries; in 1970, over 50 per cent of crude steel was produced by countries which imported 45 per cent of their fuel requirements for energy alone. Such a wide choice of production options exists that, given marketing, technological and financial ability, few developing countries exist in which the industry cannot be developed. The direct reduction process, in particular, offers opportunities for the establishment of steel industries in developing countries.

It has been possible to identify those developing countries which, in the sense of known mineral and energy reserves, are in a favourable position to establish an iron and steel industry, and to designate them favourable (when they have five of the eight parameters mentioned above), less favourable (three parameters), or least favourable (less than three parameters).

It is emphasized, however, that this assessment has been made in the light of known resources only, and must be considered in this respect. Furthermore, the concept of five favourable parameters does not necessarily imply that all resources for any particular production route exist; some countries in this category may need to import essential resources in order to complement those existing. Again, other countries, classified as less favourable, may have an abundance of one or more resources which, taken in conjunction with other factors, such as proximity to markets, may warrant further consideration by decision-makers.

The most significant conclusion to be drawn from these figures is that while the developing countries have a dominant share of world resources of gas, oil and hydro-electric energy potential, and a good share of ores, they suffer a lack of coal, particularly coking coal. It would appear, therefore, that for many developing countries the electric furnace method, utilizing both scrap and directly reduced iron, offers the most favourable development possibility; this method has the added advantages of flexibility of size and lower plant costs.

In the blast furnace method, the substitution of charcoal for coke is an acceptable and fully feasible technology. Its utilization will call for an early decision with respect to forest establishment, however, in order that sufficient supplies can be ensured by long-term harvesting and replanting strategies. The paramount importance of preserving environmental balance in the developing countries may limit the utilization of charcoal, if programmes for adequate replanting are not given priority.



	Engineers	Technicians	Adminis-trative workers	Skilled workers	Semi- and unskilled workers	Total
Total demand to 2000	60,000	150,000	230,000	640,000	920,000	2,000,000
Average annual demand, 1975-1985	1,800	4,500	7,000	19,500	28,000	61,000
Average annual demand, 1986-2000	2,800	7,000	11,000	30,000	43,000	93,000

Capital requirements

Replacements and new investments: their order of magnitude

It is expected that new iron and steel production facilities with a total capacity of 380 million tons will be added to the world's steel-making capacity over the period 1975-1985 with a possible further 765 million to 1,080 million tons being added over the period 1986-2000. In the two periods cited above, replacement of existing capacities will most probably be of the order of 240 million and 450 million tons respectively. The developing countries' share in these new production capacities and replacements would be 115 million tons (1975-1985) and 339 million tons (1986-2000). 6/ The estimated average annual expansion of production is shown in the table below, in millions of tons:

	1975-1985		1986-2000	
	World total	Developing countries a/	World total	Developing countries a/
New capacity	38	10.9	51-72 b/	19.6
Replacement	24	0.6	30	3.0

a/ China not included.

b/ 51 million tons would involve an increase in investment of 37 per cent, 72 million tons an increase of 89 per cent.

6/ Although several production variants are presented in Chapter II, only one steel production capacity variant is examined here, corresponding to the production by the year 2000 of 378 million tons with a plant utilization factor of 85 per cent.

The 38 million tons additional annual capacity estimated for the period 1975-1985 is very close to the present level of investment in iron and steel plants. Bottlenecks may occur in certain regions or countries owing to infrastructural shortcomings or lack of skilled labour.

Calculating average capital costs

New steel-making capacities of the magnitude of 35-40 million tons annually are currently under construction. However, as these are based on contracts agreed upon in various years and under widely differing conditions, their capital cost can only be approximately indicated. For the purposes of this study, an average price of $600 per ton has been taken. The rationale for the assumption of this figure was:

(a) The capital cost figure selected is based on installed capacity of crude steel-making; it would have been higher had it been calculated on the basis of the expected operating rate of 75-95 per cent capacity.

(b) The expansion of steel-making capacities involves investment in both new and existing plants (green-field investments and round-outs). The capital cost figure quoted for iron and steel mills covers:

- Mills of different size, hence at different points on the capital costs degression curve;
- Mills using different production methods, such as blast furnace and basic oxygen furnace; direct reduction and electric furnace; and scrap melting;
- Mills with rolling and finishing facilities, greatly varying in terms of size and equipment.

(c) Using aggregate data relating to the current decade, the capital costs have been elaborated separately for plants using blast and basic oxygen furnace ($648 per ton of capacity) and those using direct reduction and electric furnace techniques ($[illegible]02 per ton of capacity). For the latter, a steel-making capacity of 0.5 million tons was assumed as was a direct reduction capacity to meet 70 per cent of the metallic requirements of the electric furnace.

(d) For developing countries unable to afford the plants described above, smaller steel-making capacities of 200-[illegible]00 tons per day can be achieved through the installation of an integrated plant using direct reduction and electric furnace methods, or through the expansion of existing re-rolling or scrap-melting plants.

Given appropriate bar, rod and section-rolling facilities, the capacity of these integrated mills using direct reduction and electric furnace methods may be as high as 0.5 million tons, while the investment costs may be as low as $180 per ton of steel-making capacity. Depending on the product mix, operation may be deemed economic at an annual production level of 200,000 - 400,000 tons. Capital cost degression in respect of both direct reduction and electric furnace methods is considered low at levels above 500,000 tons per year.

(e) Rolling and finishing facilities have an appreciable effect upon capital costs, though the exact extent thereof is often only vaguely defined in investment figures published. The capital costs usually vary between $90 and $300 per ton, but they may be much higher, depending on the size of the operation and its end-product. In this area, the economies of scale are particularly important.

(f) The manufacture of "rounds", such as wire rod, concrete reinforcing bars and light and medium structurals, which account for more than half of the steel consumed in the developing countries, is deemed economic at an annual production level of more than 100,000 tons. The investment needed in a merchant bar mill is of the order of $70 per ton of capacity. An efficient level for the manufacture of most flat-rolled products is in the range of 1-3 million tons.

(g) In view of the capital cost degression of the rolling and finishing capacity as well as the local demand for steel, the priority given by developing countries to self-sufficiency in non-flat products would appear logical. It might be economically desirable for these countries to export continuous-cast slabs, billets and bloom until such time as demand (1-3 million tons) for flat products justifies the installation of rolling and finishing facilities. The capital cost figures are certainly influenced by the fact that, in the developing countries, rolling and finishing operations are assumed to be less diversified, and manufacture is more oriented towards non-flat products.

(h) In the case of mills using blast and basic oxygen furnaces, the fixed assets account for 68.9 per cent of total capital costs, whereas in the case of mills using direct reduction and electric furnace methods, they account for 74.5 per cent. Project implementation and pre-operating expenses account for 9.6 per cent of total capital costs in the case of the first mills and 8.2 per cent in that of the second mills. In respect of the mills using blast and basic oxygen furnace methods, the infrastructural investment estimates given in the study were based on experience gained in projects executed in Latin America and Europe, whereas the infrastructural investment figure quoted for the mill using direct reduction and electric furnace methods is a pro-rata estimate.

(i) The working capital required for a mill using blast and basic oxygen furnace methods was based on experience gained in Latin America, while that of the mill using direct reduction and electric furnace methods was assumed to be much lower.

(j) Investments necessary for the extraction and beneficiation of iron ore may amount to $100 per ton (including pellet plant), and those for coal mining $30-40 per ton, or even more. These investment costs are not included in the average capital costs per ton of steel cited in the report: however, they would have to be taken into consideration if mining operations were carried out locally or if the level of past export earnings were to be maintained.

(k) No attempt has been made to estimate price escalation in the long term. However, this must be taken into consideration, should specific national studies on financing be made. For example, steel plant equipment went up some 80 per cent in price in the period 1965-1975, while building and construction costs increased by an even greater amount in many parts of the world.

(l) Interest payments may account for an additional $42 per ton in the case of the capital costs estimated for a plant using blast and basic oxygen furnace methods, and an additional $10 per ton in those plants using direct reduction and electric furnace methods. However, these additional costs have not been considered in this study.

(m) The proportion of foreign to local capital is of major importance to steel projects in the developing countries. This proportion differs in respect of the various fixed assets, such as plant and spares, transport, construction and civil engineering works. On an average, this proportion might be 60:40.

Capital requirements, 1975-2000

The estimated capital expenditure involved in replacing and expanding iron- and steel-making facilities are:

(Billions of dollars, 1975)

Plant	Per year, 1975-1985 World	Per year, 1975-1985 Developing countries	Per year, 1986-2000 World variant A	Per year, 1986-2000 World variant B	Per year, 1986-2000 Developing countries
Replaced	7.2	0.2	9.0	9.0	0.9
Expanded	6.4	0.8	9.7	15.1	2.1
New	11.8	5.2	14.4	18.0	8.3
Total	25.4	6.2	33.1	42.1	11.3
Grand total, period	254.0	62.0	496.5	631.5	169.5

Assuming that, on an average, 40 per cent of the capital costs would be met from local currency, some $3.7 billion and $6.8 billion foreign exchange would be required annually in the respective periods. Further assuming that, on an average, 50 per cent of these amounts would be financed through medium- and long-term loans, foreign resources required to finance the steel industry in the developing countries (not including China) would be of the order of $2 billion in the period 1975-1985, and $4 billion in the period 1986-2000.

As a comparison, reference is made to the flow of financial resources from selected developed countries 1/ to developing countries and multilateral institutions which amounted to $26.8 billion in 1974 and an estimated

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1/ Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany (Fed. Rep.), Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom and United States.

$37.5 billion in 1975, and comprised both official and private net disbursements. 8/ The sharp increase from 1974 to 1975 was linked with the rise in private export credits from $2.5 billion to $6.2 billion.

In determining the total capital expenditure, consideration should be given to the cost of establishing or adapting the infrastructure: these costs, however, have not been entered into in depth in the study, owing to their high degree of variance.

8/ World Bank Annual Report 1976, table 3, p. 100.

Chapter II

WORLD STEEL PRODUCTION AND CONSUMPTION TO THE YEAR 2000

A. FORECAST TO 1985 AND 2000

In this chapter, steel production and consumption are projected to the year 1985, and alternative growth variants are given for the year 2000. In addition to the specific approach adopted in this study, various other forecasting methods are discussed. Steel production and consumption projections are presented for economic groups and geographical regions. Of the significant determinant factors, particular consideration was given to long-term production and consumption trends and to new steel capacities planned in specific countries. Also presented are the results of a quantitative investigation into historical steel production and consumption patterns Owing to the strict schedule for this study, the preliminary quantitative findings could not be incorporated in the projection, though the methodology used may serve as an input to the development of a more sophisticated projection procedure.

Patterns in steel production

Steel-making has long been regarded as the traditional foundation for the development of heavy industry. Historically, the industry's growth rate has tended to be rapid during the early or formative phase, only to decline or become negative in later periods of development. The long-term growth pattern of the iron and steel sector usually provides a clear demarcation between the industry's early and mature phases of development. Consequently, growth rates for iron and steel production differ widely between countries where the industry is in its mature phase and those where steel production has only recently started.

The steel industry has gradually spread from traditional European centres to other developed countries and, in recent decades, to developing countries. The global share of the traditional steel producers has generally decreased while world totals have increased. For example, in the period 1936-1938, Western Europe and North America accounted for over 70 per cent of crude steel production, and the USSR, with over 14 per cent of world output, was also a prominent producer. By way of contrast, Japan accounted for less than 5 per cent of world production, while the developing countries' share amounted to only 1 per cent.[1/]

1/ Stahl und Eisen, [illegible] ([illegible]), Number [illegible], p. 568.

Since 1945, the geographical pattern of steel production has undergone major changes which reflect the type of long-term growth pattern described above. In 1974, the developing countries' share in world steel production was 5.1 per cent (as against 1.6 per cent in 1955), while Japan's share increased from 3.5 per cent to 16.5 per cent over the same period.[2] This consistent pattern constitutes a useful, although by no means infallible, guide to the future scenario of world production. Thus far, the production pattern has been roughly similar from one country to another, a characteristic which also lends itself to forecasting exercises.

Forecasting future development

In planning future steel production capacity for a plant, country, or group of countries, the first step must be to make projections for the markets the new capacity will serve.[3] These projections should be made in terms of specific steel products such as plates, bars, structurals, wire, sheets and piping. In planning for a specific plant, attention to product detail is essential (exact grades and sizes). For national or sub-regional planning, however, product detail need not be so precise. The planning can be carried out on the basis of expected total steel consumption, which is usually expressed in terms of raw steel equivalents (i.e. the consumption of steel products divided by a factor of 0.7 or a little higher).

In the case of the present study, it was found impractical to attempt forecasts in terms of broad product categories. Detailed product information will be necessary for planning at project or national levels. The method normally employed for a study of this nature is the sectoral approach, according to which future production is forecast for specific steel-consuming industries such as construction, machinery, automobiles and shipbuilding, often in relation to the estimated gross national product. Steel consumption factors, generally based on past experience, are established for each consuming industry, whence envisioned steel requirements can be derived.

2/ See Table 1. (Numbered tables are to be found at the end of this Chapter.)

3/ This study distinguishes between projections of demand and consumption on the basis of the model employed in the projection exercise. Ideally, a projection of demand is preferable to one of consumption, and where the model uses income and/or price variables, the result are referred to as a demand forecast. In those cases where the model is a simple extrapolation of previous consumption trends, the results are described as projected or expected consumption.

Unfortunately, however, this method, although generally considered to be highly effective, supplying as it does the type of product detail described above, is also the most time-consuming, requiring voluminous data inputs - particularly when it is applied to more than one country. And it often happens that the required date are not available, especially from developing countries. Thus, for planning at the project level, the method is extremely useful, but it is beyond the scope of a broad study such as the present one.

In developing the model upon which the forecasts given in this study are based, projections by the International Iron and Steel Institute (IISI), Brussels, were taken as the starting point. The IISI projections, in turn, are based on the steel-intensity method, which relates steel intensity - defined as steel consumption per unit of gross national product (GNP) or gross domestic product (GDP) - to GNP per capita. By combining steel-intensity factors with forecasts of population and GNP levels, it is possible to arrive at projections of steel consumption for countries, groups of countries, and the entire world.4/ The figures were adjusted to reflect developments that have taken place in the industry since the original IISI forecasts were carried out in 1971-1972 and projected on the basis of expected growth potential in the developing countries, together with complementary information derived from national development plans. Other inputs included the information gathered by UNIDO in the course of its technical assistance activities over the past decade.

The economic fluctuations that occurred between 1972 and 1976 were taken into account, as was information that was not available to the original IISI forecasters. Among the non-quantitative factors considered in the revision, planned expansion and investment in the iron and steel industry were accorded particular importance. This information was compiled on a country-by-country basis, often at the project level. National demand projections were also considered, as were production estimates and the intention to produce for both domestic and/or foreign markets. As the information from various sources regarding planned rates of capacity and possibilities of project delays diverged somewhat, it had to be analysed in the light of past experience to determine its worth as an input to the projections, it being remembered that the establishment of iron and steel complexes can take up to ten years.

4/ OECD - Forecasting Steel Consumption, Paris, 1974. IISI - Projection 85, Brussels, 1972. World steel demand for 1985 is projected according to the Brussels method.

Two world growth paths, corresponding to growth rates of 3 and 4 per cent of world steel production and consumption, were assumed for the period 1985-2000. Available information on planned expansion and historical patterns of consumption and production, growth rates for the various economic groups and geographical regions have been used.

The fundamental assumption is that the global growth rate of production/consumption will drop from the levels achieved in 1955-74 to 3.8 per cent in 1975-85, to settle between the 3 per cent low and 4 per cent high indicated above. Both growth rates were considered in relation to country groupings, consideration being taken of percentage changes in world production and consumption. Per capita consumption and production figures were used to test the impact of the various growth rates on the level of steel consumption and production. One production variant was elaborated on a country and sub-regional basis (Africa, Asia and Latin America for the years 1985 to 2000). The results are considered alternative scenarios, on the basis of which a quantitative assessment can be made of various growth expectations and their impact on resource consumption and capital requirements. In this context, special consideration was given to the views expressed in the Lima Declaration and Plan of Action.

Consumption and production in 1985

In its original forecast, IISI estimated that 1,144 million tons of steel would be produced in 1985. Though the forecast was carried out in full awareness of the pattern of previous cyclical fluctuations, the subsequent boom of 1973-74, and the suddenness and severity of the 1975-76 recession, made a slight reduction necessary. This recession was equivalent to the elimination of all or part of one year's growth from the long-range picture. Thus, the original forecasts constituted an over-estimate of the order of 10 per cent.

It is far more difficult to evaluate the possible extent of future changes in the price and availability of the various inputs for steel production. In the long term, this will probably be somewhat negative for steel consumption, but not markedly so.

With respect to the substitution of materials such as aluminium, plastics and concrete for steel, the easiest and most logical substitutions may have already taken place, and these are fully reflected in the data for past periods upon which future projections are based. The rate of substitution is likely to be lower in the future, hence substitute materials may find increasingly less application. Furthermore, although the costs of other materials relative to steel have been low for many years, this trend now seems to be declining and may even reverse. The plastics and aluminium industries may have reached maturity and their rate of technological advance is slowing down and becoming more comparable to that of the steel industry.

In the light of the above, a slight reduction in the IISI forecast of 1,144 million tons for 1985 might appear justified. According to the methodology used in the present study, some 1,069 million tons of steel production/consumption are expected for 1985, corresponding to a 3.8 per cent annual growth rate in world steel demand between 1974 and 1985.[5/] The growth rates of steel consumption and production in the different groups of countries would be the following:

Assumed growth rates of steel consumption and production, 1974-1985
(Per cent)

	Consumption	Production
Western Europe	2.7	2.2
EEC	2.3	1.7
Other Western Europe	3.9	4.6
Eastern Europe (excluding USSR)	4.2	4.0
USSR	3.1	3.4
North America	2.5	2.0
USA	2.4	2.0
Canada	2.8	2.0
Oceania	3.6	2.0
Japan	3.6	3.7
Average, developed coutries	3.0	2.8
China	6.7	7.5
Africa	6.5	23.3
Asia	7.7	11.2
Latin America	8.2	11.2
Average, developing countries[a/]	7.8	12.0
South Africa and Rhodesia	4.5	6.5
World Total	3.8	3.8

Source: UNIDO estimates.

a/ Not including China.

5/ While the present study was under preparation, IISI published a preliminary corrected estimate for 1985 of 1,058 million tons. (Discussion paper: "Some economic aspects", Annex 3, IISI, Annual Meeting and Conference, 10-13 October 1976.) The reason given is different, however. The decrease is derived from the better yield of steel-making connected with the spread of continuous casting. This means that IISI has de facto not changed its consumption forecast for 1985 for the time being.

In general, the share of the developed countries in world steel consumption will probably continue to decrease, although some countries are expected to maintain, or slightly increase, their particular levels. The share of the developing countries will probably reach 15.9 per cent in 1985 (compared with 10.5 per cent in 1974). In 1985, steel consumption per capita will be of the order of 700 kg in the developed countries, a level that compares with consumption in the United States and Japan in 1974.6/ The geographical pattern of world steel consumption for 1985 (Figure 1) demonstrates the substantial percentage increases forecast for the developing countries in the three geographical regions. Consumption per capita projected for Latin America in 1985 is expected to be roughly comparable with the levels achieved in Eastern Europe in the mid-1950s, whereas the per capita figures for developing countries in the other two regions would be considerably lower than recent levels in the developed countries.7/

In view of the probable production pattern in 1985, the major net steel exporters (EEC and Japan) are not expected to expand their share in total world exports beyond the present levels. At the same time, the present imbalance between production and consumption common to developing countries will probably be redressed. In 1985, production in both developed and developing countries will be largely determined by existing capacities as well as by those investment projects currently under preparation or in the course of execution. Except for Western Europe (not including the EEC) and Eastern Europe, the developed countries' share in world production will probably decrease in the period 1974-1985. It is estimated that production in the developing countries will represent 11.7 per cent of world total in 1985. 8/ The increases in the shares of each of the three developing regions are shown in Figure 2, together with corresponding shifts in the shares of the developed market and centrally planned economies.

It is not expected that the developing countries will be able to expand their steel capacities so as to match their estimated consumption requirements of 170 million tons in 1985. Even an ambitious annual growth rate of 12 per cent cannot result in production greater than 125 million tons by

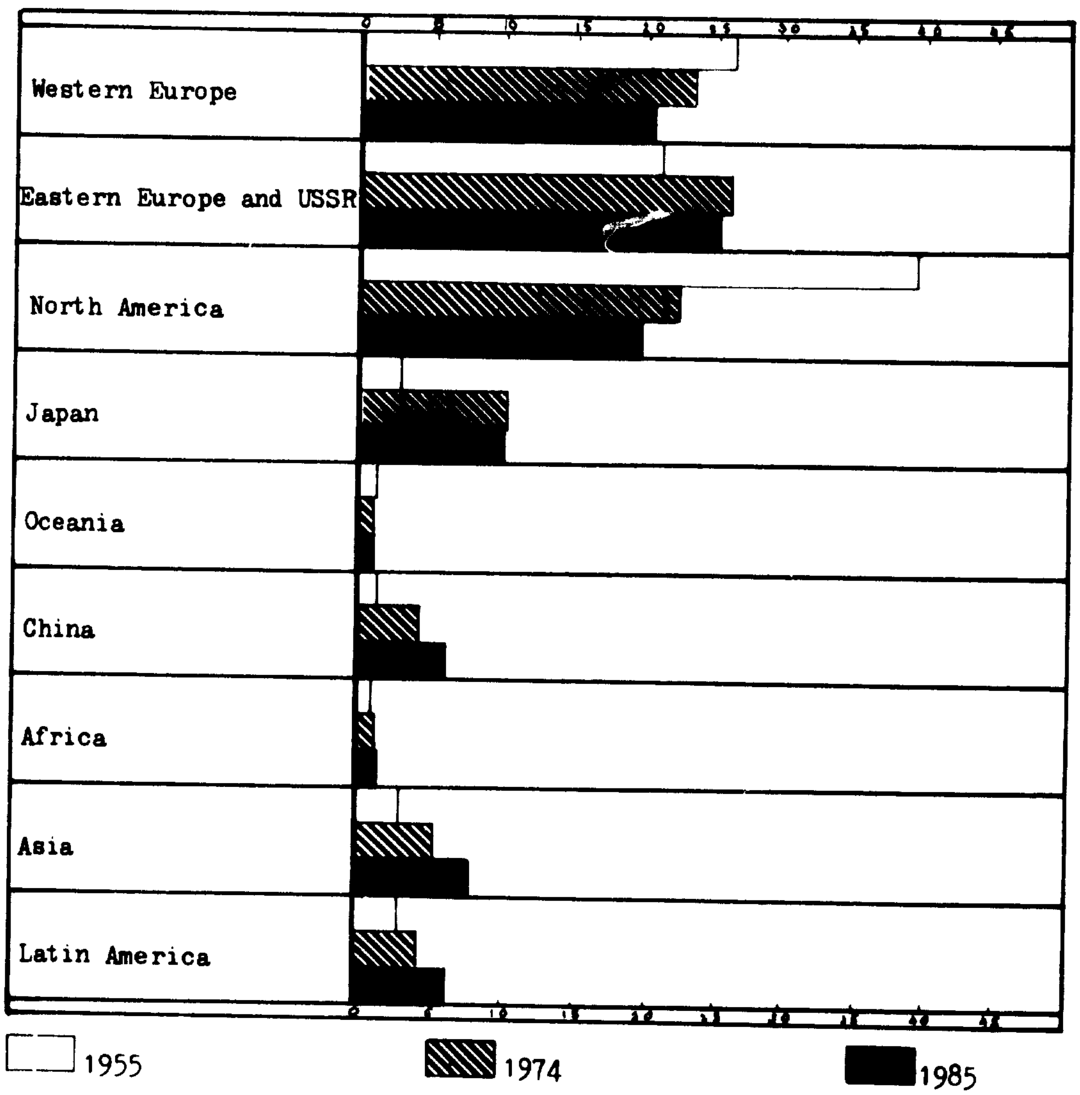
6/ See Table 4.

7/ Ibid.

8/ See Table 1.

1985,[9] which means that the net import of crude steel equivalents will probably exceed 40 million tons of steel in that year. Compared with the 38.1 million tons imported in 1974, this quantity seems to offer no absolute improvement in terms of the developing countries' steel deficit.

Figure 1. Geographical pattern of world steel consumption
(Per cent shares)

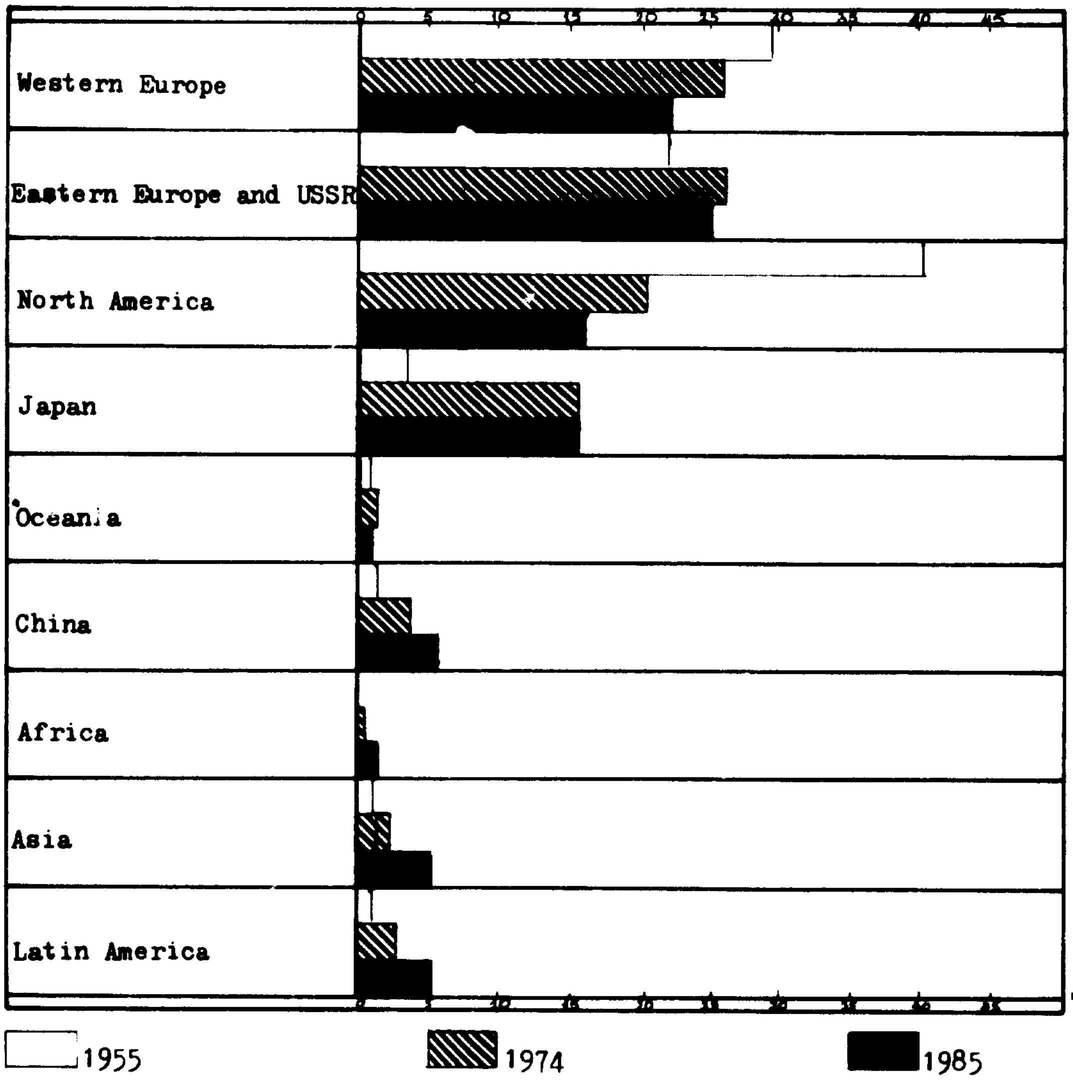


9/ A more detailed analysis of the development potentials of sub-regions and countries are given later in the Annex to this Chapter.

Growth of steel consumption and production, developed countries, 1985-2000

The growth paths of 3 and 4 per cent for world steel production and consumption are shown in Tables 5 and 6. These postulated growth rates compare with rates of approximately 5 per cent in 1955-1974, and an assumed rate of 3.8 per cent for the period 1975-1985.[10]

Figure 2. Geographical pattern of world steel production
(Per cent shares)



10/ See Table, page 32.

Steel consumption and production growth rates: developed countries
(Per cent)

	Growth Variant	Consumption	Growth Variant	Production
1955-74		4.7		4.9
1965-74		4.4		4.6
1975-85 (expected)		3.0		2.8
1986-2000 (hypothetical)				
	I a	1.5	A 1	1.8
	I b	2.0	A 2	1.5
	II a	2.0	B 1	3.1
	II b	2.5	B 2	2.6

Source: Tables 1, 2, 5, and 6.

Postulated growth rates in the developed countries for the period 1986-2000 are shown in the table above. Consumption growth rates of 2 per cent or below are roughly equivalent to those achieved by the United States during the period 1955-1974. By way of contrast, the USSR, Eastern Europe, and the EEC countries have enjoyed a growth rate more than double that of the United States during the past two decades, while Japan's growth rate was 7-9 times that of the United States during the same period. On the basis of these historical trends, an average growth rate of 2 per cent was thought reasonable, although a rate of 2.5 per cent cannot be excluded.

As for the possible pattern of steel production in the developed countries, indicative growth rates were assumed of roughly the same magnitude as those adopted for steel consumption (see table above). Variation in growth rates among developed countries was not considered and, for the purposes of this study, the same rate of growth was assumed for each sub-group.11/

Shown below are the consumption/production ratios for all developed countries in the period 1955-1974 together with hypothesized results for 1985 and 2000, which were derived using the assumptions indicated above:

11/ See Table 6.

		Per cent
1955		95.3
1960		95.4
1970		95.3
1974		93.1
1985		94.6
2000	A 1 - I b	97.2
	B 2 - II b	94.4

Source: Tables 1, 2, 5 and 6.

One alternative (Production variant A1 and consumption variant Ib) for 2000 would result in a narrower margin for net steel exports, whereas opportunities for additional exports would be greater in the case of the second alternative (B2-IIb). Since similar growth rates were used for each sub-group of developed countries, the expected net export or import performance of the groups remained unchanged.

In the light of these assumptions, projected steel production in the developed countries would range from a low of 1,142 million tons (variant A1) to a high of 1,373 million tons (variant B1) in the year 2000. Accordingly, the developed countries' share in world steel production may drop from the 82 per cent projected for 1985 to 69-71 per cent by 2000.

Additional insights into future consumption patterns may be gained by examining trends in consumption per capita. The results of this examination provide further justification for the assumed steel consumption growth rates in the developed countries. As mentioned before, steel consumption per capita in the United States and Japan amounted to almost 700 kg in 1974. In the United States it has exceeded 600 kg for most years in the past two decades (see Table 4), reaching a high of 680 kg in 1974. The consumption pattern in Japan is distinctly different, however, ranging from 206 kg in 1960 to 695 kg in 1974. In the long run, per capita consumption levels of 900 kg or more are not inconceivable. In fact, such a figure will probably be indicative of average steel consumption in most developed countries by the year 2000.

If the assumed steel consumption growth rates of 2.0 and 2.5 per cent are applied to present per capita data for developed countries, other than the United States and Japan, hypothetical levels are obtained which are roughly comparable with levels at present achieved in those two countries. Consumption levels in the centrally planned economies are expected to exceed the benchmark figure of 700 kg per capita by some 17-34 per cent. Owing to a slow rate of population growth, centrally planned economies in Eastern Europe may reach higher levels of steel consumption per capita than the USSR by the year 2000, although growth rates for total consumption may be lower. Thus, the per capita consumption figures implied by the assumed growth rates would appear to fall into an acceptable range in light of present consumption patterns.

Growth of steel consumption and production, developing countries, 1985-2000

Consumption is assumed to increase 2-4 times faster in the developing countries than in the developed countries over the period 1985-2000. Annual consumption and production growth rates for the developing countries are shown below (in per cent):

	Consumption		Production	
1955-1974		8.3		11.8
1965-1974		9.9		9.2
1975-1985		7.8		12.0
1986-2000	Growth variant		Growth variant	
	I a	7.1	A 1	7.7
	I b	5.8	A 2	8.3
	II a	9.4	B 1	7.8
	II b	8.3	B 2	9.4

Source: Tables 1, 2, 5 and 6.

Several factors are implicit in the assumed growth rates for the developing regions. First, since most of these countries are still at a stage where steel intensity (steel consumption as a proportion of GNP) should continue to increase, the assumed steel consumption rates will probably exceed the corresponding GDP growth rates. Secondly, Africa can be expected to maintain higher growth rates than the other two developing regions, mainly as a consequence of the initially small base upon which future growth is measured. Thirdly, the growth rates for Asia and Latin America are expected to be approximately equal.

With regard to steel production, the assumed growth rates range from 7.7 to 9.4 per cent for the developing countries. As shown in the table below, the scenario calls for a production increase in excess of 200 per cent between 1974 and 1985. A similar proportionate increase would have to occur between 1986 and 2000. According to these scenarios, the developing countries' share in steel production would range from 22.7 to 25.0 per cent, while their share in world steel consumption could vary from 23.7 to 34.0 per cent.

Steel production and consumption in developing countries, 1974-2000

	Production		Consumption	
	Millions of tons	Percentage share in world total	Millions of tons	Percentage share in world total
1974	36.1	5.1	74.2	10.5
1985	125.0	11.7	170.0	15.9
2000 Low (A)	378.0	22.7	395.0	23.7
2000 High (B)	481.0	25.0	655.0	34.0

Source: Tables 1, 2, 5 and 6.

Despite such impressive rates of growth, production is not likely to prove adequate to satisfy steel demand in the developing countries as a whole in the year 2000. The historical and hypothesized trends in the production/consumption ratio between 1955 and 2000 derived from the various growth scenarios are shown below:

		Per cent
1955		26.2
1960		42.7
1965		51.6
1970		59.4
1974		48.7
1985		73.5
2000	A1-Ib	95.7
	A2-Ia	87.8
	B1-IIb	68.8
	B2-IIa	73.4

Source: Tables 1, 2, 5 and 6.

In the course of industrialization, steel consuming sectors have tended to grow faster than the domestic steel-making capacities. However, in the developing countries, some exceptions to this general relationship between consumption and production may be expected. A number of developing countries in Asia, Africa, Latin America and the Middle East are amply endowed with both natural and financial resources, favourable geographical locations and limited local steel consumption. These countries have the potential to develop into significant net exporters, provided that they can obtain access to foreign markets. Assuming that the main factor influencing production levels up to the year 2000 will be consumption in the developing countries themselves, an expanded role may be anticipated for these countries as steel exporters.

The indices for per capita steel consumption derived from the growth scenarios are shown below. By 2000, consumption per capita will have increased substantially regardless of the growth scenario considered.

(1974 = 100)

	1985	2000	
		Low (A)	High (B)
Africa	132	274	389
Asia	169	279	397
Latin America	177	273	391

Source: Table 4.

Steel consumption per capita was calculated for only two alternatives. The resultant averages for the developing countries correspond approximately to the per capita steel consumption levels of countries in Western Europe (excluding EEC) in 1955 and 1960 (109 and 145 kg respectively). Figures for Latin America relating to 2000 would appear to correspond to average levels achieved in Western Europe in the 1960s, while the level of consumption in Asia would be comparable with those achieved in Western Europe (excluding EEC) and Japan in 1955. The higher growth rates estimated for Africa in this period would not affect its lag in per capita consumption relative to the other developing regions.

Sub-regional distribution of steel-making capacities in Africa, Asia and Latin America, 1985-2000

The steel-making capacity required to achieve the production levels elaborated for 1985 and 2000 provides a basis for the estimation of capital requirement. The possible sub-regional distribution of steel-making capacities using available information on present plans, projects and intentions contributed to the development of the scenarios presented above.

The capacity estimates for 1985 are mostly based on project information and national development plans. Necessary lead-times, delays in implementation, ambiguous definitions of capacity, and other uncertainties may limit the value of such an approach. This information, however, was used as a starting point to the identification of possible development paths.[12]

Project schedules, expected capacities, national development plans and regional estimates were not explicitly or automatically incorporated into the work. In any event, the time-horizon of this study exceeds the limits of governmental or project planning. The information was used to indicate future capacity distribution, at regional and sub-regional levels. It is a tentative assessment reflecting hypotheses and is not intended to be an explicit indication of government or corporate thinking. The assessment was made on the basis of:

(a) Information on:

- Preparatory and construction stages of raw steel-making projects;
- National development plans;
- Government intentions and priorities.

(b) Performance analysis:

- Comparison of production capacity targets with average steel consumption in 1972-1974, and known growth rates;
- Comparison of production capacity targets with previous production performance and capacity utilization.

(c) Examination of determinant factors:

- Availability of financial resources;
- Availability of energy and raw materials;
- General infrastructure, in physical and human terms.

(d) International context:

- Export markets;

12/ A country-by-country summary of the salient features of these plans is provided in the Annex to this Chapter.

- Comparison with other estimates from regional and international sources;
- Comparison of steel consumption per capita and production levels with figures from other countries or regions.

The sub-regional classification used in the tables is purely geographical and does not correspond to any political or economic groupings.[13/] Though the sub-groups are incidental in this sense, the geographic proximity of neighbouring countries may lead to various forms of co-operation and complementarity in the establishment of production capacities within a sub-region, owing to the high transport costs and economies of scale characteristic of the iron and steel industry. Such complementarity can be established both in the primary production of steel, and in the stages of forming and shaping primary steel into a variety of finished products.

In some cases, the sub-regional or national development potentials are of interregional significance, as indicated by developments in North Africa, the Middle East, East Asia, and Latin America. Such projects or plans are the outcome of a favourable combination of financial and natural resources. The raw steel-making capacities of Africa, Asia and Latin America in the years 1965-2000 are summarized below. (For sub-regional distribution, see Tables 7, 8 and 9.)

(Million tons)

	1965[a/]	1975[b/]	1985	2000
Africa	0.4	1.0	16.5	58.0
Asia	10.0	20.0	66.5	198.0
Latin America	10.0	22.0	70.3	190.0
	20.4	43.0	153.3	446.0

Source: Tables 7, 8 and 9.

a/ Estimates, based on 80 per cent operating rate.

b/ Estimates, based on 85 per cent operating rate.

In order to attain the expected capacity of 153.3 million tons by 1985, 11 million tons of new steel capacity must be installed annually. For the developing countries, this annual growth should double in the period 1986-2000, to reach 446.0 million tons of steel-making capacity by the end of the century.

13/ This grouping of countries corresponds to the one used by the Population Division, Department of Economic and Social Affairs of the United Nations Secretariat in "Selected World Demographic Indicators by countries, 1950-2000". ESA/P/W p. 55, 28 May 1975.

Steel-making capacity is defined as the production of crude or raw steel, which has not yet been rolled, and is usually in the form of ingots, blooms, billets, or slabs. An appreciable proportion of investment in the steel industry is made in milling, finishing, and processes not necessarily integrated with raw steel-making, such as production of plates, sheets, bars, angles or shapes. In this Chapter, reference is not made to investment in these fields, nor is it reflected in the table below, regardless whether they are attached to primary steel-making operations or carried out separately.

Expansion of raw steel-making capacities, developing regions: 1965-2000[a]

(Millions of tons)

	1965-75	1976-85	1986-2000
Africa, growth in period	0.6	15.5	41.5
Average annual growth	0.06	1.6	2.8
Asia, growth in period	10.0	46.5	131.5
Average annual growth	1.0	4.7	8.8
Latin America, growth in period	12.0	48.0	120.0
Average annual growth	1.2	4.8	8.0
All developing countries, growth in period	22.6	110.0	293.0
Average annual growth	2.3	11.0	19.5

Source: Tables 7, 8 and 9.

a/ For replacement costs not included in this table, see Chapter VI.

The rate of operation indicates the production level in relation to full capacity. At a regional level, a 90 per cent rate of operation is considered favourable. Owing to the difficulty of bringing newly installed capacities fully on stream, operational rates may vary from 75 to 90 per cent in developing regions with a high rate of investment in new steel plants. In some circumstances, however, the rates of operation may be lower. Furthermore, market conditions as well as the continuity of supply of coal, coke, electricity, oil and ore influence the rate of operation. The production levels indicated below may be considered feasible in the developing countries by 1985 and 2000.

Operating and production levels in raw steel-making, developing countries

	1985		2000		
Operating rate					
Per cent	80	90	80	85	90
Production level					
Millions of tons	123	138	357	379	401

The dynamics of steel-making capabilities

In the present context, steel-making capabilities are discussed in terms of a region's or country's production capacity, and expressed in per capita terms. Accordingly, the steel-making capabilities of countries and regions may be defined in such relative terms as low (up to 100 kg per capita), medium (101-400 kg per capita), and high (over 400 kg per capita).

In 1975, all sub-regions, except Eastern Asia (101 kg per capita), fell into the low category. The range of per capita capabilities was quite varied, however. For example, five African and two Asian sub-regions had steel-making capabilities of no more than 15 kg per capita, whereas the Middle East and Turkey as well as various Latin American sub-regions were to be found among the higher sub-groups within the low category.

By 1985, Eastern Asia, South-West Asia, and the three Latin American sub-regions may have reached the medium level. None of the Asian sub-regions is expected to remain at the lowest level, while both North and West Africa may move to higher sub-groups within the low category.

By 2000, the southern sub-region of Latin America is expected to have achieved production capabilities exceeding 400 kg per capita, while North Africa, East and South West Asia as well as the two other Latin American sub-groups will have attained medium production capability (101-400 kg per capita). Half of the sub-regions, however, will probably still remain in the low production category, though within the higher sub-groups thereof.

Long-term trends in world steel consumption and production

In addition to the data presented earlier on the planned expansion of the steel industry, careful attention was given to long-term trends in world steel consumption and production while developing the scenarios discussed above. The results of this analysis served as inputs for the assumptions regarding growth rates at the global, regional and sub-regional levels.

The implicit assumption maintained throughout this Chapter has been that world steel consumption will in the long-term coincide with production. For the short term, it has been generally assumed that the relationship between steel consumption and production will vary, but systematically. Figures 3 and 4 show the pattern of steel consumption and production in several countries, regions and economic groupings. A comparison of the consumption and production paths offers a clear indication of trade patterns and shifts from net exporter to net importer status in certain cases.

Between 1955 and 1974, the EEC and Japan consistently maintained significant trade surpluses. In 1974, for example, Japan exported over 35 per cent of its total production, while the EEC figure was in excess of 18 per cent. As shown in Figure 3, the United States shifted from net steel exporter status to that of net steel importer over the same period.

In many other developed countries, the general trend has been for steel production to keep pace with the increase in domestic demand. In the case of the centrally planned economies, their share in both world production and consumption has risen in the past two decades, reaching 26 per cent in 1974.

Figure 3. Parallel growth of steel consumption and production per capita in larger areas

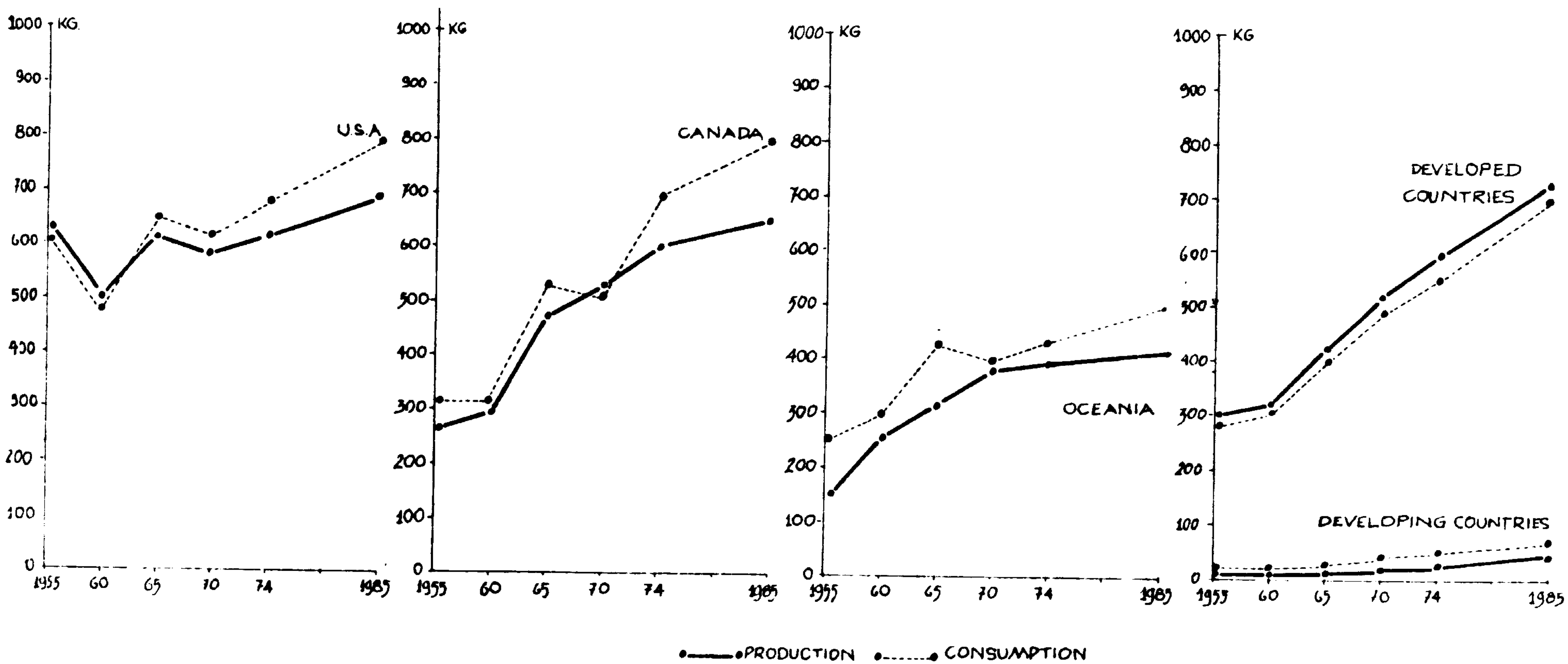
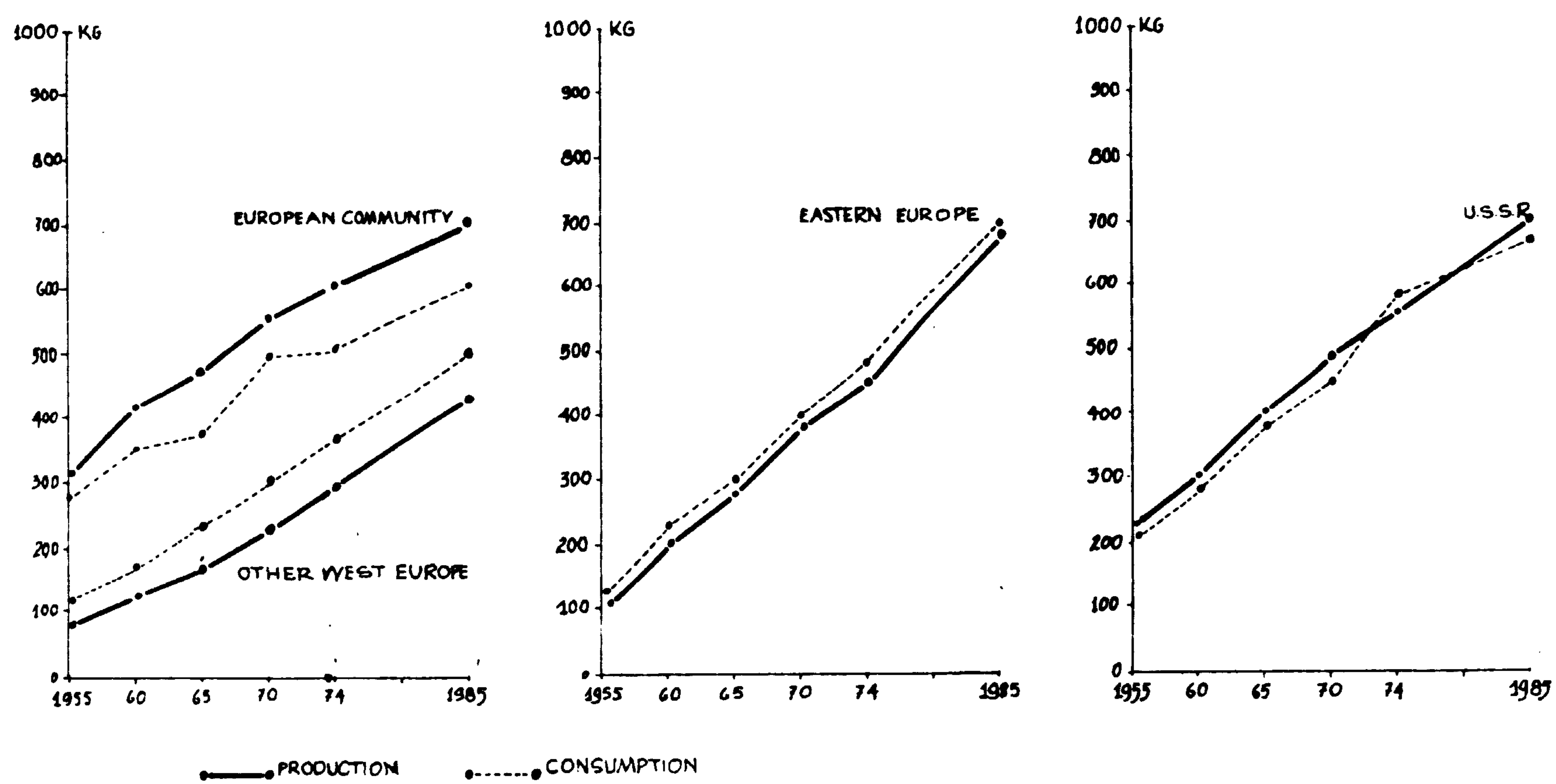


Figure 4. Parallel growth of steel consumption and production per capita in larger areas



With regard to the developing countries, the gains in steel production have not substantially altered the fact that this economic group has relied heavily on steel imports. Production increased from 16.4 million tons in 1965 to 36.1 million tons in 1974. Simultaneously, steel consumption rose from 31.8 million tons to 74.2 million tons.

With regard to per capita levels of steel consumption, anticipated levels for 1985 and 2000 have been discussed earlier. Historically, steel consumption per capita almost doubled in the developed countries between 1955 and 1974, increasing from 279 to 549 kg per capita. By way of contrast, the corresponding figures for the developing countries were only 5 per cent of the average achieved in the developed countries in 1955 and 6.9 per cent in 1974. In absolute terms, the gap between the developed and developing countries was larger in 1974 than it had been two decades earlier. The general distribution of steel consumption per capita indicates that more than 60 per cent of the world's population achieved levels of 50 kg or less, and 42 per cent of world population only achieved levels of 30 kg or less in 1974. 14/

In general, per capita steel consumption is thought to be a particularly useful indicator of economic development and the stage of industrialization. Considerable emphasis was attached to per capita trends in the course of developing the assumptions presented in the various growth scenarios. Certain qualifications, however, should be added with regard to the interpretation of per capita figures. One limitation arises from the fact that different quantities of steel are expressed in terms of a common physical unit, and variation in the steel quantity across countries can mean that this unit of measure is sometimes distorted. Furthermore, technical progress can lead to a lower use of steel per unit of output in many industries, and this trend may not be reflected in per capita figures. Bearing these points in mind, per capita consumption figures have been utilized in the present study for purposes of verifying some of the trends implied in the growth scenarios at the national and regional levels.

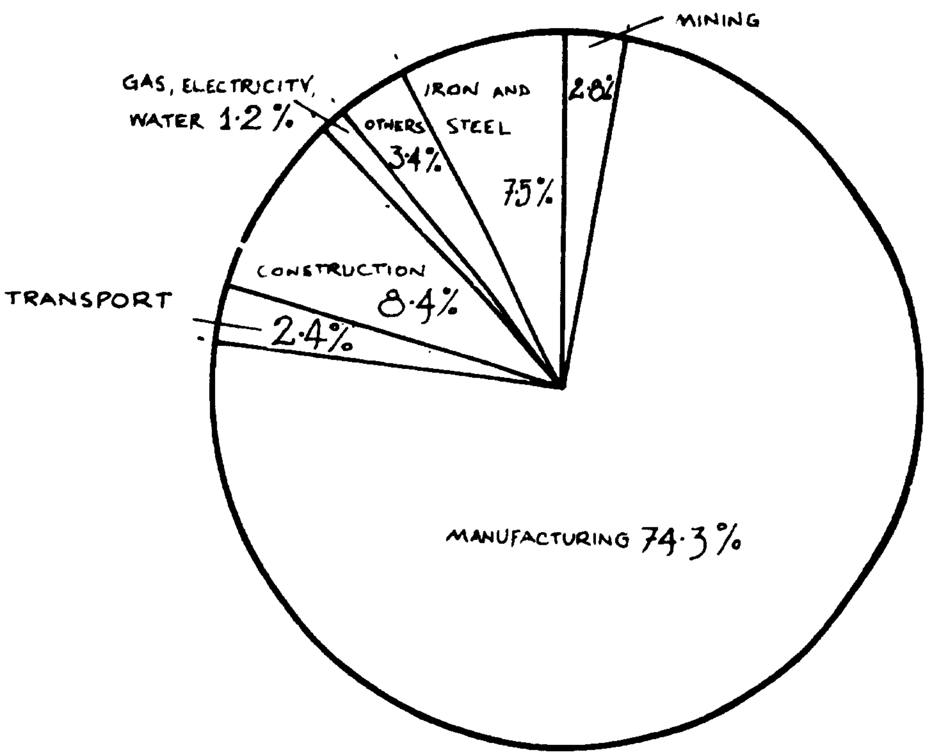
The main determinants of steel consumption

The pattern of steel demand in a developed market economy is illustrated by Figure 5 on the basis of steel consumption statistics for the United Kingdom. 15/ Approximately 74.3 per cent of the steel was allocated to the

14/ See Table 4.

15/ Iron and Steel Industry, Annual Statistics for the United Kingdom, [illegible], pp. [illegible]3 - 6[illegible].

Figure 5. Distribution of steel consumption according to the main sectors of the economy



Source: Iron and Steel Industry, Annual Statistics for the United Kingdom, pp. 63-64.

manufacturing industries, 8.4 per cent to construction, and 2.8 per cent to mining. For purposes of the present study, this type of relationship was thought to be roughly indicative of steel consumption patterns in most developed countries.

The manufacturing industry is the predominant steel consumer: a small increase in the size of the manufacturing sector can lead to a disproportionately larger increase in the demand of steel. This relationship between steel demand and the growth of manufacturing is likely to be even more exaggerated in the developing countries, and an analysis is given later in this Chapter.

The specific steel intensity of the various sectors may change in time owing to the following factors: steel consumers' better use of steel; improvement in the quality of steel; new substitutes for steel appear, and old ones improve.

In the medium term, patterns of steel consumption and production are determined by the variations in over-all industrial and economic activity resulting in steel cycles some four years in duration. The last cycle ended with the deep recession in the third quarter of 1975. These fluctuations are linked with the fact that steel demand is a derived demand which depends on the output in various steel-consuming sectors of the economy.

B. QUANTITATIVE ANALYSIS, 1950-1973

The methodology for analysing iron and steel production

The steel sector plays a prominent role in the industrial development of most countries. Its importance is a natural consequence of typical changes in the pattern of aggregate demand which occur in the course of economic development or growth. Creation of the necessary infrastructure (in construction and transportation, for example) usually accompanies, or even precedes, a country's industrial development. The demand for steel products increases substantially and is a prominent feature of over-all industrial requirements in the initial phase. At first, growth in demand is often satisfied through imports, and it is not unusual, therefore, for the steel industry to be one of the first industries to receive government encouragement through import substitution programmes.

In more advanced phases of development, the demand for steel products continues to grow as countries begin to manufacture for export and produce intermediate industrial supplies and/or capital goods for the domestic market. Although its relative importance varies systematically with levels of development attained, the iron and steel sector remains a major contributor to over-all growth throughout most of the development process. The fact that the steel industry has always exhibited a marked tendency to follow a growth pattern closely related to the level of industrialization has influenced the choice of methodology used in this study.

The methodology adopted draws heavily on the structuralist approach to sectoral development [1, 2, 6], 16/ in which it is presumed that the sectoral production pattern is largely a function of differences in countries' levels of income. Universal factors, involving both supply and demand, are thought to contribute to systematic variations in the growth pattern of steel production as over-all development takes place. These factors can be summarized as follows:

(a) Similar variation in the composition of demand for consumer and investment goods with rising per capita income;

(b) Availability of similar production technologies;

(c) Similar patterns of resource allocation among industry, agriculture and services as per capita income increases.

The two versions of the structural model employed in the industrial context are:

A: $$\ln x = a + b \ln y + c \ln N$$

and

B: $$\ln x = a + b \ln y + c \ln N + d (\ln y)^2$$

where x = per capita value added by iron and steel; 17/ y = gross domestic product (GDP) per capita; and N = population in millions.

Gross domestic product per capita serves as an over-all index of development: it is thought to be a major determinate of the demand pattern for steel over time. The distribution of total demand among investment, government consumption and private consumption changes with the level of

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16/ References, page 74.

17/ Value added at factor cost in 1970 dollars was used. The definition of the iron and steel sector conforms to that used in the UN International Standard Industrial Classification (ISIC 371).

per capita income and thus has a significant impact on the demand for steel. With regard to supply, the level of per capita income tends to be closely related to the relative costs of labour and capital inputs; it is thus indicative of the production growth path in capital-intensive sectors, such as iron and steel.

The second independent variable, population, allows for the effect of economies of scale. Together with per capita income, it provides a means of measuring the influence of market size and the importance of economies of scale to the iron and steel sector.[18/]

The equations cited above were calculated for 40 - 50 countries,[19/] using annual data on value added by the iron and steel sector during the period 1960-1973. The regressions were calculated for the total country sample and for the following sub-groups: developing countries; developed market economies; large countries; and small countries. The latter two groups which are frequently found in studies of structural change are determined according to their populations; large countries being defined as those with a population of at least 15 million in 1965, and small countries as those with a population of less than 15 million.[20/] Examining the data in this fashion provides additional insight into the relationship between growth of the iron and steel sector, domestic market size and economies of scale.

Structural models such as this are not intended to yield normative conclusions. The results indicate average or "normal" growth paths for the iron and steel sector; they refer to what can be anticipated on the

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18/ A third variable is traditionally included $(\ln y)^2$ for statistical reasons. The typical growth path for steel production is widely believed to be non-linear. In order to test uniformity in the growth paths of different countries, the log quadratic term is employed to take account of possible non-linearities. [1, pp. 143-145 and 2, p. 395.]

19/ The number of countries varied from year to year according to the data available.

20/ This distinction is largely arbitrary, and the results are not substantially altered, even if a dividing line of 10 or 20 million is used. However, in order to provide results comparable with previous studies [1 and 2], a dividing line of 15 million was chosen.

basis of information available. For projection purposes, the growth paths of countries with the expected income and population levels provide a useful reference point.21/

Growth paths for steel production

On the basis of data for 1973, Figures 6 and 7 illustrate the growth paths of steel production in respect of countries arranged according to economic grouping (developed market economies and developing countries) and size. They summarize the regression results, and relate the average growth path for iron and steel to increases in per capita income. The growth path is defined in terms of value added, which is expressed as a percentage of GDP.

Figure 6 shows iron and steel production for developed market economies and developing countries. This grouping is roughly equivalent to dividing countries according to their levels of per capita income. The growth paths are denoted by unbroken lines. Few data are available for the $600-1,000 per capita income range (broken line), and the curves for this range, therefore, should be regarded only as tentative. In developed market economies, value added by iron and steel reaches a maximum of about 1.5 per cent of GDP at a per capita income level of $2,000, whereafter it declines.22/ In the developing countries, steel production increases steadily throughout the $200-600 income range. Comparison of the two curves leads to the conclusion that during the period of transition from $600 to $1,000 per capita income, growth in this sector accelerates relative to average GDP growth. More precise definition of this portion of the curve is hampered by the lack of data.

In Figure 7, growth paths for large and small countries in the $300-2,500 GDP per capita range are shown. Once again, a portion of the intermediate income range should be regarded as tentative for the reasons given above. Both growth paths, however, are truncated at income levels where isolated countries

21/ By the same token, the structural models are not intended to provide purely mechanical projections. To make a justified estimate of output, specific information on the country's economic, institutional and other pertinent characteristics must be taken into account, and these are only partly reflected in the explanatory variables used in this study.

22/ The tendency to decline at high levels of income is due, at least in part, to changes in the countries' over-all economic structure. The share of services in GDP increases rapidly at these levels. As a result, the percentage of GDP accounted for by total manufacturing and by individual sub-sectors declines since their growth rates do not usually match that of services in this income range.

Figure 6. Growth path of steel production, by economic grouping, 1973.

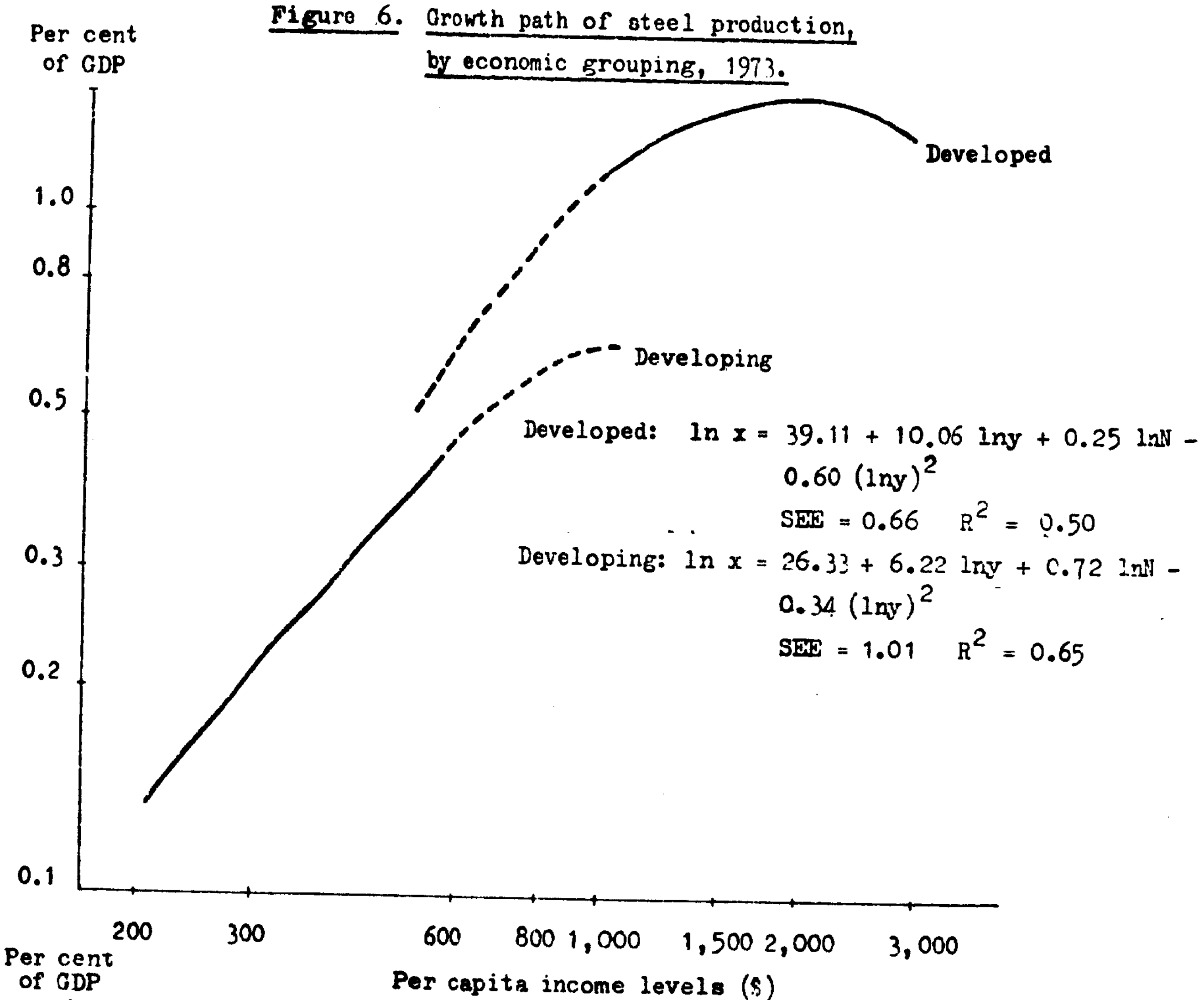
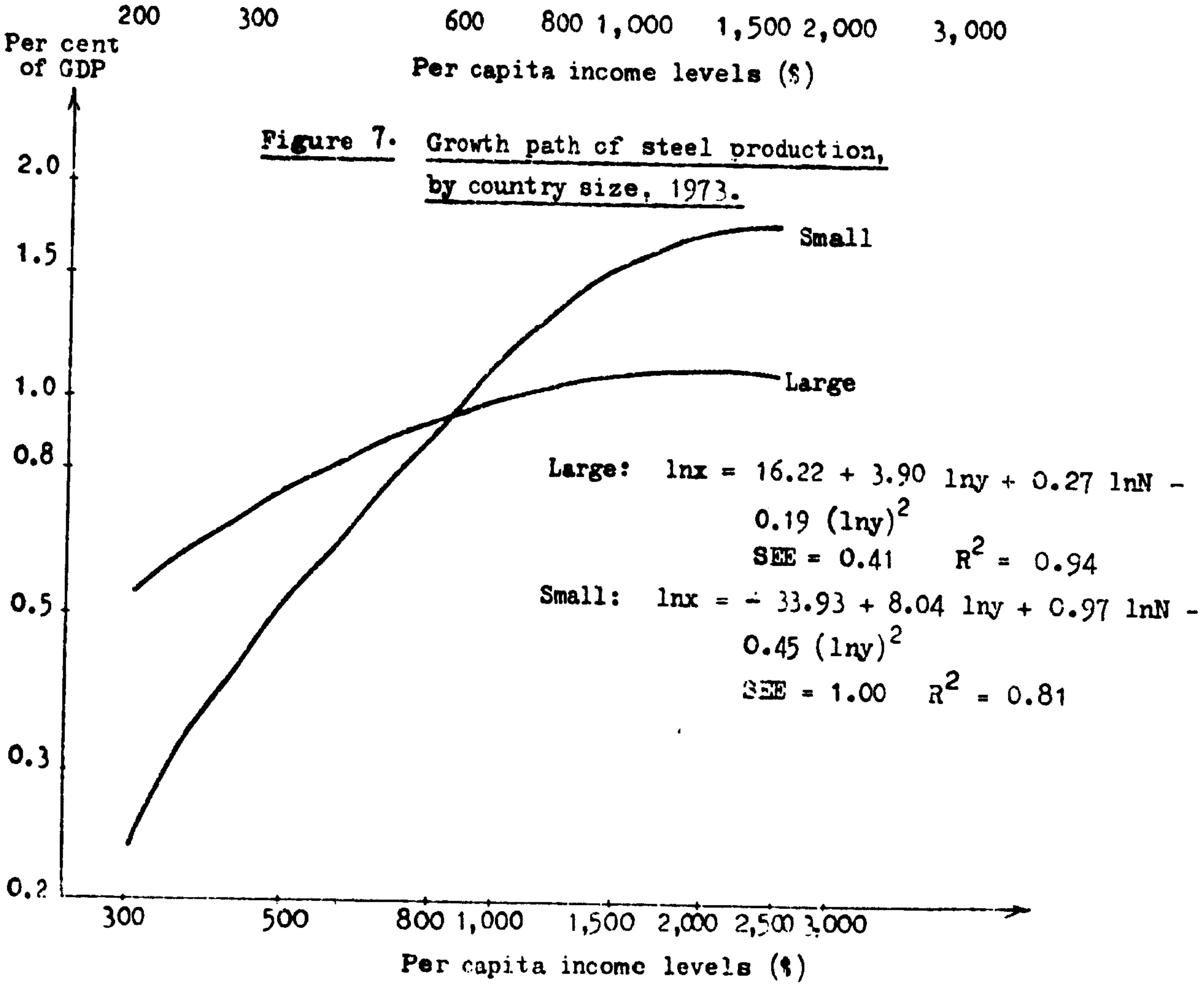


Figure 7. Growth path of steel production, by country size, 1973.



have been excluded.[23] Thus, the extremities of the curves may be regarded as reasonable indications of the growth paths.

Figure 7 demonstrates the extent to which market size and economies of scale influence production growth in iron and steel. At lower income levels, market size apparently delays the decision to expand domestic steel production, thus forcing the smaller countries to rely upon steel imports to a large extent. Once per capita income reaches $600, the share of iron and steel in GDP tends to increase sharply. Once per capita income exceeds $800, the relative importance of the sector becomes greater in small countries than in large. There is also evidence that at intermediate levels of per capita income ($600-800) countries begin to export certain basic steel products.

The regression results

Using the two structural equations cited above, the average percentage change in iron and steel production can be estimated on the basis of a percentage change in one of the explanatory variables. In Equation A, for example, a value of 1.28 for the coefficient b implies that, on average, steel production increases by 1.3 per cent for a one per cent increase in GDP per capita.[24] These derivations conform to the traditional economic concept of elasticity.[25] In the case of GDP per capita, the figure derived is known as a growth elasticity while, for population, it is described as a size elasticity.

The table on page 57 summarizes the elasticity estimates for selected time periods in each country grouping. Average elasticities have been estimated for five-year periods during both the initial and terminal phases of the time period under study. This practice (known as pooling of cross sectional or annual data) has been adopted because average patterns based on

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23/ For example, the growth path drawn for large countries does not take into account the United States which had a GDP per capita of over $5,000 in 1973, since no other data were available in this range. A similar cutoff point was applied to isolated countries below the $300 per capita level in 1973.

24/ The relationship between GDP per capita and steel production is slightly different for Equation B. The concept applied in this section is defined in more detail in the description of the table on page 57.

25/ Formally, the elasticity of x on y is defined as:

$$E(x,y) = \frac{\text{percentage change in } x}{\text{percentage change in } y} = \frac{\partial x/x}{\partial y/y} = \frac{y}{x} \cdot \frac{\partial x}{\partial y}$$

data for several years are generally more suitable indicators than equations relating to a single year.[26/]

Comparison of the summary results for developed market economies and developing countries provides an approximate indication of the influence the stage of development may have on iron and steel production. The growth elasticities are considerably larger than the size elasticities, which suggests that marginal gains in per capita income, unlike marginal increases in population, lead to significant increases in steel production. Growth in per capita income stimulates steel production more in the developing countries than in the developed countries. In the developing countries, growth elasticities exceed a value of 2.0, which indicates that steel production would increase by over 2 per cent for a 1 per cent increase in GDP per capita. In the developed market economies, growth elasticities have declined, in recent years, to less than unity. It can reasonably be expected, therefore, that, in the coming decade, the iron and steel sector will become more important than hitherto for countries with lower or medium income levels, while the converse will hold true for more developed countries.

Dividing the country sample according to size also results in two distinctly different sets of elasticity estimates. The sector's production is considerably more responsive to marginal increases in GDP per capita or population in small countries than it is in large. This difference emphasizes the important role played by economies of scale and market size in growth of the iron and steel sector.

In the table on page 57, the growth elasticities for Equation B are not identical with the regression coefficients, since the equation contains two variables involving GDP. Using the definition of elasticity ($E = \frac{\partial x}{\partial y} \cdot \frac{y}{x}$) the following formula is derived:

$$\ln x = a + b \ln y + c \ln N + d(\ln y)^2; \quad \frac{\partial x}{\partial y} = \frac{bx}{y} + \frac{2d\ x \ln y}{y} \quad \text{and}$$

$$E_{x.y} = b + 2d \ln y$$

According to the formula, the growth elasticity will vary with the assumed level of GDP per capita. Size elasticities are identical with the regression

26/ The results for consecutive years may be tested to determine whether the coefficients in each case have the same characteristics. Where no basic difference in annual results is revealed by these homogeneity tests, the data for different years are pooled [1, pp. 163-169 and 4].

coefficients for both equations and, therefore, similar calculations were not required.

Summary of growth and size elasticities, selected years

	Developed market economies		Developing countries		Large countries		Small countries	
	Growth	Size	Growth	Size	Growth	Size	Growth	Size
			Equation A					
1960-1964	1.28	0.23	2.03	0.57	1.48	0.21	1.96	0.49
1966	1.14	0.21	2.35	0.75	1.36	0.18	2.11	0.52
1969-1973	0.98	0.20	2.12	0.63	1.31	0.05	1.86	0.70
			Equation B					
1960-1964	1.72 a/	0.26	1.42 b/	0.66	1.52	0.42	2.07	0.59
1966	1.64 a/	0.24	2.33 b/	0.75	1.45	0.40	2.49	0.60
1969-1973	1.75 a/	0.23	1.90 b/	0.69	1.47	0.28	2.28	0.86

Source: Tables 12-15.

a/ Calculated for a GDP per capita of $800.

b/ Calculated for a GDP per capita of $600.

A further indication of the extent to which these considerations influence the sector's growth path is to be found in Figure 7. On an average, the growth constraints imposed by economies of scale and small market size are not fully overcome until the country reaches a GDP per capita of $800. The iron and steel industry is a relatively important contributor to the economic growth of large countries with a per capita income range of $300-800 while, in small countries, its relative importance is usually delayed until a later growth phase, when per capita incomes range between $800 and $1,400.

Equation B shows how the growth elasticity for steel changes with small increases in GDP per capita. As per capita income ranges from below $100 (the least developed countries) to over $5,000 (the United States), the growth elasticity declines from a value of 3.5 to approximately 0.8. This fact underlines the potential significance of the iron and steel industry for economic growth in the developing countries.

A summary of the regression equations employed in this study are shown in Tables 12-15. In fact, more than 100 equations were calculated for the two structural models, the four country groupings and the 14-year time period. All the results could not be reproduced in this study. An indication of the trends observed in the complete set of regressions is given later in this Chapter

In general, both structural equations perform satisfactorily in terms of explaining historical changes in production in the iron and steel sector. In the case of large countries, over 90 per cent of the variation in production (identified by the coefficient of determination, R^2) can be explained by the equations. The proportion of explicable variance is lower for the small country regressions (70-80 per cent), which suggests that factors other than GDP and population may influence production, although to a lesser extent. The regression results for both developing countries and developed market economies are similar to those for small countries.

The regression coefficients for large countries are stable and show little change over time, especially in the case of Equation A, whereas those for small countries show a downward trend over time. Thus, the equations would appear to give a more reliable indication of future trends in respect of large countries than of small. A further important criterion governing the use of the equations is the standard error estimate, in which lower values are preferred. Here too the equations performed best in respect of large countries.

Use of the method

The methodology described above provides some insight into steel production patterns in the course of economic development and growth; its possible applications are discussed below. Although some of the results are promising, it must be borne in mind that they are only preliminary indications. Considerably more investigation would be required to determine the validity and the implications of using the structural models to anticipate future production patterns.

One means of testing a model's capacity to anticipate future growth is to make hypothetical projections on the basis of historical data. Using the present model and Equation B, hypothetical projections were made for 1972 on the basis of data for 1963. The results for individual countries and the projected steel production in 1972 as a percentage of the actual steel production recorded for that year are given below. (Table 16 gives the hypothetical projection results for each country.)

Distribution of hypothetical steel projections

	Projected production as percentage of actual production (By number of countries)						
	Under-estimation (Per cent)				Over-estimation (Per cent)		
	50-75	75-90	90-95	95-105	105-110	110-125	125-150
Unadjusted method	4	3	-	2	2	2	3
Adjusted method	2	3	-	4	2	2	3

Two alternative assumptions were tested. The first procedure was to assume that the growth path calculated on the basis of figures for 1963 would accurately reflect changes in steel production up to 1972. In the table above this is termed the unadjusted method. The second procedure was to assume that each country's relative deviation from the average growth path (as determined by the 1963 data) would be reduced over time. In other words, when steel production either exceeded or lagged behind the 1963 average, the proportionate discrepancy would decline over time and the country would tend to merge with the average growth path in later years. This technique is based on the use of the residuals from the 1963 regression, the residuals being the difference between a country's actual and expected steel production in 1963 and consequently a measure of the extent to which that country deviates from the growth path. For example, a positive residual indicates that steel production exceeded the average for that year, the statistical assumption being that the absolute value of the 1963 residual did not change over the projection period. The residual, therefore, would be seen to decline in relation to the growing output.

Other assumptions have been examined elsewhere, but considerably more work would be required to deterimine the technique best suited to projecting steel production and to identify different techniques applicable to different countries /6, pp. 32-35/. On the basis of the results shown in the table above, the adjusted method would seem to perform slightly better than the unadjusted one. Using the adjusted method, over half of the country projections were within ± 25 per cent of actual production, while slightly less than half the country projections were within the same range when the unadjusted method was used. Similar results were obtained when the calculations were carried out for 25 small countries.

As stressed earlier, the estimated growth patterns are regarded as average or normal paths; they are not indicative of the performance to be expected in any given country. In the case of projections, this would imply that the structural model could be used to project steel production for a number of countries in any one group. In a group sample, country peculiarities reflecting differences in resource endowments or development policies would not have the same impact as they would in individual country projections.

Accordingly, a second set of hypothetical projections were developed to verify further the structural model's capacity to project steel production in groups of countries. Where the growth path of individual countries tends to approach the average for the group, projections on this basis would be more reliable than those for specific countries. Hypothetical projections made for both the large and small country groups using regression equations for 1963 and Equation B are shown below:

Hypothetical steel projections for large and small countries, 1963-1972

(Projected as percentage of actual group average)

	Simple group average[a]		Total value added over total population[b]	
	Large	Small	Large	Small
Unadjusted method	99.0	82.8	125.0	85.4
Adjusted method	101.3	102.4	103.9	100.6

Source: UNIDO, based on data supplied by the UN Statistical Office.

a/ The simple average for actual production in large and small countries was calculated by averaging per capita steel production for the total number of countries in each group.

b/ The average was determined by dividing total value added in the iron and steel sector for the countries included by total population of the same group.

For purposes of comparison with the individual country projections, the same equational form and time period was employed. Various methods of calculating the group averages for actual production in 1972 are available, and two different averages were tested in this report. Both the unadjusted and adjusted projections provided very encouraging results. The preliminary tests support the supposition that structural models may constitute an element in actual projections, particularly in those for groups of countries of the same size and/or income levels.

Consumption patterns in iron and steel

As in the case of the production analysis, a cross-sectional approach has been adopted to the study of steel consumption. Unlike a time series approach, this method permits the researcher to identify the impact of common factors affecting consumption patterns in all countries for given years or groups of years. When the identified relationships between steel consumption and its determinant factors remain stable over time, the statistical results provide a reasonable guide to future conditions.

The assumptions

The basic hypothesis is that per capita steel consumption as observed at a given time in different countries is subject to the same set of broadly similar factors, such as access to the same types of production technology, similar ratios between the price of steel and other goods, and similar patterns of steel utilization.

Owing to the common influence of these universal factors, it may be expected that, all things being equal, countries will tend to display similar patterns of steel consumption. In reality, however, all things are not equal: countries differ in many respects and these national idiosyncracies are likely to influence the universal factors determining the steel consumption patterns. For the purposes of this study, however, it has been assumed that the only relevant difference between countries is their level of economic development. Consequently, it may be argued that countries enjoying the same level of development tend to have the same per capita level of steel consumption or, in other words, that differences in per capita levels of steel consumption among countries are attributable solely to differences in levels of economic development.

On the basis of this hypothesis, a statistical relationship may be sought to fit the general function (c) = f(y), where (c), the variable to be explained (the dependent variable in the regression equations), is per capita steel consumption, and (y), the "explanatory" variable (the independent variable in the regression equations), is the level of economic development.

As a first step towards estimating this function, the variables have to be defined in statistically measurable terms. The measure used for (c) is the apparent consumption of steel equivalents expressed in kilogrammes per capita.27/ Following a line of reasoning analogous to that described for the production models, GDP per capita has been chosen as the measure best reflecting the level of economic development (y). Data for both (c) and (y) are available on a yearly basis throughout the 1950-1970 period and for 45 market economies.28/

The next step in the estimation procedure is to specify the form of the functional relationship to be investigated. Ideally, the mathematical statement of the function should transmit either empirical or theoretical knowledge about the relationship between per capita steel consumption and GDP per capita. However, very little is known about the linkage between the two variables, except that the consumption of steel generally increases in relation to economic development. Hence the researcher is not able to select the form of relationship on the basis of a priori assumptions. In such cases, the usual recourse is to ascertain the most appropriate type of function through empirical experiments. The following five equations have been selected in an initial attempt to provide a plausible expression of the

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27/ Apparent consumption is defined as domestic production plus imports less exports. For a more detailed definition of apparent consumption and steel equivalents, see United Nations Economic Commission for Europe, Steel, CE 2/R-1.

28/ See United Nations Economic Commission for Europe, op. cit., Add. 1 (Appendix) Table II, pp. 3-4. The 45 countries are: Developed countries: Canada, United States, Austria, Belgium, Denmark, Finland, France, Germany (Fed. Rep.), Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, Yugoslavia, Australia, New Zealand, Japan, Israel, South Africa. Developing countries: Turkey, India, Korea (Rep. of), Pakistan, Philippines, Egypt, Iran, Iraq, Algeria, Morocco, Liberia, Tunisia, Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Venezuela, Peru, and Uruguay.

relationship between (c) and (y)[29]:

C	$\ln c = a + b \ln y$
D	$c = a + b \ln y$
E	$\ln c = a - b/y$
F	$\ln c = a - b/y - d \ln y$
G	$\ln c = a + b \ln y - d(\ln y)^2$

where (a), (b) and (d) are constants.

A particular hypothesis about the elasticity of consumption per capita in relation to GDP per capita is implicit in each of these functions (see table on the next page). It is important to note that the characteristics stated in the table are valid only when the coefficients of the variables in the five equations for $c = f(y)$ exhibit the expected signs.

Elasticity is defined in the context of the consumption analysis as $\varepsilon_{c,y} = \frac{\Delta c/c}{\Delta y/y}$ where Δc and Δy are differentials. It should be noted that this approach differs from the production approach of this report not only in the choice of variables involved in the definition of elasticity, but also by virtue of the fact that in this case the variables are measured in real terms as opposed to the value terms used in the production approach.

In Equation C, a constant positive value of $\varepsilon_{c,y}$ is assumed throughout the domain of positive GDP per capita. This assumption obviously contradicts the intuitive belief that the ratio between the relative changes of (c) and (y) is likely to decrease, at least in the upper range of GDP per capita. However, if intuition is correct, the analytical performance of the equation should prove relatively poor, at least when tested in respect of developed countries.

Implicit in the four equations described below is that the elasticity coefficient, ε, decreases with the rise of (y). It is thus expected that at higher levels of (y), larger increments of (y) will be necessary to produce a given decrease of ε.

In Equation D, it is assumed that the decline in $\varepsilon_{c,y}$ is proportional to the rise in (c). In other words, it is assumed that the proportion by which (c) changes in response to small changes in (y) depends upon the level

29/ These forms have been applied in several instances. See, for example, FAO, Agricultural Commodities-Projections for 1975 and 1985, vol. II, Rome 1967.

Characteristics of the elasticity functions

Elasticity function ε	$f'(\varepsilon)$	$f''(\varepsilon)$	$\varepsilon > 1$	$\varepsilon = 1$	$\varepsilon < 1$	$\varepsilon = 0$	Limit of ε when y approaches ∞
b	0	0	$b > 1$	$b = 1$	$b < 1$	$b = 0$	
b/c	$-b/c^2$	$2\ b/c^3$	$c < b$	$c = b$	$c > b$		0
b/y	$-b/y^2$	$2\ b/y^3$	$y < b$	$y = b$	$y > b$		0
$(b/y) - d$	$-b/y^2$	$2\ b/y^3$	$(b/y) - d > 1$	$y = b/(d+1)$	$(b/y) - d < 1$	$y = b/d$	$-d$
$b - 2\ d \ln y$	$-2\ d/y$	$2\ d/y^3$	$b - 2\ d \ln y > 1$	$\ln y = (b-1)/2\ d$	$b - 2\ d \ln y < 1$	$\ln y = b/(2\ d)$	$-\infty$

of per capita steel consumption.[30] For low levels of (c) - more precisely, as long as c<b - the declining elasticity is greater than 1. When c>b, the value of ε falls below 1, but remains positive. Actually, the function must be positive for the set of all non-negative real numbers comprised in this domain. This means that no saturation of steel consumption is admitted; however high a level of (c), a rise in (y) would still mean an additional increase in (c).

Equation E displays the same analytical properties as Equation C, except that it relates the decline in ε to GDP per capita, rather than to steel consumption per capita.

Both Equations F and G are distinct from the above equations in that they admit negative elasticities. In the case of Equation F, elasticity equals 0 as (y) reaches a level determined by the parameters b and d ($y = b/d$). At this level of (y), the per capita consumption of steel is maximum; when (y) becomes greater than b/d, any increase in income per capita determines a decrease in steel consumption. The negative elasticity, however, cannot fall indefinitely, it must find a limit at d.

In the case of Equation G, the elasticity is negative for $y > e^{b/2d}$; its negative value tends towards infinity as y approaches infinity.

Since, according to historical data per capita steel consumption is actually growing in all countries, the saturation point will evidently not be reached in the near future. Therefore, the analytical validity of equations that imply a level of saturation followed by a decrease in steel consumption per capita is highly hypothetical.. Consequently, even if an empirical testing of Equations F and G proves to be largely satisfactory, the reader should not be precipitous in concluding that the estimated pattern of steel consumption is leading to future saturation.

The results

The five equations were tested for: all countries; developed countries; and for developing countries - in several time periods between 1950 and 1970. The results obtained for the pools of years 1950-52, 1959-61, 1968-70 are shown in Table 17.

30/ A similar hypothesis is used in Guiducci, G., "Middle-range forecast of steel consumption in OECD countries" in: Forecasting steel consumption, cross-section and time-series approaches, OECD, Paris 1974.

All countries. In this case, the coefficients of determination (R^2) are fairly high and (y) is found to be a significant explanatory variable of the model $c = f(y)$. On these grounds, the hypothesis of a typical cross-country pattern in the relationship between (c) and (y) can be accepted. (The small t ratios found for the variables of Equations F and G are due to the high collinearity between the terms in (y); therefore, they do not necessarily place the significance of (y) in doubt.)

Judging by the R^2, Equations D and E appear to be slightly less appropriate analytical instruments than Equations C, F and G. Therefore, the idea that the elasticity of steel consumption varies in proportion to the level of actual consumption or the level of development would not seem quite as justified as the less direct relations implied in the other equations.

The R^2 of regression D is not comparable with those obtained for the other regressions because in this particular case the dependent variable is the antilogarithm of $\ln c$. Since the variance of c is larger than the variance of $\ln c$, it might be expected that, other things being equal, the R^2 would be larger for regression D than for the others. However, since the R^2 was actually lower, it may be assumed that Equation D does not perform as well as the others.

The regression of Equation F reveals an unexpected sign for the coefficient (d). This means that instead of having a maximum at a positive value of (y), given by $y = b/d$, it has a minimum at a negative value of (y), given by $y = b/-d$. In other words, the estimated equation rejects the hypothesis of saturation implied in Equation F. The estimated results differ from the anticipated characteristics stated in Row 5 of the table on page 64 as follows:

Elasticity function ε	$f'(\varepsilon)$	$f''(\varepsilon)$	$\varepsilon > 1$	$\varepsilon = 1$	$\varepsilon < 1$	$\varepsilon = 0$	Limit of ε when y approaches ∞
$\frac{b}{y} + d$	$\frac{-b}{y^2}$	$\frac{2b}{y^3}$	$\frac{b}{y} + d > 1$	$y = \frac{b}{1-d}$	$\frac{b}{y} + d < 1$	$y = \frac{b}{-d}$	d

The regression of Equation G shows the expected signs and thus the fitted function must pass through a maximum at some positive value of (y). However, the value of (y) at which the fitted curve reaches its maximum extends so far that the existence of a maximum cannot be meaningfully integrated in the analysis.

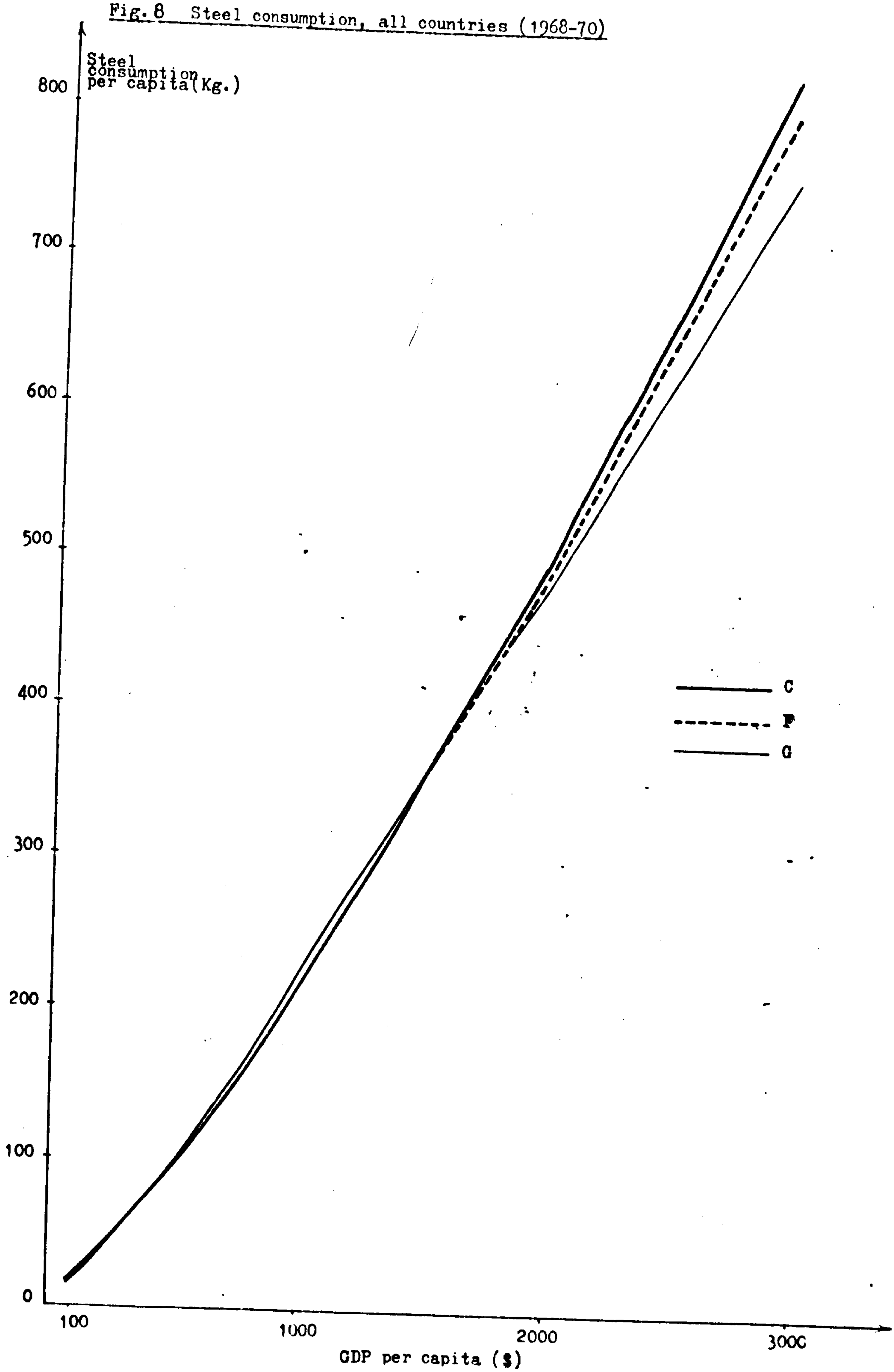
It would thus appear that the superiority of fit obtained by Equations F and G over D and E is not due to the saturation hypothesis supposedly implicit in the curves of F and G. It is due rather to the fact that these two curves fit the observations in a segment along which the rate of change in steel consumption varies relatively little (the segment approximating a straight line). This is not a feature of curves D and E, which implies that at low levels of GDP per capita, the change in the growth rate of (c) is relatively rapid.

If Equations D and E are discarded, three curves (C, F and G) are left to represent the pattern of relationship between (c) and (y). These curves have a very similar R^2; actually, when considering the segments fitted to the observations, they are even similar in shape. Therefore, the slopes of the elasticity functions derived from the three curves are also very similar (a zero rate of change in Equation C, and a relatively low rate of change in F and G).

Thus, it may be tentatively concluded that in the pattern of all countries a linear, or close-to-linear, form can be used to approximate the actual relationship between per capita steel consumption and GDP per capita (Figure 8), the corollary being that the elasticity of per capita steel consumption to GDP per capita is either constant or slowly declining. (Of course, this conclusion is subject to many limitations. Among the most fundamental of them is that, owing to the lack of a firm theoretical basis, it is impossible to ignore the possibility of the correlations found between the variables being spurious. Furthermore, even if one is convinced that it is not spurious, one must still admit that other models not tested in this report might display a better image of the actual relationship.)

Examples of steel consumption levels and elasticity values corresponding to selected GDP per capita values are shown in the table on page 69. In examining the table, attention should be focused on the figures given for Equations C, F, and G, which perform best in this analysis. According to these figures, the typical steel consumption pattern ranges from 30 to 800 kg

Fig. 8 Steel consumption, all countries (1968-70)



per capita as GDP per capita rises from $225 to $3,000 (1963). Within this range, the consumption of steel is elastic in relation to GDP per capita (a function is elastic when $|\varepsilon| > 1$.) Actually, the lowest level at which steel consumption becomes inelastic is $3,240 (Equation G).

Estimated steel consumption and elasticity values according to selected levels of GDP per capita, sample of all countries, 1968-1970

	Level of GDP per capita (dollars 1963)	Steel consumption (kg per capita)	Elasticity value
Equation C	225	31	1.26
	800	154	1.26
	1,000	204	1.26
	3,000	814	1.26
Equation D	225	-91	-2.11
	800	266	0.72
	1,000	310	0.62
	3,000	518	0.37
Equation E	225	49	1.97
	800	171	0.55
	1,000	225	0.44
	3,000	302	0.15
Equation F	225	31	1.31
	800	156	1.24
	1,000	205	1.24
	3,000	790	1.22
Equation G	225	31	1.37
	800	162	1.22
	1,000	211	1.14
	3,000	743	1.08

The results presented in the table relate to all countries. It is conceivable, however, that steel consumption patterns are influenced by group factors which convey the influence of the "universal factors" in a specific way within given groups of countries, thus making it necessary to split the sample and to estimate separate patterns for sub-groups. For instance, all countries have access to the same technology, but the techniques adopted by countries with relatively abundant labour are likely to differ form those adopted by countries with relatively abundant capital. Similarly, all countries have access to international markets, but countries pursuing protectionist policies will tend to import (and export) less than free-trade countries.

For the purpose of constituting two samples, the 45 countries discussed earlier were arranged in two groups: Group A comprising 24 developed countries, and Group B comprising 21 developing countries.31/ The patterns for both groups were found to differ significantly from the common pattern.

Developed countries. In this case, sub-division of the sample reduced the standard error of estimate, thus increasing the statistical accuracy of Equations C, E, F and G, but increasing the standard error of estimate of D. The coefficients of determination (R^2) were reduced in all cases except Equation E. Thus, with the exception of this equation, Group A fails to satisfy the assumptions underlying the functional form as closely as the sample comprising all countries. Equations F and G perform best in terms of analytical power and statistical accuracy. According to these Equations, the 1968-1970 steel consumption pattern in developed countries increased from approximately 260 to 610 kg per capita as GDP per capita rose from $1,000 to $3,000 (see table below and Figure 9).

31/ Countries are classified as developed or developing according to standard United Nations practice. The rationale underlying the principle of stratification is that the structural differences between developed and developing countries cannot be fully reflected by a cardinal measure such as GDP per capita. An ordinal arrangement which takes into account the multiplicity of differences between developing and developed countries may tend to reveal the existence of "group factors" otherwise ignored by the common pattern.

Estimated steel consumption and elasticity values according to selected levels of GDP per capita, sample of developed countries 1968-1970

	Level of GDP per capita (dollars 1963)	Steel consumption (kg per capita)	Elasticity value
Equation F	1,000	260	1.011
	2,000	468	0.723
	3,000	613	0.628
Equation G	1,000	258	1.066
	2,000	477	0.703
	3,000	606	0.491

Compared with the sample of all countries, the main effect of Group A on the elasticity of steel consumption in relation to GDP per capita is that the value of ε declines much more rapidly: Equation F, for example, becomes inelastic at $1,065 per capita and Equation G at $1,135. In the common pattern, however, the lowest level of inelasticity was found to be more than $3,000. Thus, among developed countries whose GDP per capita levels are higher than $1,100, two countries differing by 1 per cent in GDP per capita would be expected to differ by less than 1 per cent in steel consumption per capita.

The above considerations in respect of Group A are restricted to the period 1968-1970. A comparison of the results obtained in different periods reveals the existence of a time effect which causes the pattern to rotate counter-clockwise from 1950 to 1970. This time effect is demonstrated by the fact that the consumption of steel predicted at a GDP per capita level of $2,000 varied from 354 kg in 1950-52 to 468 kg in 1968-70 in Equation F, and from 361 to 477 kg for the same time periods for Equation G.

Developing countries. In this case, splitting the sample results in a lower R^2 for all regressions, and in a lower standard error of estimate only for Equations C and D. In other words, the regression equations are both less appropriate and less accurate when applied to the data of developing countries. The "best" equations are C, F and G. Consumption and elasticity values predicted by these Equations are shown on page 74. In this table the pattern of steel consumption in developing countries covers an approximate range of 11 - 100 kg per capita as GDP per capita increases from $100 to $800 (see Figure 10).

Fig. 9 Steel consumption, developed countries (1968-70)

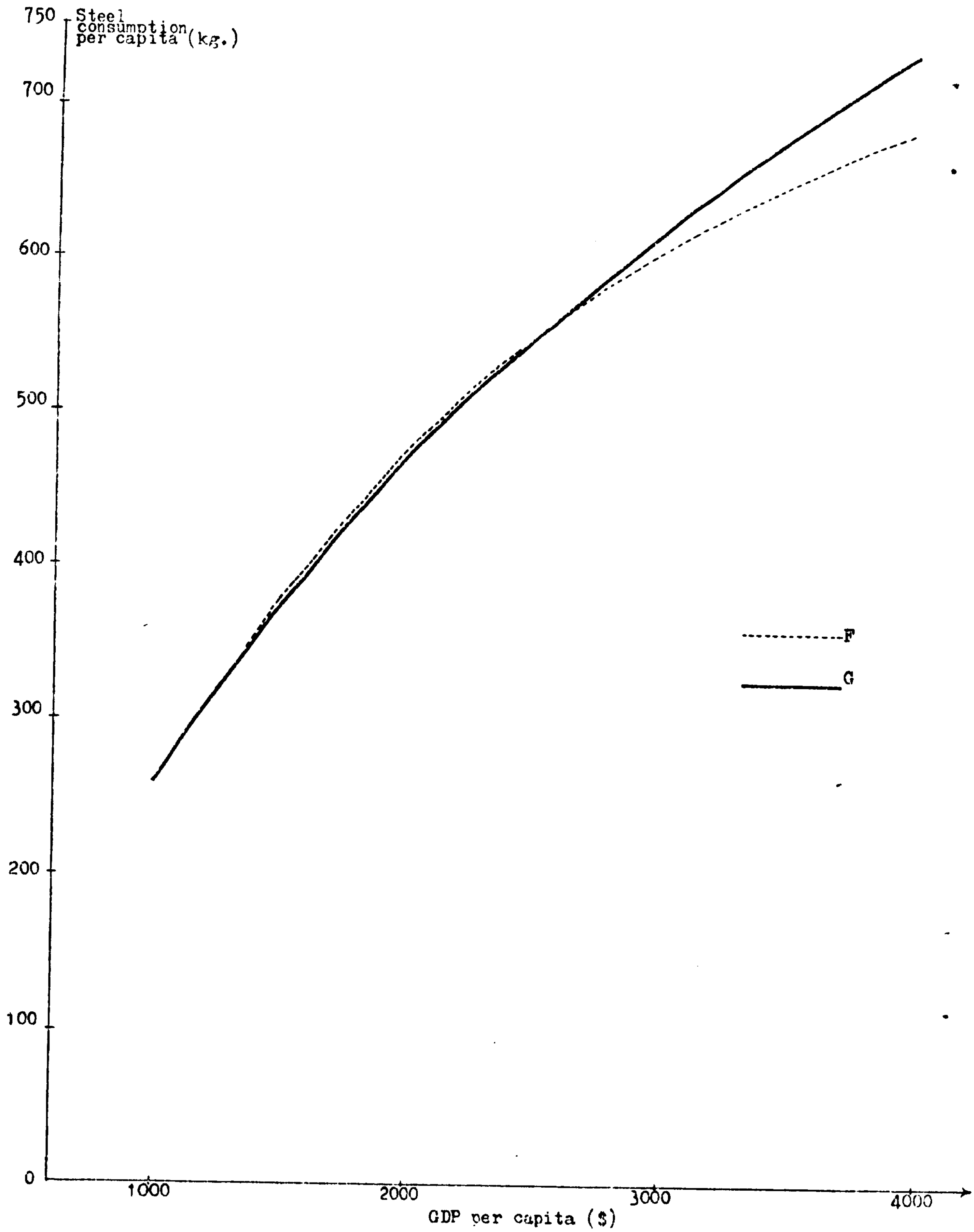
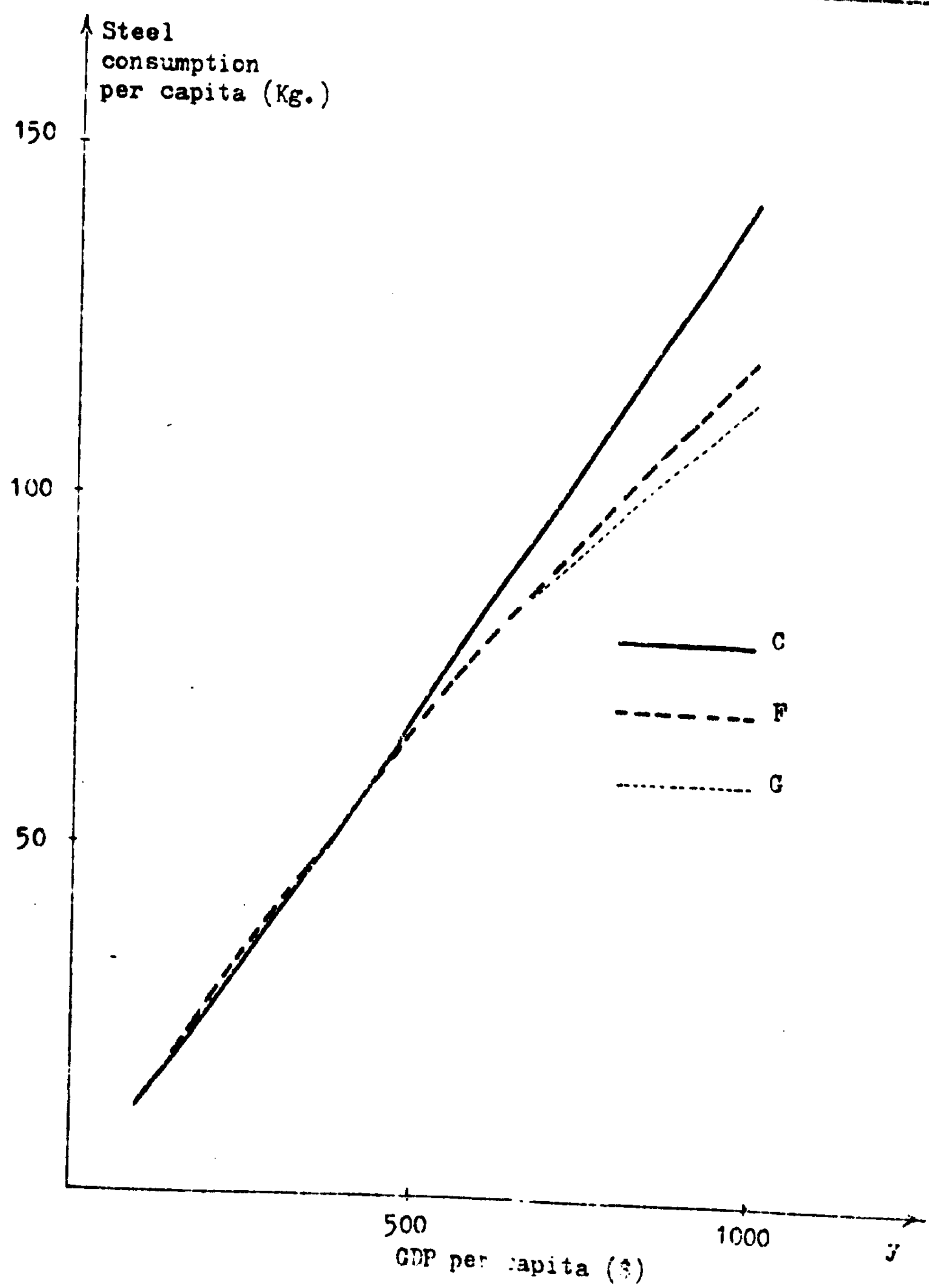


Figure 10. Steel consumption, developing countries (1968-70)



Estimates steel consumption and elasticity values according to selected levels of GDP per capita, sample of developing countries, 1960-1970

	Levels of GDP per capita (dollars 1963)	Steel consumption (kg per capita)	Elasticity value
Equation C	100	12	1.068
	225	15	1.068
	800	113	1.068
Equation F	100	11	1.448
	225	19	0.850
	800	100	0.787
Equation G	100	11	1.347
	225	15	0.731
	800	96	0.340

As mentioned before, the elasticity values of developing countries are found to be lower than those of developed countries. Thus, a change in GDP per capita in a developing country would be associated with a smaller change in per capita steel consumption than it would in a developed country. This is hardly surprising when one recalls that in developing countries GDP is less dependent upon industry than in developed countries. Similar to Group A, the pattern in developing countries is very sensitive to time, although no clear trend can be ascribed to the shift.

In conclusion, it may be said that the analysis reveals the relevance of sample stratification to the study of the relationship between steel consumption and GDP. The relatively low R^2 found in the sub-samples suggest, however, that more appropriate functional forms should be employed in this context. It would also appear essential to introduce time-shift variables that would account for the quite significant time-effects found in Groups A and B.

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Table 1. World steel production, 1955-1985

	1955		1960		1965		1970		1974		1985	
	Million tons	Per cent	Million tons	Per cent	Million tons	Per cent	Million tons	Per cent	Million tons	Per cent	Million tons	Per cent
Western Europe	79.4	29.5	108.8	31.4	128.9	28.1	160.2	26.9	185.0	26.0	236.0	22.1
European Economic Community	27.9	27.1	97.9	28.3	113.9	24.8	137.6	23.1	155.6	21.9	188.0	17.6
Other Western Europe	6.5	2.4	10.9	3.1	15.0	3.3	22.6	3.8	29.4	4.2	48.0	4.5
Eastern Europe	13.9	5.2	21.2	6.1	28.5	6.2	40.1	6.7	48.9	6.9	75.0	7.0
USSR	45.3	16.8	65.3	18.8	91.0	19.9	155.9	19.5	136.2	19.5	196.2	18.3
North America	110.3	40.9	95.3	27.5	131.0	28.6	130.3	21.9	145.6	20.5	181.0	16.9
USA	106.2	39.4	90.0	26.0	121.9	26.6	119.1	20.0	132.0	18.6	164.0	15.3
Canada	4.1	1.5	5.3	1.5	9.1	2.0	11.2	1.9	13.6	1.9	17.0	1.3
Japan	9.4	3.5	22.1	6.4	41.2	9.0	93.3	15.7	117.1	16.5	174.0	16.3
Oceania	2.2	0.8	3.7	1.1	5.4	1.2	7.0	1.2	8.0	1.1	10.0	1.0
Developed countries	260.5	96.7	316.4	91.3	426.0	93.0	546.8	91.9	640.8	90.3	872.0	81.6
China	2.9	1.1	18.5	5.3	12.2	2.7	18.0	3.0	27.0	3.8	60.0	5.6
Africa	0.0	0.0	0.2	0.1	0.3	0.1	0.9	0.2	1.3	0.2	13.0	1.2
Asia	2.1	0.8	4.5	1.3	8.1	1.8	11.6	1.9	17.1	21.4	55.0	5.2
Latin America	2.2	0.8	4.7	1.4	8.0	1.7	13.2	2.2	17.7	2.5	57.0	5.3
Developing countries a/	4.3	1.6	9.4	2.8	16.4	3.6	25.7	4.3	36.1	5.1	125.0	11.7
South Africa and Rhodesia	1.6	0.6	2.2	0.6	3.4	0.7	4.9	0.8	6.0	0.8	12.0	1.1
World total	269.3	100.0	346.5	100.0	458.0	100.0	595.4	100.0	709.9	100.0	1,069.0	100.0

a/ Not including China

Table 2. World steel consumption, 1955-1985

	1955		1960		1965		1970		1974		1985	
	Million tons	Per cent	Million tons	Per cent	Million tons	Per cent	Million tons	Per cent	Million tons	Per cent	Million tons	Per cent
Western Europe	72.2	26.7	94.4	28.2	113.7	25.0	153.1	25.9	163.2	23.0	218.0	20.3
European Economic Community	62.3	23.0	80.7	24.1	91.4	20.1	123.5	20.9	127.0	17.9	163.0	15.2
Other Western Europe	9.9	3.7	13.7	4.1	22.3	4.9	29.6	5.0	36.2	5.1	55.0	5.1
Eastern Europe	14.6	5.4	24.2	7.2	30.9	6.8	41.5	7.0	51.4	7.3	81.0	7.6
USSR	43.3	16.0	63.5	19.0	86.8	19.1	110.2	18.7	137.5	19.4	192.0	18.0
North America	107.4	36.7	95.6	28.6	138.6	30.5	138.4	23.4	159.6	22.6	209.0	19.6
USA	102.3	37.8	90.0	26.9	128.1	28.2	127.3	21.5	144.1	20.4	188.0	17.6
Canada	5.1	1.9	5.6	1.7	10.5	2.3	11.1	1.9	15.5	2.2	21.0	2.0
Japan	7.2	2.7	19.1	5.8	28.5	6.3	69.9	11.8	75.8	10.7	112.0	10.5
Oceania	3.5	1.3	4.6	1.4	7.6	1.7	7.2	1.2	8.8	1.2	13.0	1.2
Developed countries	248.2	91.8	301.7	90.2	406.1	89.4	520.3	88.0	596.3	84.2	825.0	77.2
China	3.7	1.4	8.5	2.5	11.6	2.6	22.5	3.8	30.8	4.3	63.0	5.9
Africa	2.2	0.8	2.4	0.7	3.1	0.7	4.7	0.8	7.0	1.0	14.0	1.3
Asia	7.2	2.7	10.9	3.3	16.7	3.7	19.8	3.4	36.6	5.2	83.0	7.8
Latin America	7.0	2.6	8.7	2.6	12.0	2.6	18.8	3.2	30.6	4.3	73.0	6.8
Developing countries a/	16.4	6.1	22.0	6.6	31.8	7.0	43.3	7.4	74.2	10.5	170.0	15.9
South Africa and Rhodesia	2.0	0.7	2.4	0.7	4.5	1.0	4.9	0.8	6.8	1.0	11.0	1.0
World total	270.3	100.0	334.6	100.0	454.0	100.0	591.0	100.0	708.1	100.0	1,069.0	100.0

a/ Not including China

Table 3. Steel consumption and production growth rates

	1955-1974		1965-1974	
	Consumption Per cent	Production Per cent	Consumption Per cent	Production Per cent
Western Europe	4.4	4.6	4.1	4.1
European Economic Community	3.8	4.1	3.7	3.5
Other Western Europe	7.1	8.3	5.5	7.8
Eastern Europe	6.8	6.8	5.8	6.2
USSR	6.3	6.0	5.2	4.6
North America	2.1	1.5	1.6	1.2
USA	1.8	1.2	1.3	0.9
Canada	6.0	6.5	4.4	4.6
Japan	13.2	14.2	11.5	12.3
Oceania	5.0	7.0	1.6	4.5
Developed countries	4.7	4.9	4.4	4.6
China	11.8	12.5	11.5	9.2
Africa	6.3	24.0	9.5	17.7
Asia	8.9	11.7	9.1	8.7
Latin America	8.1	11.6	11.0	9.2
Developing countries a/	8.3	11.8	9.9	9.2
South Africa and Rhodesia	6.7	7.2	4.7	6.5
World total	5.2	5.2	5.1	5.0

a/ Not including China

Table 4. Steel consumption per capita (kg)

	1955	1960	1965	1970	1974	1985	2000 A	2000 B
Western Europe	231	289	331	432	450	568	710	768
European Economic Community	280	347	375	491	495	604	762	825
Other Western Europe	109	145	225	268	343	482	591	639
Eastern Europe	155	246	303	395	476	698	865	937
USSR	221	296	376	454	545	682	819	892
North America	591	481	648	612	681	797	949	1,030
USA	671	498	659	621	680	798	957	1,036
Canada	325	313	536	519	689	792	886	981
Japan	80	206	288	670	695	915	1,136	1,234
Oceania	248	291	434	373	421	504	550	581
Developed countries	279	318	404	495	549	692	844	915
China	6	13	16	29	37	67	122	122
Africa	10	9	11	14	19	25	52	74
Asia	9	12	16	17	29	49	81	115
Latin America	37	40	49	66	97	172	265	379
Developing countries[a]	14	16	21	25	38	64	105	150
South Africa and Rhodesia	118	123	197	183	226	263	307	307
World total	99	112	138	164	182	222	266	308

a/ Not including China

Table 5. World steel consumption 1985-2000

	1985		2000											
			Variant I						Variant II					
			Ia			Ib			IIa			IIb		
	Million tons	Per cent	Gr. Rates	Million tons	Per cent	Gr. Rates	Million tons	Per cent	Gr. Rates	Million tons	Per cent	Gr. Rates	Million tons	Per cent
Western Europe	218	20.3	1.5	273	16.4	2.0	293	17.6	2.0	293	15.2	2.5	318	16.6
European Economic Community	163	15.2	1.5	205	12.3	2.0	219	13.2	2.0	219	11.4	2.5	238	12.4
Other Western Europe	55	5.1	1.4	68	4.1	2.0	74	4.4	2.0	74	3.[illegible]	2.5	80	4.2
Eastern Europe	81	7.6	1.5	101	6.1	2.0	109	6.5	2.0	109	5.7	2.5	118	6.1
USSR	192	18.0	1.5	240	14.4	2.0	258	15.5	2.0	258	13.5	2.5	281	14.6
North America	209	19.6	1.5	261	15.6	2.0	281	16.9	2.0	281	14.6	2.5	305	15.8
USA	188	17.6	1.5	235	14.1	2.0	253	15.2	2.0	253	13.1	2.5	274	14.2
Canada	21	2.0	1.4	26	1.5	1.9	28	1.7	1.9	28	1.5	2.6	31	1.6
Japan	112	10.5	1.5	140	8.4	2.0	151	9.1	2.0	151	7.8	2.6	164	8.5
Oceania	13	1.2	1.4	16	1.0	2.2	18	1.1	2.2	18	0.9	2.6	19	1.0
Developed countries	825	77.2	1.5	1,031	61.9	2.0	1,110	66.7	2.0	1,110	57.7	2.5	1,205	62.6
China	63	5.9	5.5	140	8.4	5.5	140	8.4	5.5	140	7.3	5.5	140	7.3
Africa	14	1.3	8.0	44	2.6	7.2	40	2.4	10.0	58	3.0	9.5	55	2.9
Asia	83	7.8	7.0	229	13.8	5.7	191	11.5	9.3	315	16.4	8.2	270	14.0
Latin America	73	6.8	7.0	201	12.1	5.5	164	9.8	9.4	282	14.6	8.1	235	12.2
Developing countries [a]	170	15.9	7.1	474	28.5	5.8	395	23.7	9.4	655	34.0	8.3	560	29.1
South Africa and Rhodesia	11	1.0	4.1	20	1.2	4.0	20	1.2	4.1	20	1.0	4.1	20	1.0
World total	1,069	100.0	3.0	1,665	100.0	3.0	1,665	100.0	4.0	1,925	100.0	4.0	1,925	100.0

a/ Not including China

Table 6. World steel production, 1985-2000

	1985		2000											
			Variant A						Variant B					
			A1			A2			B1			B2		
	Million tons	Per cent	Gr. rates	Million tons	Per cent	Gr. rates	Million tons	Per cent	Gr. rates	Millions tons	Per cent	Gr. rates	Million tons	Per cent
Western Europe	236	22.1	1.8	309	18.6	1.5	296	17.8	3.1	371	19.3	2.6	345	17.9
European Economic Community	188	17.6	1.8	246	14.[illegible]	1.5	236	14.2	3.1	296	15.4	2.6	275	14.3
Other Western Europe	48	4.5	1.8	63	3.8	1.5	60	3.6	3.1	75	3.9	2.6	70	3.6
Eastern Europe	75	7.0	1.8	98	5.9	1.5	95	5.7	3.1	118	6.1	2.6	110	5.7
USSR	196	18.3	1.8	257	15.4	1.5	246	14.8	3.1	309	16.1	2.6	287	14.9
North America	181	16.9	1.8	237	14.2	1.5	227	13.6	3.1	285	14.8	2.6	265	13.8
USA	164	15.3	1.8	215	12.9	1.5	206	12.3	3.1	258	13.4	2.6	240	12.5
Canada	17	1.6	1.8	22	1.3	1.5	21	1.3	3.1	27	1.4	2.6	25	1.3
Japan	174	16.3	1.8	228	13.7	1.5	219	13.1	3.1	274	14.2	2.6	255	13.2
Oceania	10	1.0	1.8	13	0.8	1.5	13	0.8	3.1	16	0.8	2.6	15	0.8
Developed countries	872	81.6	1.8	1,142	68.6	1.5	1,095	65.8	3.1	1,373	71.3	2.6	1,277	66.3
China	60	5.6	4.9	123	7.4	5.3	131	7.9	5.9	142	7.4	5.9	142	7.4
Africa	13	1.2	9.4	50	3.0	9.4	50	3.0	9.4	50	2.6	11.0	62	3.2
Asia	55	5.2	7.6	166	10.0	8.5	187	11.2	7.8	170	8.8	9.7	222	11.6
Latin America	57	5.3	7.2	162	9.7	7.9	179	10.[illegible]	7.[illegible]	165	8.6	8.6	197	10.2
Developing countries a/	125	11.7	7.7	378	22.7	8.3	416	25.0	[illegible]8	385	20.0	9.4	481	25.0
South Africa and Rhodesia	12	1.1	4.1	22	1.3	4.1	22	1.3	5.0	25	1.3	5.0	25	1.3
World total	1,069	100.0	3.0	1,665	100.0	3.0	1,665	100.0	4.0	1,925	100.0	4.0	1,925	100.0

a/ Not including China

Table [illegible]. [illegible] in Africa, [illegible]

	1965			1975			19[illegible]			2000		
	Population (millions)	Steel production million tons	Production per capita (kg)	Population (millions)	Steel production million tons	Production per capita (kg)	Population (millions)	Steel capacity million tons	Capacity per capita (kg)	Population (millions)	Steel capacity million tons	Capacity per capita (kg)
North Africa												
Algeria	11.9	0.015	1.30	16.8	0.221	13	23.5	4.5	191	36.7		
Egypt	29.4	0.250	8.50	37.5	0.4	11	47.2	3.5	74	64.6		
Libya	1.6	-	-	2.3	-	-	3.1	1.0	322	4.7		
Mauritania	1.1	-	-	1.3	-	-	1.6	1.0	625	2.3		
Morocco	13.1	-	-	17.5	0.005	-	23.8	1.0	42	35.9		
Sudan	13.5	-	-	18.3	-	-	25.1	-	-	39.0		
Tunisia	4.6	-	-	5.7	0.150	26	7.5	1.0	133	10.9		
Total North Africa	75.2	0.3	4	99.4	0.8	8	131.8	12.0	91	194.1	37.0	191
West Africa												
Nigeria	48.7	-	-	62.9	-	-	84.4	2.0	24	134.9		
Other countries	40.4	-	-	51.3	-	-	67.0	0.5	7	100.8		
Total West Africa	89.1	-	-	114.2	-	-	151.4	2.5	16	235.7	8.0	34
East Africa												
Ethiopia	22.2	-	-	27.9	-	-	35.7	-	-	53.7		
Kenya	9.5	-	-	13.3	-	-	18.6	0.25	13	31.0		
Tanzania	11.5	-	-	15.4	-	-	21.1	0.50	24	34.0		
Uganda	8.6	-	-	11.4	0.015	1.2	15.4	0.15	10	24.1		
Zambia	3.7	-	-	5.0	-	-	6.9	0.25	36	11.6		
Other countries (without Rhodesia)	59.5			76.4			81.9					
Total East Africa	83.3	-	-	108.2	0.015	0.14	143.9	1.50	10	224.8	7.0	31
Central Africa												
Zaire	18.7	-	-	24.5	-	-	32.1	0.3	9	49.5		
Other countries	17.1	-	-	20.8	-	-	26.3	0.2	8	38.2		
Total Central Africa	35.8	-	-	45.3	-	-	58.4	0.5	9	87.7	6.0	68
Total Southern Africa (excluding Rep. of South Africa)	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL AFRICA	[illegible]	0.3	1	370.2	0.8	2	489.5	16.5	34	748.1	58.0	78

Table 8. Population, steel production and steel-making capacity in Asia, 1965-2000

	1965			1975			1985			2000		
	Population (millions)	Steel production million tons	Production per capita (kg)	Population (millions)	Steel production million tons	Production per capita (kg)	Population (millions)	Steel capacity million tons	Capacity per capita (kg)	Population (millions)	Steel capacity millions tons	Capacity per capita (kg)
East Asia (excluding China and Japan)												
Hong Kong	3.7	-	-	4.2	0.1	24	4.8	0.1	21	5.6		
Korea, North	12.1	1.3	107	15.9	3.5	220	20.2	7	346	27.5		
Korea, South	27.7	0.1	4	33.9	2.0	59	41.3	8	194	52.0		
Mongolia	1.1	-	-	1.4	-	-	1.9	-	-	2.7		
Total, East Asia	44.6	1.4	31	55.4	5.6	101	68.2	15.1	221	87.8	34.0	387
South-East Asia												
Burma	24.8	-	-	31.2	0.040	1	39.7	0.1	3	54.9		
Indonesia	105.1	-	-	136.0	0.120	1	175.5	1.5	9	237.5		
Malaysia	9.1	-	-	12.1	0.197	16	16.1	0.5	31	22.1		
Philippines	32.0	-	-	44.4	0.279	5	60.8	2.0	33	39.7		
Singapore	1.9	-	-	2.2	0.231	105	2.6	0.4	154	3.1		
Thailand	30.6	-	-	42.1	0.440	10	57.8	1.2	21	85.6		
Other countries	44.2	-	-	55.8	-	-	70.7	1.5	21	98.7		
Total, South-East Asia	247.7	-	-	323.8	1.3	4	423.2	7.2	17	591.6	33.0	56
Central South Asia												
Afghanistan	15.1	-	-	19.3	-	-	25.2	0.6	24	36.7		
Bangladesh	58.8	-	-	73.7	0.1	1.3	98.0	0.4	4	144.3		
India	482.4	6.3	13	613.2	8.0	13	782.4	20.0	26	1,059.4		
Iran	24.7	-	-	32.9	0.7	21	44.9	9.0	200	66.6		
Pakistan	52.4	0.012	0.2	70.6	-	-	97.4	2.0	20	146.9		
Other countries	22.4	-	-	28.1	-	-	35.6	-	-	47.3		
Total, Central South Asia	655.8	6.3	10	837.8	8.8	11	1,083.5	32.0	29	1,501.2	96.0	64
South West Asia												
Iraq	8.0	-	-	11.1	-	-	15.6	2.0	128	24.4		
Kuwait	0.5	-	-	1.1	-	-	1.8	-		3.2		
Saudi Arabia	6.8	-	-	9.0	-	-	12.1	1.0	83	18.6		
Syria	5.3	-	-	7.3	-	-	10.1	0.2	20	15.8		
Turkey	31.2	0.4	13	39.9	1.6	40	51.7	7.0	135	72.6		
Other countries (including Abu Dhabi and Qatar)	12.2	-	-	15.9	-	-	21.8	2.0	91	34.2		
Total South West Asia	64.0	0.4	6	84.3	1.6	19	113.1	12.2	108	168.8	35.0	207
TOTAL ASIA	1,012.1	8.1	8	1,301.3	17.3	13	1,688.0	66.5	39	2,349.4	198.0	84

Table 9. Population, steel production and steel-making capacity in Latin America, 1965-2000

	1965			1975			1985			2000		
	Population (millions)	Steel production million tons	Production per capita (kg)	Population (millions)	Steel production million tons	Production per capita (kg)	Population (millions)	Steel capacity million tons	Capacity per capita (kg)	Population (millions)	Steel capacity million tons	Capacity per capita (kg)
Caribbean and Central America												
Cuba	7.8	-	-	9.5	0.24	25	11.7	0.5	43	15.3		
Mexico	42.9	2.3	54	59.2	5.3	90	82.8	18.0	217	132.2		
Trinidad and Tobago	0.9	-	-	1.0	-	-	1.1	1.2	1,091	1.3		
Other countries	28.1	-	-	36.1	-		46.9	0.5	11	68.4		
Total, Caribbean and Central America	79.1	2.3	29	105.8	5.5	52	142.5	20.2	142	217.2	51.0	235
Latin America, Northern Region												
Brazil	82.5	3.1	38	109.7	8.4	77	145.1	25.0	172	212.5		
Colombia	18.7	0.24	13	25.9	0.34	13	35.1	2.0	57	51.1		
Peru	11.4	0.09	8	15.3	0.4	26	20.4	3.0	147	30.6		
Venezuela	9.1	0.45	50	12.2	1.1	90	16.3	8	491	23.6		
Other countries	12.4	-	-	16.5	-	-	21.9	1.0	46	32.5		
Total Latin America, Northern Region	134.1	3.8	28	1[illegible]9.6	10.3	57	238.8	39.0	163	350.7	110	314
Latin America, Southern Region												
Argentina	22.2	1.4	63	25.4	2.2	87	28.7	9.0	314	32.9		
Chile	8.5	0.5	59	10.3	0.5	49	12.3	2.0	163	15.4		
Uruguay	2.8	0.015	5	3.1	0.016	5	3.4	0.1	29	3.9		
Total Southern Region	33.5	1.9	57	38.8	2.7	70	44.4	11.1	250	52.2	29	556
TOTAL LATIN AMERICA	247.3	8.0	32	324.2	18.5	57	425.7	70.3	165	620.1	190	306

Table 10. Dynamics of relative steel-making capability (kg/capita) in the developing countries

	1975						1985						2000					
	Low			Medium		High	Low			Medium		High	Low			Medium		High
	-15	16-50	51-100	101-200	201-400	401 and over	-15	16-50	51-100	101-200	201-400	401 and over	-15	16-50	51-100	101-200	201-400	401 and over
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Africa																		
East Africa	x						x							x				
Central Africa	x						x								x			
North Africa	x								x							x		
Southern Africa (less Rep. of South Africa)	x						x						x					
West Africa	x							x						x				
Total Africa	x							x							x			
Asia																		
East Asia				x							x						x	
South East Asia	x							x							x			
Central South Asia	x							x							x			
South West Asia		x								x							x	
Total Asia	x							x							x			
Latin America																		
Caribbean and Central America			x							x							x	
Tropical South			x							x							x	
Temperate South			x								x							x
Total Latin America			x							x							x	
Number of sub-regions	7	1	3	1			3	3	1	3	2		1	2	3	1	4	1
Number of sub-regions	11			1			7			5			6			5		1

Table 11. Steel production per capita

	1955	1960	1965	1970	1974	1985	2000 A	2000 B
Western Europe	254	333	376	453	511	615	747	835
European Economic Community	328	421	467	548	606	[illegible]96	853	954
Other Western Europe	72	115	152	220	278	421	502	561
Eastern Europe	147	216	279	382	453	676	779	871
USSR	231	305	294	477	540	696	815	911
North America	607	480	612	576	621	690	801	896
USA	640	499	627	581	623	696	812	908
Canada	261	296	464	523	604	642	706	788
Japan	105	235	417	895	1,074	1,422	1,714	1,917
Oceania	156	234	309	363	383	388	401	450
Developed countries	293	334	423	520	590	732	868	970
China	5	28	17	23	33	62	101	124
Africa	–	1	1	3	4	27	76	96
Asia	3	5	8	10	13	32	70	92
Latin America	12	22	32	47	56	134	261	311
Developing countries a/	4	7	11	15	19	48	103	129
South Africa and Rhodesia	95	113	149	183	199	286	338	384
World total	99	116	139	165	182	222	266	308

a/ Not including China.

Table 12. Summary of regression results for large countries, selected years

	Equation	a	b	c	d	Standard error estimate	R^2	F
1960	A	-8.90	1.54 (11.94)*	0.20 (1.32)		0.53	0.92	71.45
	B	-20.73	5.04 (3.08)*	0.43 (2.50)	-0.27 (2.14)	0.47	0.94	62.29
1963	A	-8.05	1.42 (12.31)*	0.20 (1.44)		0.47	0.92	75.87
	B	-16.64	3.92 (2.43)	0.37 (2.16)	-0.19 (1.56)	0.45	0.93	56.94
1966	A	-7.60	1.36 (13.26)*	0.18 (1.46)		0.43	0.93	87.96
	B	-17.36	4.14 (2.99)*	0.40 (2.56)	-0.21 (2.01)	0.40	0.95	73.79
1970	A	-6.85	1.33 (13.05)*	0.06 (0.51)		0.42	0.93	86.11
	B	-17.28	4.23 (2.76)	0.28 (1.75)	-0.21 (1.90)	0.38	0.95	70.08
1960-1964	A	-8.50	1.48 (25.34)*	0.21 (3.01)*		0.48	0.91	321.65
	B	-19.19	4.60 (6.65)*	0.42 (5.22)*	-0.24 (4.12)*	0.42	0.93	276.12
1969-1973	A	-6.69	1.31 (27.19)	0.05 (0.91)		0.40	0.92	375.88
	B	-16.80	4.09 (5.97)*	0.28 (3.64)*	-0.20 (4.07)*	0.36	0.94	319.97

Source: UNIDO, based on data supplied by the UN Statistical Office.

Note: T-values are shown in parentheses. An asterisk denotes statistical significance at a confidence level of 99 per cent.

Table 13. Summary of regression results for small countries

	Equation	a	b	c	d	Standard error estimate	R^2	F
1960	A	-9.66	1.69 (6.06)*	0.40 (1.50)		0.99	0.70	18.44
	B	-18.39	3.30 (0.21)	0.51 (1.04)	-0.29 (0.60)	1.03	0.70	11.53
1963	A	-12.71	1.98 (8.95)*	0.48 (1.45)		1.00	0.81	42.50
	B	-28.59	6.89 (1.77)	0.57 (1.71)	-0.37 (1.26)	0.98	0.82	29.70
1966	A	-13.81	2.11 (8.22)*	0.52 (1.32)		1.12	0.78	37.22
	B	-30.95	10.32 (2.17)	0.60 (1.59)	-0.61 (1.73)	1.07	0.82	28.29
1970	A	-12.42	1.88 (10.21)*	0.65 (2.29)		0.92	0.82	53.51
	B	-33.79	8.24 (2.42)	0.81 (2.87)	-0.47 (1.87)	0.87	0.84	40.72
1960-1964	A	-12.61	1.96 (18.06)*	0.49 (2.97)*		0.97	0.80	171.75
	B	-27.72	6.61 (3.55)*	0.59 (3.60)	-0.35 (2.50)	0.94	0.80	123.43
1969-1973	A	-12.47	1.86 (20.09)*	0.70 (4.93)*		0.92	0.81	208.24
	B	-34.77	8.45 (4.99)*	0.86 (6.16)*	-0.48 (3.89)*	0.85	0.83	163.75

Source: UNIDO, based on data supplied by the UN Statistical Office.

Note: T-values are in parentheses. An asterisk denotes statistical significance at a confidence level of 99 per cent.

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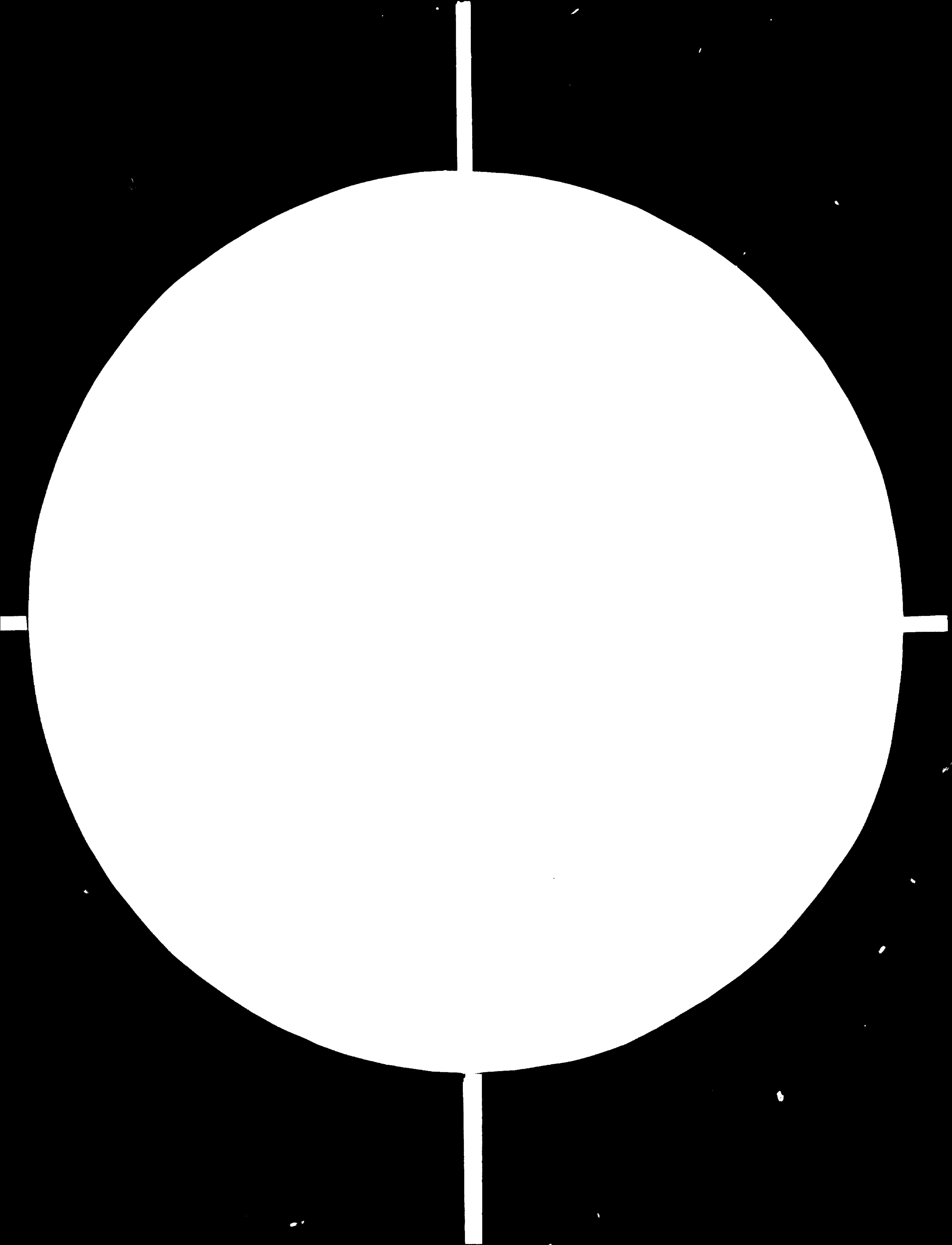

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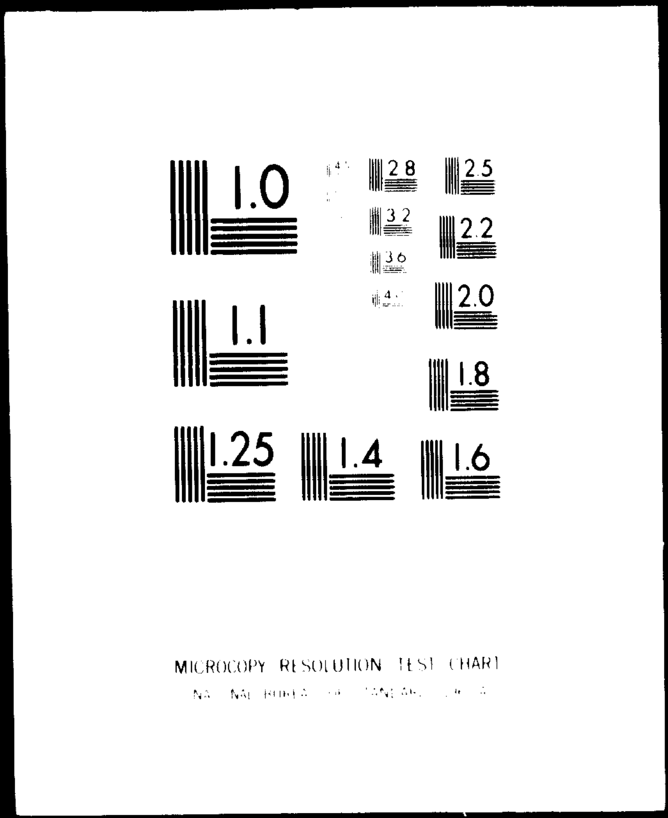

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Table 14. Summary of regression results for developing countries, selected years

	Equation	a	b	c	d	Standard error estimate	R^2	F
1960	A	-11.52	1.82 (3.79)*	0.41 (1.61)		1.07	0.57	7.19
	B	-42.65	12.61 (1.74)	0.61 (2.20)	-0.94 (1.49)	1.02	0.65	6.06
1963	A	-13.82	2.13 (5.54)*	0.61 (3.70)*		0.91	0.71	17.48
	B	-17.33	3.34 (0.51)	0.63 (3.23)*	-0.10 (0.19)	0.94	0.71	10.86
1966	A	-15.69	2.36 (5.44)*	0.75 (3.82)*		1.09	0.70	17.43
	B	-16.73	2.71 (0.38)	0.75 (3.23)*	-0.03 (0.05)	1.13	0.70	10.85
1970	A	-13.87	2.13 (6.10)*	0.62 (3.97)*		0.88	0.70	20.50
	B	-27.47	6.65 (1.19)	0.67 (3.91)*	-0.38 (0.81)	0.89	0.71	13.61
1960–1964	A	-13.17	2.03 (11.87)*	0.57 (7.42)*		0.89	0.66	77.11
	B	-29.48	7.66 (2.83)	0.66 (7.65)	-0.49 (2.09)	0.88	0.68	55.07
1969–1973	A	-13.91	2.12 (14.19)*	0.63 (9.40)*		0.85	0.70	111.13
	B	-24.88	5.76 (2.61)	0.68 (9.37)*	-0.30 (1.65)	0.84	0.71	76.33

Source: UNIDO, based on data supplied by the UN Statistical Office.

Note: T-values are shown in parentheses. An asterisk denotes statistical significance at a confidence level of 99 per cent.

Table 15. Summary of regression results for developed market economies, selected years

	Equation	a	b	c	d	Standard error estimate	R^2	F
1960	A	-7.72	1.36 (5.25)*	0.25 (1.91)		0.71	0.63	16.76
	B	-40.38	10.63 (1.63)	0.30 (2.30)	-0.66 (1.42)	0.70	0.67	12.44
1963	A	-6.89	1.25 (4.54)*	0.22 (1.71)		0.72	0.57	12.80
	B	-27.99	7.13 (0.98)	0.25 (1.84)	-0.41 (0.81)	0.72	0.58	8.59
1966	A	-5.95	1.14 (4.66)*	0.21 (1.90)		0.62	0.60	14.21
	B	-26.50	6.75 (1.05)	0.24 (2.04)	-0.38 (0.87)	0.62	0.62	9.61
1970	A	-5.07	1.03 (3.99)*	0.21 (1.89)		0.61	0.54	11.07
	B	-31.62	8.14 (1.11)	0.24 (2.06)	-0.48 (0.97)	0.61	0.56	7.68
1960-1964	A	-7.08	1.28 (11.24)*	0.23 (4.18)		0.68	0.59	77.90
	B	-31.15	8.03 (2.82)	0.26 (4.74)*	-0.47 (2.37)	0.67	0.61	56.06
1969-1973	A	-4.66	0.98 (8.76)*	0.20 (4.32)*		0.59	0.51	54.09
	B	-31.05	8.01 (2.61)	0.24 (4.82)*	-0.47 (2.30)	0.58	0.53	39.27

Source: UNIDO, based on data supplied by the UN Statistical Office.

Note: T-values are shown in parentheses. An asterisk denotes statistical significance at a confidence level of 99 per cent.

Table 16. Hypothetical projections of steel production for large countries, 1972

Country	Projected production unadjusted	Actual production[a/] adjusted
Argentina	77	78
Brazil	133	106
Canada	109	99
Colombia	112	145
France	72	119
Germany (Fed. Rep.)	69	106
India	83	132
Italy	101	81
Japan	79	88
Korea (Rep. of)	147	103
Mexico	145	104
South Africa	58	99
Spain	66	57
Turkey	98	52
United Kingdom	114	122
United States	110	141

Source: UNIDO calculations

a/ For a description of the assumptions employed in the two sets of projections, see p. of the text.

Table 17. Consumption study, sample regression results, all countries

		Intercept	Coefficient b	Coefficient d	Coefficient of determination	Standard error of estimate	F value
Equation C	1950–1952	-3.98	1.33 (23.64)		0.812	0.597	
	1959–1961	-4.26	1.38 (28.81)		0.864	0.511	
	1968–1970	-3.40	1.26 (33.09)		0.894	0.428	
Equation D	1950–1952	-522.23	105.81 (16.26)		0.672	69.07	
	1959–1961	-702.63	137.59 (19.35)		0.741	75.72	
	1968–1970	-1,013.91	191.59 (22.28)		0.792	96.52	
Equation E	1950–1952	5.06	-292.11 (-15.13)		0.639	0.828	
	1959–1961	5.53	-399.21 (-19.20)		0.738	0.710	
	1968–1970	5.86	-444.05 (-18.48)		0.724	0.690	
Equation F	1950–1952	-3.51	-18.76 (-0.65)	1.26 (10.90)	0.813	0.598	278.83
	1959–1961	-3.12	-54.71 (-1.60)	1.23 (11.19)	0.866	0.508	421.37
	1968–1970	-3.03	-21.45 (-0.65)	1.21 (14.40)	0.894	0.424	545.34
Equation G	1950–1952	-6.12	2.07 (2.95)	-0.06 (-1.06)	0.814	0.597	280.21
	1959–1952	-8.79	2.90 (4.49)	-0.12 (-2.35)	0.869	0.503	432.31
	1968–1970	-5.62	1.97 (3.65)	-0.06 (-1.32)	0.895	0.427	551.57

Table 18. Consumption study, sample regression results, developed countries

		Intercept	Coefficient b	Coefficient d	Coefficient of determination	Standard error of estimate	F value
Equation C	1950–1952	-2.26	1.08 (12.35)		0.685	0.518	
	1959–1961	-1.97	1.06 (14.14)		0.741	0.374	
	1968–1970	-1.27	0.98 (13.59)		0.725	0.322	
Equation D	1950–1952	-773.42	144.72 (10.90)		0.629	78.326	
	1959–1961	-1075.28	193.07 (12.13)		0.678	79.400	
	1968–1970	-1599.57	273.75 (12.39)		0.687	98.963	
Equation E	1950–1952	5.82	-540.42 (-11.26)		0.644	0.550	
	1959–1961	6.23	-736.15 (-13.54)		0.724	0.387	
	1968–1970	6.64	-1005.19 (-13.83)		0.732	0.318	
Equation F	1950–1952	-0.98	-91.85 (-0.60)		0.687	0.520	75.73
	1959–1961	0.83	-263.00 (-1.36)		0.748	0.372	102.17
	1968–1970	3.12	-574.89 (-2.17)		0.743	0.314	99.57
Equation G	1950–1952	-4.99	1.94 (1.12)		0.687	0.520	75.54
	1959–1961	-10.89	3.74 (2.20)		0.750	0.371	103.38
	1968–1970	-14.31	4.69 (2.76)		0.743	0.314	99.71

Table 19. Consumption study, sample regression results, developing countries

		Intercept	Coefficient b	Coefficient d	Coefficient of determination	Standard error of estimate	F value
Equation C	1950–1952	-3.62	1.23 (8.96)		0.585	0.635	
	1959–1961	-4.03	1.32 (10.02)		0.630	0.590	
	1968–1970	-2.41	1.07 (9.26)		0.596	0.479	
Equation D	1950–1952	-133.44	30.43 (9.70)		0.622	14.451	
	1959–1961	-155.58	34.73 (9.92)		0.625	15.668	
	1968–1970	-222.53	47.94 (9.42)		0.605	21.155	
Equation E	1950–1952	3.86	-162.03 (-7.14)		0.472	0.715	
	1959–1961	4.35	-236.09 (-9.00)		0.578	0.630	
	1968–1970	4.50	-218.43 (-8.66)		0.564	0.498	
Equation F	1950–1952	-4.07	11.57 (0.24)		0.585	0.640	39.47
	1959–1961	-2.82	-37.19 (-0.51)		0.632	0.594	49.74
	1968–1970	-0.42	-68.40 (-1.01)		0.604	0.479	43.37
Equation G	1950–1952	-1.65	0.47 (0.27)		0.586	0.639	39.63
	1959–1961	-9.11	3.21 (1.67)		0.636	0.590	50.70
	1968–1970	-6.94	2.71 (1.63)		0.603	0.480	43.32

Note: T-values are shown in parentheses. An asterisk denotes statistical significance at a confidence level of 99 per cent.

Annex to Chapter II

STEEL PRODUCTION CAPACITIES IN THE DEVELOPING COUNTRIES OF AFRICA, ASIA AND LATIN AMERICA[1/]

(An approximative assessment)

AFRICA, 1965-1985

North Africa

The North African region (comprising Algeria, Egypt, Libya, Mauritania, Morocco, Sudan and Tunisia) is the only area on the African continent where significant steel-making capacities are in operation apart from Rhodesia and South Africa. The actual production level is modest: 0.8 million tons in 1975. Given favourable conditions, however, a steel-making capacity of 12 million tons may be in operation about the middle of the 1980s. If 75 per cent of this capacity is utilized, 10.5 million tons of steel by 1985 may be a realizable figure.

Algeria

A major portion of North Africa's steel projects is in construction or under consideration in Algeria, which country may well become the biggest steel-producer in the region by 1985, with a capacity of 4.5 million tons, some of it for export. Annual steel consumption in this country reached 1 million tons in 1972-1974, as compared with 232,000 tons per year in 1965-1967. It is estimated that production will be in excess of 2 million tons by 1980. For 1990, a figure of 12 million tons is forecast. The 4.5 million ton capacity to be installed by 1985 is an intermediate projection made on the basis of existing plants, projects and long-term expectations.

Egypt

In Egypt, average annual steel consumption rose from 791,000 tons in 1965-1967 to 973,000 tons in 1972-1974. Capacity expansion in Helwan and other areas is for a projected 3.5 million tons per year by 1985.

1/ This Annex should be read in conjunction with the data given in the preceding tables, in particular Tables 7, 8, 9 and 10, as well as Annex Figure 1. Except where references are given, the data provided have been derived from information gathered in the course of UNIDO activities in the iron and steel sector.

Libya

Arc furnaces with continuous caster capacity of 21,000 tons per year will be in operation in Libya from 1976 onwards. The annual average of steel consumption reached 655,000 tons in 1972-1974. The coastal steel plant at Misurata is envisaged to have an initial capacity of 0.5-1.0 million tons by 1985. Part of this production will be for export. One of the significant features of the project is heavy infrastructural facilities created, such as a port, a power station, a water desalination facility and a gas pipeline.

Mauritania

The Arab Company for Metallurgical Industries, a joint Mauritania-Kuwait concern, is to establish a 1 million tons/year steel complex at Nouadhibou. As the local market is rather limited, this project is export-oriented.

Morocco

Morocco has established a national steel company, known as SONASID (Société Nationale Sidérurgique). According to the current development programme, a 1 million tons/year integrated mill will be in operation at Nador in 1979. Annual steel consumption reached 392,000 tons in the years 1972-1974.

Sudan

The Sudan possesses high-grade iron ore deposits in its coastal regions but no steel-making project has yet been undertaken, with the exception of a mill to produce concrete reinforcing rods and sections, using imported billets.

Tunisia

The 97,000 tons/year capacity of the integrated steel works at El-Fulladh is expected to be raised to 200,000 by 1977. Steel consumption was 302,000 tons per year in 1972-1974. In 1973, a letter of intent to set up a 1 million tons/year direct reduction plant was signed, but according to some reports the projected capacity of the plant has been raised to 1.5 million tons/year. It is envisaged that an electric furnace with 0.5 million tons capacity may be added to the direct reduction facility.

West Africa

In West Africa (taken to include Benin, the Cape Verde Islands, Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo, and Upper Volta), forecasts of steel production in 1985 are based mainly on the development of the Nigerian integrated steel mill at Ajaokuta, which will actually be the prevailing steel producing capacity in this sub-region. The existing plant consists of electric arc furnaces (capacity 24,000 tons per year), ingot casting and a rod mill. It is also reportedly planned to establish an integrated iron and steel plant using the sponge iron-electric furnace route. Steel consumption is expected to increase from 0.7 million tons annual average in 1972-1974 to 3.5 million tons by 1980.[2/]

East Africa

The main potential steel producers among the developing countries of this sub-region (taken to include Burundi, Comoro Islands, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Reunion, Rwanda, Somalia, Rhodesia, Uganda, Tanzania, and Zambia) are Tanzania and Zambia, where several steel projects are under preparation or being implemented. Uganda produced 15,000 tons of steel in 1975, but information regarding expansion plans is not available.

Tanzania

Plans contemplate the building of an integrated iron and steel mill based on domestic ore and coal reserves with production scheduled to begin in 1980. According to the report of a World Bank mission (March 1975), demand by 1979 will reach an estimated 200,000 tons/year, of which about 120,000 tons will be in the form of primary materials. The report mentioned that owing to the financial problems and uncertainties associated with the demand projections, the estimate is a fairly broad one.

Zambia

The steel mill at Chisasa, in Zambia's north-western province, is being supplied by a German steel company with direct reduction facilities, electric furnaces, wire and rod mill, power supply, workshop and other

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2/ Third National Development Plan, 1975-1980, pp. 156-157.

ancillary equipment. It is estimated that by 1980, the production capacity of the mill will reach 250,000 tons per year, a figure well in excess of local demand: the project is thus export-oriented.

Central Africa

The forecast of steel production for this sub-region (Angola, Central African Republic, Chad, Congo, Equatorial Guinea, Gabon, Cameroon, and Zaire) is mainly based on Zaire's steel development programme for this period. The Zaire National Executive Council has signed an agreement with an Italian group which will assist the steel mill run by the Société Nationale de Sidérurgie at Maliku during the first ten years of operation. The capacity of the mill is expected to rise to 250,000 tons per year, the annual capacity in the first of two phases being 120,000 tons.

Southern Africa

In this sub-region (comprising Botswana, Lesotho, Namibia, Republic of South Africa and Swaziland) the only steel producer is the Republic of South Africa whose steel industry started in 1911. Steel production is reportedly planned to increase from 6.8 million tons in 1975 to 13.3 million tons in 1984. However, as certain major projects have been postponed recently, an eventual decline in growth can be expected.

PROSPECTS FOR 2000

North Africa

Additional steel production capacity of 25 million tons may be expected to be set up between 1985 and 2000, some 38 per cent of this increase possibly being located in Algeria.

By the year 2000, Mauritania, Morocco and Tunisia may be expected to double their 1985 steel production. The average per capita production capacity should bring this region to the upper level of the "medium" group of steel-producing countries shown in Table 10.

West Africa

More than half the projected steel-making capacity of this region will probably be established in Nigeria. In view of the large population of the country, however, the expected production capacity of 5 million tons per year (38 kg per capita) is rather on the low side. Some other countries in the region, such as Ghana or Liberia, may consider setting up major facilities, although in the case of Liberia, the main pre-occupation will be to ensure stable foreign markets.

East Africa

Countries such as Kenya, Tanzania, Uganda and Zambia, which may have established steel-making facilities in 1985, are expected to strengthen their position. Ethiopia is envisaged to initiate steel production in the period 1985-2000. On the whole, the sub-region will have a relatively modest steel-making capability in 2000.

Central Africa

Considering the availability of ore and coal, together with other economic aspects, significant developments can be expected in Zaire, which might establish more than two thirds of the steel-making capacity expected. The sub-region may attain a level of 68 kg steel production per capita thus placing it in the upper level of the "low" group of steel-producing countries.

Southern Africa

With the exception of the Republic of South Africa, no new major steel facilities are envisaged in this sub-region.

ASIA, 1965-1985

East Asia

This sub-region (comprising Hong Kong, Democratic People's Republic of Korea, Republic of Korea and Mongolia) represents the highest steel production per capita in the whole region. The Democratic People's Republic of Korea produced 3.5 million tons of steel in 1975. Its steel consumption was 2.8 million tons per annum in 1972 and 1973, and 3.4 million tons in 1974. Steel production capacity is planned to reach 12 million tons within the new six-year planning period, 1977-1982. However, in view of the long implementation periods of steel projects, only 9 million tons steel-making capacity has been accounted for in the table.

The Republic of Korea produced 2 million tons of steel in 1975 at the Pohang Steel Mills. By 1979 additional facilities may bring that figure up to 5.5 million tons. A second steel mill in the Naktong River estuary region is planned for completion in 1982, its initial annual production capacity being 7 million tons. Construction has since been postponed and the Government has decided to reconsider project plans at the end of 1977 or the beginning of 1978. Steel consumption increased from 591,000 tons in 1965-1967 to 3 million tons in 1972-1974 (4.1 million tons in 1974).

South East Asia

This sub-region, comprising Burma, Indonesia, Laos, Malaysia, Philippines, Portuguese Timor, Singapore, Thailand and Viet-Nam, is the least developed in Asia in terms of steel production per capita (4 kg in 1975 compared to 101 kg for East Asia). Steel consumption averaged 4.8 million tons in 1972-1974. At a growth rate of 8 per cent, which might be a very conservative estimate, it may increase to 11.2 million tons by 1985. At their meeting in September 1975 steel experts in the ASEAN group estimated a 10 per cent growth rate up to 1985, by which time the production capacities installed would hardly meet half the calculated demand.3/

3/ Far Eastern Economic Review, 26 March 1976.

In Indonesia, steel consumption averaged 0.9 million tons in 1972-1974. The abundance of natural gas combined with the country's proximity to large deposits of high-grade iron ore appear to justify large-scale investment in the iron and steel industry. A wide variety of steel projects are under consideration, and the Krakatau steel complex may be expected to produce as much as 1 million tons of steel in 1979.

In Malaysia, local steel consumption was 646,000 tons per year in 1972-1974. The east coast of the Malaysian peninsula is being considered as the site for a new steel plant with an initial capacity of 0.5 million tons.

In the Philippines, annual steel consumption totalled 1.1 million tons in 1972-1974. The country has drafted a regional ASEAN steel project envisaging an investment of $1.6 billion and the production of 2.5-3.0 million tons of slabs, blooms, billets and plates. In the initial stage, iron ore would be imported from Australia, India and other countries prior to gradual replacement by domestic ore. The plant may be built in two stages: the first (a capacity of 1.0-1.5 million tons of raw steel per year) is scheduled to start in 1982, the second (an additional capacity of 1.5 million tons) is expected to be operational 2-3 years later.

Steel demand in Singapore is expected to increase rapidly from the level of 1.2 million tons per annum registered in 1972-1974. No integrated plant is reportedly under consideration at present.

In Thailand, annual steel consumption averaged 0.9 million tons in 1972-1974. About 40 semi-integrated steel-making plants were in operation in the early 1970s, with a total capacity of 550,000 tons. Almost 80 per cent of the steel was used in construction, predominantly as reinforcing bars and rods.[4/] A steel-making capacity of 1.2 million tons has been forecast for 1985.

Middle South Asia

This sub-region (comprising Afghanistan, Bangladesh, Bhutan, India, Iran, Nepal, Pakistan and Sri Lanka) has the largest population in Asia. India and Iran are the main steel producers, with Iran leading as far as steel production per capita is concerned.

4/ SEASI Quarterly, April 1973, p.11.

In Afghanistan, reports indicate that steel plant with a capacity of 1 million tons per year is likely to be built with Iranian help.

In Bangladesh, the Chittagong plant, has a rated capacity of 25,000 tons. Raw material shortages may restrict utilization of capacity. It is to be expected that reconstruction and modernization will take place in the latter part of the period.

Steel production in India fluctuated around 6.5 million tons for some years before 7.1 million tons were produced in 1974, and 8.0 million tons in 1975. According to a statement by the Indian Minister of Steel and Mines in May 1976, it was indicated that a capacity utilization factor of over 84 per cent was being achieved (compared with 65-73 per cent for many years previous) and a higher factor of 94 per cent was being aimed at by 1980. The low capacity utilization factor was attributed to irregularities and difficulties associated with energy supply as well as to labour and management problems.

Domestic demand for finished mild steel is estimated to reach some 10 million tons by 1978/1979. Steel consumption in India increased from 6.9 million tons in 1965-1967 to 8.6 million tons in 1972-1974. According to the official "Selected Output Projections" of the Fifth Five-Year Plan (1974-1979), steel production is expected to rise to 20.5 million tons in 1985-1986.

Iran emerged as a steel-producing country in 1973 when the Isfahan works started production. Consumption rose from 1.0 million tons in 1965-1967 to an average 2.5 million tons in 1972-1974. According to estimates, consumption may rise to 12 million tons by 1983. Government plans call for expansions to match the increase in national demand and to export steel, especially to the Persian Gulf countries. The two large state-owned steel companies may increase their production capacities to 3.5 million tons each by the early 1980s and up to a total of 9-10 million tons by 1985. The implementation of the Government plans may be influenced by start-up periods required as well as by the priority given to steel projects in the future.

In Pakistan, if the Pipri plant of the Pakistan Steel Mills were to develop according to schedule, it would reach full-scale operation by 1978, with a targeted production of 1 million tons per year. Additional steel production capacity is envisaged after 1980. It is expected that iron ore and coal for the Pipri plant will be imported from Australia. Contacts have also been established with other ore-exporting countries, including Mauritania and Swaziland. Steel consumption reached 0.4 million tons per year in 1972-1974.

South West Asia

This sub-region, comprising Cyprus, Iraq, Jordan, Kuwait, Lebanon, Saudi Arabia, Syria, Turkey, Yemen, and People's Democratic Republic of Yemen, is expected to achieve a high rate of growth in steel production. The steel consumption of the sub-region reached 2.6 million tons in the years 1965-1967 and 6.1 in 1972-1974.

In Iraq, steel consumption increased from 284,000 tons in 1965-1967 to 985,000 tons in 1972-1974. The installation of electric furnaces is reportedly planned to provide a capacity of 1.0 million tons by 1981.

In Saudi Arabia, the Petromar project was originally planned in the eastern region of the country with an initial production target of 1 million tons of steel per year, whereafter it would gradually increase to 10 million tons per year. However, owing to uncertainties, only the initial capacity is now being considered for completion by 1985. Changes in planning are probable. Steel consumption in the years 1972-1974 totalled 0.8 million tons.

In Syria, the construction of a mini-steel works has reportedly been commissioned with an annual capacity of 120,000 tons, which, according to plans may rise to 600,000 tons.

In Turkey, steel consumption reached 1.9 million tons per annum in 1972-1974. Major capacity additions are under implementation and two new "greenfield" projects are in the preparatory stage. The country's steel-making capacity thus may reach approximately 5 million tons by 1980, and 7 million tons by 1985.

Abu Dhabi and Qatar are reported to be examining the erection of 1 million tons and 350,000 tons of direct reduction capacity, respectively. Sponge iron would be used locally to produce raw steel. (Abu Dhabi and Qatar are included under "Other countries" in Table 8.)

PROSPECTS FOR 2000

East Asia[5/]

The relative steel-making capability of the Democratic People's Republic of Korea and the Republic of Korea is much higher than that of any other sub-region or country in Asia. However, a slowing down in the rate of growth is expected in the period 1985-2000. By 2000, the per capita steel production capacity may reach 387 kg.

South East Asia

An internationally significant increase in steel-making may take place in this area during 1985-2000. The five ASEAN countries could boost their steel production capacities to more than 20 million tons, even though this would still meet less than half of their estimated demand in 2000.

A significant difference between local consumption and local steel-making capability was reported in 1975 - 24 kg per capita steel consumption as against 6 kg steel production per capita. According to estimates made in 1975 by ASEAN steel experts, steel demand may reach 61 kg per capita in 1985, as compared with only 16 kg per capita production.

According to an earlier forecast prepared by the SEA Iron and Steel Institute,[6/] steel demand was to reach 11.2 million tons in 1985, i.e. 38 kg steel consumption per capita. The expectation for 2000 was 35.7 million tons of steel consumption, i.e. 82 kg per capita. In view of the conservative nature of the SEA Iron and Steel Institute forecast, steel consumption per capita has been estimated at 100 kg while demand would reach 43.8 million tons in 2000. Some 56 per cent of demand is expected to be met by regional production, the balance being supplied largely by Australia and Japan. Whereas the five ASEAN countries alone were expected to have steel-making capacities of 26 million tons, the sub-region would have 33 million tons, thanks to steel industry development in other countries in the area.

5/ Not including China.

6/ South East Asia Iron and Steel Institute, "Study of the Trend of Production and Consumption of Iron and Steel", November 1975 (mimeographed).

Middle South Asia

In India, per capita steel production rose from 4.50 kg to 13 kg in the decade 1955-1965, but no comparable rise in capacity took place during the subsequent decade. By 1985, it is expected that a second substantial increase will have taken place, bringing steel production capacity per capita to 26 kg in that year.

Further expansion of steel-making capacity in India will be largely a matter of capital allocation, since the human and technical resources, including plant design capabilities, are already available. In the early 1990s, a third decisive step is expected to be taken to expand steel facilities in the country, and indications are that steel demand may rise to 50 million tons (47 kg per capita). Such a development might justify the consideration of 53 million tons of steel producing capacity. However, if India becomes a major net exporter of steel, a figure closer to 60 million tons would appear justified.

In Iran significant development of the steel industry is expected although an eventual decrease in oil revenue might retard the implementation of some of the country's steel projects. Three variants of per capita steel production capacity (300, 350 and 400 kg) have been calculated corresponding to production levels of 20, 23 and 26 million tons of steel. The lowest is deemed most probable.

In Afghanistan, it is assumed that the 1 million tons of steel-making capacity now under consideration will become operational in the same period.

South West Asia

In Turkey production capacity is expected to increase to 20 million tons of steel (275 kg/capita steel-making capacity). The Arab countries in this sub-region contain a population of 95.4 million and 15 million tons of raw steel production capacity. The sub-region with 207 kg per capita would be close to the North African sub-regional group attaining 191 kg per capita.

Iron-making in the Arab countries will be largely based on the direct reduction process. In Kuwait, the Gulf States, and to a large extent, Saudi Arabia, production will be export-oriented, whereas in Iraq and Syria it will most likely supply local metal-fabricating and engineering industries.

LATIN AMERICA, 1965-1985

A steel production capacity of 70 million tons might be achieved by 1985. This capacity figure is rather on the low side, compared with earlier estimates such as those made by ILAFA,[1/] which indicated a projected production capacity of 87.3 million tons.

The estimated growth rate of steel production in Latin America from 1965-1985 is comparable with that of Spain (1.2 million tons in 1955, and 11.1 million tons in 1975) and Japan (9.5 million tons in 1955, and 102.2 million tons in 1975) a decade earlier.

For the purposes of this Annex, Latin America has been divided into the following sub-regions: Caribbean and Central America, Tropical South America and Temperate South America. In spite of significant discrepancies in levels of steel production among the countries within each sub-region, these three groups of countries were rather close as far as steel production per capita at the sub-regional level in 1975 was concerned. Each sub-region contains one major steel producer: Mexico in the Caribbean and Central America; Argentina in Temperate South America; and Brazil in Tropical South America. The future development of these leading steel producers will have a decisive effect upon the respective sub-regions. It should also be noted that Venezuela is becoming an important steel producer.

The Caribbean and Central America

Of the countries in this sub-region (Barbados, Cuba, Dominican Republic, Guadeloupe, Haiti, Jamaica, Martinique, Puerto Rico, Trinidad and Tobago, Windward Islands, other Caribbean islands, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua and Panama), Cuba produced 240,000 tons of steel in 1975 and production is expected at least to double by 1985.

Mexico, which imported 50 per cent of its steel consumption requirements 20 years ago, aims to become self-sufficient in steel in the near future. In 1972-1974, annual consumption totalled 5.3 million tons, and

1/ IISI, Annual Conference, October 1975, Mexico City, Report of Proceedings, pp. 42-43.

production 4.8 million tons. The installed steel-making capacity was expected to reach 9.9 million tons by the end of 1976, and to be in the neighbourhood of some 12.3 million tons by 1980, following the start-up of the second phase of Las Truchas.8/ If the constraints already identified can be overcome, the installed steel production capacity might be between 16 and 18 million tons by 1985.

In Trinidad and Tobago, preparatory work has started on a $220 million iron and steel complex that will utilize the country's plentiful hydrocarbon resources. Government will be the main shareholder, with several international companies holding minority shares. When completed in mid-1978 the venture is expected to produce 1.2 million tons of steel billets a year. The bulk of the production will be exported to Holland and Japan.

Tropical South America

Brazil plays a leading role in steel production, not only in the subregion (which comprises Bolivia, Brazil, Colombia, Ecuador, Guyana, Paraguay, Peru, Surinam, and Venezuela), but also in Latin America as a whole. Steel consumption in Brazil averaged 10 million tons in 1972-1974. Since steel production was 7.7 million tons per year, the steel deficit of 2.3 million tons had to be met through imports. Despite efforts to increase steel production, the deficit may be 8.6 million tons by 1980, with an expected demand of 22.4 million tons of ingots compared with a production of 13.8 million tons.9/ The deficit may be even larger by 1985. Installed steel production capacity was 9.3 million tons in 1975 and may increase to at least 25 million tons by 1985. Additions to existing capacities and new greenfield projects would seem to substantiate this figure, despite its apparent lowness. The growth rate of steel consumption, which exceeded 13 per cent for many years, and other local conditions conducive to steel-making, bode well for the further accelerated development of the steel industry.

In Colombia, annual steel consumption averaged 0.7 million tons in 1972-1974, 50 per cent of which was met through local production. Domestic coking coal reserves have been estimated at 2.3 billion metric tons: the

8/ B. Trillo, The Steel Industry in Mexico, IISI, Ninth Annual Conference, Mexico City, 13-15 October, 1975, Report of Proceedings, p.77.

9/ Fred Woods de Lacerdag, "Outlook of the Brazilian Steel Industry", IISI, Ninth Annual Conference, Mexico City, 13-15 October, 1975, Proceedings, p.60

deposits are said to be of high quality with a low sulphur content. The steel works at Paz del Rio will be expanded to produce 1 million tons of steel ingots in [illegible], and a greenfield plant is also planned.

In Ecuador, a 400,000 ton capacity steel plant using direct reduction is scheduled to start production in 1980, full capacity being envisaged for 1985.

In Peru, the present steel-industry development programme aims at gradually meeting national steel demand, and self-sufficiency in steel is envisaged for 1979. Average annual steel consumption is 0.7 million tons (1974: 0.9 million tons), compared with local production of 0.4 million tons. The programme which also aims at providing an export surplus of semi-finished and finished steel products, comprises two major projects which are expected to increase the annual steel production capacity of the country to 8 million tons by the end of the 1980s. SIDERPERU, the state-owned iron and steel corporation, is planning to expand its steel-mill at Chimbote to a capacity of [illegible] million tons by 1985. The second project is the establishment in two stages of a steel mill at Nazca on the southern coast of Peru. The first stage provides for a production level of 2 million tons of liquid steel, the second stage for twice as much. According to preliminary plans, the first stage will be completed in 1983, and the second in 1988.

Venezuela has decided to devote considerable funds derived from its oil revenue to increasing steel production. Steel consumption totalled 2.3 million tons per annum in 1972-1974 (1974: 2.7 million tons), and production was slightly above 1.0 million tons in the same period. Steel consumption could reach 6 million tons by 1985. SIDOR, the national steel company, is planning to increase production capacity to 5 million tons by 1980. Being situated on the banks of the river Orinoco, the SIDOR steel mill is favourably located in terms of accessibility to coke imports and future steel exports. In addition, it enjoys the supply of cheap energy from the Guri hydro-electric dam on the river Caroni. The planned Zulia steel mill is still being debated, the steel production capacity target of which has been set at 10 million tons by the mid-1980s.

Temperate South America

Of the countries in this sub-region (comprising Argentina, Chile and Uruguay), Argentina has a large steel industry. In 1973, a national plan was formulated in order to define the development programme for this industry. At present, there are two integrated steel mills in Argentina, which produced 2.4 million tons of steel in 1974, accounting for 58 per cent of the country's steel consumption which in that year reached 4.2 million tons of raw steel. In 1974-1975, the Government decreed that a third integrated steel mill be set up near Bahia Blanca, involving an estimated investment of $2.7 billion. The mill is planned to start producing raw steel in the early 1980s, the initial capacity being 3.8 million tons per year and rising eventually to 8 million tons.

In Chile, the one integrated steel mill in operation produced 0.5 million tons in 1975. Consumption averaged 0.7 million tons in 1972-1974, and the capacity of the existing steel mill may be doubled during this decade. Furthermore, plans are under government review for the establishment of another steel mill with an initial annual capacity of 1 million tons.

PROSPECTS FOR 2000

Caribbean and Central America

Steel production in Mexico will have a decisive influence on production levels in the Caribbean and Central America. Population is expected to grow at a rate of more than 3 per cent per year in the period 1985-2000. Bearing in mind that the per capita steel production capacity in Mexico has been estimated at 217 kg in 1985, analysis has shown that steel production per capita will likely be 300 kg, and steel-making capacity 46 million tons by 2000: the total steel-making capacity of the sub-region is estimated at 51 million tons.

Tropical South America

Steel production in this sub-region will, to a large extent, be determined by that of Brazil, which country is expected to attain a steel production capacity per capita of 283 kg, i.e. 75 million tons in 2000.

This target figure includes 35 million tons of new capacity at an annual rate of increment of 2.3 million tons.

Venezuela will become the sub-region's second leading steel-maker. It may attain a steel production level of 18 million tons in 2000, i.e. 847 kg production per capita. This per capita production level corresponds to that of highly industrialised countries, such as Sweden in the 1970s. It is expected that a major part of the steel produced will be exported. In Peru, production capacity is estimated at 9 million tons, which figure would appear rather conservative.

Although expected to expand their steel production in this period, both Colombia and Ecuador will still be in the lower category of steel producers.

The sub-region is expected to attain a capacity of 314 kg per capita steel production in 2000 which would place it among the leaders in the middle category of the world steel producers.

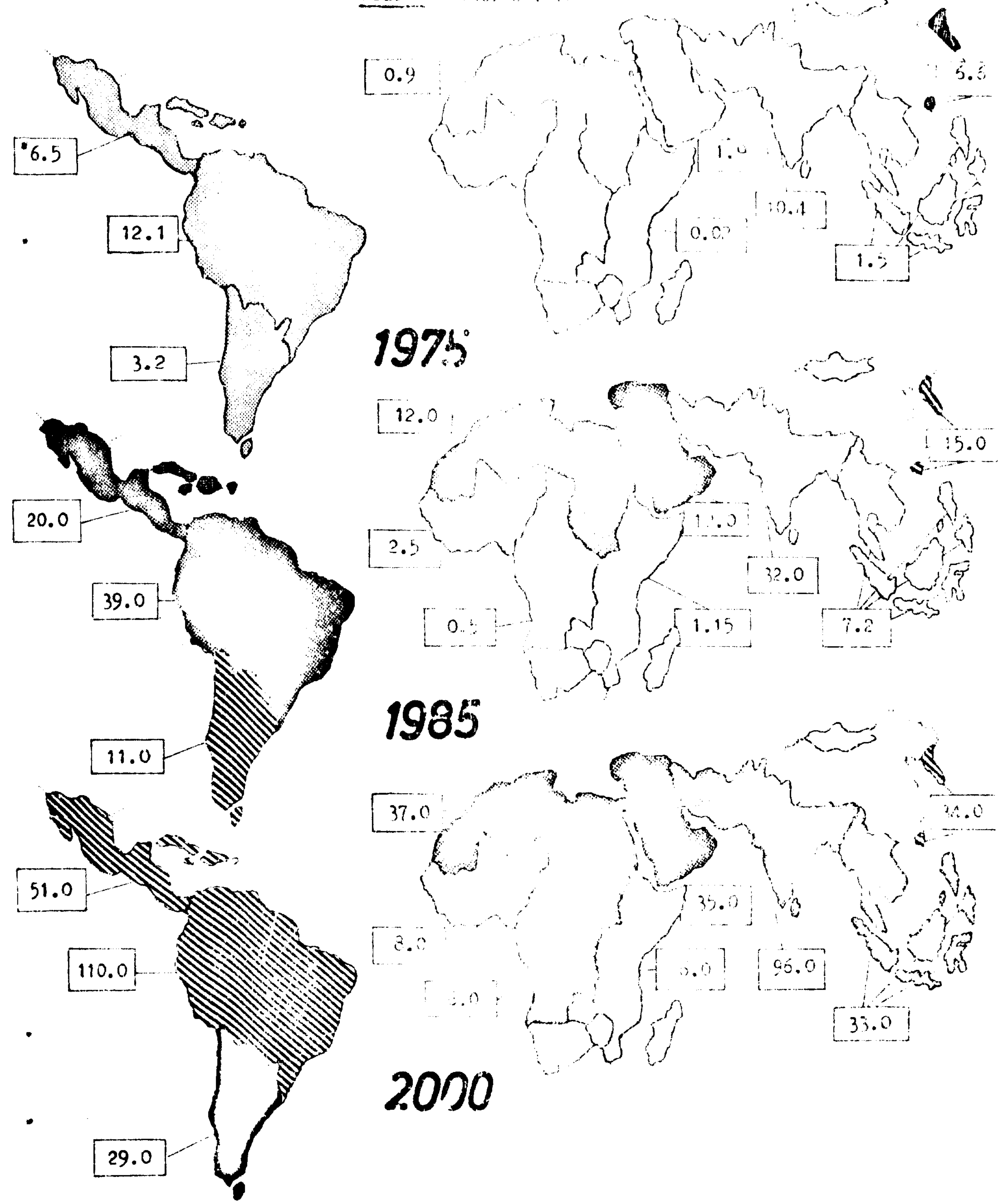
Temperate South America

Argentina is expected to attain a capacity of 669 kg per capita steel production, i.e. 22 million tons in 2000. It is thus anticipated that this country might become an important exporter both of steel and engineering products.

By 2000, Chile is expected to more than treble its 1985 steel facilities and steel development will also take place in Uruguay. This sub-region would be the only sub-region in the developing regions with a steel production capacity per capita surpassing 400 kg (557 kg/capita).

Sub-regional distribution of steel-making capacities in the developing countries.

<u>Source:</u>



Total capacity-million tons:

Steel-making capacity - Kg per capita

Chapter III

THE IRON AND STEEL TRADE OF DEVELOPING COUNTRIES: STRUCTURE, PROSPECTS AND POLICIES [1]

Introduction and main policy conclusions

In view of the target set in the Lima Declaration of increasing the developing countries' share in total world industrial production to at least 25 per cent by the year 2000, efforts to expand the iron and steel sector assume great importance owing to its leading role in the development process. This implies the need for considerable restructuring and change in the composition of trade in iron and steel over the next quarter of a century.

Table 1 summarizes the iron and steel trade situation for a sample of 50 developing countries in 1973. Exports from these developing countries to the developed countries amounted to only $1,423 million, whereas those from developed to developing countries amounted to $6,013 million. Similarly, large imbalances exist in exports of coal and coke (a steel input) as well as of machinery and transport equipment which have a high steel content. [2] The burden caused by these foreign exchange expenditures can only be reconciled if the world-wide sectoral restructuring implicit in the Lima target is realized.

1/ This section is adapted from a preliminary report prepared by the UNCTAD secretariat on the trade implications of restructuring the world iron and steel industry, in compliance with resolutions adopted at the Second General Conference of UNIDO in March 1975 and at UNCTAD IV in May 1976.

2/ Developed country exports of coal and coke amounted to $149 million and those of machines and transport equipment to $30,688 million, whereas the reverse flow of coal and coke was only $8 million (data for machinery and transport equipment not available).

Table 1. Structure of the iron and steel trade of developing countries, by processing stage, 1973
($ millions)

Exports by source and destination \ Stage of processing	Ore and concentrates	Semi-manufactures	Finished manufactures	Total
From developing to developed	719	529	175	1,423
From developing to developing	20	246	60	326
From developed to developing	4	5,274	735	6,013
Net developing country exports	715	-4,745	-560	-4,590

Source: Data supplied by 50 developing countries (see Table 2).

The table also shows that the exports of developing countries are mainly composed of ore and concentrates and semi-manufactures, whereas the reverse flow from developed countries consists of semi-manufactures and finished manufactures. While the developed countries will continue as major suppliers of finished manufactures, achievement of the Lima target implies a shift in the product composition of developing country exports from ore and concentrates to semi-manufactures and greater import substitution in semi-manufactures.

Furthermore, the small amount of trade among the developing countries themselves as compared with trade with developed countries is apparent. If the Lima target is to be attained, the share of trade among the developing countries in their total iron and steel trade must increase for a number of reasons: general instability of export and import prices of higher order processed iron and steel in developed countries; tariff, non-tariff and transport cost barriers to trade; restrictive business practices and cartel policies resulting from the monopolistic/oligopolistic market structure in those countries; and most importantly, because of the opportunities for restructuring iron and steel trade patterns in favour of the developing countries whose steel production, consumption and concomitant trade are expected to grow dynamically over the next 25 years. These shifts in the trade patterns towards increased intra- and interregional trade on the part of the developing countries, in the face of competition from developed countries, can occur, only if immediate steps are taken by the developing countries to create a stable co-operative environment conducive to such trade among themselves.

Developing country trade flows in 1973

This section provides an analysis of developing country trade flows in iron and steel production on the basis of data at four levels of aggregation (total value of iron and steel trade; raw materials; semi-manufactures; and finished manufactures) for 50 developing countries in 1973. While trade data for only one year in respect of these countries may not conclusively identify the trade patterns of the developing countries, they will, for most cases, provide an indicative picture of the trade patterns likely to continue. Having discussed over-all trade flows in the preceding section, focus here is placed on intraregional and interregional trade.

As shown in Table 2, exports from developing countries to other developing countries were valued at some $326 million in 1973 or 16 per cent of their total exports to the world. The bulk of this trade originated in Latin America (32 per cent), Asia (52 per cent) and the Middle East (9 per cent).

Exports from North Africa were distributed as follows: intraregionally $2.2 million or 84 per cent of total exports, with exports to the Middle East amounting to $0.3 million (10 per cent). Exports to other countries in the African region ("Other Africa" in Table 2) accounted for only $138,000.

Total exports of iron and steel products from "Other Africa" were somewhat less than those for North Africa. Intraregional exports amounted to $3.4 million or 89 per cent of total exports while interregional exports valued at $341,000 or 9 per cent went to North Africa with the remainder distributed among the other regions.

Latin America is one of the three most active trading regions in iron and steel products, Asia and the Middle East being the other two. Total exports from Latin America to other developing countries amounted to $105.0 million or about 15 per cent of its over-all exports to the world. Exports from Latin America were primarily interregional ($97.5 million or 93 per cent), the remaining exports going to other regional groupings listed in Table 2: "Other Developing" (Yugoslavia), Asia, Middle East and "Other Africa". This constitutes a sound basis for the possible expansion of trade with these areas in the future.

The total exports of iron and steel products from the Middle East to developing countries amounted to $30.4 million or a 9 per cent share in total exports of all developing countries. As in other regions already considered, interregional trade dominated, with exports to other regions amounting to $16.6 million (55 per cent), of which 25 per cent went to Asia and 17 per cent to North Africa.

The share of Asia in total developing country exports was roughly half of the total trade of the developing countries among themselves: its exports amounted to $169 million (52 per cent). Intraregional trade was also marked in Asia and exports amounted to $119.5 million (71 per cent). The interregional exports from Asia were to Middle East (17.2 million or 10 per cent); Latin America ($22.4 million or 13 per cent); Other Africa ($7.4 million or 4 per cent); North Africa ($2.4 million).

Iron and steel products valued at $15.2 million were exported to all other developing countries from the regional grouping "Other Developing" (Yugoslavia). Its relative share in total developing country trade in iron and steel products amounted to 5 per cent. Since this classification is not based on geographic considerations, it is not surprising that no intraregional trade is carried out. The bulk of this region's trade in the year under consideration was, therefore, interregional: North Africa $7.2 million or 47 per cent; the Middle East, $4.3 million or 28 per cent; and Asia, $3.5 million or 23 per cent.

Trade data alone cannot accurately reflect levels of development in iron and steel fabrication, particularly those of vertical integrated production capabilities. They do, however, provide an indication of the relative dependence and ability of the developing countries in world markets for iron and steel. The data presented here provide, for the first time, a global insight into iron and steel trade both within and between regions. These trade flows among and within developing countries have shown that, relatively speaking, a large amount of intraregional trade goes on in iron and steel products, and a surprising amount of interregional trade. This pattern is most notable in the geographically distant countries in Africa,

Table 2. Developing country trade in iron and steel products in 1973, by stage of processing

(Thousands of dollars)

Regions and countries, by stage of processing	Total		North Africa		Other Africa b/		Developing America		Middle East		Asia		Other Developing	
	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
A. Total iron and steel														
World	6,597,491	1,[illegible],513	469,[illegible]	36,16[illegible]	575,[illegible]	226,1[illegible]	1,653,315	694,361	1,292,[illegible]	[illegible],311	2,141,147	7[illegible],504	462,492	261,865
DMEC	5,319,817	1,226,763	3[illegible]	[illegible]3,[illegible]	487,327	210,150	1,455,256	474,372	919,622	18,874	1,[illegible]32,699	403,191	255,012	106,326
EEC	[illegible],061,611	521,496	306,[illegible]	10,543	322,033	165,353	456,192	195,791	497,215	13,813	306,027	74,158	172,121	61,837
EFTA	200,530	35,685	5,020	40	10,405	171	59,912	11,273	39,580	563	35,466	4,331	50,147	19,307
Other DMEC	3,057,675	669,581	53,845	2,636	154,889	44,656	942,164	267,908	382,828	4,498	1,491,206	324,70[illegible]	32,743	25,181
Socialist countries	693,507	196,723	62,432	9,756	54,182	1,044	17,324	15,705	235,239	6,322	143,652	44,243	180,677	119,652
Developing countries	348,145	326,101	18,900	2,613	15,868	3,825	132,380	105,037	60,038	30,361	114,101	169,026	6,859	15,239
North Africa	3,373	17,116	3,104	2,202	102	341	2	25	157	5,068	7	2,366	-	7,164
Other Africa	3,160	12,937	44	138	3,052	3,421	1	888	42	908	21	7,394	-	236
America	137,020	120,022	29	0	1,106	2	125,383	97,510	2,933	98	2,560	22,363	5,009	48
Middle East	30,356	40,468	5,792	272	597	17	33	2,116	23,688	16,585	160	17,211	87	[illegible],268
Asia	143,64[illegible]	132,84[illegible]	3,630	1	7,646	33	6,873	2,189	17,918	7,620	105,81[illegible]	119,476	1,763	3,523
Oceania	-	-	-	-	0	-	-	-	0	-	-	-	-	-
Other developing	30,595	2,617	6,301	-	3,365	11	87	2,309	15,300	91	5,541	216	-	-
B. Ore and concentrates														
World	36,590	761,590	59	8,024	236	210,490	22,701	362,811	-	24	6,689	180,222	6,905	20
DMEC	3,746	679,289	8	5,599	225	204,892	197	318,179	-	-	3,317	150,600	-	20
EEC	180	240,157	8	5,599	14	160,349	113	172,927	-	-	45	1,272	-	11
EFTA	211	9,602	-	-	211	-	-	9,593	-	-	-	-	-	9
Other DMEC	3,355	329,530	-	-	-	44,543	83	135,659	-	-	3,272	149,328	-	-
Socialist countries	719	40,276	-	1,130	-	917	-	12,177	-	-	5	26,052	714	-
Developing countries	29,194	19,628	22	14	-	-	20,189	16,889	-	-	3,346	2,725	5,637	-
North Africa	-	14	-	14	-	-	-	-	-	-	-	-	-	-
Other Africa	-	29	-	-	-	-	-	-	-	-	-	29	-	-
America	25,406	14,580	-	-	-	-	20,189	14,580	-	-	232	-	4,985	-
Middle East	-	469	-	-	-	-	-	-	-	-	-	469	-	-
Asia	3,776	2,107	-	-	-	-	-	-	-	-	3,114	2,107	652	-
Oceania	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other developing	22	2,431	22	-	-	-	-	2,309	-	-	-	121	-	-

Table 2 (continued)

Regions and countries, by stage of processing	Total Imports	Total Exports	North Africa Imports	North Africa Exports	Other Africa Imports	Other Africa Exports	Developing America Imports	Developing America Exports	Middle East Imports	Middle East Exports	Asia Imports	Asia Exports	Other Developing Imports	Other Developing Exports
C. Semi-manufactures[a]														
World	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	365,886	[illegible]	218,413
DMEC	[illegible]	[illegible]	[illegible]	7,545	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,604	[illegible]	[illegible]	[illegible]	[illegible]
EEC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	565	[illegible]	[illegible]	[illegible]	[illegible]
EFTA	[illegible]	[illegible]	[illegible]	[illegible]	7,092	[illegible]	[illegible]	[illegible]	32,635	25	[illegible]	[illegible]	25,754	17,871
Other DMEC	[illegible]	254,915	[illegible]	[illegible]	143,382	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31,577	[illegible]
Socialist countries	[illegible]	[illegible]	[illegible]	[illegible]	34,553	[illegible]	[illegible]	2,462	204,642	4,549	[illegible]	15,345	171,774	[illegible]
Developing countries	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	137,477	[illegible]	11,055
North Africa	[illegible]	[illegible]	[illegible]	[illegible]	6	[illegible]	1	–	73	4,044	1	1,569	–	[illegible]
Other Africa	[illegible]	[illegible]	37	3	[illegible]	1,754	1	[illegible]	25	[illegible]	21	[illegible]	–	170
America	[illegible]	[illegible]	[illegible]	–	[illegible]	1	[illegible]	[illegible]	[illegible]	10	2,160	20,789	–	1
Middle East	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	[illegible]	[illegible]	7,754	[illegible]	13,902	[illegible]	[illegible]
Asia	[illegible]	[illegible]	[illegible]	–	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oceania	–	–	–	–	[illegible]	–	–	–	[illegible]	–	–	–	–	–
Other developing	[illegible]	[illegible]	[illegible]	–	[illegible]	11	[illegible]	–	[illegible]	54	[illegible]	[illegible]	–	–
D. Finished manufactures[b]														
World	[illegible]	[illegible]	[illegible]	37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DMEC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EEC	[illegible]	[illegible]	[illegible]	70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EFTA	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other DMEC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5,493	[illegible]	[illegible]	[illegible]	[illegible]
Socialist countries	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Developing countries	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	353	[illegible]
North Africa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25	[illegible]	[illegible]	[illegible]	[illegible]	–	[illegible]
Other Africa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	–	[illegible]	–	[illegible]
America	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	135	[illegible]	[illegible]	[illegible]	24	47
Middle East	[illegible]	[illegible]	[illegible]	51	139	[illegible]	[illegible]	114	[illegible]	[illegible]	[illegible]	[illegible]	36	[illegible]
Asia	[illegible]	[illegible]	[illegible]	[illegible]	4,729		[illegible]	234	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	311
Oceania	[illegible]	[illegible]	–	–	–	–	–	–	–	–	0	–	–	–
Other developing	[illegible]	41	[illegible]	–	923	–	[illegible]	–	[illegible]	27	404	14	–	–

Source: Data provided by [illegible] developing countries. Because of the limited nature of the sample, import and export data may not entirely correspond in all cases.

a Pig iron, ferro-alloys other than ferro-manganese, ingots and other primary forms, iron and steel bars and shapes, universals, plates and sheets, hoop and strip, rails, wire, tubes and pipes, castings, finished structures, storage tanks, drums, gas cylinders, wire cables, not insulated, netting, nails, nuts and bolts.

b Tools, cutlery, [illegible], domestic utensils, locksmiths' wares, [illegible], articles of iron and steel, n.e.s., central heating apparatus, sinks and wash basins of iron and steel.

Asia and Latin America. Whatever the commercial and other bases for these trade links may be, they should be further exploited and expanded to promote the industrialization goals implicit in the Lima target.

Developing country trade in iron and steel products

In contrast to the price behaviour of most commodities where the largest fluctuations occur at the raw material stage and become smaller at more advanced stages of processing, iron ore prices tend to follow the reverse pattern, i.e. they are quite stable in comparison with the higher order of processed steel products. For example, the prices of intermediate steel products (merchant bars, heavy sections, heavy plates and cold-reduced sheet) vary much more through time than do, for example, the export prices of iron ore from Brazil and India. This oscillation is most obvious in the case of heavy plates, the prices of which fluctuated during the period 1966-1975 from $88 to $402 per ton (457 per cent). By contrast, prices of iron ore in Brazil and India varied only slightly from $6.85 to $7.75 per ton in the case of India (13 per cent) and from $9.30 to $14.90 per ton in the case of Brazil (60 per cent).

The explanation for these disparities is to be found in the way in which prices are established in these two markets. Traditionally, iron ore is sold after negotiations between buyer and seller who agree to quantities and prices for the coming year. This method is still used, though mainly by established mining companies whose ore has long been on the market. However, contracts for longer periods are customary in the mining ventures which came into operation during the 1950s. In order to raise the capital investment required to start mining, owners have to guarantee markets for a long time ahead, at least up to the break-even point. Such long-term contracts, entered into as a guarantee for investment, may run to a considerable length of time: some have been concluded for a period of 40 years.

The steel market in developed countries is highly cyclical, more so than the economies themselves. This cyclical activity is due to the effect not only of frequent excess capacity arising out of fluctuating stocks of steel products maintained by both steel producers and steel consuming industries, but also of the pronounced accelerator/multiplier interaction on this sector. This leads to volatile steel prices compared with the more stable iron ore prices.

Developing country exports of iron ore have almost doubled from some 80 million tons in 1968 to 148 million tons in 1973. Given the relative price stability and the rising volume of exports, export earnings have become important to ore-producing countries, and thereby make the trade-off for diverting this ore to domestic use an important consideration for planning domestic steel production capacity. For ore-abundant countries, like Brazil, the cost is not serious, but for others it could be, if they had to rely on steel exports to the developed countries in order to warrant domestic production at efficient levels. The decision to move downstream into steel production must, therefore, take into consideration the trade-offs between stable export earnings and prices at the iron ore and pellet level, on the one hand, and the relatively unstable earnings and prices that will be encountered, on the other hand, if exports of steel are dependent on developed country markets. The development among developing countries of stable long-term trade links for iron and steel products may help to avoid risks resulting from fluctuations of the steel market in developed countries.

Despite the successful development of the direct-reduction/electric furnace method to produce sponge iron, and then steel, using natural gas and/or gasified fuel oil, great quantities of coking coal are still required in the blast furnace to produce iron on a large scale. Therefore, with the exception of those developing countries that have plentiful resources of natural gas, most steel production in the developing countries will be dependent on imports of coking coal. In contrast to most trading configurations between developed and developing countries, it is developed countries, by and large, which have abundant coal resources and are, therefore, the major exporters of coal and coke. The volume of developing countries' imports of these products shows a gradual upward trend over the period 1964-1973 with imports amounting to more than five million tons (of both types) in the latter year. Perhaps more important, however, has been the growing value of these imports which reflects the rising price of coal and the concomitant rise in foreign exchange expenditure on the part of the developing countries over the period. The f.o.b. unit value of coking coal per ton has virtually doubled from $22.24 per ton in 1964 to $42.01 per ton in

1973. When transportation costs are added to these prices, the high foreign exchange costs of iron and steel resulting from this one input become apparent and must be considered in the planning equation.

Developing country imports of ingots and other primary forms of iron and steel from developed countries have risen from a low of 986,000 tons in 1964 to over 5 million tons in 1973, which reflects the growing steel consumption and import intensities of the developing countries over this ten-year period. These trade flows also provide some indication of the scope for using import-substitution policies in this sector by the developing countries.

While the developing countries have demonstrated an incr sing ability to export iron and steel products (SITC 67), rising from a low base of only $103 million in 1964 to $668 million in 1973 (more than six-fold), their imports of similar products have increased from $1.6 billion in 1964 to $5.1 billion in 1973 (more than three-fold). Although generalized, these statistics provide some insight into the prospects which exist for trade in iron and steel products among the developing countries. Increased steel-making capacity on the part of the developing countries should reduce imports of many specific iron and steel items from the developed countries via import substitution.

Despite the prospects of growing import substitution in iron and steel products by the developing countries, their dependence on imports of capital equipment for manufacturing, construction and infrastructure in general will continue to increase as the industrialization process continues. The developing countries' indirect imports of steel in the form of machinery and transportation equipment have risen from $9 billion in 1967 to $30.1 billion in 1973 (334 per cent). This trend can be expected to continue in the future in most developing countries, since import substitution of these items can only occur at a much higher level of industrialization. However, the more advanced of the developing countries may be able to tap this high growth market by exporting higher order steel products to lesser advanced developing countries.

<u>Foreign exchange savings resulting from import substitution</u>

The installation of iron and steel-making capacities by developing countrie will yield some foreign exchange savings as locally produced iron and steel products are substituted for imports of similar goods.

However, the savings are not automatic, particularly during the initial start-up and "learning" period, nor are they "one for one" in that the value of an item formally imported is a measure of the foreign exchange saved. The amount of capital costs to be borne in foreign currency terms is an important variable that must be taken into consideration in any exchange saving equation. These costs are a function of the degree of industrialization in the developing country in question. Thus, initially the foreign exchange component of the total expenditures will be very high as most machinery and other items have to be imported. Once industrialization is well under way, however, the proportion of equipment that can be produced locally will rise.

In computing foreign exchange benefits, it is not unrealistic to assume that most developing countries which have developed, or are planning to develop a steel industry possess iron ore and pay the greater part of their wage bills in domestic currency: consequently, these costs are not considered here. As far as other materials are concerned, however, almost any combination is possible, ranging from almost total self-sufficiency in, to heavy dependence on imports of, such inputs as coke, coal, oil, limestone, gas, and hydro-electric power.

Table 3 sets out the foreign exchange benefits accruing from steel production in a blast furnace/basic oxygen system plant as computed for four "typical" cases, although a wider range of possibilities does exist. As can be seen, savings range from $161 to $196 per ton depending on the various assumptions used. The foreign exchange benefits are likely to be much the same with the direct reduction/electrice furnace technology.

Implications of the Lima target for developing country imports of iron and steel products from developed countries

As mentioned previously, the Lima industrial production target underscores the paramount importance of the iron and steel sector which contributes most significantly to the development process. In view of the relationship between steel consumption and level of GDP per capita, it follows that iron and steel consumption and production in the developing countries will have to expand enormously over the next 25 years. This dynamic growth will have to be accompanied by increased international trade in iron and steel products. Not only will this trade volume grow as the Lima target is approached, but the structure and composition of trading patterns will also shift. These

Table 3. Savings in foreign exchange from steel production[a]

(US dollars)

Case	Percentage of cost borne in foreign exchange: Capital	Percentage of cost borne in foreign exchange: Operating	Foreign exchange cost in producing steel (per ton)	Gross foreign exchange saving (per ton)	Net foreign exchange saving (per ton)
A	70	30	100	261	161
B	50	30	81	261	180
C	70	15	84	261	177
D	50	15	65	261	196

Source: UNCTAD estimates

a/ Maximum capacity working and operating efficiency assumed throughout. These figures are derived from the following estimates of the costs and benefits of operating a 5 million tons per year integrated blast furnace/basic oxygen system plant: capital costs $639; production costs $206 (operating costs $110 plus capital costs $96); for a final cost per ton of $261. The figures include an allowance for scrap losses and credits. A capital charge of 15 per cent has been used, reflecting both interest and depreciation. For the purposes of these calculations, it is assumed that the cost of imported equipment is reflected in the proportion of the financing of any loan that has to be paid in foreign currency.

shifts will not take place solely at the expense of the developed countries currently dominating iron and steel trade, however; as the developing countries begin to trade more in semi-manufactured iron and steel products among themselves, exports from the developed countries will shift more towards plant, equipment and technological know-how for the new steel industries, as well as the host of complementary capital equipment required for expanding infrastructure, construction and other emergent manufacturing sectors in the developing countries.

It would be expected that, as the levels of economic development in the developing countries improve, imports of iron and steel products would initially grow at a rapid rate and then at a somewhat slower rate as their economies approach industrial maturity. A curve fitted to observations of steel imports of 88 developing countries from 20 developed countries in relation to a share of the developing countries' respective GDPs follows the anticipated pattern, thus underscoring both the anticipated growth in international trade in iron and steel products as per capita GDP rises, and the growth that must occur in imports by developing countries of complementary goods and services from the developed countries. The plotted observations are estimates derived from the following regression equation:

1973 steel imports (SITC 67) = f (population, per capita GDP)

$$\ln Ms = \ln B_0 + \ln B_1\ Pop + \ln B_3\ PCGDP$$

$$R^2 = .61 \quad 1.34 + 0.88 \qquad + 0.81$$

(T test values) (1.7 (9.8 (1.7)

This also demonstrates that growth of iron and steel imports expressed as a percentage of GDP will affect most developing countries which, at present, are passing through the earlier phases of the industrialization cycle. The iron and steel import elasticity for developing countries is estimated to be 0.81 which implies that, for every one per cent increase in GDP per capita, imports of iron and steel products should increase by eight tenths of one per cent. Relating this to the results of another study,3/ and given that the Lima target in respect of world production of semi-manufactured and manufactured goods will materialize, that population will continue to grow at an annual rate of 2.5 per cent, and that the annual GDP growth rate of 7.5 required to meet the Lima target by 2000 will be attained, imports of iron and steel products are likely to grow at an approximate annual rate of 6.25 per cent. In constant 1973 value terms, and taking that year's figures for developing country imports of iron and steel products of $5.1 billion (SITC 67) as a base, together with the annual growth rate given above, imports of iron and steel products from developed countries could attain a value of approximately $26.2 billion, or a 514 per cent increase in value by the year 2000.

3/ UNCTAD document TD/185/Suppl. 1, p. 3, p. 6. These growth rates imply that the per capita growth rate is 5.0 per cent.

Tariff and non-tariff barriers to the export of iron and steel products by developing countries

Developing countries contemplating the expansion and/or development of their iron and steel exports to developed country markets need to take into account the trade obstacles generated by tariffs and non-tariff barriers (NTBs). As might be expected, the tariffs increase with the stage of processing, e.g. from raw material inputs through semi-manufactures to finished manufactures. This pyramid effect is shown in Table 4, which provides data on the tariffs levied on iron and steel products in the European Economic Community (EEC), Japan and the United States; taken together these account for over 90 per cent of developed country imports of semi-manufactured and manufactured products from the developing countries. The tariffs of the United States display the most escalation through the three stages of processing. On average, the tariffs for the countries covered in Table 4 vary from duty-free at the raw materials level, to 6.7 per cent for intermediate semi-manufactures and to 10.2 per cent for finished manufactures. Developing countries planning to gain access for their exports of processed steel products to developed country markets should take into account the effect that this escalated tariff profile may have on their competitive position, particularly on their exports of finished products.

Table 4. Average nominal tariffs on selected iron and steel products by stage of processing: EEC (1972); Japan (1972); United States (1974) (per cent)

Stage of processing	EEC	Japan	United States	Total
Raw materials	0.0	0.0	0.0	0.0
Semi-manufactures	6.6	7.4	6.2	6.7
Finished manufactures	8.7	9.9	12.2	10.2

Source: UNCTAD calculations.

When examining the tarrif structure, it is also imperative to note the existence of preferential tariff regimes which affect current and potential exports of iron and steel products from developing countries. Two major preference systems should be considered: the Generalized System of Preferences (GSP), and the Special Preferences offered by the EEC to 46 developing countries in Africa, the Caribbean and Asia under the Lomé Convention.

The GSP schemes of most countries giving preferences provide for duty-free treatment of those iron and steel products included in the product coverage of the scheme. The product coverage of the schemes in the EEC, Japan and the United States provide for most of the developing countries' exports of these products. While most of the GSP schemes in operation are "open-ended", i.e. not subject to a priori quantitative restrictions, the schemes in the EEC, Japan and the United States contain quotas under which the combined imports of the developing countries are accorded duty-free treatment up to a predetermined quota level; all imports in excess of this level are subject to the full Most Favoured Nation (MFN) duties. In the EEC and Japan, the schemes also contain "maximum country amounts" under which imports from individual beneficiaries no longer enjoy preferential treatment once a predetermined share of the over-all quota has been attained. These restrictions are, however, applied on a year-to-year basis so that all countries have equal access to the quotas at the start of the new year. The quantitative restrictions embodied in the United States scheme are known as "competitive need criteria". If a single beneficiary's imports (or group of beneficiaries aligned in a customs union, free trade area etc.) of a single item exceed $25 million or 50 per cent of total United States imports of that item, the beneficiary is permanently denied preferential treatment on the item in question (unless re-granted after presidential approval).

These restrictions which cause uncertainty, in addition to a number of product exclusions, stringent "rules of origin" qualifying goods for preferential treatment, as well as discriminatory beneficiary lists, make it necessary for each developing country to apprise itself of its eligibility under each separate GSP scheme and in respect of each iron and steel item it wishes to export. The indeterminate duration of the GSP and possible changes in the administrative rules affecting its operation should also be considered.

In addition to the GSP, the other most important special preferential scheme is that of the EEC in respect of 46 developing countries in the

African, Caribbean, and Pacific region (ACP). These countries primarily represent the association of African and Malagasy States, members of the Yaoundé Convention and a number of Commonwealth members. Under the "EEC-ACP Convention of Lomé", the 46 member states are accorded duty-free preferential treatment on all industrial and primary products in chapters 25-99 of the Brussels Tariff Nomenclature. It is important to note that this accord affects 21 out of the 29 developing countries identified as the least developed. As distinct from the GSP, the Lomé Convention also treats all ACP member-states as one area in terms of qualifying their exports for rules-of-origin purposes. Thus, by virtue of this "cumulative treatment" clause, the avenue for co-operative industrialization efforts is opened and allows member-states to specialize and combine inputs for duty-free export to the EEC.

The "Tokyo Round" of Multilateral Tariff Negotiations (MTN) is currently being held under the auspices of the General Agreement on Tariffs and Trade (GATT). As in the past, the negotiations centre on the reduction of MFN customs tariffs. For the first time, the removal and/or reduction of non-tariff barriers (NTBs) are being negotiated.

Existing tariff barriers and the GSP should be considered jointly because any reductions in the tariffs on products now covered by the GSP will erode the existing preferential margins currently enjoyed by the developing countries, while deep tariff cuts by the MTN in respect of those products not now included in the GSP, nor ever likely to be, are in the interests of the developing countries. Whatever strategy the developing countries adopt with regard to the MTN, the following considerations should apply:

(a) Increased security of the GSP should be ensured, i.e. it should become a binding commitment, and its duration should be extended beyond the initial ten-year period;

(b) Preferences should be applied in a non-discriminatory manner to all developing countries;

(c) The tariff margins from preferences should be preserved to the extent possible within the context of the GATT;

(d) Where this has not already been done, GSP rates should be reduced to zero;

(e) Existing limitations on preferential imports (tariff quotas, ceilings, maximum country amounts, competitive need criteria) should be removed;

(f) Products not included nor likely to be included in the GSP should be subject to deeper than average tariff cuts, which should be implemented in advance in favour of developing countries;

(g) Maximum attention should be devoted to the elimination of escalated tariffs or the pyramiding of tariffs as the scale of processing escalates.

The tariff regimes, and the rationale underlying their present structure, currently in force in the developing countries should be scrutinized and re-evaluated in the light of the present industrialization and trade expansion goals. It may be necessary to make significant changes in these regimes to accommodate these plans, particularly as regards the iron and steel sector and the growth of the manufacturing sector. Tariff reform which enhances the profitability of the domestic production of iron and steel and capital goods could overcome the existing constraints on growth in the manufactures sector.

Co-ordination of tariff reform efforts between developing countries should also be attempted. In this regard, maximum attention should be devoted to designing a tariff regime to take into account the complementarity which exists among developing countries, and particularly among those at different stages of industrialization. On a broader front, consideration should be given to formulating preferential tariff schemes among the developing countries at the sub-regional and interregional levels.

In addition to tariffs there exists an additional set of obstables to trade in iron and steel; these are the generally ad hoc restrictions referred to as non-tariff barriers (NTBs). They are broadly defined as any measures other than tariffs which restrict imports; they include import licences, exchange controls, quotas, import surcharges, valuation procedures, documentation requirements, and customs fees and deposits. Table 5 provides a list of NTBs affecting exports of iron and steel products to several developing country markets. They are divided into four groups: (i) foreign trade policies; (ii) administrative practices; (iii) internal policy and regulations; and (iv) private practices. The table indicates that steel imports by the ten major steel-trading countries are subject to 31 of 39 NTBs in at least one of those developed countries, and that eight of these practices are in effect in all of the developed countries.

Table 5. Non-tariff barriers facing steel imports

	Belgium	Canada	France	Germany	Italy	Japan	Luxembourg	Netherlands	United Kingdom	United States
Foreign trade policies										
Import licences						x				
Exchange controls			x			x				
Quotas			x							
Export limitations										x
Biased procurement	x	x	x	x	x	x	x	x	x	x
Transport rebates	x		x	x	x		x	x		
Wage tax rebates			x							
Marketing assistance	x	x	x	x	x	x	x	x	x	x
Tied foreign aid			x							x
Indirect tax rebates	x			x	x		x	x	x	
Import surcharges							x			
Anti-dumping laws		x		x						x
Administrative practices										
Advertising rules										
Marketing regulations										x
Document requirements	x	x	x	x	x	x	x	x	x	x
Classification rules	x	x	x	x	x	x	x	x	x	x
Valuation procedures	x	x	x	x	x	x	x	x	x	x
Customes fees and deposits			x		x	x			x	
Other customs rules	x	x	x	x	x	x	x	x	x	x
Penalties	x	x	x	x	x	x	x	x	x	x
Internal policy and regulation										
Direct payments	x								x	
Depreciation	x	x	x	x	x	x	x	x	x	x
Investment incentives	x		x		x	x	x	x	x	x
Low-cost loans			x	x		x				
Overpriced purchases			x							
Internal tax rebates									x	
Direct taxes										
Indirect taxes	x	x			x			x		
Price controls	x		x	x	x	x	x	x	x	x
Credit controls										
Advertising rules										
Patents and trademarks										
Health and safety rules										
Technical specifications			x							
National security rules										
Private practices										
Cartels	x	x		x	x	x	x	x	x	x
Exclusive supply agreements	x		x	x	x	x	x	x	x	x
Freight-rate discrimination						x				

Source: C. MacPhee, Restrictions on International Trade in Steel (Lexington, Mass., Heath and Co., 1974)

Unlike tariffs, it is very difficult to quantify NTBs in order to estimate the degree of trade restrictiveness they cause. Important steel restrictions, such as licensing, exchange controls, prejudice in government procurement practices, anti-dumping laws, administrative practices, non-economic internal policies and some restrictive business practices, cannot be transformed into tariff equivalents. Some NTBs in certain developed countries can, however, be quantified by estimating their ad valorem tariff equivalents: quotas; "voluntary" export restraints; domestic biased purchasing; import surcharges; various forms of export subsidies, such as direct payments, credit financing, penalties, and tax rebates; prior deposit requirements; document costs; customs fees; various forms of domestic subsidies, such as direct payments, internal tax rebates and input subsidies; indirect taxes and freight-rate discrimination.

Using appropriate elasticities in conjunction with these quantifiable NTBs, it has been estimated[4/] that for 1968 (1969 for the United States) steel imports excluded by NTBs imposed by these developed countries amounted to about $1.7 billion, with the United States alone accounting for more than $1 billion. The small number of NTBs amenable to such quantification in relation to the total number of barriers erected indicates that this may represent only a minimum figure.

Some developed countries have recently imposed legislation requiring the steel industry to install various pollution controls. These environmental measures have the reverse effect of an NTB in that they could lead to increases in the domestic price of iron and steel products after the costs of the pollution control equipment have been absorbed by the firms. This could lead to an increase in the importation of iron and steel products from developing countries which do not impose such controls. Any increase in imports will, however, depend on the extent of the increased cost of producing these products and their initial competitive position vis-à-vis import prices. It has been estimated that the average annual total direct and indirect costs of environmental control as a percentage of the value of shipments amounts to 1.364 per cent for the iron and steel industry in the United States. Based on various assumptions, this could lead to an

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4/ See Table 5, source.

average annual increase in exports of these products by the developing countries to the United States ranging from 2.7 per cent to 5.5 per cent over the period 1973-1977.5/

Because of the ad hoc manner in which NTBs are imposed, the political motivations prompting their introduction, and the difficulties associated with their measurement, it will be very difficult to negotiate effectively the elimination or reduction of the NTBs in the Multilateral Tariff Negotiations. Nevertheless, the developing countries should mount and maintain continuous pressure in international fora for the removal or reduction of NTBs on specific products of interest to them. It therefore behoves the developing countries to take into account both these NTBs and tariffs when considering the export of iron and steel products to developed countries.

Transport costs as a barrier to developing country exports of iron and steel

Transportation costs insofar as they affect iron and steel products are a third major factor to be considered by developing countries when planning the future patterns of trade in this sector, since ocean transportation costs, in particular, can reduce whatever competitive advantage their exports would otherwise have in developed country markets.

Conventional analysis of international trade flows typically ignore or play down the importance of transportation costs. This is justifiable only if transportation costs are small as compared with other barriers to trade. However, it has been estimated that in 1965 OECD imports of metal manufactures (the highest order of processing and therefore the most indicative measure for the purposes of structural considerations) from all sources displayed nominal protection by tariffs and transportation costs of 8 an 12 per cent respectively.6/ This may hamper the efforts of developing countries located relatively far from main markets in their efforts to

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5/ UNCTAD document TD/B/C.2/150/Add.1./Rev.1, Tables 13 and 14.

6/ J. M. Finger and A. J. Yeats, "Effective Protection by Transportation Costs and Tariffs: A Comparison of Magnitudes", The Quarterly Journal of Economics, Vol. XC, February 1976.

pursue higher orders of processing in iron and steel for export purposes. Thus, it may behove the developing countries to pursue efforts aimed at the development of national (possibly regional or sub-regional) shippers' organizations or such bodies in order to facilitate their access to developed country markets and strengthen their effective consultation and negotiation powers with shipping conferences or carriers, as well as prepare the way for the anticipated trade in iron and steel products among developing countries.

Ocean freight-rates for iron and steel products are primarily determined by steamship conference agreements since these products are usually shipped by regular cargo services. Steel rates are generally levied by the conferences on a per ton basis. From the point of view of exporters, a major feature of this conference system is the lack of price-competition among carriers, which may allow ocean freight-rates to rise higher than they would in a more competitive situation. Such practices as deferred rebates or other loyalty arrangements reduce the flexibility of exporters to exercise choice when independent carriers are available.

The degree of discrimination in ocean freight-rates may also be related to the market strength of the users of the shipping services. With few exceptions, if any, the developing countries are small users of shipping services for higher-order processed steel products: they are therefore "captive" clients from the point of view of the conferences, and subject to any rates these impose.

Organization of the international iron and steel market: a barrier to developing country exports

The structure of steel markets at the national level can be characterized either as monopolistic (public or private) or oligopolistic. The extent of monopoly power associated with these structures depends on several factors, such as: whether the industry (a) is nationalized; (b) is a government-sanctioned privately owned monopoly; (c) has government financial participation and/or control; (d) is vertically integrated; (e) has domestic production capacity exceeding domestic demand levels; (f) faces competition from imports; and (g) indulges in cartel-type practices, at domestic and/or wider international levels.

Most of the steel-producing sectors established or planned in developing countries are state-owned or controlled enterprises with natural or state-endowed monopoly characteristics. Although the scale of operations is sometimes large relative to the current domestic demand for iron and steel products, domestic demand can, in many cases, be satisfied only in certain products. Both these situations require participation in international trade: in the first case, there is a need to seek export markets as a vent for excess capacity; and, in the second case, there is a need to import iron and steel products to meet demand, especially that for specialized products.

In those developed countries where a monopoly does exist, national domestic cartels are usually present on either a de facto or a de jure basis. National cartels are overt or covert agreements by its members to restrain domestic competition through market sharing, the maintenance of a uniform pricing policy, the determination of guidelines for members' investment and specialization policies, the setting of production quotas, and the like.

"Voluntary" export restraints have reinforced the export cartel arrangements of steel-exporting countries. "Pure" export cartels affect only competition in foreign markets, while the "mixed" ones affect competition in both foreign and domestic markets. A further distinction is that national export cartels involve exporters from several countries.

Since 1953 the principal steel producing groups in the EEC have operated under what is known as the "Brussels Entente". In essence, this is a central convention of national federations of steel manufacturers which organizes the export of steel to third countries. The main function of the Entente is to operate a minimum-price system whereby all prices are based on Antwerp. However, on occasion the Entente has also operated export quotas.

Japanese law permits the establishment of export cartels. As far as iron and steel products are concerned, four cartels govern export trade: for wire rod, steel products, iron and steel products, and tube and pipe fittings of malleable cast iron. Additional cartels exist for semi-manufactured and manufactured articles of steel (e.g. construction steel, sewing machines, automotive components and accessories, machine tools, bicycles, and tableware). 48 Japanes firms are involved in the four cartels mentioned above, two of which export to the entire world market, the remaining two being oriented towards selected areas. The restrictions imposed by these cartels include the setting of minimum prices and sales quantities.

Purely national export cartels can be authorized in the United States, though none currently exist involving the iron and steel industry. Anti-trust legal proceedings have, however, been initiated with respect to metal-rolling mills and rolling-mill machinery.1/

The uniqueness of the iron and steel sector helps to explain its present market structure, as well as the harmonized market practices it employs. Given these realities, imports, which constitute the principal source of potential competition, are restrained by various measures of the cartel variety, as well as by government-sanctioned trade policies. It has been noted that while MFN tariff rates have, in general, been gradually reduced over the years, the escalated tariff structure still hinders the efforts of developing countries to export higher orders of processed steel products, despite the GSP. The selective lists of products and the quantitative restrictions of the GSP with respect to iron and steel exports have also been noted, as have the non-tariff barriers in the form of "orderly marketing arrangements" and restrictive business practices embodied in the export cartelization of the international steel market. When all these factors are taken together, the prospects for an active and growing exporting role by the developing countries in developed country markets do not appear bright. This is not to suggest that, given the present situation, no room exists for growth in developing country trade, but excessive reliance on exports to these markets, particularly as a vent for the excess capacity of new plants, which arises prior to the maturation of domestic demand, could prove to be hazardous in the light of the realities of the existing market.

In their capacity as traditional net exporters of iron and steel products to the developing countries, the developed countries are likely to maintain their foothold in developing country markets, especially where their trans-national affiliates are participating in the development of the iron and steel industry. In addition, the possibility exists for subsidiaries and affiliates

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1/ In 1952, a consent judgement was entered requiring the cancellation or modification of these agreements.

of transnational corporations to participate in international cartel arrangements, organized by their parent organizations, the objectives of which may be to maintain existing trade patterns in iron and steel, rather than facilitate the evolution of new patterns involving greater participation by developing countries. It will take a substantial effort by the developing countries to overcome the inertia resulting from these traditional established commercial ties.

The steel-producing and -consuming developing countries may gain some insights into how best to expand trade in this sector among themselves by closely scrutinizing the practices of their counterparts in the developed countries. Steel production and trade should be rationalized, but not only from the narrow national point of view. With or without regional participation in formal integration schemes, new participatory initiatives require priority attention. One of the first priorities should be aimed at improving existing, and creating new, intergovernmental machinery and institutions in order to harmonize better the national and common interests of the developing countries with respect to this sector. Close attention should be paid to the establishment of complementary agreements between those developing countries with export capacity and those with import requirements. Such agreements might include industrial co-operation at the enterprise level between developing country steel producers; international sub-contracting, which contributes not only to the generation of employment, but also to the creation of skills, the transfer of technology, and the development of entrepreneurial capacity; joint ventures among developing countries; and changes in import barriers, whether preferential or non-discriminatory, designed to augment the measures mentioned above.

Chapter IV

TECHNOLOGY OF STEEL-MAKING

Choice of processes

The processes by which iron ore and scrap are converted into steel have undergone tremendous technological changes within the past two decades. However, as the time required to bring a new process from conception to wide-scale commercial use often covers many years, only processes that have reached the level of commercial application and those now at an advanced state of development and likely to be in full use before 1990 are considered in this Chapter. The processes considered here are those that are applicable to the production of ordinary steels, but comments are included where appropriate on the direction that technological change may take in relation to the production of steel in the last decade of the present century.

The choice of processes is influenced strongly by:

(a) The cost and availability of iron ore and steel scrap;
(b) The cost and availability of coking and steam coal, oil, natural gas, electricity, charcoal, and other fuels;
(c) The cost and availability of capital for the purchase and construction of facilities;
(d) The availability of trained operative and technical staff (these requirements increasing with the size of the plant and the sophistication of the products made);
(e) Transportation facilities available to move the large tonnages of raw materials involved;
(f) Environmental considerations, principally the disposal of water and waste rock from mining, and slags from smelting and refining operations.

Of the many different steel production processes employed in the past, only a limited number have survived in the face of competitive forces. It is these processes mainly that must be considered when discussing the development of steel industries in various countries. However, sight must not be lost of the possibility that one or two processes which have become obsolete in highly industrialized countries may be suitable for calling back into service elsewhere.

The processes covered are based on the beneficiation and agglomeration of iron ores, the reduction and smelting of ores and agglomerates, the melting and refining of raw steel, the casting and solidification of raw steels and the hot and cold processing of raw steel into commercially usable forms and products. To relate the technological considerations to other parts of this study, the raw material, fuel and electrical needs of each process are discussed briefly. An intimate relationship exists between the scale of demand for steel, the nature and size of the production facilities, the types of fuels and the supply of electricity that influence the choice of an economically feasible production facility.

The processes that would be considered in planning steel production are discussed in the sequence in which they are normally employed. It should be recognized, however, that the production facilities in any given case need not necessarily include all elements of the technological base.

Iron ore processing and agglomeration

In the production of iron and steel from iron ores, it is economically advantageous if the ore contains a high percentage of iron, low percentages of oxide impurities and low percentages of the so-called "tramp elements" (copper, tin, lead, etc.). The physical character of the ore is of great importance, influencing as it does the operating efficiency, energy requirements and production capacity of the reduction and smelting units employed.

Beneficiation

Ores that contain 60-65 per cent iron are considered excellent quality. The presence of oxides such as silica, alumina and titania (the gangue in an ore) at levels of up to 8 per cent is acceptable, but higher levels are undesirable, except in special cases. Phosphorus and sulphur content normally should also be very low. The tramp elements should be less than a few tenths per cent each, generally, but in ores for an integrated steel plant (e.g. one producing a wide variety of steels from iron ore and using coal as the primary fuel), concentrations of these elements must not be greater than approximately 0.20 per cent, if serious contamination of the steel products is to be avoided. The elements arsenic and antimony should normally be less than 0.02 per cent each. By using an oxidizing roast, it is possible to remove sulphur and arsenic from the ore. This operation is expensive, however.

In many cases, large tonnages of commercially usable ores can be extracted from low-grade deposits, provided means can be found to reduce the gangue content and remove moisture and other volatile constituents so as to obtain a product containing at least 55 per cent iron and less than 8 per cent gangue. At the same time, steps can be taken to improve the physical properties of the ore so that it may be smelted more efficiently. In the language of the industry, the raw ore may be "beneficiated" to improve its chemical and physical characteristics. Virtually without exception, it is more economical to remove the gangue constituents in an ore prior to the smelting or reduction stages, rather than later in the processing sequence because of the large increase in the use of energy needed for the removal of these materials in smelting and melting operations. Usually, it is necessary to crush and grind an ore to a fine size before it can be beneficiated.

Agglomeration

Often, the iron ore from a high-grade deposit is initially in the form of coarse material that can be crushed and screened to a diameter of 1-3 centimetres, and this may be used directly by the steel plant. The fine fraction of the ore may be stockpiled for later use. With increased extraction of ore from the deposit, the amount of ore that is too fine to use directly increases. Also, it is probable that lower-grade areas of the deposit will have to be developed and mined at a later stage. These low-grade ores would have to be beneficiated through one or more of the methods outlined above.

Although fine-grained iron ores and concentrates can be utilized in the production of steel, and systems employing the fluidized-bed concept for the reduction of iron ores operate successfully on ores in the approximate size range 0.1-1.0 mm, most processes for iron ore reduction and smelting encounter serious difficulties when fine ores and concentrates are used. Throughput is lower, energy consumption is generally much higher, and losses of iron from the system in the forms of dust and waste are exceedingly high. To counter this, ore and concentrate agglomeration processes are employed. These processes may feature high temperatures, as in sintering, pelletizing and hot pressing, or cold-setting bonding agents, such as hydraulic cements or lime. It is often of advantage in subsequent processing steps if fluxes such as lime have been incorporated into the material at the agglomeration stage.

Sintering has progressed from its early auxiliary status to a fundamental role in ore preparation, i.e. in the improvement of metallurgical qualities. Sintering facilities are usually located adjacent to where the sinter is to be used. These facilities offer a useful means of disposing of dusts and roll scale produced by other operations in the steel plant.

The large-scale industrial application of pelletizing commenced in the 1950s. It developed as a method complementary to sintering, for the treating of concentrates too fine grained to be sintered in the usual way. The benefits derived from pelletizing, when correctly applied are: uniform lump-size, strength, good reducibility, high iron content, and uniform chemical composition.

The pelletizing plant is usually located near the mine and ore concentrator. The primary reasons for this are: (a) the economical size of a concentrator-pelletizing plant is one that produces many millions of tons of product per year, and a facility may supply several steel plants at different locations; and (b) shipment of the very fine concentrates over long distances leads to a serious loss of the material and to contamination of the environment by the material, which is readily air-borne when dry. Modern pelletizing techniques have led to the installation of additional capital equipment near many mines, improving their general efficiency. In ore-exporting countries, high-capacity pelletizing plants may be located in large ports, where ore concentrates and fine ores arrive from various sources Ore-importing countries often prefer to build pelletizing plants at the ports of arrival. Pelletizing plants can also advantageously be built at iron- and steel-works equipped with sintering facilities, thus making full use of both methods of agglomeration.

Iron-making

Over 95 per cent of the iron ores and agglomerates produced in the world are smelted to produce pig iron, which in turn is the major metallic material used in steel-making. Virtually all of the 650 million tons of pig iron consumed in the world in 1975 were produced by the iron blast furnace; only a few million tons were produced by electric furnace smelting operations (chiefly in Norway and Venezuela). As a rule, pig iron from the blast furnace is used in the liquid form (hot metal) directly in steel-making operations. A small fraction is cast into pigs for use by the foundry industry and as charge material for steel-making furnaces.

Iron blast furnace

The iron blast furnace has long been the principal means employed for the reduction of iron ores and agglomerates. The process has undergone major improvements in the last two decades, however, and furnaces have grown enormously in size.

The modern blast furnace is designed to produce crude liquid iron (hot metal) for the manufacture of steel having a composition of approximately 4.2 per cent carbon, 0.5-1.2 per cent manganese, 0.4-1.2 per cent silicon, less than 0.05 per cent sulphur, and a level of phosphorus that is determined by the composition of the ore or agglomerates being smelted. For typical taconite-type pellets, the phosphorus content of the liquid iron may be less than 0.05 per cent, for the usual iron ores it may be as high as 0.4 per cent, and for ores very high in phosphorus (such as are found in northern Europe) it may contain as much as 1.9 per cent phosphorus. The furnace is also employed to produce relatively small quantities of merchant pig irons (for sale outside the producing plant) predominantly for use by the foundry industry. These products usually contain more silicon (1-3 per cent) and possibly more manganese and phosphorus than is the case for pig iron used in steel-making.

Furnace size

Furnaces with interval volumes of 4,000 cubic metres are not unusual today; indeed, some are being built with volumes of up to 5,000 cubic metres. These furnaces can smelt as much as 19,000 tons of ore to produce 12,000 tons of hot metal per day.

The size of blast furnace chosen for a given steel plant will be influenced by the demand for liquid iron for steel-making. Although a single large unit producing 3 million tons of hot metal per year might provide a certain supply of iron at a relatively low apparent unit cost, the use of two smaller units with individual capacities of 1.6-1.8 million tons might in fact provide the hot metal at a lower over-all cost to the steel works. The reason for this is that when the supply comes from just one furnace, the loss of production of hot metal when that furnace closes down for repairs and relining, or because of sudden outages, shuts down all the steel-making operations. On the other hand, the loss in production would be only approximately 40 per cent if one of the two smaller blast furnaces were out of commission. The practical scale for the use of a blast furnace ranges from 0.5 million to approximately 3.5 million tons of hot metal per furnace. The current trend in large integrated steel plants is to install furnaces with capacities of 7,000-12,000 tons of hot metal per day, e.g. 2.5 million to 4 million tons of product per year.

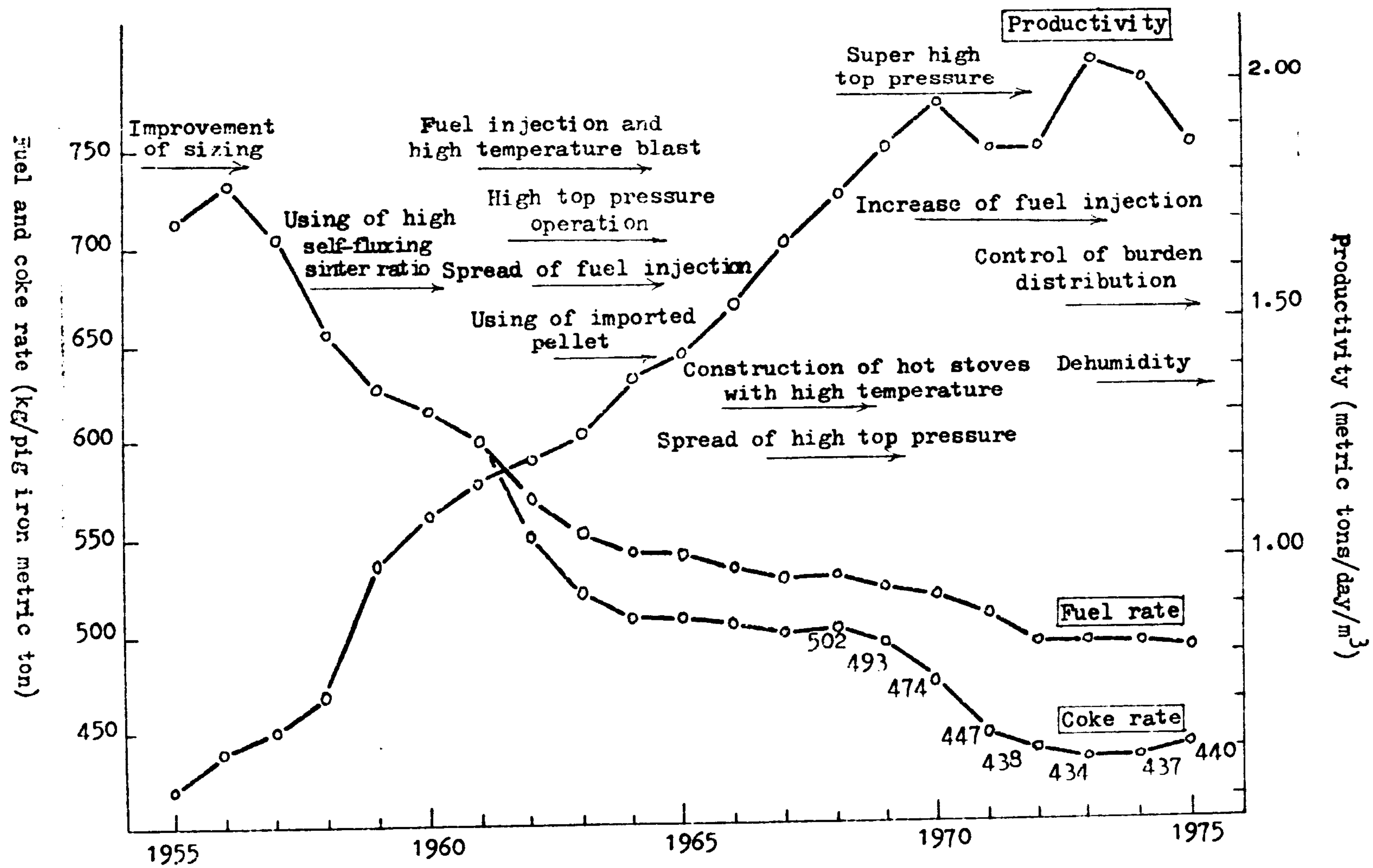
Size is only one of the factors that influence efficiency in blast furnace operations. The main areas of improvement in plant and operational technology, as well as their impact on productivity and fuel and coke rate, introduced in Japan during the last two decades, are illustrated in Figure 1.

Trends in productivity, fuel rate and coke rate

As illustrated in Figure 1, the average coke consumption per ton of pig iron produced has been dropping rapidly in recent years in Japan. It is currently at its lowest point. In 1972, the average values by country ranged from approximately 625 kg/ton of pig iron in the United States to 450 kg/ton in Japan. The average for all countries in that year was approximately 585 kg/ton. As indicated above, the coke rate is influenced to some degree by the amount of fuels that are injected into the tuyeres. The rate of injection of natural gas does not exceed 70 m^3 n/ton (0.65 G cal); fuel oil at 40-60 kg/ton (0.4-0.6 G cal), but it may be as high as 90-120 kg/ton 0.9-1.2 G cal) in some furnaces, and oil injection of 130 kg/ton (3.7 G cal) has been reported. Practices for the injection of a mixture of these fuels and an emulsion of oil and water have been developed successfully. The effect of the injection of these fuels on the coke rate varies a great deal with the fuel, the furnace and the type of operation. One kilogramme of oil replaces 1.0-1.4 kg coke, the higher rate being approximately equivalent on the basis of energy. With gas, the replacement ratio is 1.0:1.2 and it is 1.0:0.9 for coal.

The practice of injecting other fuels into the tuyeres to reduce coke consumption will continue to expand in areas where supplies of gas and oil are available, and the net effect will be to decrease the cost of energy in blast furnaces. On the other hand, in regions where coal for coking purposes is plentiful, the practice may not be economical and, in addition, if coke consumption is decreased the steel works is deprived of the oil, tar and gas that are produced in the coking operation.

Figure 1. Blast furnaces in Japan: trends in productivity, fuel rate and coke rate, 1955-1975.



Source: Gyoichi Suzuki, Journal of the Fuel Society in Japan, Vol. 54, No. 573, January 1975.

The injection of gases into the stack of a blast furnace is a highly sophisticated operation which may lend itself to situations where gas is plentiful and coke is scarce and expensive. Further, the use of gas in this manner may place the blast furnace in closer competition with direct reduction systems. The method may be used extensively after 1985, as coals suitable for coking become scarcer. Its use will require a well-trained and skilled work force and a strong supporting technical staff.

Oxygen gas can also be used in some circumstances to increase the production of a furnace and to reduce the coke rate. Enrichment of the air blast by the addition of 2-5 per cent oxygen gas by volume is often employed. This brings the oxygen content of the blast to 23-25 per cent.

Three major trends are expected to be followed in blast furnace operations in the next three decades. In areas where coke is expensive, the trend will be to reduce the coke rate as far as possible by the injection of fuels into the tuyeres and hot gasses into the stack. By 1985, it is expected that coke consumption in normal operations will be at its lowest level thus far, perhaps 350 kg/ton of pig iron and an auxiliary fuel consumption for tuyere injection of 100 kg (equivalent)/per ton. The total energy consumption would be approximately 3.1 G cal/ton pig iron. Gas injection will be used beyond 1985; however, even though coke consumption may be reduced to 250 kg/ton pig iron, the increased use of auxiliary fuels will probably keep total energy consumption at approximately 3 G cal per ton pig iron.

The second trend will be followed in regions having adequate supplies of coals which are not suitable for coking, but which can be converted to a new ty, coke called "form-coke". It is probable that this will be the principal fuel in the blast furnace, the use of injected fuels being limited. Form-coke will not become available on a large scale for at least five years. Coke rates in the range of 450-500 kg/ton pig iron, and the use of an equivalent of 25-50 kg coke per ton of pig iron as injected fuel, appear to be feasible (3.5 G cal/ton pig iron total).

The third pattern will be followed where supplies of reasonably good coking coals are available to the end of the century. Coke rates of 475-525 kg and the equivalent in injected fuels of 25-50 kg coke per ton of pig iron can be expected (e.g. a total of 3.7 G cal/ton pig iron).

To sum up, the following forecast coke rate for Japan in 1985, in the context of expected blast furnace operational characteristics, might be regarded as indicative of future trends elsewhere:

Mean volume of blast furnace (m^3)	3,050.0
Coke rate (kg pig iron/ metric ton)	400.0
Oil injection (kg pig iron/metric ton)	80.0
Fuel rate (kg pig iron/metric ton)	480.0
Blast temperature (°C)	1,250.0
Blast humidity (9/Nm^3)	10.0
O_2 enrichment (per cent)	2.5
Top pressure (9/cm^2)	1,650.0
Sinter ratio / Pellet ratio (per cent)	82.0
Coke ash (per cent)	12.0

Source: Toshio Ikeshima, "Reduction of coke rate and new coking processes using non-coking coal", paper submitted to the IISI Conference, Tokyo, 1976.

Thus, in 1985, a reduced coke rate will be expected as a result of: increasing oil injection (+ 28 kg); raising the blast temperature (+ 140°C); reducing humidity (- 5 g/Nm^3); and increasing top pressure (+ 650 g/sq. om.). The lowest coke rate in Japan is expected to be 350 kg.

Charcoal

As, in certain regions of the world, abundant supplies of charcoal can be obtained, it should not be overlooked as a blast furnace fuel. It is highly reactive, but it is not strong and cannot withstand the abrasion of the charge in a furnace of the usual height. Nevertheless, it can be used very satisfactorily in a shorter, smaller furnace. It may, therefore, be possible to operate a small furnace with a capacity of 400-500 tons/day iron in regions where charcoal is available. With a well-prepared burden of sinter or pellets, a coke rate of 750 kg/ton iron should be possible. Such a furnace would need stoves capable of heating the blast up to 1,100°C, but the auxiliary parts of the system would be relatively simple to construct and operate. Except in unusual circumstances, the cost would not be very high.

Because charcoal is low in ash and sulphur, the sulphur content of the pig iron should be easily controlled. When this form of fuel is used, however, afforestation programmes should be introduced in the interests of environmental conservation.

Slag

The principal by-products from blast furnace operations are slag and blast furnace gas. Slag is produced at a rate ranging from 50 to 175 kg/ton hot metal. The first figure results from the use of low-grade ores and coke that is high in ash, and the second from the use of very high-grade ores, coke that is low in ash, and extensive use of natural gas or oil injection in the tuyeres. Values in the range of 200-250 kg slag per ton of hot metal are usual in modern operations. Blast furnace slag can be used for land-fill, railroad ballast and raw material for cement manufacture, if the composition is controlled properly.

Blast furnace gas

Blast furnace gas is generally of low quality and its generation in conventional practice is in the range of 1,800-2,400 m^3N/ton metal when producing pig iron for steel-making. The calorific value of the gas rises and the volume declines with the use of oxygen in the blast. The yield of gas declines roughly in proportion to the total of fuels, coke, oil and gas consumed in the furnace, the ratio of gas in coke equivalent being approximately 3.5-3.7 m^3N/kg. It is seldom economical to transport the gas long distances because of its low calorific power; hence it should usually be used directly in or in the near vicinity of the steel plant. If pre-heated and enriched with coke oven gas, it can be used as a general fuel. As approximately one third of the gas yield is used within the blast furnace plants, the net output of gas for other uses is approximately 1.1-1.4 G cal/ton pig iron.

Electric smelting

The electric smelting furnace is used for producing pig iron and hot metal only where electric energy is cheap and abundant (e.g. in Norway and eastern Venezuela). The heat necessary for the smelting is provided by current passing from the electrodes through the charge. Energy and fuel requirements are relatively high, being approximately 1,800-2,400 kWh electricity and 350 kg coke per ton of metal produced. However, the electrical requirements can be considerably reduced by pre-heating and pre-reducing the iron oxides in the charge.

The metallic product of electric smelting is liquid pig iron, which is very similar to the product of the iron blast furnace. The slag is similar in many respects to that of the blast furnace, and the amount is determined directly by the gangue content of the ore feed and the ash in the coke. The extra electrical energy required per 1 per cent increase in gangue in the ore and 1 per cent ash in the coke is approximately 75 kWh and 35 kWh per ton of pig iron, respectively. Accordingly, it is particularly advantageous to use high-quality ores and low-ash coke in electric smelting operations.

Direct reduction

Processes employed to reduce iron ore to solid metallic iron other than the iron blast furnace are called "direct reduction" processes. The end-product is called by various names, such as "sponge iron", "metallized iron ore", "reduced pellets", and "direct reduced iron". The grey, metallic, sponge-like matter produced by early processes was called sponge iron because of its appearance. In this Chapter, all forms of the product of direct reduction processes are called direct reduced iron.

A number of direct reduction processes have reached the stage of industrial use, and several have been in use successfully for a number of years. The processes may be classified according to the general classes of reductant and fuel employed (gas or solid fuel), and by the nature of the reduction system. The shaft furnace, gas-retort system and fluidized bed employ gas as the fuel and reductant. The rotary kiln and the solid fuel-retort system employ solid fuels. However, all of the direct reduction processes that have reached general commercial use, employ gas as the fuel and reductant.

Natural gas is the principal type of gas employed, but it must be reformed (i.e. converted to hydrogen and carbon monoxide) before it is suitable for use. In addition, it should contain very little sulphur. Fortunately, desulphurization and reforming of natural gas can be accomplished by systems that have been in use for years, systems that are incorporated readily as stages in direct reduction operations. Coke oven gas can be used also, and some of the more volatile of the petroleum products (such as naphtha) can be converted to gas and used. The supply and demand for natural gas and these premium liquid fuels in many parts of the world, however, are so high that these commodities may not be available on a large enough scale for direct reduction processes, or they may be too expensive. On the other hand, in regions having large supplies of natural gas and petroleum-based liquid fuels, use of these direct reduction processes may be practical. Even in these regions, however, it must be borne in mind that such fuels may become too costly for this purpose by 1990 or 2000 because of the demands for their use in transportation, the food-producing industries and so forth.

In principle, it is possible to gasify coals and to use the gas produced for direct reduction. However, the cost of such gas, based on its energy content and world prices for ordinary coals, would be approximately twice the cost of oil on the international markets. In addition, the capital cost for gasifying the coal, when added to a gaseous direct reduction process, results approximately in a doubling of the capital cost of the reduction system. Some technical problems exist also that have not been fully resolved. Thus, except in very unusual circumstances, it would not be feasible to install a gaseous direct reduction process for gas derived from coal.

Solid reductant processes utilizing the rotary kiln or the retort-type system have met with varied success in different countries. Although they have not reached the advanced stages of large-scale commercial exploitation, these processes can be considered for use on a production scale in the range of from 50 to several thousand tons of metallic product per day.

The capacity of most direct reduction systems ranges from a few hundred to a few thousand tons per day. Thus, in practical terms, their maximum capacity is that of a small blast furnace. If a plant with a capacity of over 0.6 million tons of product per year is required, it should be built to contain two or more such systems.

The iron product from a direct reduction plant is generally suitable for use as the charge for steel-making in an electric arc furnace, and it could be used in an open hearth furnace. It is also suitable as an alternative to scrap in the various types of oxygen steel-making furnaces; however, the principal metallic source for these furnaces is liquid pig iron. Direct reduction iron can also be utilized by the foundry industry as the charge to electric arc melting furnaces and cupolas.

The gangue constituents in direct reduction iron products should be limited in order to avoid the generation of large amounts of slag in the steel-making furnaces. The ores or concentrates being processed should therefore be low in gangue, i.e. silica and alumina. The total of these two constituents optimally should be less than 3 per cent. If the total is over 6 per cent, serious penalties may be expected in terms of energy consumption and operating conditions in the melting furnace.

With an installed capacity of some 6 million tons and more than 20 plants in operation all over the world, the direct reduction process accounted for 1.5 per cent of total world pig iron production in 1975. Further and rapid growth is expected. Fifty new plants were reported under construction or in planning in 1976; 20 of these, larger in average size than existing ones, are to be operational by 1980. In that year, the total installed direct reduction capacity may therefore be more than 30 million tons, representing 5 per cent of total world pig iron production. Expected growth in production between 1980 and 1985 could increase this share to 8 per cent. A hypothetical 20 per cent share in iron-making would require direct reduction capacities of 200-240 million tons by the year 2000, depending on the total new iron requirement of steel-making by that time.

Retort system (gas)

This process employs four retorts in which four batches of ore in the form of pellets or lump raw ore are processed simultaneously. The ore in each retort is processed through a four-step cycle: pre-heating of the raw ore; reduction; cooling and carburization; and discharging and recharging. Thus, one reactor is in each step at any given time. Each step requires slightly less than three hours for completion. The reformed gas first passes down through a batch of reduced ore in order to be carburized and cooled. With the installation of heat recovery systems, the energy requirement for the process has been brought down to 3.2-3.3 G cal per ton of product.

Fluidized bed system (gas)

In this process, a stream of gas passes up through a bed of fine particulates and agitates them so that the bed has many of the characteristics of a fluid. A hot reducing gas passing through the bed of fine iron ore concentrates (less than 2mm) reduces the ore while the bed is kept in a "fluidized state".

The hot, fine metallic product from a fluid bed production system can be charged directly into a steel-making furnace in order to save heat and avoid briquetting, which may be troublesome. However, the problems of handling and storing this reactive product have not yet been solved.

The consumption of energy in a fluidized bed system is a little greater than it is in the other gaseous reduction systems because of the energy consumed in fluidizing the beds. Approximately 3.4-3.7 G cal are required per ton of product.

Rotary kiln (solid fuel)

In this process, the ore and solid reductant are introduced at the upper end of a long, inclined, refractory-lined cylinder that rotates about its long axis.

The fuel requirement is approximately 5 G cal per ton of direct reduction iron (i.e. one ton of low-rank coal or lignite), with no recovery of the thermal or chemical energy in the waste gases. Since only the fixed carbon in the coal is effective as a reductant, the direct energy consumption in the kiln may possibly be reduced to below 3.3 G cal.

In recent years, several plants have been built employing the rotary kiln as the reduction system. The capacities of the units range from 20,000 to 400,000 tons of direct reduction iron per year. The largest is approximately 100 metres long and five metres in diameter. Thus, with the most recent advances incorporated into the design, it apparently is feasible to operate units with annual capacities of as little as 20,000 tons, and as much as 500,000 to 600,000 tons. It should be possible to operate smaller kilns on char obtained from wood and other organic materials. Such chars are highly reactive, however, as is the char produced from the fixed carbon of low-rank coals and lignites.

The process has been employed to produce high-quality metallic iron from which powdered iron is made. By its nature, it is suited to relatively small-scale operations (less than 30,000 tons per year). However, it can be adapted to a wide range of ores, and it is suitable for the production of direct reduction iron which, in turn, could be used as raw material for the small-scale production of steel in electric or open hearth furnaces. Its use would be practical in areas where labour is abundant and supplies of char from coal, lignite or organic materials are available. Approximately 300 kg of char would be required per ton of direct reduction iron product. The kiln is heated by burning directly a readily available fuel such as coal, oil, gas or wood. Some of the heat could be supplied by burning the gases evolved from reactions taking place in the kiln.

Steel-making

There are four principal processes by which the common types of steel (carbon and low-alloy) are produced on an industrial scale today. These are: the basic oxygen furnace (LD/BOF or OBM/Q-BOP); the Basic Bessemer; the electric arc furnace; and the open hearth furnace. The principal raw materials used are hot or cold pig iron, iron and steel scrap, and direct reduction iron.

The fluxing agents, necessary for the formation of the slag, are limestone and burnt lime. Some fluorspar may also be used. Small quantities of iron ore or agglomerates may be needed, and a supply of gaseous oxygen is also required with some operations. The principal alloying agent is ferro-manganese, and relatively small amounts of ferrochromium, nickel and molybdenum are needed if some of the more common low-alloy steels are to be produced. The processes differ to some degree in the proportions of pig iron, scrap and direct reduction iron used in the charge. They also differ in the sources of energy required. In producing the common types of steel, approximately 6 kg of ferromanganese (containing 75 per cent manganese) are required. The type of furnace to be employed is determined principally by local factors, which in turn determine such matters as the availability of scrap and the feasibility of producing pig iron or direct reduction iron. The availability of fuel and electricity is also important, as is the technical infrastructure in the community, which may determine whether supplies of oxygen and sources of reasonably good-quality refractories are available. One of the most important factors is the expected level of demand for the steel products, which determines the size of the steel-making unit.

Oxygen steel-making processes

A steel-making shop usually has two vessels in order that one can be serviced and repaired while the other is in operation. Also, with carefully controlled operations, one vessel can be tapped and charged while the other is being blown, following which operations are reversed. In this way, a shop equipped with two furnaces can produce well over 50 heats per day. A modern shop with two 50-ton vessels can be expected to produce 800,000 tons of raw steel a year, while a shop with two 300-ton vessels can produce over 4 million tons per year. It is important that the shop be equipped with high-capacity equipment for charging the furnaces and handling the ladles of liquid steel. The buildings should be tall to accommodate bins above the level of the furnace from which ore, limestone and fluorspar can be charged to the furnace.

The normal charge to the furnace consists of approximately 0.8 tons of liquid pig iron, 0.3 tons of scrap and 75 kilogrammes of burnt lime per ton of raw liquid steel to be produced.

Recent advances in steel-making using the basic oxygen furnace are: (a) decreased heat times; (b) improved control of the slag, which also improves lining life (some linings are now lasting to over 6,000 heats, as compared with the more conventional life of 800-1,200); (c) improved means for controlling the furnaces; (d) better means for charging the furnaces; and (e) development of facilities for collecting and utilizing the waste gases.

This type of furnace requires less energy than others for its operation. Approximately 75 kWh of electricity are required per ton of raw steel, for the operation of cranes and equipment to charge and tilt the furnace and for the production of oxygen. Only some 0.2 G cal of fuel, in the form of oil, natural gas or coke oven gas per ton of raw steel is required to dry and heat the ladles and the refractory lining of the vessel. If the waste gases are collected and utilized, approximately 0.5 G cal of energy can be recovered. Facilities for this, however, are expensive relative to the value of the heat recovered. Except for the electricity required and with the usual furnace and facilities, the heat recovered from the system in the form of steam compensates for the fuel used for auxiliary purposes in the shop.

The OBM/Q-BOP type of furnace is similar in many respects to the LD/BOF furnace. The important difference is that the oxygen for refining is injected into the metal bath through special nozzles, or tuyeres, that are installed in the bottom of the vessel, and no oxygen lance is needed. The ratio of scrap to hot metal in the charge, and the yield of raw steel from the charge, are both a few per cent higher than they are for the LD/BOF system.

The OBM/Q-BOP process was developed a number of years after the LD/BOF process was invented (1949). However, it has advantages over the older process only in somewhat limited conditions, and it is not expected to replace the LD/BOF process in the same way that that process replaced the open hearth and Basic Bessemer furnaces in the years between 1950 and 1965.

Basic Bessemer process

The Basic Bessemer process is reasonably well suited to using hot metal with a high phosphorus content (1.5-2 per cent) for the production of many steels of commercial quality such as concrete reinforcing bars, light structural products, and hot rolled sheets and light plates. The process has fallen into disuse for three principal reasons: (a) The supplies of iron ore of high quality have replaced those ores that were high in phosphorus and which were smelted to produce hot metal suitable for the Basic Bessemer furnace. In addition, processing methods have been developed by which the phosphorus can be removed from the Basic Bessemer ores; (b) Phosphate fertilizers were obtained from Basic Bessemer slags. However, fertilizers from this source are not competitive with those produced from phosphate rock; (c) For many uses, Basic Bessemer steel is not competitive with steels produced by other modern methods.

Despite these disadvantages, the Basic Bessemer process may still be considered for use in refining high-phosphorus hot metal The process is simple, inexpensive to operate, small in scale, and has a very short heat time.

Open hearth process

The open hearth furnace is a reverberatory type furnace that has a shallow dish-like hearth on which the charge of iron and steel scrap, pig iron, iron ore and limestone is placed. The furnace is able to operate on a charge that can range from essentially all scrap to all pig iron, and the pig iron can be either liquid or solid. Where no liquid pig iron is available, the charge is all cold scrap and pig iron; however, in integrated plants where there are supplies of scrap and liquid iron, the charge will range from 30 per cent hot metal and 70 per cent scrap to the reverse ratio. This flexibility is one of the major advantages of the process. Although the acid version of the process is used now in only a few locations, it is most often employed for the production of high-quality forgings from a charge consisting principally of carefully selected scrap and a little cold pig iron.

The open hearth process is very flexible with regard to size, raw materials required and fuels that can be used. A small (100 ton/heat) furnace that melts scrap can produce 60,000-100,000 tons of steel a year. On the other hand, a large modern shop with ten 500-ton furnaces operating on a mixture of hot metal and scrap can produce 2 million tons annually. The energy requirement for fuel per ton of steel ranges from 1.5 to 0.9 G cal per ton of steel. Approximately, 38 kWh electrical energy is required per ton of steel for running auxiliary equipment and for the production of oxygen.

The principal disadvantages of the open hearth are the high capital cost of the plant and the high cost of refractories. In addition, the large labour input required for operating the furnace is a disadvantage where labour is scarce or expensive.

Electric furnace process

The principal electrically powered furnace employed for the production of steel is the arc furnace which operates on three-phase alternating current. The coreless induction furnace is used to a minor extent.

The usual charge to the furnace is iron and steel scrap. Direct reduced iron materials are finding greater use with increased production of that material. Liquid pig iron is used only rarely because problems arise from the amounts of carbon and silicon that must be oxidized. Large quantities of carbon monoxide gas and slag are formed, both of which complicate the operation of the furnace.

In recent years, the electric arc furnace has become the principal process employed where scrap and direct reduction iron are the main raw materials available. One ton of good-quality scrap is required to make one ton of raw steel. The yield on direct reduction iron depends on the percentage metallization and the gangue content of the charge material. At 3 per cent gangue in the raw ore and 95 per cent metallization, 1.10 tons of direct reduction iron are required to produce one ton of steel. If metallization is 85 per cent, approximately 1.16 tons are needed.

The time required to make a heat of steel depends to a significant degree on the size of the transformer installed with the furnace. Many furnaces now have a power of 400 kVA per ton of steel capacity, and the newer high-powered furnaces may have over 550 kVA per ton. With the newer furnaces, heat times of less than 1.5 hours for producing carbon steels are not unusual. With the older furnaces, heat times of 4-5 hours are common.

Several practices have been developed for the melting of direct reduction iron. It has been found advantageous not to use more than approximately 65 per cent of the material in the charge, if the balance consists of scrap. Some operators like to follow the same practice with direct reduction iron in the charge that they follow when melting an all-scrap charge. Others prefer it if all of the scrap and approximately half of the direct reduction iron to be used in the furnace is charged at the beginning of the heat. After the initial charge is melted down, the balance of the iron is fed continuously. The operation of the furnace is carefully balanced by providing energy, lime and the direct reduction iron at carefully controlled rates. This practice is well suited to the melting of direct reduced pellets. It is generally considered, however, that the design of the conventional electric arc furnace is not ideal for the melting of direct reduced materials, especially those containing over 4 per cent gangue and which result in the formation of a large volume of slag. Further advances in furnace design are expected.

Electric furnaces for steel-making range in size from 5 to 500 tons per heat. Furnaces with capacities in the 50-100 ton range are well suited as melting units for use with a direct reduction plant. The larger furnaces are commonly used for producing carbon steels from scrap where the output of raw steel may be in the range of 600,000-1.5 million tons per year. The total consumption of electrical energy for producing carbon steels from scrap may be as low as 475 kWh per ton of raw steel. A more typical figure, however, is 550 kWh per ton. When 50-60 per cent direct reduction iron is used in the charge, the balance being scrap, energy consumption will be 630-650 kWh per ton of raw steel.

<u>Casting operations</u>

Liquid raw steel must be solidified under well-controlled conditions if the resulting steel is to have a good surface and be free of internal defects. An important consideration in the choice of methods for producing the solidified steel is to avoid loss of some of the steel as scrap, the objective being to obtain a high yield of blooms or slabs from the liquid steel.

Two types of casting operations are now in general use. The first, the traditional method, is ingot casting, which is used extensively in both large and small steel plants. The second is continuous casting, which has been under development for many years. (Currently, only some 10 per cent of all steel made in the United States is continuously cast, the figure for Japan being approximately 20 per cent.) The method is used most extensively where merchant and structural sections are produced by the electric furnace, particularly non-integrated steel producers that utilize scrap and direct reduction iron. In these operations, the advantage of a high yield of finished steel from raw steel reduces the capital outlay for steel-making facilities.

In continuous casting, the consumption of energy per ton of cast product is approximately 20 kWh of electrical energy and 0.44 G cal of miscellaneous fuels. The comparable figures for ingot casting are 2 kWh and 0.03 G cal respectively. It is to be recognized that the difference is more than offset by the energy requirements for primary rolling of ingots, a step which is not required when producing strand cast products.

The continuous casting process can be expected to expand because of the savings in energy it offers and its higher yield compared with conventional ingot casting.

Changing technological patterns of steel-making

Despite the difficulty of forecasting the evolution of individual steel-making processes known today, certain trends are identified in this study:

(a) The decline of the Bessemer and Thomas processes, to some 1.5 per cent of world steel production in 1975;

(b) A decrease in open-hearth steel-making, although the process is still used in steel plants in various parts of the world (30.8 per cent of the world steel production in 1975);

(c) The phenomenal spread of basic oxygen furnaces since the mid-1950s, accounting for 50.8 per cent of crude steel production in 1975;

(d) An increase in electric furnace processing, which has more than doubled from 7 per cent in 1950 to 16.9 per cent of steel production in 1975.

World steel production by these furnace types has increased from 187.6 million tons in 1950 to 650 million tons in 1975 (Table 1). Considering all

Table 1. **World steel production by furnace type: 1950-1975**

Year	Oxygen converter a/		Open hearth		Bessemer, Thomas converter		Electric furnace		Total
	Million tons	Per cent of total	Million tons	Per cent of total	Million tons	Per cent of total	Million tons	Per cent of total	Million tons
1950	-	0.0	147.9	78.7	26.5	14.1	13.5	7.2	187.9
1955	0.8	0.3	210.5	77.9	37.3	13.8	21.6	8.0	270.2
1960	14.2	4.1	248.6	71.8	45.4	13.1	38.1	11.0	346.2
1965	80.8	17.7	278.4	61.0	39.3	8.6	58.0	12.7	456,4
1970	243.9	41.1	233.8	39.4	25.5	4.3	87.2	14.7	593.5
1975	330.0	50.8	200.0	30.8	10.0	1.5	110.0	16.9	650.0

Source: 1950-1973, Statistisches Bundesamt, Aussenstelle Dusseldorf;
1975, Mitchell, Hutchins Inc. (estimates).

a/ Includes small percentage of steel produced in all other furnaces.

the steel-making projects under construction and in preparation, it can be anticipated that the use of basic oxygen furnaces will increase to nearly 70 per cent of crude by 1985.

In the light of the expanding use of direct reduction and the trend towards transforming primary energy (including nuclear energy) into electricity, the electric furnace will be used to an increasing degree in world steel-making (about 20 per cent in 1985, and 38 per cent in 2000) at the expense of the open hearth process in particular, which will probably decline to 10 per cent of world steel production in 1985 and to 2 per cent by the year 2000.

Whereas the basic oxygen furnace will probably have achieved its highest share in world steel production by 1985, it is expected to decline subsequently to 60 per cent of world production in the period 1986-2000. (These indications, though corresponding to expected trends, are, however, hypothetical and provisional, and must be regarded in this light.)

Rolling and finishing

A wide variety of rolling mills are employed to convert ingots and continuously cast bars into finished products. The type of rolling operations and the plant facilities required are designed to manufacture steel products of precisely controlled shapes and physical properties.

Primary mills

Ingots must undergo "primary" reduction in a primary, or roughing, mill where the steel is kneaded or worked to obtain a cross section close to that of the finished product. Steel destined for merchant and structural products is rolled into intermediate sections called blooms. That destined for plate, hot rolled sheet, and cold rolled sheet products is rolled into slabs. Primary mills are not needed for continuously cast steels because of the nature of the internal structure and because of the smaller cross sections that are possible.

The energy requirements for primary mills are approximately 35 kWh and 0.44 G cal per ton of steel produced. The yield from ingots of steel blooms and slabs will range from 75 to 95 per cent, depending on the product. This compares with the yield from liquid raw steel of continuously cast products ready for rolling of 90 to 98 per cent.

The forecast demand for crude steel will doubtless be influenced by the expansion of the continuous casting process, which permits better yields. Earlier production forecasts for crude steel, therefore, might decrease on a global basis by about 6.6 per cent (70 million tons) by 1985.1/

It is anticipated that continuous casting will be used much more extensively in future steel-producing facilities. However, the advantage of continuous casting (the omission of the primary mills) is offset to some degree by the need for very close control of the operations.

Merchant mills

Merchant mills may range from high-capacity, fully automated units, to simple rolling operations involving manual labour. The choice of mill depends on the type of product and the rolling capacity required. A second re-heating and rolling may be necessary to obtain the desired cross section. The average energy requirement is 65 kWh and 0.58 G cal of miscellaneous fuels per ton of finished product. The yield from blooms or strand cast bars is usually quite high (95-98 per cent).

Structural products

Light structural products, such as angles, bars and small beams are produced in a manner very similar to that discussed in the previous paragraph. The production of heavier structural sections, such as H-beams, large channels, and piling bars, requires larger and heavier mills. The throughput of these mills is proportionately higher, owing to the cross-section of products which include railway tracks and accessories and tube blanks.

As mills manufacturing medium and heavy structural products usually have a relatively high capacity - more than 200,000 tons per year - proportionately large markets are necessary to justify their installation. Furthermore, such mills should be adequately equipped with a wide range of rolls and roll stands so that a broad spectrum of products can be offered.

Average energy consumption when producing structural products from blooms is estimated at 42 kWh of electricity and 0.58 G cal of miscellaneous fuels. The average product yield from blooms is approximately 95 per cent.

1/ "Some Economic Aspects", by James Driscoll, Managing Director, British Steel Corporation, Annual Meeting of the International Iron and Steel Institute in Osaka, October 1976, p. 5.

Hot rolled flat products

This product category includes flats, skelp for small welded pipe and tubing, hot rolled bands, and light and heavy plates. Narrow products, such as flats and skelp can be produced on merchant mills. Hot rolled bands and light-weight plates are usually produced on the hot mills used to roll products for subsequent cold rolling. Wide and heavy plates are usually produced on specially designed plate producing mills.

Where annual demand for hot rolled sheets and plates reaches several million tons, the modern continuous hot mill is used. The mill which is extremely expensive and has an enormous capacity, includes a conditioning yard where slabs are inspected and surface defects removed. Several large heating furnaces are required to provide the mill with an adequate supply of properly heated slabs.

Hot-rolled flat products have many different applications, such as: all types of cold-rolled sheet products; all but the largest sizes of welded pipe; formed and welded structural members; frames and bodies for trucks and rolling-stock. Though subject to variation, energy requirements in plate production are similar to those quoted for hot mill operations: 105 kWh and 0.70 G cal of miscellaneous fuels per ton of product.

Small-scale hot-rolling operations

Modern methods and equipment for processing steels into various hot-rolled products have been developed principally to minimize the number of man-hours required for all operations, to increase the rate of production, and to improve the product in terms of metallurgical quality and configurational control. Where relatively small quantities of simple products are required, equally simple equipment and processing methods can be used. When these simple methods are used, however, the man-hours and energy consumption per ton of product are relatively high. These disadvantages may be offset if low-cost labour is in abundant supply. Within limits, it is possible to use simple heating and rolling equipment for the production of such items as concrete reinforcing bars, small structural sections, small flats and fence posts from small ingots obtained by melting local scrap. It is also possible to obtain these products direct by re-rolling certain types of scrap steel. For example, rails can be re-rolled in the course of which scrapped rail is heated and slit longitudinally to obtain three discrete pieces (head, flange and web) which are then rolled into various simple shapes. Discarded railroad car axles can also be re-rolled. Heavy sheets and plates taken from discarded structures and vessels can be cut by shears or torch for use in re-rolling operations. By this means, relatively small tonnages of steel for local use can be obtained.

Cold-rolled flat products

Cold-rolled flats are required in the manufacture of most types of steel containers, automobile bodies, household appliances, light-weight equipment, such as farm machinery, and roofing and siding for dwellings and other buildings. The facilities and equipment for converting hot-rolled coils or sheets into cold-rolled products are not only greatly varied, but very costly.

Relatively simple facilities may be employed in the small-scale manufacture of a limited range of cold-rolled products. Small hot-rolled sheets can be pickled and then rolled on a simple reversing mill, whereafter they can be hand-dipped for hot-galvanizing or hot-tinning, or used directly as "black plate". Small-scale production does not offer as good a control of shape, thickness, and physical and mechanical properties as does the use of highly mechanized and automated facilities; nevertheless, the products can be satisfactorily used for a number of purposes. One major disadvantage of hand hot-dipped tin plate is that the tin coating is relatively heavy, thus making the product very costly.

Cold mill operations involving a number of processing steps consume an estimated 270 kWh of electrical energy and 0.83 G cal of miscellaneous fuels per ton of finished product. In small-scale hand operations, energy consumption would be similar to that estimated for the manufacture of merchant products.

Various levels of integration in steel-making

In planning the iron and steel industry, the choices to be made are not solely linked to the major processing stages, such as agglomeration, iron-making, steel-making, rolling and finishing. Consideration must also be given to the level of integration of the subsequent stages. According to the traditional classification, an integrated plant would carry out all operations from the production of pig iron using iron ores and coal to the manufacture of finished products. Non-integrated steel plants need not have smelting furnaces; they could rely on steel scrap as the principal raw material.

In the past, in a period of growing iron and steel demand with consequent low scrap availability, the construction of integrated steel plants with coking facilities was considered necessary. Today, however, the direct reduction process offers an alternative to total dependence on scrap supplies and, if combined with electric arc furnaces and continuous-casting, offers another possibility of integrating iron- and steel-making in one plant.

Traditional integrated plants require an enormous amount of capital, complex technology and large production scales in order to operate efficiently. Non-integrated scrap/electric furnaces, or the more recent direct reduction electric furnace continuous casting/rolling systems, need less capital and the scales of production can also be much lower As world steel demand continues to grow, however, it will be necessary o build integrated steel mills in various parts of the world, as well as establish small and medium-scale plants using scrap and/or reduced ores.

As indicated earlier, there is a trend towards increasing the unit capacity of sintering plants, blast furnaces, converters and rolling facilities and combining them into huge integrated industries. The use of computers is an important factor in increasing unit production and ensuring precision and accuracy.

As regards processing, the main international cost/price relationships will be determined by the large complexes with 10-20 million tons capacity. Most of these are established in traditional steel-making countries of Europe, the United States, the USSR and Japan, but their numbers are increasing also in Brazil, Mexico, North Africa, China, India, North and South Korea and other developing countries. However, small and medium-sized units will still be able to work efficiently provided there is a good local scrap or reduced ore and energy supply, they are close to the consumers, or they can offer products responding to specific market requirements.

The design and manufacture of steel plant equipment

Steel plant equipment and structural materials

The manufacture of steel plant equipment forms part of the industrial machinery sector, which comprises a large number of manufacturers operating either as independent engineering firms or in association with major steel-making companies. The design and engineering groups are very often part of, or dependent on, the steel or equipment manufacturers.

The traditional steel-making countries, and to an increasing degree Brazil, China, India, and Mexico, carry out their own engineering and manufacturing work, as well as that of other clients.

It is a generally accepted rule of thumb that plant machinery is equivalent to one-tenth of the installed production capacity; excluding the weight of structural materials needed. A more specific estimate is given below (in metric tons):

	Million tons of capacity			
	0.5	1.0	2.0	5.0
Gas route plants				
Equipment	45,500	85,500	160,000	
Structurals	20,000	35,000	60,000	
Blast furnace route				
Equipment			220,000	400,000
Structurals			175,000	320,000

Source: "Steel production in the Arab world by the year 2000 with particular reference to capital equipment", M.M. Luther, Chairman, Projects and Equipment Corporation of India, New Delhi, June 1976, Annexes III and IV.

Indigenous supply of spare parts

The development of engineering capabilities might well begin with the production of spare parts to meet local demand, which can be assumed to be of the order of 2,400-3,200 tons per million ton capacity, depending on the age of the equipment and the maintenance standards.2/ In order to be able to identify national technological constraints on manufacturing facilities, careful assessment should be made of the distribution of spare parts in terms of their component raw materials (iron, steel and non-ferrous castings,

2/ "Scope of Manufacture of Steel Plant Equipment in Mexico", Volumes I-III, by Ch. L. Sengupta, UNIDO expert, assisted by UNIDO-NAFINSA Team, Mexico City, May 1976, Volume II, XII-5-6.

forgings, and structural steel) and their weight requirements. Particular attention should be paid to facilities for the manufacture of medium and heavy spares. In Mexico, for example, medium and heavy spares account for as much as 70 per cent of total expenditure on spares, even though in quantitative terms they are relatively small.

The development of a spare parts manufacturing capability is of necessity a complex process, governed by such factors as the following:[3/]

- Uncertain quality of indigenous supplies;
- Lack of interest on the part of local industries in producing custom-made spares with little prospect of repeat orders;
- Government tariff and customs policies pertaining to imports;
- Price of locally manufactured spare parts as compared with that of imported spares;
- Reluctance of steel plant management to try locally manufactured spares instead of original spare parts from abroad;
- Availability of foreign exchange.

In addition to workshops attached to individual plants, a central workshop might produce important spares and assemblies common to all steel plants, such as mill spindles, table frames, rope and brake drums for cranes, and roll housings.

Developing local engineering and production capabilities

In developing local engineering and production capabilities, priority should be given to light and medium-weight equipment for rolling mills and finishing lines. The incorporation of heavy capital rolling equipment, such as mills for blooms, slabs, and wide hot and cold strip, in initial stages of development is not recommended, owing to the need for additional heavy manufacturing equipment for casting, forging and machining.

The light and medium-weight equipment may include mills for billets, bars, wire rods, light structurals, merchants, transfer and cooling beds, coilers, shears, and saws. Finishing lines may include straighteners, saws, shears, as well as bundlers for structurals, bars and rods. Rolling mill equipment includes repetitive items such as mill stands, cooling beds, roller tables, coilers, coil conveyors and straighteners.

3/ See Sengupta, op. cit., Volume II, XII-3.

The development of a steel plant manufacturing industry can ensue along one of three main lines, depending on the circumstances:

(a) A design and engineering company can be formed to specialize in the purchase and development of equipment designs. Standard components and assemblies can be bought from other suppliers, while existing foundries, forges and equipment factories within the country can manufacture other parts. The design and engineering company which would be instrumental in promoting the establishment of facilities for heavier and more sophisticated types of equipment, would need a competent inspection department, a strong team for construction supervision and commissioning, a warehouse facility with cranage, and a medium-sized assembly shop for testing, checking, and rectification;

(b) Manufacturing companies producing similar equipment could expand and restructure their organization to meet local requirements;

(c) A new plant could be set up to manufacture equipment and spare parts.

In preparing contracts for steel plant construction, consideration should be given to the inclusion of a heavy fabricating and machining workshop. In the course of the actual construction, a substantial part of the equipment could be manufactured in the workshop, utilizing mainly the contractor's supervisory skills and local labour. Upon completion of the plant, the workshop could be operated by an appropriate organization as a separate entity to provide a national heavy engineering facility. This procedure might ensure the availability of an experienced and trained indigenous labour force and of the tools that would permit locally made steel to be consumed in the manufacture of a large proportion of the capital equipment and spare part needs of the national industrialization programme.

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<u>Case study</u>

Greater participation in the steel capital goods market is foreseen for developing countries that have steel-making capacity. Long-term plans to invest in their own steel industry might enhance this development. These are typical of the considerations that led to the foundation in India in 1958 of the Heavy Engineering Corporation at Ranchi. The Corporation was "to function as the centre of gravity for the heavy metallurgical industry", servicing steel works located within a radius of 800 km.4/

Production commenced in 1963, with an installed capacity of 80,000 metric tons of heavy machinery, as follows:

Coke oven and by-product equipment	7,700
Blast furnace equipment	5,500
Steel-making equipment	7,000
Crushing and grinding equipment	3,150
Crane equipment	6,570
Rolling mill equipment	34,500
Spare parts for metallurgical equipment	1,080
Mining equipment	880
Excavators	4,950
Press forging equipment	1,360
Heavy oil-drilling rigs	5,500
Miscellaneous heavy machine parts and assemblies	1,810
	80,000

Some 25,000 tons of structurals per year were used. A foundry and forge plant with an annual capacity of 31,750 metric tons of grey-iron castings, 37,112 metric tons of steel castings, and 26,529 metric tons of forging was set up to meet, first of all, the needs of the company, but in addition supplies of heavier ranges of castings and forgings required by a number of public and private sector units in India. In due course, presses with capacities of 1,000, 1,650, 2,650, and 6,000 metric tons were added to the plant.

The third unit of the company is a plant for the manufacture of 10,000 metric tons per year of heavy machine tools such as radial drilling machines, horizontal boring machines, centre lathes and double-column planing machines.

The company's design office, the largest such unit in India, is engaged in the development of designs for the metallurgical industry and other strategic sectors such as cement, fertilizer, chemicals, and oil. It has 17 bureaux and 330 designers.

4/ S.C. Hadera, "Heavy Engineering Corporation Back-bone of India's Industry", submitted to the Third International Symposium on the Iron and Steel Industry, Brasilia, 14-21 October 1973.

The Indian example illustrates the impact of steel-making on heavy engineering, which once started, cannot be restricted to the serving of only one industrial branch. As regards size, smaller countries may find other scales of operation worth aiming at. Even in India, only one third of the production capacity[5/] could be utilized up to the early 1970s. In a sector such as heavy capital goods, the appropriate balance of engineering, production and marketing capability can be assessed only in the course of time.

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Environmental management

Types of pollution

The iron and steel industry produces gaseous, liquid and solid contaminants. The gaseous contaminants include sulphur and nitrogen oxides, ammonia, and carbonoxides and particulates such as iron, silica, and limestone. The liquid contaminants are tars, oils, phenols, cyanides, ammonia, heavy metal ions, low pH, suspended solids, and some BOD (Biochemical Oxygen Demand - a measure of the biologically degradable portion of the waste loading). The solid contaminants are largely fines of the raw materials such as carbon, iron, silica, and limestone. As a plant becomes "environment conscious", it tends to convert more and more of its gaseous and liquid contaminants to solid wastes, which then become one of its major concerns. The sources and types of major contaminants in this industry are given in Figure 2. Specific quantities and concentrations of each contaminant in waste water are shown in Table 2.

If contaminants produced at source in iron- and steel-making plants are scrubbed into liquid wastes or trapped in solid wastes, the principal air pollution will emanate from the coke plant. Treatment of these contaminants is becoming more common, however; many of them are being converted, reduced in concentration, or eliminated altogether.

The following table shows the usual emission levels of gases and solid particles from coke plants:[6/]

5/ Op. cit. p. 23.

6/ I. Codd, "Pollution Control and the Iron and Steel Industry", Third Interregional Symposium on the Iron and Steel Industry, Brasilia, Brazil, 14-21 October 1973.

	Kg/ton dry coke
Coal and coke dust	2.0
Coke oven gas	0.7[a]
SO_2	0.63
H_2S	0.12
Phenols	0.13
Aromatics	0.21
HCN	0.07
NH_3	0.14
Pyridine bases	0.02

a/ Approximately 0.4 per cent of total gas make: 300 m^3/ton coke.

Other air contaminants may be released from power-plant, lime-kiln, or sintering operations Power plant contaminants consist largely of SO_x, while contaminants from the kiln and sintering are mainly particulate (with the addition of SO_x in the case of sintering). The amount of SO_x in the stack gases from each of these operations depends largely upon the sulphur content of the fuel used.

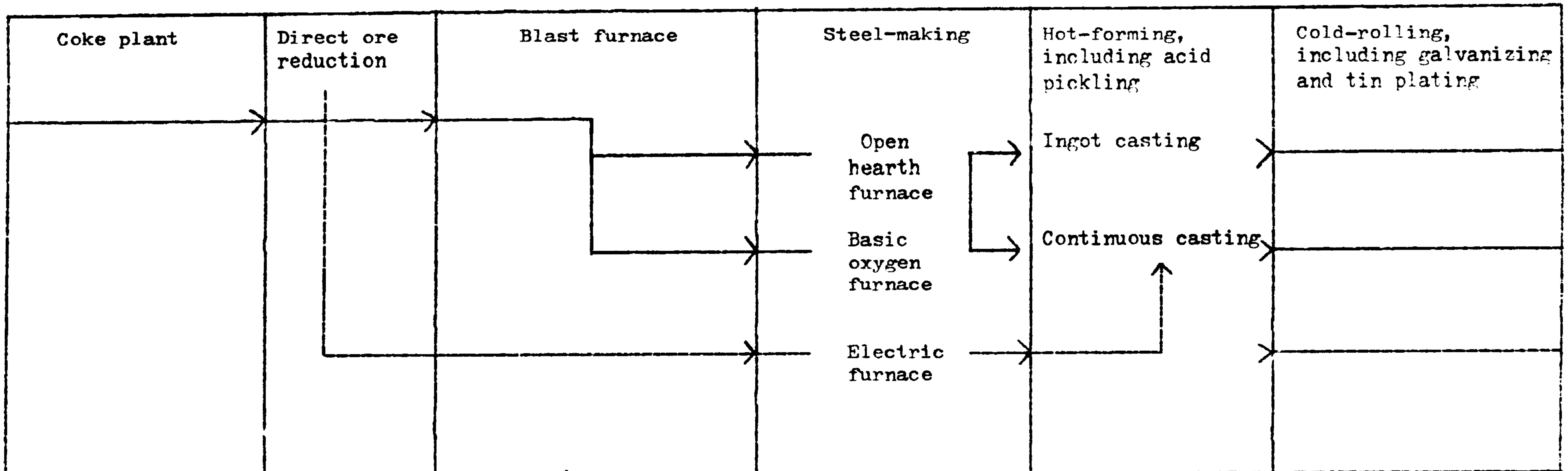
Sources of pollution

In conventional processing, most contaminants originate in the coke-oven or in sintering, pelletizing and blast-furnace operations. Coke ovens generate most of the chemical contaminants, while the other operations generate the solid matter. The finishing operations of hot-forming and cold-rolling add pollutants in the form of metals, acids, oil and iron-scale. Power plants add oxides of sulphur and nitrogen.

Some 2.5 tons of raw material (coal, iron ore, scrap, limestone) are needed to produce one ton of liquid steel. One ton of raw material becomes liquid steel, 0.385 ton becomes slag, leaving 1.115 tons of residual gaseous, liquid and solid wastes.

If all of these wastes (with the exception of those from the coke-plant) are converted to solid, it can be seen that the production of one ton of liquid steel results in the production of 0.923 tons of solid contaminants.

Figure 2. Major sources and types of pollution in the iron and steel industry[a]



Coke plant		Direct ore reduction	Blast furnace			Steel-making			Hot-forming, including acid pickling		Cold-rolling, including galvanizing and tin plating	
Gaseous	Liquid		Gaseous	Liquid	Solid	Gaseous	Liquid	Solid	Liquid	Solid	Liquid	Solid
Ammonia Steam Hydrogen Sulphide	Ammonia BOD Cyanide Phenol pH		Ammonia	Ammonia Cyanide Phenol	Suspended solids			Suspended solids	Oil and grease Chloride Sulphate Iron Acidity	Suspended solids	BOD Cyanide Oil and grease Suspended solids Chromium Iron Tin Cyanide	Suspended solids

a/ Other sources, but of relatively minor contamination, include the yards (ore, coal, and scrap), sintering steam generation, lime kiln and cooling towers.

Table 2. Waste-water contaminants from a typical iron and steel mill

Contaminant	Coke plant	Blast furnace	Steel manufactur	Hot-forming	Cold-rolling, including acid pickling
		(Gallons per ton of product)			
Total waste-water	3,000	5,700 (2,200 excluding cooling water)	4,000	7,500	2,200
		(Pounds per ton of product)			
Phenol	0.55	0.02	-	-	-
Cyanide	0.32	0.09	-	-	0.05
Ammonia	0.32	0.25	-	-	
BOD_5	3.2	-	-	-	2.0
Suspended solids	-	55	30	40	7.0
Oil	-	-	-	3.5	9.0
Acidity	-	-	-	-	10.0
Iron	-	-	-	-	4.0
Chloride	-	-	-	-	5.0
SO_4					4.0
Total Cr	-	-	-	-	0.5
$Total^{VI}$	-	-	-	-	0.4
PO_4	-	-	-	-	0.4
Zinc	-	-	-	-	1.0
Tin	-	-	-	-	0.7

Source: C. Wm. Rice Corporation for the U.S. Environmental Protection Agency: "Industrial profile study on blast furnaces and basic steel products"; Contract W. 68-01-0006 (1971).

Unless all of this waste is returned to the furnaces as scrap, additional quantities of contaminants will be generated in the course of finishing the steel. At least 50 per cent (and usually 75 per cent) of this solid matter is iron.

Pollution control

Even though the technology for effective removal of most contaminants from effluent exists, their complete removal at plant level is costly. The decision to invest in pollution control in a steel mill, therefore, depends upon both the physical and economic limitations of the plant. The modern steel mill is even more affected by these limitations than other industries because of the great volumes of gaseous, liquid and solid wastes entailed in its operation.

Baghouse filters, cyclone separators, electrostatic precipitators, and both solid and liquid scrubbers are used to control pollution. Water contaminants are removed through neutralization, sedimentation, flotation and concentration. Sometimes biological treatment is required to reduce BOD. Solid wastes are settled or filtered out of scrubber and plant process water wastes as well as refined from both blast furnace and BOF slag. The ferrous portions of the solids are re-used in the furnaces while the slags may be sold for use in other industries. No really positive steps have been taken at the international level to reduce noise or aesthetic contamination.

The United States Environmental Protection Agency has suggested the following treatment technology:1/

Production process	Treatment
Coke	Cooling water recirculation; dilution of still waste with cooling water system blow-down; biological oxidation of combined still waste blow-down stream
Iron manufacturing	Polyelectrolytes, classification, sludge thickener, vacuum filtration of thickener under-flow, cooling and recycle
Steel manufacturing	Thickener
Hot-forming	Scale pit and oil flotation skimming
Cold-finishing pickle rinse water	Neutralization and settling
Cold-rolling	Chemical coagulation and dissolved air flotation

1/ United States Environmental Protection Agency, "The Industrial Wastes Studies Programme: Summary Report on the Iron and Steel Industry" (SIC 3312), 19 January 1972.

It maintains that by utilizing this technology, the effluent levels shown in Table 3 can be achieved for each of the five major processes.

Table 3. Achievable waste-water effluent loads
(pounds per ton of product, i.e. coal coked, hot metal produced or steel undergoing finishing, in addition to suspended solids)

	SO_4	NH_3	Fe	BOD_5	Cr	Phenol	Suspended solids	Oil and grease	Acidity
Coke	-	0.070	-	0.700	0.060	0.110	-	-	-
Pig iron	-	0.050	-	-	0.018	0.004	1.000	-	-
Steel-manufacturing	-	-	-	-	-	-	0.100	-	-
Hot-forming	-	-	-	-	-	-	6.200	0.900	-
Pickle rinse water	2.500	-	0.100	-	-	-	-	-	0.100
Cold-rolling	-	-	-	1,300	-	-	-	-	-
	-	-	-	9.0COD	-	-	2.500	1.870	-
Galvanizing	-	-	0.290	-	-	-	-	-	-

These results can be attained in new plants, where it is possible to treat each mill waste separately, in the most effective manner. In older, integrated iron and steel mills where it is no longer either technically or economically practical to treat the liquid waste-water from each operation individually, it may be segregated into three different categories:

Total mill effluent (except pickling liquors and coke plant effluent);

Pickling liquors;

Coke plant waste-waters.

In the "total mill" category, once the separation has been made, effluent can be treated by settling the scale in large retention pits followed by sand filtration to remove the major portion of the oils. If, however, the proportion of emulsified oil to total oil is high, chemical treatment to "crack" the oil emulsion will be required. Pickling liquor wastes can be used to crack the emulsions. The oil recovered from the total effluent should be used as auxiliary fuel in the blast furnace or power plant boilers; the scale recovered from the pit should be returned to the blast furnace feed. Palm oil effluents can be used again as a lubricant in the cold-rolling mill and as a source of fatty acids for various industries.

In the second category, if sulphuric acid is used for pickling, it is best treated by concentration techniques involving either evaporation or solvent extraction with subsequent re-use of the ferrous sulphate and residual sulphuric acid. However, pickling with hydrochloric acid is recommended whenever possible since the acid can be recovered and re-used more easily by roasting into iron oxide and hydrochloric acid.

Coke plant wastes are left over from the ammonia still and light oil decanter following extraction of the major part of the ammonia, tars and oils. Some residual quantities of both ammonia and light oil remain, however, as well as phenols, cyanide and chlorides. These are treated best by biological oxidation, preferably in a nearby municipal sewage treatment plant, or by carbon adsorption or chemical oxidation. The use of one of these three processes, after ammonia and tar removal and in conjunction with recycling for cooling and quenching, can help to avoid water pollution. Tars removed from the decanters may be burned in the furnaces, and the ammonia may be sold for the production of fertilizer using ammonia or ammonium sulphate. Coke oven gas, after removal of ammonia and tars, may be re-used as fuel in the blast furnace.

Dust is controlled best by good house-keeping practices. Coke oven emissions are eliminated by closed operations and wet scrubbers.

Stack gases containing SO_x and H_2S can be desulphurized with an efficiency of 70–90 per cent by spraying with a suspension of either limestone or magnesium sulphite. For removing the particulate matter from these gases or from primary dust emissions collected in plant, multicyclones, electrostatic precipitators, fabric filters, or scrubbers can be used. The selection of the proper treatment unit for particulate matter depends primarily upon the average size of particle to be removed and the desired removal efficiency, as well as upon economics, space, and equipment availability.

In steel-making, the fines in the gaseous emissions are concentrated by electrostatic precipitation in a dry condition. Final scrubbers are recommended - especially on electric arc furnaces, which produce a large amount of dust - whenever final emissions must be maintained at less than 65 mgs/m^3.

Most of the contaminants of an iron and steel mill are solids, and it is very important to the economy of the industry to recover and recycle as much of these as possible. The re-use of the solids found in millscale, blast furnace dust, sinter plant dust, slag, lime dust, scrap and scarfing powder is recommended for reasons of economy as much as for pollution reduction. The particulates recovered - with the exception of slag - can be incorporated in the sinter mix, in pellet and coke making, and in powder metallurgicals. Blast furnace slag can be used in the production of cement, insulation of building materials, and in making aggregates for road-building. BOF slag is valuable for its iron as well as its relatively high phosphorus content. The iron can be reclaimed and used again in the plant while the phosphorus content can be used as a fertilizer input.

New processes that result in less environmental pollution are:

- Dry (instead of wet) quenching of coke;
- Hydrochloric acid (instead of sulphuric acid) pickling;
- Direct reduction of iron ore (instead of coking and blast furnace).

Cost of controlling pollution

Gaseous and liquid pollution control costs may be expressed either as a percentage of production costs or in terms of dollars per ton of product. In the first instance, the factor will be 1 to 2 per cent, in the second \$2-\$5 per ton of steel produced. These costs are sufficiently low to be spent by plants in developing and developed countries alike. They may be abosrbed in the price of the steel and passed on to the consumer. Costs may be reduced still further in future by establishing integrated industrial complexes containing steel mills and such auxiliary industries as fertilizer, cement and other oonstruction operations.

Assessment of environmental impact

Environmental impact statements

An environmental impact statement is a clear-cut assessment of the effect on the environment of a contemplated new development, in this instance the construction of an iron and steel mill, the expansion of an existing one, or a change in production techniques. An unbiased and expert assessment will reveal to all concerned the potential effect of the development on the people, air, water, and land in the immediate area. If it is seen that the effect will be too severe, one of the following alternatives - or a combination of them - may be considered:

- Modification of the proposed production plan;
- Installation of proper pollution controls;
- Relocation in an area where the environmental consequences would be less severe;
- Acceptance of life in an environment of poorer quality and modification of life style to accommodate plant production.

Regardless of the final decision, the impact statement, in pointing out the effects and providing the alternatives, is of utmost value. Regulations to protect the environment should be enacted and enforced in the area surrounding the mill in order to ensure a minimum degree of protection. For healthful uncontaminated air, for example, the atmosphere might be maintained at less than 0.03ppm CO, 0.002ppm SO_2, and 60 micrograms per cubic metre of particulates.

Pollution during construction and operation

Certain non-recurrent operations during the construction of the mill affect the environment. Noise and dust are the two most annoying. If it is seen that these problems are going to continue during actual plant operation, they should be taken into account at the onset of the project. When the plant is in actual production, the environmental guidelines established must be maintained by the plant personnel. The plant manager must ensure that his production techniques include appropriate environmental controls.

Plant location

From the environmental standpoint, iron and steel mills should be located wherever the air, water and land can assimilate with little or no environmental damage the contaminants normally discharged by the plant. Some damage is almost inevitable, but the degree should be a measure of the will of the local population and the government of the area, and not that of the industrial plant. It is not to be expected that all communities and governments will demonstrate the same will to preserve the environment to the same degree. However, communities and governments in all parts of the world should safeguard the environment for mankind as a whole by establishing and maintaining minimum standards of pollution control.

Although the opinion is sometimes expressed that developing countries are reluctant to devote scarce funds to pollution control, experience has shown that it is wiser to incorporate environmental conservation controls at the very outset rather than to adopt remedial action at inordinate cost at a later stage.

Steel production sites should be compared on a total production cost basis. Here, environmental control costs may play a significant role in the final decision, since all other costs may be of a similar order of magnitude. This is especially true in small countries where costs of land, transportation, power and labour costs are comparable throughout the country. Ideally, production facilities should be located on large, relatively clean watercourses which are not used for other municipal purposes, where the prevailing wind is strong, upward and away from any habitation and where great areas of land are available for slag or other solid waste disposal.

Over-all effects of environmental controls

Despite the current trend, especially in developed countries, towards direct reduction of iron ore, its value to the industry is not significant in environmental and economic terms. Admittedly, environmental contaminants and hence costs are less with direct reduction than with the conventional coke oven, blast furnace and BOF steel-making processes. However, total environmental costs in the conventional production of steel account for such a small percentage of plant production costs (2 per cent) that even if environmental control costs were to be halved, the benefit gained would hardly suffice to justify changing production plans solely to protect the environment.

Since production costs are largely governed by raw material, labour, and transportation costs rather than environmental costs, the production of iron and steel in developing countries using conventional methods would appear acceptable. Owing to the relatively low cost of environmental control, production costs should always include complete environmental control in both developing and developed countries. Whenever possible, direct reduction of iron ore, electric arc steel-making furnace and continuous-casting methods of steel production (billets only) should be considered, since less environmental damage is incurred.

This is best achieved under the following conditions:

(a) Steel billets, rather than slabs or blooms are the desired end-product;

(b) Sponge iron from direct reduction can serve as a partial substitute when scrap for the BOF is scarce;

(c) Production flexibility is desired;

(d) A developing country starts its domestic steel production with relatively low consumption;

(e) The environment is capable of absorbing the great amounts of small particulates which may originate from the electric arc furnace in spite of scrubber controls.

Conclusions and recommendations

The production of iron and steel need not be unduly constrained by environmental factors since the control technology is known and abatement costs are relatively insignificant in comparison with other production costs. Plants should be located primarily on sites which permit minimization of all production costs, including environmental control costs. These production costs may also be minimized by locating plants in integrated industrial complexes. Considerable research, evaluation and pilot experimentation are necessary, however, in order to optimize these complexes (which may contain a different mix of industries for each site). Wherever possible, steel products should be manufactured using direct reduction, electric arc furnaces and continuous casting sequences, thereby minimizing environmental damage.

Chapter V

RESOURCES

The geographical distribution of the major natural resources essential to steel production will be central determinants in the future development of the global iron and steel trade. Four of these resources relate to energy - total coal, natural gas, oil, and hydro-electric energy 1/ - and the others relate to raw materials or are combined fuel and reductants - iron ore, coking coal, charcoal, and manganese ore - as well as fluxes. Identified reserves of the major resources and their geographical apportionment are shown in Figure 1 and Table 3. It has been possible to identify those developing countries which, in the sense of known mineral and energy reserves, are in a favourable position to establish an iron and steel industry. Figure 2, derived from Tables 4, 5 and 6, identifies those developing countries where the availability of resources may be designated favourable (five resources present), less favourable (three resources), or least favourable (less than three resources).

It must be emphasized that this assessment has been made in the light of known reserves only. It is likely, however, that future exploration will reveal more resource deposits in the developing countries.

Iron ore

Global reserves of iron ore are estimated at approximately 700 billion tons, with positively identified deposits totalling 250 billion tons. Future exploration will undoubtedly lead to a revision of this figure as large reserves are expected to be found in previously unexplored areas of Africa, Asia, Australia, and Latin America. In any event, known iron-ore resources in Brazil, Canada, Sweden, the United States and USSR suffice for several decades at least. 2/

Recent estimates from a variety of expert sources indicate that the developing countries possess at least 210 billion tons of iron ore, or over 30 per cent of total world resources (see Figure 1 and table below).

1/ Total energy requirements (by source) for the iron and steel industry for the period 1985-2000 are shown in Table 1, total energy consumption for the same period being shown in Table 2. All numbered tables are at the end of this Chapter.

2/ Commodity Data Summaries 1974. Mining and Minerals Policy, page 81.

Calculated iron-ore reserves in selected developing countries

	Percentage of world total	Billions of tons
Africa	4.2	
Algeria		1.6
Angola		1.2
Gabon		1.2
Libya		3.5
Zaire		5.0
Asia	8.6	
China		31.0
India		21.5
Latin America	17.6	
Bolivia		40.0
Brazil		72.0

It should be stressed once again that in the course of future exploration, particularly in the developing countries, far greater iron ore resources than are accounted for at present will be found.

Manganese ore

Land-based deposits of this ore, the manganese content of which generally ranges from 25 to 50 per cent, are currently estimated at 3 billion tons and are more than adequate to meet expected world demand for the rest of the century. Furthermore, extensive ocean-floor deposits have been identified, particularly in the Pacific. More than 40 per cent of known reserves, or some 1.2 billion tons, are located in the developing countries:

Calculated manganese reserves in selected developing countries

	Percentage of world total	Billions of tons	Millions of tons
Africa	20.0	0.6	
Gabon			450.0
Morocco			50.0
Asia	5.0	0.14	
China			20.0
India			100.0
Latin America	15.0	0.45	
Argentina			100.0
Bolivia			20.0
Brazil			250.0
Chile			22.0
Peru			54.0

Coal/coking coal

In 1973 world coal reserves were estimated at 8,143 billion tons, of which only 429 billion tons (5 per cent) were suitable for coking. The developing countries possess only 5.2 per cent (22 billion tons) of known coking coal reserves, which, however, are very unevenly distributed:

(a) Only three countries, China, India and Colombia, account for some 98 per cent of the total coking coal reserves of the developing countries;

(b) Some 89 per cent of the developing countries' coking coal reserves are concentrated in Asia: China, India, Iran, Korea (Democratic People's Republic), Korea (Republic of), Mongolia, the Philippines, Taiwan, and Vietnam;

(c) With the exception of South Africa and Rhodesia, no other African country is known to possess reserves of coking coal;

(d) Only five Latin American countries, Brazil, Chile, Colombia, Mexico and Peru, possess significant reserves of coking coal;

(e) No developing country in Oceania has any identified coking coal reserves.

The known reserves of the developing countries might well be larger than currently estimated: future exploration might disclose new coking coal deposits in other developing countries, however there can be no doubt that at present the lack of this resource will prove a serious handicap to many prospective iron and steel producers in developing countries. The requisite imports will continue to be a serious drain on foreign exchange reserves in the developing countries.

Oil

Nearly 80 per cent of known world oil reserves, estimated at some 75 billion tons in 1973, are located in developing countries, some 60 per cent being accounted for by the 13 member states of the Organization of Petroleum Exporting Countries (OPEC): Algeria, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates and Venezuela. Several other developing countries, such as Argentina, Chile, China,and Mexico, have significant oil reserves and large-scale prospecting is at present being carried out in a number of other developing countries.

After the substantial rise in the coke price in 1970, oil was used in blast furnaces. The consumption of oil per ton of steel production had been on the increase in many countries during the 1960s, despite a drop in the United States owing to a reduction in steel manufacture using the open-hearth process.

The extent to which fuel oil will be used in steel-making operations in the future, will largely depend on the evolution of the relative costs of coking coal, gas, and oil. However, it must be stressed that oil cannot totally replace coking coal in blast furnaces, and the total energy requirement per ton of steel changes very little irrespective of the fuel used.

Natural gas

In 1973, the total world reserves of natural gas were estimated at nearly 63 billion m^3, of which some 46 per cent were located in developing countries. (See Figure 1.)

Natural gas is mainly used in direct reduction processes. In 1969, natural gas provided 18 per cent of the energy needs of the steel industry in the United States, and in the USSR it reached a 23 per cent share in 1972. In steel works in Europe, the proportion of natural gas used has been much smaller, averaging about 5-6 per cent of energy requirements, while the steel industry in Japan does not have a tradition of using natural gas. The basic reason for these fluctuations in the use of this energy resource is that gas must be available at a lower price on site than other fuels, since coal-fired direct reduction or blast furnace methods are still cheaper than gas-fired direct reduction.

Another source of energy in developing countries is the natural gas which is currently flaring at the rate of over 175 billion m^3 per year, and which represents more potential mWs than the total steam power plant capacity of all the developing countries. Less than one per cent of this wasted energy, i.e. 1.5 billion m^3 of natural gas, would suffice to fuel the production of 3 million tons of steel. In fact, the total amount of gas currently flared could be used to fuel over 80 per cent of the planned steel capacity in the developing countries by the year 2000.

Electricity

The use of electricity to produce iron and steel throughout the world is constantly increasing, climbing from 7.2 per cent in 1950 to 17.4 per cent in 1974. Shown below is the percentage of electrically produced total iron and steel output in selected major steel-producing countries in the period 1965-1973:

	1965	1973
France	9.0	10.6
Germany (Federal Republic)	8.5	19.9
Italy	37.4	39.9
United States	10.5	18.2

The use of electricity will continue to increase as specific electric energy requirements per ton of steel gradually decline.

Potential hydro-electric resources

Some 1,425 GW or 63 per cent of the world's total potential hydro-electric resources are located in the developing countries, only 4.1 per cent of which however, are being developed at a realistic average maximum flow capacity (Gav). At present, the developing countries account for only 20 per cent of total hydro-electric energy output, and much of their future energy requirements could be covered by the exploitation of water resources which have not yet been utilized.

Africa possesses nearly 20 per cent of the world's hydro-electric resources, but produces only 2.3 per cent of the world's hydro-electric energy. Half of the hydro-electric energy generated in Africa comes from three dams: the Aswan dam on the Nile in Egypt, the Akoganito dam on the Volta river in Ghana, and the Kariba dam on the Zambezi river, which demarcates Zambia and Rhodesia.

Nearly half of Africa's potential hydro-electric resources are located in Central Africa, but only 5 per cent of these have been exploited. The Congo river in Zaire alone has an estimated potential of 32,000 mW, and this would represent the largest concentrated source of hydro-electric power in the world. Hydro-electric resources in East Africa represent 30 per cent of the continent's potential, an amount roughly equal to the total hydro-electric resources of Europe, whereas in North Africa resources represent only 4 per cent of total African hydro-electric potential.

Latin America, which has 14.5 per cent of the world's hydro-electric potential, has already harnessed 4.8 per cent thereof, thus surpassing the other developing country regions in this respect. Unfortunately however, some 65 per cent of Latin America's potential is represented by the Amazon, the world's largest river by a factor of five, which flows mostly through unpopulated and inaccessible jungle areas. Consequently, most hydro-electric development in this region has taken place in the Paraña river basin in southern Brazil, the Orinoco basin in Venezuela, the Magdalena basin in Colombia, and on other smaller rivers running off the western slopes of the Andes in Ecuador and Peru.

Asia has the largest potential of all, 28.3 per cent of total world hydro-electric resources and a potential of some 640,000 mW, of which only 4.3 per cent has been developed. The rivers draining the Tibetan plateau represent the bulk of Asia's total hydro-electric potential, 78 per cent of which is located in the following five countries:

	Per cent
China	50
India	10
Burma	8
Indonesia	6
Pakistan	4

The potential of Oceania, which has not yet been tapped, is less than 1 per cent of the world total. Most of it is represented by the rivers which carry the heavy rainfall from the central plateau of Papua New Guinea down to the sea.

Much of the development of these hydro-electric resources described above is limited by a variety of climatic and geographical constraints. It is worthy of note, however, that, assuming a specific energy consumption per ton of steel of 550 kWh in 1985 and 400 kWh in 2000, and using scrap re-cycling methods, less than 5 per cent of the potential represented by the developing countries' untapped hydro-electric resources would provide enough energy to meet steel production targets established subsequent to the Lima Declaration.

Charcoal

The use of charcoal as a furnace fuel is certainly worthy of consideration in countries rich in tropical forests and lacking in coal. Argentina, Brazil, India, and Malaysia have long used charcoal in iron smelting, and certain African countries, such as Ghana and Kenya, are reportedly increasing the utilization of their forests for charcoal production on an experimental scale. Charcoal is technically suitable as a furnace fuel, and fuel consumption (0.7 tons per ton of iron) is less than in the case of coke. The main difficulty with charcoal is obtaining supplies adequate to sustain economically feasible levels of production: a 25,000-30,000 hectare eucalyptus plantation would be needed to sustain a blast furnace operation with an annual output of 100,000 tons of pig iron. Estimates of growth stocks in the forests of the developing countries vary, but it is generally considered that these countries possess some 30 per cent of world forest reserves. This would provide many of them with a sufficient source of charcoal for significant local production of pig iron using small blast furnaces. Care, however, must be taken that the ecological balance is not impaired.

In the blast furnace method, the substitution of charcoal for coke is an acceptable and fully feasible technology. Its utilization will call for an early decision with respect to forest establishment, however, in order that sufficient supplies can be ensured by long-term harvesting and replanting strategies. The paramount importance of preserving environmental balance in the developing countries may limit the utilization of charcoal, if programmes for adequate replanting are not given priority.

Scrap

The three basic sources of scrap are: revert or mill-generated scrap; industrial scrap; and obsolete metal.

Revert or mill-generated scrap is produced as raw steel and processed into semi-finished and finished products. In conventional processes, cropping and trimming results in a scrapping of some 15 per cent of raw steel input from the ingot to the semi-finished stage. Continuous casting can reduce this loss to 5 per cent. Scrap losses between the stages of raw steel and finished product can average nearly 30 per cent of the raw steel input. This revert scrap, the properties of which are well known, produced as it is on the premises, may be re-cycled to satisfy scrap requirements.

Industrial scrap is generated by other specialized industrial manufacturing sectors in the course of producing finished goods. In industrialized countries, scrap losses of this kind are estimated at 30 per cent in the automotive industry, 20 per cent in the appliances industry and 15 per cent in the heavy machinery industry. Steel mills generally pay good prices for industrial scrap, and its availability can be forecast on the basis of fluctuations in economic activity.

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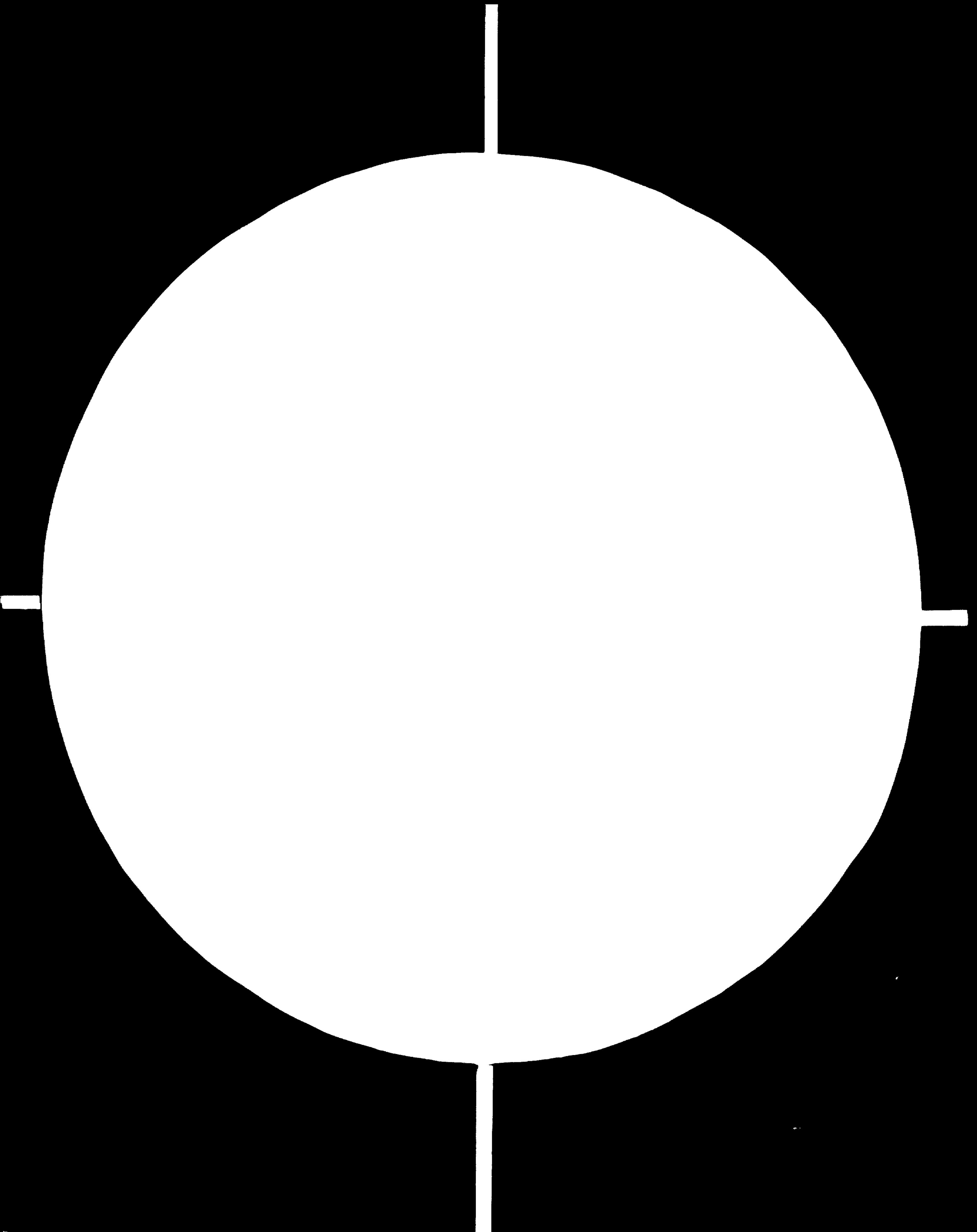

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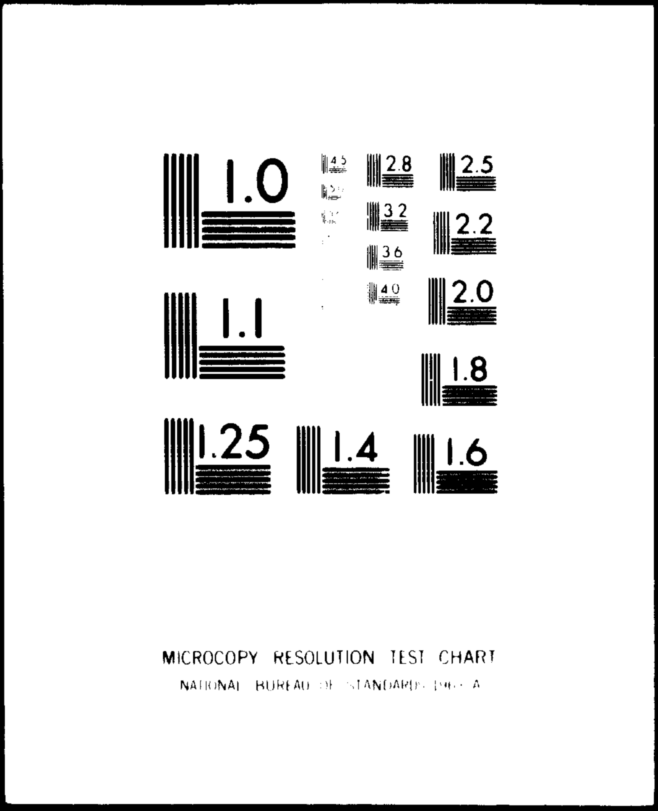

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Obsolete metal is obtained by re-cycling discarded industrial products with a high iron and steel content, such as motor vehicles, heavy machinery and appliances, as well as metal structures or forms from demolished buildings or bridges. These sources provide the majority of scrap consumed by the steel industry throughout the world: such sources are obviously most readily available in those countries with the longest history of industrialization. In the past, some industrialized countries have exported large quantities of obsolete metal. These exports will decrease, however, as domestic demand for scrap grows in the industrialized countries, a number of which are also increasing their electric furnace steel-making capacities. A continuation of these trends will reduce the amount of obsolete metal available to the developing countries.

Future scrap requirements will depend on the relative popularity of the three major steel-making processes[3/]. At present, over 50 per cent of world steel output is produced by means of a variation of the basic oxygen process, in which the amount of scrap in the charge varies from up to 28 per cent in many plants in Europe and the United States to 7-10 per cent in some of the newly built mills in Japan. About 30 per cent of world steel production is made in open-hearth furnaces, which can take a complete cold metal charge of 100 per cent scrap, or an 80 per cent hot metal charge with 20 per cent scrap. On an average, scrap would constitute 45-50 per cent of the charge in the open-hearth method.

The third conventional steel-making method based on scrap consumption is the electric furnace which is finding increasing use. World percentages of steel made by this method rose from 11 per cent in 1960 to 17.4 in 1974. Since this method, with very few exceptions, requires a 100 per cent scrap charge, an increasing global demand for scrap can be predicted, with obvious concomitant escalations in the price of scrap, irrespective of source.

In the future, most steel will be produced by the basic oxygen process (which requires less scrap than the open-hearth processes): an estimated 70 per cent by 1985, and 57 per cent by 2000. However, the increase in electric furnace capacity to an estimated 20 per cent of global output in 1985 and 41 per cent in 2000 will more than compensate the decline of the open hearth. Satisfying the scrap demand of the steel industry, and particularly its growing electric furnace

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3/ Table 7. Forecast distribution of steel processes, 1974-2000.

sector, will become increasingly difficult. The following estimates of future scrap requirements have been made based on the likely amounts of steel to be produced by the available processes, the optimal technology of scrap use, and the possible supply of sponge iron as a substitute for scrap.

Future scrap demand in millions of tons

	Global	Developing countries
1985	150 - 650	110
2000	965 - 1,200	270 - 340

These figures could well be exceeded as 465 million tons of scrap were consumed throughout the world in 1974, a record year.

By all estimates, scrap prices will remain high; particularly, if scrap has to be imported when global demand for steel is high. The international benchmark is the price of No. 1 Heavy Melting steel scrap f.o.b. United States ports, which is subject to considerable fluctuation as indicated below:

	$ per ton
Average 1972	35
April 1974	132
December 1974	83
Current 1976	75-80
1980 estimates	135-140

World scrap prices have tended to follow or exceed the above prices; in 1974, when raw steel output reached 710 million tons, the USSR succeeded in selling its scrap at prices that at times exceeded $ 200 per ton. Developing countries will naturally consume domestic scrap before resorting to imports, but in planning future capacities they must take into account that steel-making facilities, once installed, must be on-going. The locally available scrap supply might seem ample at first, but, in reality, it only suffices for a year or two of production, proving insufficient thereafter, and necessitating costly imports of scrap.

Sponge iron as a substitute metallic source will hardly replace scrap before 1985. Global sponge iron capacity was of the order of 10 million tons in 1974, and almost wholly captive, the sponge iron being totally consumed in the steel-making process of its manufacturers. Facilities representing another 10 million tons capacity are under construction or active consideration in the Federal Republic of Germany, Saudi Arabia, the United States, and elsewhere. These amounts, from these plants, however, could only replace but a small fraction of the scrap, the demand for which may conceivably be as high as 500 million tons in 1980. Even if, as some predict, sponge iron production reached the 50-60 million-ton level in 1985, it could still only compensate some 10-20 per cent of the scrap demand in that year. It is clear that until well beyond 1985 sponge iron will serve as a supplement to, and not a substitute for, scrap.

Scrap in the developing countries is obviously limited since most developing countries, by definition, are only now beginning to establish the industrial plant to manufacture capital goods with a high steel content. As the manufacturing sectors of these countries expand, more industrial scrap will be locally available; however, this process will not transpire overnight. If they have not already done so, developing countries might set about systematizing the assessment and collection of their local metallic scrap supplies: a measure vital to any country contemplating electric furnace steel-making.

Atomic energy and steel-making

The application of atomic energy to steel production would involve the use of a reactor to generate both electricity and the hot reducing gas needed in the direct reduction process. Two methods are considered feasible:

(a) Using the heat from a high-temperature, gas-cooled reactor to re-form hydrocarbon gas for the direct reduction of iron ore, the 1,600°F + temperature being indirectly supplied by the hot helium from the reactor. The direct reduction sponge iron thus obtained would be refined to steel in an electric furnace powered by heat from the reactor.

(b) Using reactor heat to obtain hydrogen (by splitting water) which is then used for the direct reduction of iron ore obviating the use of fossil fuel.

The overriding problem is to design a safe, long-life catalytic reformer that can be heated by hot helium gas from the reactor. Among the countries now active in developing this technology are: Germany (Federal Republic of), Japan, Switzerland, the United States, and the USSR.

In the Federal Republic of Germany, research on high-temperature gas-cooled reactors has long been under way at the Jülich nuclear research plant in co-operation with General Atomic of San Diego and the Government of Switzerland. The main lines of development are directed towards nuclear coal gasification and direct reduction.

In Japan, the drawingboard design of a 50 mW multi-purpose high-temperature gas-cooled reactor (1,000°C) has been completed by the Japan Atomic Energy Research Institute which is also testing materials (e.g. hastelloy) for reactor construction. An in-pile gas loop is being built at Oarai. Other work is being carried out by the Agency of Industrial Science and Technology on a basic design for a pilot steel plant for completion in 1978. The key components of this plant will be a steam reformer and a heat exchanger.

In Switzerland, the Confederate Institute for Reactor Research is studying the application of high-temperature gas-cooled reactor process heat to steel-making as well as to zinc and aluminium production.

In the United States, the Energy Research and Development Administration is reportedly planning a crash development programme for high-temperature gas-cooled reactors which could be used in the steel as well as other industries. General Atomic of San Diego has built 1,000°F steam-producing reactors and is now studying the construction of high-temperature gas-cooled reactors capable of achieving the 1,600°F + necessary to produce steel. Leading United States steel companies and the American Iron and Steel Institute are also studying the employment of high-temperature gas-cooled reactors.

In the USSR, the Atomic Energy Institute (I. V. Kurchatov) is studying the use of nuclear reactors to provide electric energy and process heat in the metallurgical industries.

A number of other agencies are studying nuclear steel-making under the aegis of the European Nuclear Steelmaking Club, established in 1973.

These include: British Steel Corporation, United Kingdom; Centre de Recherches Metallurgiques, Belgium; Institut de Recherches de la Siderurgie Francaise, France; and Centro Sperimentale Metallurgico, Italy.

Figure 1. Distribution of resources of raw material for the iron and steel industry

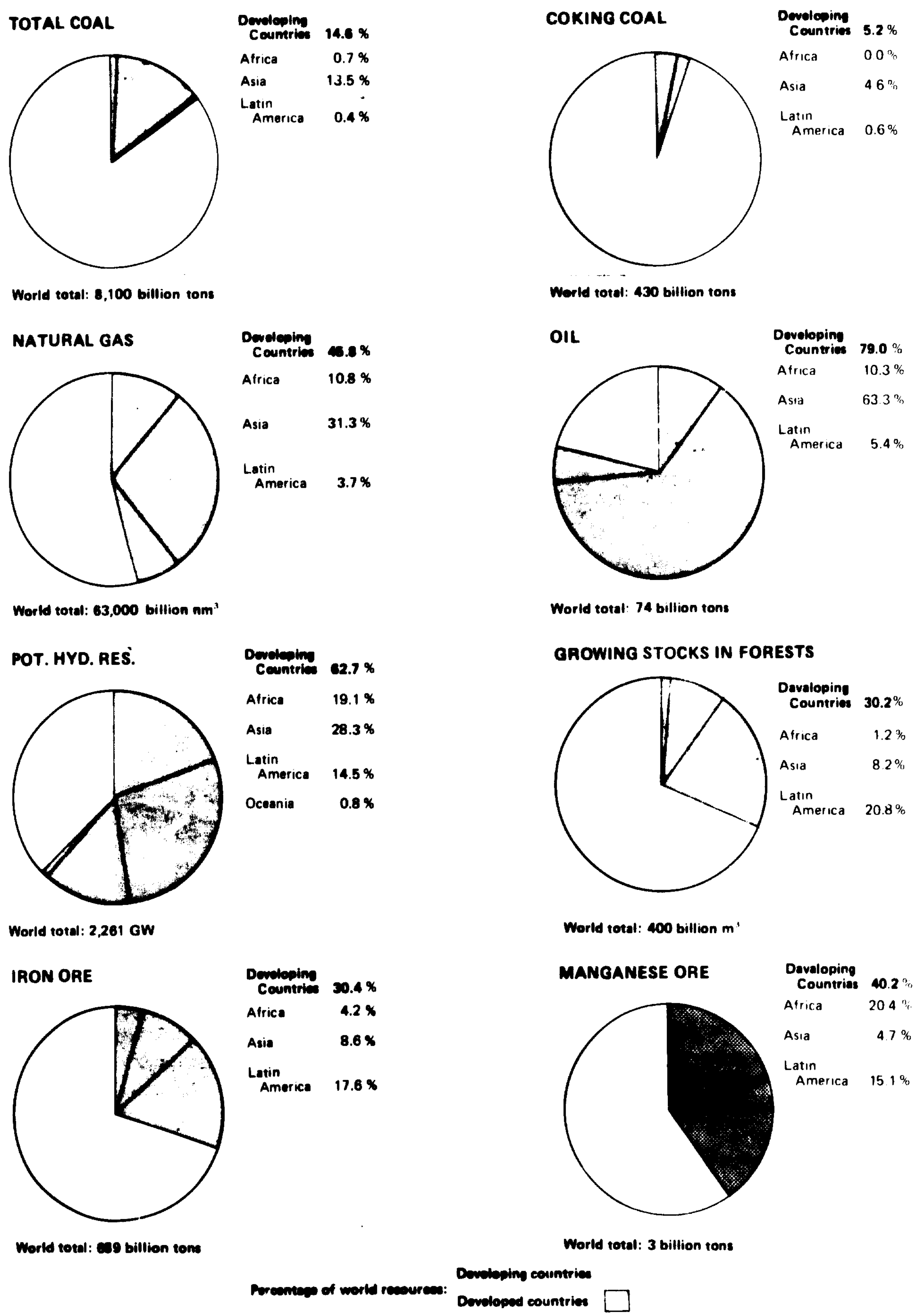


Figure 2. Assessment of developing countries' natural resources for establishment of an iron and steel industry

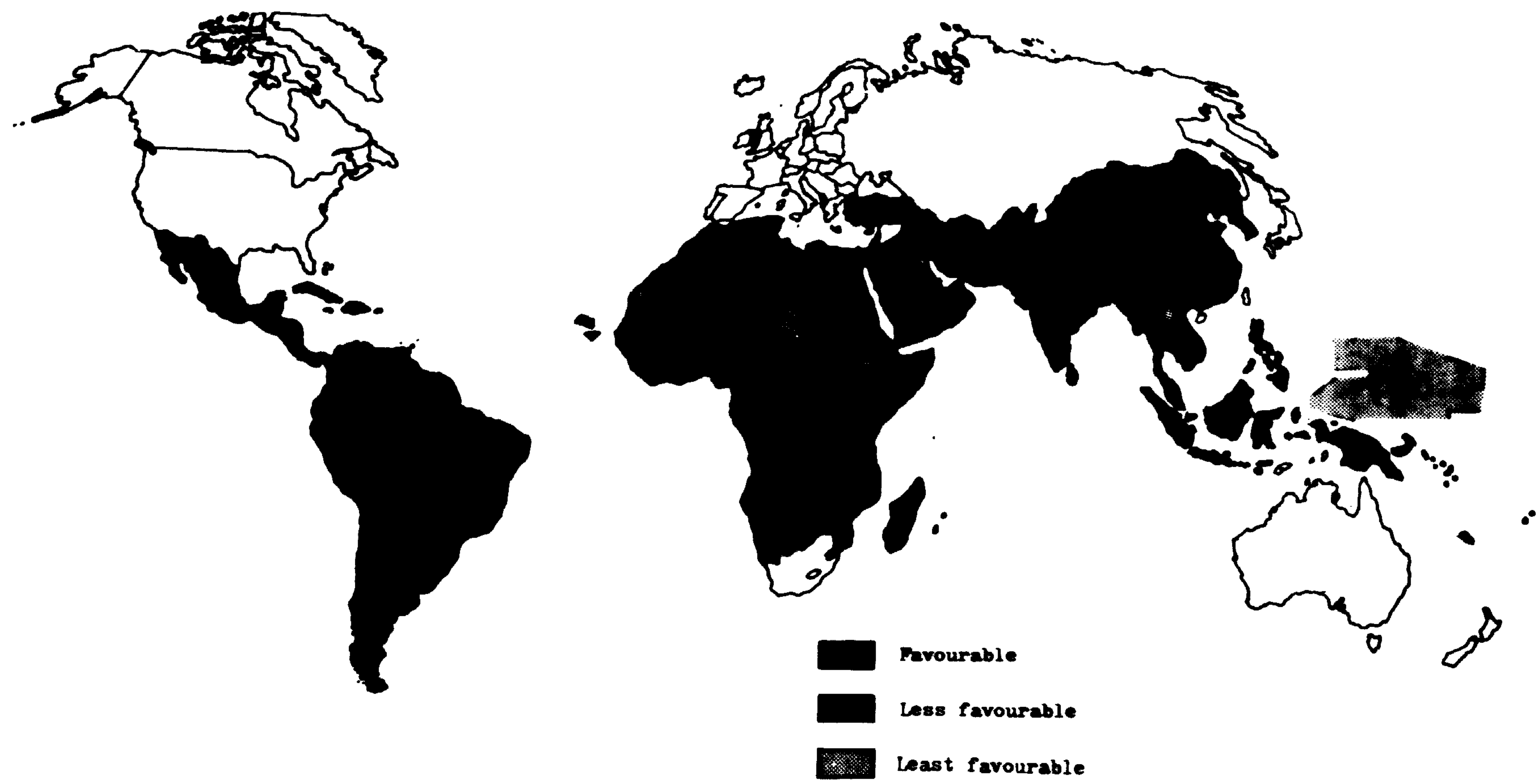


Table 1. Energy requirements for the iron and steel industry: [illegible] countries, [illegible]

Figures shown as absolute value / percentage (percentage below the line).

	[illegible]							[illegible]						
	Total	of which					Coking coal	Total	of which					Coking coal
	million tce	Coal million tons	Coke million tons	Oil million tons	Natural gas billion m^3	Electricity billion kWh	for coke million tons	million tce	Coal million tons	Coke million tons	Oil million tons	Natural gas billion m^3	Electricity billion kWh	for coke million tons
World	666 c/ / 100.0	6[illegible] / [illegible]	[illegible] / 39.[illegible]	[illegible] / 17.7	[illegible] / 15.5	31[illegible] / 18.0	441	606-7[illegible] / 100.0	[illegible]-64 / [illegible].1	3[illegible]-35[illegible] / 45.[illegible]	1-[illegible] / 0.3	88-102 / 19.3	464-537 / 25.3	464-536
Developing countries a/	115-1[illegible] / 100.0	9-10 / 7.9	44-49 / 34.4	12-13 / 17.4	22-24 / 15.4	61-68 / 24.9	66-74	182-227 / 100.0	18-[illegible] / 9.9	101-126 / 49.8	1-1 / 0.7	23-28 / 23.1	128-152 / 16.5	152-189
Developing countries b/	80-99 / 100.0	6-12 / 7.4	29-34 / 32.3	8-9 / 14.5	44-52 / 18.1	17-19 / 27.8	44-51	141-175 / 100.0	14-17 / 9.6	76-94 / 48.4	1-1 / 0.6	19-23 / 23.9	102-127 / 17.5	114-141
Africa	10-11 / 100.0	0.3-0.4 / 3.2	1.7-2.0 / 15.8	0.5-0.5 / 7.4	3.5-4.2 / 24.2	7-9 / 49.5	3-3	20-25 / 100.0	1-1 / 5.0	5-7 / 24.4	- / -	5-6 / 36.8	22-28 / 33.8	8-11
Asia a/	67-74 / 100.0	6-7 / 8.9	26-29 / 39.0	8-9 / 17.4	10-11 / 15.7	32-35 / 19.0	39-44	103-130 / 100.0	11-14 / 10.8	62-79 / 54.1	1-1 / 1.[illegible]	10-13 / 20.6	64-81 / 13.3	93-119
Asia b/	3[illegible]-38 / 100.0	3-4 / 9.0	14-17 / 39.1	4-5 / 17.4	5-6 / 15.5	15-18 / 19.0	21-26	61-78 / 100.0	7-9 / 1[illegible].9	37-47 / 54.4	1-1 / 1.3	6-8 / 20.3	37-49 / 13.1	56-71
Latin America	38-44 / 100.0	[illegible] / 7.1	13-15 / 31.[illegible]	4-4 / 13.9	8-10 / 18.6	22-25 / 29.4	20-23	60-71 / 100.0	6-7 / 10.1	34-40 / 50.[illegible]	- / -	7-9 / 23.0	42-50 / 16.1	51-60

Conversion factors: 1 ton coal = 1 ton coal equivalent (tce) = 7 million kcal = 7,000th; 1 ton coke = 0.9 tce;
1 ton fuel oil = 1.[illegible] tce = 10,000th; 1,000 m^3 natural gas = 1,332 tce; 1,000 kWh electricity = 0.33 tce;
1 ton coking coal = 0,665 tons coke.

a/ Including China. b/ Excluding China. c/ Figures in denominator percentage.

Table 2. Energy consumption, 1985-2000

Region	Total energy 1974		Total energy consumption 1985		Total energy consumption 2000		Energy consumption in iron and steel 1985		Energy consumption in iron and steel 2000	
	Million tce	Per cent	Million tce	Per cent	Million tce	Per cent	Million tce	Percentage of total energy consumption	Million tce	Percentage of total energy consumption
World	7,971	100.0	11,300	100.0	18,300	100.0	666	5.9	606-700	3.3-3.8
Developing countries a/	1,329 c/	16.7	3,366	29.8	10,576	57.8	115-129	3.4-3.8	182-227	1.7-2.1
Developing countries b/	803 c/	10.1	2,345	20.8	7,876	43.0	80-99	3.4-4.2	141-175	1.8-2.2
Africa	140	1.8	213	1.9	416	2.3	10-11	4.7-5.2	20-25	4.8-6.0
Asia a/	866	10.9	2,678	23.7	9,314	50.9	67-74	2.5-2.8	103-130	1.1-1.4
Asia b/	344	4.3	1,657	14.7	6,614	36.1	32-38	1.9-2.3	61-78	0.9-1.2
Latin America	319	4.0	475	4.2	846	4.6	38-44	8.0-9.3	60-71	7.1-8.4

Source: World Energy Supplies, 1950-1974, United Nations, 1976, Series JN 19;
E. Parikh, "Energy problems of developing countries", Working paper, IIASA, Laxenburg, 1976; and UNIDO.

a/ Including China (in 1985: 1,021 million tce; in 2000: 2,700 million tce).

b/ Excluding China.

c/ Including Oceania (4 million tons in 1974).

Table 3. World reserves of raw materials needed for iron and steel industry

Country	Total coal 1/		Coking coal 2/		Natural gas 1/		Oil 1/		Potential hydraulic reserves 2/		Growing stocks in forests 4/		Iron ore 5/		Manganese ore 5/	
	million t	Per cent W.	million t	Per cent W.	billion m^3	Per cent W.	million t	Per cent W.	GW	Per cent W.	million m^3	Per cent W.	million t	Per cent W.	million t	Per cent W.
World Total	8,134,374	100.0	429,732	100.0	62,846	100.0	74,280	100.0	2,261.0	100.0	395.020	100.0	[illegible],000	100.0	3,000	100.0
Developing countries	1,193,293	14.6	22,167	5.2	28,846	45.8	58,679	79.0	1,416.5	62.7	122,267	31.0	209,827	30.4	1,206	40.2
Africa 6/	59,120	0.7	...	...	6,788	10.8	7,632	10.3	432.5	19.1	4,607	1.2	28,658	4.2	611	20.4
North Africa	141	n.g. 8/	...	...	4,936	7.9	4,68[illegible]	6.3	25.8	1.1	206	0.1	6,288	0.9	69	2.3
West Africa	359	n.g.	...	...	1,370	2.2	2,495	3.4	53.2	2.4	1,336	0.3	11,967	1.7	79	2.6
East Africa	7,935	0.1	...	...	72	0.1	-	-	140.1	6.2	2,827	0.7	2,428	0.4	2	0.1
Central Africa	720	n.g.	-	-	399	0.6	457	0.6	206.1	9.2	241	0.1	7,61	1.1	460	15.3
Southern Africa	49,965	0.6	...	...	11	n.g.	-	-	5.4	0.2	...	...	[illegible]	0.1	1	n.g.
Asia	1,098,588	13.5	19,637	4.6	19,703	31.3	46,998	63.3	639.6	28.3	32,435	8.2	59,283	8.6	142	4.7
East Asia	1,012,450	12.5	9,560	2.2	165	0.3	2,026	2.7	359.1	15.1	7,875	2.0	31,457	4.6	20	0.7
South East Asia	1,771	n.g.	...	...	1,066	1.7	1,856	2.5	173.7	7.6	20,178	5.1	1,780	0.2	17	0.6
Middle South Asia	83,084	1.0	10,077	2.3	11,524	18.3	9,420	12.7	108.7	4.8	3,533	0.9	24,892	3.6	102	3.4
South West Asia	1,335	n.g.	-	-	6,948	11.0	33,694	45.4	18.1	0.8	849	0.2	1,154	0.2	3	0.1
Latin America	35,570	0.4	2,530	0.6	2,355	3.7	4,049	5.4	328.5	14.5	82,195	20.8	121,886	17.6	453	15.1
Caribbean and Central America	10,021	0.1	210	0.1	505	0.8	470	0.6	40.2	1.8	1,480	0.4	3,744	0.5	7	0.2
Tropical South America	19,069	0.2	2,250	0.5	1,572	2.5	3,226	4.3	215.9	9.5	79,368	20.1	115,292	16.7	324	10.8
Temperate South America	4,570	0.1	70	n.g.	278	0.4	353	0.5	72.4	3.2	1,344	0.3	2,850	0.4	122	4.1
Oceania 7/	15	n.g.	-	-	-	-	-	-	17.9	0.8	100	n.g.	-	-	-	-

Source: 1/ Statistical Yearbook 1974, pp. 170-179. Total represents only the summation of the figures shown in the columns of the UN Statistical Yearbook.

2/ Energy Use by the Steel Industry in North America, Battelle Memorial Institute, Columbus, Ohio, 1971; Geological Survey of India News, April 1972.

3/ World Energy Conference Survey of Energy Resources, 1974, Detroit, pp. 151-189.

4/ Data for Asia and Oceania from "Forest resources in the Asia and Far East", FAO, 1976, p. 251. For other continents assessment was made on the basis of world forest resources 1963 (FAO) 340 billion m^3 and estimates of annual growth 1-2 per cent of growing stock. Forest Products Journal, Vol. 26, No.4, April 1976, p.15.

5/ Resources: The World Market for Iron Ore, United Nations, New York, 1968, pp. 26-30, Chernaja metallurgia rasvivaujtschichaja stran, Moscow, 1970, Ministerstvo chernoji metallurgii; Commodity Data Summaries 1974, Appendix I to Mining and Minerals Policy. Third Annual Report of the Secretary of the Interior under the Mining and Minerals Policy Act of 1970, United States, 1975, pp. 80-97; Die Bergwirtschaft der Erde, Die Rohstoffwirtschaft der Länder und ihre Grundlagen, Stuttgart 1976, pp. 1-656.

6/ Excluding Southern Rhodesia and Republic of South Africa.

7/ Excluding Australia and New Zealand.

8/ n.g. - less than 0.1 per cent.

Table 4. Developing countries with favourable conditions in view of their natural resources for an iron and steel industry[a]

	Reserves, 1973							
	Coking coal million tons	Natural gas billion m^3	Oil million tons	Potential hydraulic resources GW	Growing stock in the forests million m^3	Iron ore million tons	Manganese ore million tons	Flared natural gas (1973) billion m^3
Africa								
Algeria	-	3,995	1,272	4.8	...	1,580	-	8.6
Angola	-	41	185	9.7	...	1,100	...	...
Congo	-	142	100	9.0	189	100	-	...
Egypt	-	85	288	3.8	1	433	9	...
Gabon	-	187	172	17.5	...	1,216	450	...
Libya	-	814	3,066	0.2	...	3,525	-	5.3
Morocco	-	1	0	1.0	99	149	50	...
Nigeria	-	1,370	2,495	8.3	...	266	-	20.2
Tunisia	-	41	54	0	...	75	-	...
Zaire	-	29	-	132.0	...	5,079	10	-
Asia								
China	9,500	165	2,026	330.0	7,393	31,000	20	...
India	10,077	70	118	70.0	2,700	21,500	100	...
Indonesia	-	283	1,558	30.0	8,500	500	10	...
Iran	...	10,760	9,308	10.2	...	820	1	28.2
Iraq	-	623	4,865	1.9	42	2	-	7.5
Pakistan	-	459	4	20.0	71	400	1	...
Philippines	...	1	-	7.5	1,968	920	6	-
Saudi Arabia	-	1,589	13,159	0.9	...	406	-	38.0
Turkey	-	3	20	15.2	803	145	...	...
Vietnam (Democratic Republic of)	...	...	...	53.6	912	60	-	-
Latin America								
Argentina	-	198	324	48.1	...	750	100	...
Bolivia	-	136	28	18.0	...	40,000	20	...
Brazil	150	27	101	90.2	76,375	72,000	250	...
Chile	70	80	29	15.8	1,344	1,800	22	...
Colombia	2,100	84	222	50.0	...	120	...	...
Ecuador	-	117	823	21.0	...	2	...	...
Mexico	210	306	399	20.3	595	700	7	23.0
Peru	...	72	74	12.5	2,603	1,170	54	...
Venezuela	-	1,136	1,978	11.6	...	2,000	-	14.6

Source: "Data for flared natural gas", OPEC Annual Statistical Bulletin, 1974, p.11.

a/ Countries that have at least five basic natural sources for iron- and steel-making.

Table 5. Developing countries with less favourable conditions in view of their natural resources for an iron and steel industry[a/]

	Coking coal million tons	Natural gas billion m^3	Oil million tons	Potential hydraulic resources GW	Growing stock in the forests million m^3	Iron ore million tons	Manganese ore million tons	Flared natural gas (1973) billion m^3
Africa								
Cameroon	-	-	-	33.0	...	170	-	-
Dahomey	-	213	-	1.8	1	290	-	-
Ivory Coast	-	-	-	0.8	...	2,400	13	-
Ghana	-	-	-	1.6	1,203	405	30	-
Guinea	-	-	-	6.4	...	1,544	-	-
Kenya	-	-	-	13.4	...	27	-	-
Liberia	-	-	-	6.0	56	4,000	-	-
Madagascar	-	-	-	64.0	1,625	251	...	-
Mali	-	-	-	3.5	...	400	10	-
Mauritania	-	-	-	2.0	2	465	-	-
Mozambique	-	72	-	11.3	...	261	-	...
Niger	-	-	-	9.6	...	680	-	-
Senegal	-	-	-	4.4	70	1,000	-	-
Sierra Leone	-	-	-	3.0	...	290	-	-
Somalia	-	-	-	0.2	...	170	...	-
Sudan	-	-	-	16.0	104	61	10	-
Swaziland	-	-	-	0.7	...	360	-	-
Tanzania	-	-	-	20.8	2	121	-	-
Togo	-	-	-	0.5	6	642	-	-
Upper Volta	-	-	-	12.0	...	50	26	-
Uganda	-	-	-	12.0	115	98	-	-
Zambia	-	-	-	3.8	...	1,500	1	-
Asia								
Abu Dhabi	-	1,764	4,739	-	-	-	-	12.4
Afghanistan	-	...	-	6.0	...	2,110	-	-
Bangladesh	-	235	-	1.3	72	...	...	-
Brunei	-	456	294	-	28	-	-	...
Burma	-	5	5	75.0	3,[illegible]	100	-	...
Korea (Democratic Republic of)	...	-	-	2.0	400	411	-	-
Korea (Republic of)	...	-	-	5.5	74	40	...	-
Kuwait	-	1,112	10,070	-	-	-	-	9.0
Lebanon	-	-	-	...	...	500	-	-
Malaysia	-	323	-	1.3	2,780	150	...	...
Mongolia	...	-	...	-	8	-	-	-
Nepal	-	-	-	...	373	30	-	-
Neutral Zone	-	1,472	1,423	-	...	-	-	...
Oman	-	71	454	-	...	-	-	-
Qatar	-	225	745	-	-	-	-	4.2
Sri Lanka	-	-	-	1.2	107	32	-	-
Syrian Arab Republic	-	35	181	...	...	100	-	...
Thailand	-	-	...	5.2	994	45	1	-
Latin America								
Cuba	-	-	1	...	...	3,000	...	-
Guatemala	-	-	-	1.[illegible]	...	...	...	-
Honduras	-	-	-	[illegible]	[illegible]	[illegible]	-	-
Nicaragua	-	-	-	[illegible]	...	[illegible]	-	-
Trinidad and Tobago	-	198	71	-	...	...	-	...
Uruguay	-	-	-	2.5	...	300	-	-

Source: "Data for flared natural gas", OPEC Annual Statistical Bulletin, 1974, p.11.

a/ Countries that have three to five basic raw materials for iron- and steel-making.

Table [illegible]. Developing countries that lack raw materials for their iron and steel industry a/

	Coking coal million tons	Natural gas billion m³	Oil million tons	Potential hydraulic resources GW	Growing stock in the forests million m³	Iron Ore million tons	Manganese ore million tons	Flared natural gas (1973) billion m³
	Reserves, 1973							
Africa								
Botswana	-	-	-	3.0	...	-	1	-
Burundi	-	-	-	-	...	-	-	-
Cape Verde Islands	-	-	-	-	...	-	-	-
Central African Republic	-	-	-	11.0	52	-	-	-
Chad	-	-	-	3.4	...	-	-	-
Comoro Islands	-	-	-	-	...	-	-	-
Equatorial Guinea	-	-	-	2.4	...	-	-	-
Ethiopia	-	-	-	9.2	1,015	-	-	-
Gambia	-	-	-	-	...	-	-	-
Guinea-Bissau	-	-	-	0.1	...	-	-	-
Lesotho	-	-	-	0.5	...	-	-	-
Malawi	-	-	-	0.1	10	-	-	-
Mauritius	-	-	-	0.1	...	-	-	-
Namibia	-	-	-	1.2	...	-	-	-
Reunion	-	-	-	0.1	2	-	-	-
Rwanda	-	-	-	-	...	-	-	-
Asia								
Bahrain	-	54	38	-	-	-	-	...
Bhutan	-	-	-	-	210	-	-	-
Cyprus	-	-	-	3	4	-	-	-
Hong Kong	-	-	-	-	...	6	-	-
Jordan	-	-	-	-	...	1	3	-
Kampuchea	-	-	-	-	546	5	-	-
Laos	-	-	-	... a/	1,040	-	-	-
Portuguese Timor	-	-	-	-	...	-	-	-
Singapore	-	-	-	-	-	-	-	-
Yemen	-	-	-	-	...	-	-	-
Yemen (People's Democratic Republic)	-	-	-	-	...	-	-	-
Latin America								
Barbados	-	1	-	-	...	-	-	-
Costa Rica	-	-	-	4.3	...	...	-	-
Dominican Republic	-	-	-	-	...	6	-	-
El Salvador	-	-	-	0.9	...	-	-	
Guadeloupe	-	-	-	...	...	-	-	-
Guyana	-	-	-	12.0	...	-	...	-
Haiti	-	-	-	...	...	-	-	-
Jamaica	-	-	-	...	...	-	-	-
Martinique	-	-	-	...	...	-	-	-
Panama	-	-	-	2.4	361	...	-	-
Paraguay	-	-	-	6.0	...	...	-	-
Puerto Rico	-	-	-	-	...	-	-	-
Surinam	-	-	-	0.3	39?	-	-	-
Windward Islands	-	-	-	...	...	-	-	-
Oceania								
British Solomon Islands	-	-	-	-	50	-	-	-
Fiji	-	-	-	-	30	-	...	-
French Polynesia	-	-	-	-	-	-	-	-
Gilbert and Ellice Islands	-	-	-	-	-	-	-	-
New Caledonia	-	-	-	0.1	1[illegible]	...	-	-
New Hebrides	-	-	-	-	1[illegible]	-	...	-
Pacific Islands	-	-	-	-	-	-	-	-
Papua New Guinea	-	...	-	17.8	-	-	-	-
Tonga	-	-	-	-	-	-	-	-
Western Samoa	-	-	-	[illegible].015	1[illegible]	-		-

Source: "Data for flared natural gas", UN Annual Statistical Bulletin, 1974, [illegible].

a/ [illegible] three basic raw materials [illegible] for iron- and steel-making, especially fuels and ores.

Table 7. Forecast distribution of steel processes, 1974-2000

	Distribution by process								
	Basic Oxygen Process			Electric Furnace			Others (open hearth, Bessemer, Thomas)		
	1974	1985 a/	2000	1974	1985 a/	2000	1974	1985 a/	2000
World	50.6	70	57 b/	17.4	20	41 b/	32.0	10	2 b/
Developing countries	24.7	58	61 a/	21.9	28	35 a/	53.4	14	4 a/
Africa	22.2	35	30 a/	40.7	65	70 a/	33.1	-	- a/
Asia	21.1	60	65 a/	17.5	20	28 a/	61.4	20	7 a/
Latin America	32.8	60	65 a/	28.9	35	35 a/	38.3	5	- a/

a/ UNIDO estimate based on data from Mitchell, Hutchins Inc.

b/ UNIDO Third Interregional Symposium on the Iron and Steel Industry, ID/WG.146/58, Brasilia, October 1973.

Chapter VI

CAPITAL REQUIREMENTS

According to one of the projection variants presented in Chapter II, it is conceivable that raw steel-making capacity of the order of 446 million tons will be built in the developing countries between 1975 and 2000. A tentative evaluation of the capital required to install this capacity is given in this Chapter. It goes without saying that an evaluation of this kind can only be very approximate since the capital required to build one unit capacity of raw steel varies widely according to a host of factors, the majority of which cannot be taken into account in the present context.1/

Variability of capital cost

The wide range of possible capital cost variations can be seen in Table 1, which shows the capital cost of recently established plants: costs vary between $200 and $750 per ton of raw steel (a ratio of 1:3.6) at 1975 prices.

The cause and effect relationship determining the ultimate capital cost is far too complex to be analyzed in detail here. It is possible, however, to differentiate between two broad categories of factors: the macro-parameters, on the one hand, adduceable to the environment in which the capacity is installed (for example, the cost of land, transport, and interest rates), and the micro-variables, on the other, reflecting technical alternatives. Among the latter variables, the choices of scale, process and product mix are of particular importance in determining the capital cost.2/

Tables 2 and 3 show examples of functions relating capital costs to technical variables. According to estimates provided by plant manufacturers for 1975, the capital cost of greenfield plants (BF/BOF route) decreases by as much as 100 per cent as plant size increases from 0.2 to 5.0 million tons (Table 2), while an increase from 1.0 to 5.0 million tons still offers capital cost savings of 22 per cent.

1/ In this Chapter the term 'capital cost' will be used to define the amount of dollars required to install annual capacity of one ton of raw steel, regardless of the level of capacity utilization.

2/ These variables are separated solely for expository convenience. It should be clear that the options concerning product mix, rocess, the level of capacity utilization and scale are interrelated.

Table 1. Estimated capital costs of some new steel-producing facilities

Capacity		Process sequence	Cost		
Raw steel	Finished steel		Raw steel	Finished steel	Total
(tons/year)			(Dollars per ton)		(Millions of dollars)
50,000	47,000	35 ton EF, continuous caster, small hot mill	240	255	12
50,000	47,000	D-R plant, 35 ton EF continuous caster, small hot mill	340	361	17
100,000	94,000	70 ton EF, continuous caster, small hot mill	230	245	23
100,000	85,000	70 ton EF, ingot casting, small hot mill	210	245	21
500,000	450,000	2-150 ton EF, continuous caster, merchant mills	320	355	160
500,000	450,000	D-R plant, 2-150 ton EF, continuous caster, merchant mills	426	475	213
500,000	375,000	2-150 ton EF, ingot casting, primary and merchant mills	370	500	185
500,000	450,000	1-1500 t/day blast F, coke plant, 1-100 ton BOF F, continuous caster, merchant mills	610	670	305
500,000	450,000	3-200 ton O.H. F, continuous caster, merchant mills	340	380	170
1,000,000	900,000	3-200 ton EF, continuous caster, hot mill (flat), merchant mill	346	385	346
1,000,000	900,000	D-R plant, 3-200 ton EF, continuous caster, hot mill (flat), heavy structural mill	606	670	606
1,000,000	750,000	3-200 ton EF, ingot casting, primary mill, hot mill (flat), merchant mills	390	520	390
2,000,000	1,600,000	1-6000 t/day blast F, sinter plant, coke plant, 2-150 ton BOF. plant, continuous caster, hot mill (flat), merchant mills	477	600	955
2,000,000	1,600,000	D-R plant, 6-200 ton EF, continuous caster, hot mill (flat), cold mill, galvanizing	482	603	965
8,000,000	6,000,000	Fully integrated plant: blast furnaces, coke plant BOF, continuous casters for merchant, bar and structural mills, continuous hot mill, hot and cold sheet mills, coated products, plate mill	675-750	900-1,000	6,000

Source: Paul Marshall, "A study of steel prices", Washington D.C. 1976.

As shown in Table 3, a similar phenomenon can be observed in the case of the DR/EF process. Capital cost degression can be significant up to a capacity of 0.5-0.6 million tons. Within this range, cost degression is more pronounced in DR plants than in EF plants.

Table 2. Capital cost of a BF/BOF plant in relation to plant size

Plant size (thousands of tons)	Index of capital cost
200	213
300	180
400	164
500	155
600	146
700	140
1,000	129
2,000	115
3,000	110
5,000	100

Source: Commodities Research Unit Survey.

Table 3. Capital cost of a DR/EF plant in a developing country in relation to plant size

Plant size (thousands of tons)	Index of Capital Cost				
	DR Plant	Site and other costs	DR cost	EF cost	Total a/
200	103	27	130	79	170
300	88	23	111	67	145
400	80	20	100	61	131
500	75	18	93	56	121
600	71	17	88	52	114
700	69	16	85	51	111
1,000	68	15	84	50	109
2,000	68	15	84	49	108
3,000	68	14	83	49	107

a/ EF capital cost plus 70 per cent of DR capital cost.

Source: Commodities Research Unit Survey.

Figures 1 and 2 illustrate examples of cost degression related to both capacity and production techniques. On the basis of historical data, Figure 1 shows the capital cost curve for blast furnaces. Figure 2 presents the capital cost curve for a basic oxygen furnace and both two-converter (one always in operation) and three-converter (two always in operation) systems.

Fig. 1. Capital cost per ton - capacity of blast furnace

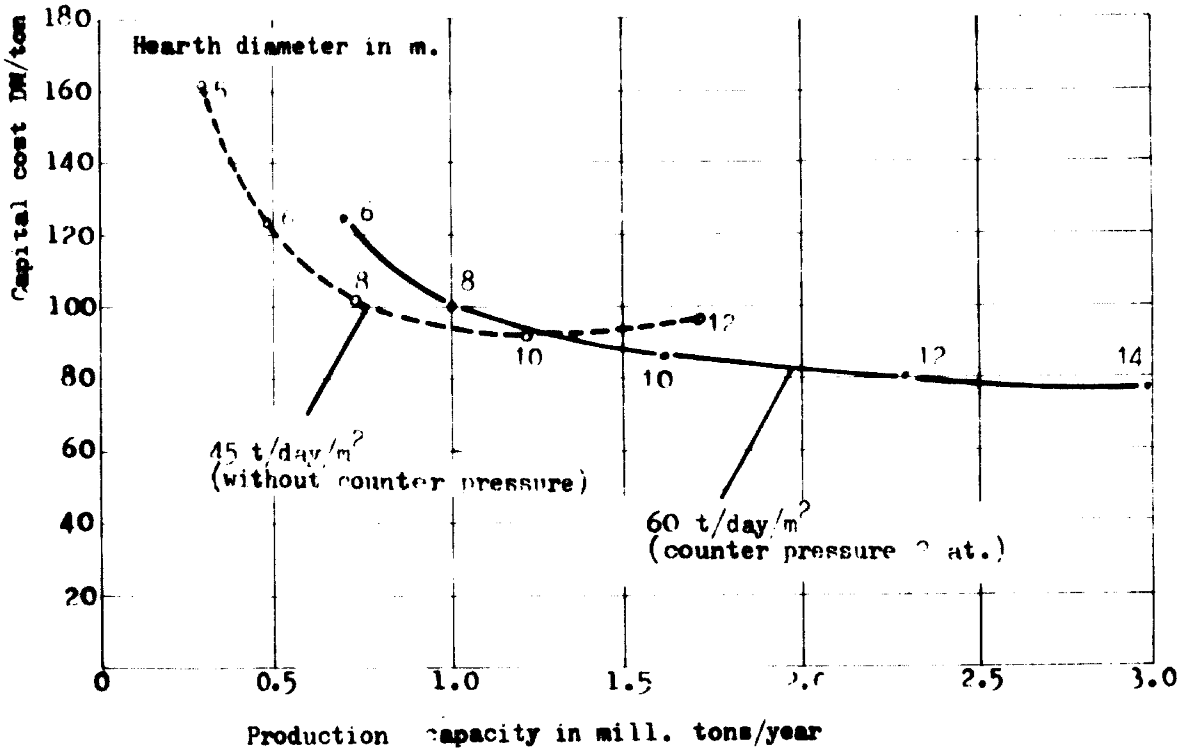
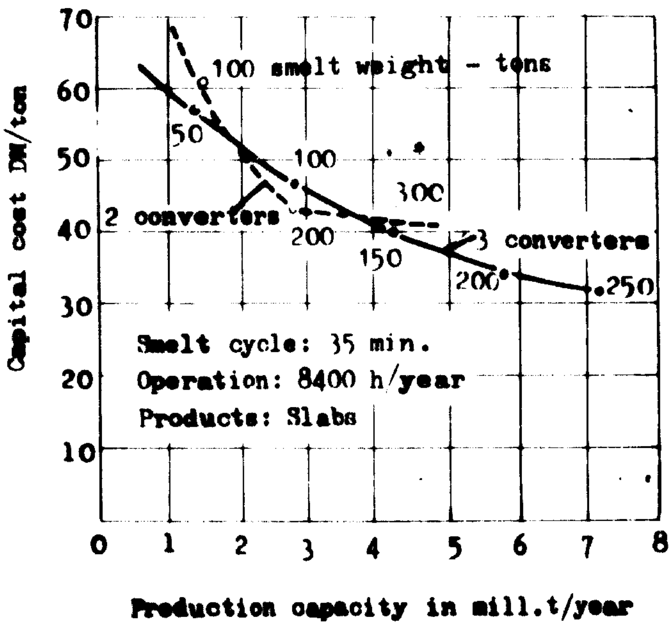


Fig. 2. Capital cost per ton - capacity of basic oxygen furnace



Source: Stahl u. Eisen, 90 (1970), No. 4.

The third technological variable which appreciably influences capital cost is product mix. The capital cost of rolling and finishing mills varies between $90 and $300 depending on the size and product mix involved: the upper limit increases even more when heavy structurals, nails and wire are among the items produced.

The economic production of 'rounds', such as wire rod, concrete reinforcing bars, light and medium structurals (which account for over 50 per cent of steel consumption in most of the developing countries) starts at a scale of 100,000 tons per year. Merchant bars require an investment of some $70 per ton, while production of the main types of flat-rolled products becomes economic in the 1-3 million ton range.

Technological assumptions

As a point of reference for the evaluation of total capital requirements, it has been assumed that a typical BF/BOF facility would have an annual capacity of 3 million tons of raw steel. As for the DR/EF route, it has been assumed that most prospective users in the developing countries will be concerned with steel-making facilities in the range of 200-300 tons per day (i.e. up to 100,000 tons per year). This scale of production can be achieved by a newly erected DR/EF integrated installation or through the backward integration of a re-rolling or scrap-melting and EF operation. The capacity of such integrated mills (DR/EF route) may rise to 0.4 - 0.5 million tons, given the appropriate bar, rod and section rolling facilities.

A comparison of capital costs for flat and non-flat product mixes should encourage the developing countries to give priority to non-flat products, if such a policy is consistent with market requirements. In estimating average capital costs, it is assumed that the rolling and finishing sections of the steel plant will be oriented towards non-flat products, though not exclusively so.

Capital cost assumptions

In view of the wide variation in capital costs, a certain degree of eclecticism becomes necessary. In this Chapter, therefore, it has been decided to focus on two figures of reference: the first, $690 for a 3-million ton BF/BOF facility; the second, $312 for a 0.5 million ton

DR/EF facility, including a direct reduction unit meeting 70 per cent of the metallic requirement of the electric furnace. The figures have been obtained on the basis of both published information and private sources and should be considered to represent the averages for the 1970s.

Capital cost structures for the BF/BOF route are shown in Table 4, and those for the DR/EF route in Table 5. In estimating the capital costs shown in Tables 4 and 5, the following elements were not considered:

(a) Mining. The investment necessary for the extraction and beneficiation of iron ore (including pellet plant) may amount to $100 per ton, while coal mining may require an investment of $30-40 per ton.

(b) Power. An in-plant power station and power grid may have to be constructed. Construction costs will be influenced by numerous factors, such as distance, capacity, voltage and route conditions.

(c) Housing. Investments of this kind are frequently associated with major steel facilities.

(d) Contingencies and unforeseen needs. It is usual practice to add 10 per cent to the estimated basic capital costs to cover construction delays.

(e) Interest paid during the construction period.

Of the components included in the calculations, the following items deserve some comment:

(a) Materials handling facilities. Together with an ore agglomeration plant and a coke plant, these facilities are considered part of the capital cost in the case of the blast furnace process.

(b) Utilities and services. Capital investment requirements include: oxygen plant, water supply facilities, repair and maintenance shops, laboratories and office buildings.

(c) Spare parts. These are estimated to range between 5-7 per cent of the value of the related equipment.

(d) Fixed assets. These account for 68.9 per cent of the total capital costs in the BOF plants and 74.5 per cent in DR/EF plants.

(e) Pre-operating expenses. These comprise the costs of training the management, maintenance and operating personnel.

(f) Costs of project implementation. These are based on the assumption that new steel capacity for the production of 2-3 million tons per year requires a minimum of 5 years for completion in developing countries which have little experience of steel-making.

(g) Infrastructural investments. These estimates of infrastructural costs are based on several Latin American and European projects. For a 3-million ton steel-making facility, it has been estimated that such installations may require an investment of around $200-250 million, including port facilities. Thus, infrastructural costs may range between $67-83 per ton.

(h) Working capital. In the case of BF/BOF mills, the working capital requirement is based on experience in Latin America. The DR/EF working capital requirement has been estimated on the assumption that requirements for this process are much lower than those for the more complex BF/BOF mills.

(i) Prices. The estimates are based on 1975 prices. Consequently, their validity is conditional upon the stability of the price system of that year. As long as price increases do not alter the system of relative prices (i.e. they affect uniformly all goods and services, which is most unlikely), the same amount of real resources will be needed to build one unit of raw steel capacity. In such a case, nominal capital costs should be multiplied by the general price index. If, however, the prices of components needed in steel-making facilities tend to rise at a disproportionately greater rate than the prices of other goods, more real resources will be needed to erect such facilities. In the latter case, both nominal and real capital costs should be revised upwards.

Total capital requirements in developing countries

On the basis of the two reference figures ($690 and $312), the total capital required to build 446 million tons of steel-making capacity can be estimated. As a preliminary step, however, further assumptions in respect of the structure of future capacity are necessary. Basically, this structure is tripartite:

1. The construction of new (greenfield) steel plants;
2. The extension of existing steel facilities (round-out);
3. The replacement of worn-out or obsolete capacity.

The first type of installation will comprise plants with a coke-oven-cum-BF/BOF-complex as well as smaller plants with electric furnaces and simplified rolling mill equipment. Apart from being more economical, a smaller mill, based on an electric furnace with continuous casting and bar mill, constitutes a means of launching a steel industry, as well as a flexible means of expanding an existing industry. However, as an electric furnace mill cannot be expected to cover more than 40 per cent of the greenfield capacity to be installed, it has been estimated that the average capital cost of greenfield mills would be of the order of \$600 per ton of capacity. In respect of investment in capacity extension, an average figure of \$360 per ton of capacity has been adopted, and for replacements, an average figure of \$300.

Table 6 shows the assumed distribution of the installation of 446 million tons of capacity according to the three types of investment. Table 7 uses the capital cost figures of \$600, \$360 and \$300 to show the amount of capital required to build up the total capacity for these three types of investment.

The total capital expenditure figure obtained for 1975-1985 is \$62 billion; that for 1986-2000 is \$169.5 billion; and the total for 1975-2000 is \$231.5 billion. The net investment required (gross less replacement) in developing countries would be \$215.6 billion (\$60.2 billion in 1975-1985, and \$155.4 billion in 1986-2000). Assuming a continuous flow of capital expenditure and a discount rate of 10 per cent, the actual value of the total net investment would be \$68 billion. This figure was obtained by applying the following formula:

$$E = \int_0^{10} I_1 \, e^{-rt} \cdot \, dt + \int_{10}^{25} I_2 \, e^{-rt} \, dt$$

where E is the actual value of the total net investment, I_1 is the annual rate of expenditure during 1975-1985, I_2 is the annual rate of expenditure during 1986-2000, and r is the discount rate.

According to United Nations statistics, the GDP of developing market economies was $601 billion in 1973.[3] Allowing for annual growth rates in real GDP of 2 per cent and of 5 per cent in price levels, the GDP of the developing countries would be of the order of $688 billion in 1975. The ratio between the 1975 value of net investment and that of GDP is approximately 9.9 per cent. In other words, given a discount rate of 10 per cent, the actual value of investment required to create an additional capacity (total capacity less replacement capacity) of 403 million tons of raw steel is equivalent to 9.9 per cent of all goods and services produced by the developing countries in 1975. Distributed over 25 years, annual expenditure would amount to 0.40 per cent of the 1975 GDP of the developing countries.

Another way of comparing the investment required with the investment ability of developing countries is to divide the sum of investment needed by the sum of annual GDP expected between 1975 and 2000. Assuming a GDP growth rate of 5 per cent, the latter sum would amount to $34,482 billion, and the net investment of $215.4 billion would be equal to 0.6 per cent of this amount.

3/ United Nations, Yearbook of National Account Statistics, Vol. III, 1975.

Table 4. Capital costs (BF/BOF route)
(3 million tons/year, 1975)

	Millions of dollars	Installed steel-making capacity (dollars per ton)	Capital cost structure (Per cent)
Coke plant	168.0	56.0	8.6
Blast furnace	225.0	75.0	11.6
Basic oxygen furnace	130.0	43.0	6.6
Continuous casters	131.0	43.0	6.6
Mixed rolling facilities	563.0	188.0	29.0
General facilities	125.0	42.0	6.5
Sub-total, fixed assets	1,342.0	447.0	68.9
Engineering, procurement and inspection (5 per cent of fixed assets)		22.0	3.4
Administration, advisory and expediting costs (6 per cent of fixed assets)		27.0	4.2
Pre-operating expenses (3 per cent of fixed assets)		13.0	2.0
Sub-total, project implementation and pre-operating expenses		62.0	9.6
Fixed capital costs		509.0	78.6
Infrastructural investments		72.0	11.1
Sub-total, fixed capital costs plus infrastructure		581.0	89.7
Working capital (15 per cent of fixed assets)		67.0	10.3
		648.0	100.0
Interest paid during implementation [a]		42.0	
GRAND TOTAL		690.0	

a/ Interest has been calculated for a four-year period based on averages of $447 + $72 = $519 on the assumption that half this sum would be financed through a loan at 8 per cent interest.

Table 5. Capital costs (DR/EF route)

	Millions of dollars	Installed steel-making capacity (dollars per ton)	Capital cost structure (Per cent)
DR (350,000 tons)	38.4	77.0	25.5
Electric furnace (500,000 tons)[a]	20.0	40.0	13.2
Six-strand caster (500,000 tons)	22.5	45.0	14.9
Merchant bar mill (450,000 tons)	31.5	63.0	20.9
	112.4	225.0	74.5
Engineering, procurement and inspection (5 per cent of fixed assets)		11.0	3.6
Administrative, advisory and expediting costs (3 per cent of fixed assets)		7.0	2.3
Pre-operating expenses (3 per cent of fixed assets)		7.0	2.3
Sub-total, project implementation and pre-operating expenses		25.0	8.2
Fixed capital costs		250.0	82.7
Infrastructural investments (15 per cent of fixed assets)		34.0	11.3
Sub-total, fixed capital costs plus infrastructure		284.0	94.0
Working capital (8 per cent of fixed assets)		18.0	6.0
		302.0	100.0
Interest paid during implementation[b]		10.0	
GRAND TOTAL		312.0	

a/ Including general and auxiliary facilities.

b/ Interest has been calculated for a two-year period based on averages of \$225 + \$34 = \$259 on the assumption that half of this sum would be financed through a loan at 8 per cent.

Table 6. Structure of expansion in steel-making in the developing countries

(Millions of tons)

	Replacement		Round-out		Greenfield		Total new installation		Total installation including replacement	
	1975–85	1986–2000	1975–85	1986–2000	1975–85	1986–2000	1975–85	1986–2000	1975–85	1986–2000
Africa	-	5.0	1.5 c/	10.0 e/	14.0	31.5	15.5	41.5	15.5	46.5
Asia	3.0 a/	20.0 b/	9.0 d/	40.0 f/	37.0	92.0	46.0	132.0	49.0	152.0
Latin America	3.0 a/	22.0 b/	12.0 e/	36.0 f/	36.0	84.0	48.0	120.0	51.0	142.0
Total, period	6.0	47.0	22.5	86.0	87.0	207.5	109.5	293.5	115.5	340.5
Annual average	0.6	3.1	2.3	5.7	8.7	13.8	10.9	19.6	11.5	22.7

a/ Estimated capacity of 1955. b/ Estimated capacity of 1975. c/ 10 per cent of total new installation. d/ 20 per cent of total new installation. e/ 25 per cent of total new installation. f/ 30 per cent of total new installation.

Table 7. Total capital expenditure in steel-making in the developing countries

(Billions of dollars)

	Replacement		Round-out		Greenfield		Total new invesment		Total investment including replacement	
	1975-85	1986-2000	1975-85	1986-2000	1975-85	1986-2000	1975-85	1986-2000	1975-85	1986-2000
Africa	-	1.5	0.5	3.6	8.4	18.9	8.9	22.5	8.9	24.0
Asia	0.9	6.0	3.2	14.4	22.2	55.2	25.4	69.6	26.3	75.6
Latin America	0.9	6.6	4.3	12.9	21.6	50.4	25.9	63.3	26.8	69.9
Total	1.8	14.1	8.0	30.9	52.2	124.5	60.2	155.4	62.0	169.5
Investment expenditure per annum	0.2	0.9	0.8	2.1	5.2	8.3	6.0	10.3	6.2	11.3

Assumptions: Greenfield investment $600/metric ton of steel; Extension (round-out) $360/metric ton of steel; Replacement $300/metric ton of steel.

Total world capital requirements

The total raw steel capacity to be built in the world (China not included) amounts to 38 million tons a year in 1975-1985, and to 51-72 million tons a year in 1986-2000 (depending on the projection variants). Accordingly, capital requirements may be estimated at either $750.5 billion or $885.5 billion (Table 8).

Table 8. World capital needed to replace and expand iron and steel-making facilities
(billions of dollars, 1975)

Plant	Per year, 1975-1985	Per year, 1986-2000 Variant A	Per year, 1986-2000 Variant B
Replaced	7.2	9.0	9.0
Expanded	6.4	9.7	15.1
New	11.8	14.4	18.0
Total	25.4	33.1	42.1
Grand total, period	254.0	496.5	631.5

Financing capital requirements

In financing steel projects, the share of the foreign and local capital components is a major consideration. The ratio between the two differs according to the fixed assets concerned. In major steel projects now under construction in Latin America, the distribution is as shown in Table 9. In general, in the developing countries, 60 per cent of the fixed assets will be paid in foreign currency and 40 per cent in local currency.

Table 9. Average structure of expenditure for fixed assets (1-2 million tons capacity, coking metallurgy)

(per cent)

	Foreign		Local		Total	
Plants and spares	74.0	80.0	25.0	20.0	50.0	100
Structures	6.5	60.0	6.5	40.0	8.0	100
Transport	6.5	88.0	1.0	12.0	4.0	100
Erection	12.0	33.0	34.5	67.0	23.0	100
Civil works	1.0	3.0	33.0	97.0	15.0	100
Fixed assets, total	100.0	57.0	100.0	43.0	100.0	100

Source: World Bank Steel project reports.

Assuming that on an average, 40 per cent of the capital costs would be met from local currency, some $3.7 billion and $6.8 billion foreign exchange would be required annually in the respective periods. Further assuming that, on an average, 50 per cent of these amounts would be financed through medium- and long-term loans, foreign resources required to finance the steel industry in the developing countries (not including China) would be of the order of $2 billion in the period 1975-1985, and $4 billion in the period 1986-2000.

As a comparison, reference is made to the flow of financial resources from selected developed countries[4/] to developing countries and multilateral institutions which amounted to $26.8 billion in 1974 and an estimated $37.5 billion in 1975, and comprised both official and private net disbursements.[5/] The sharp increase from 1974 to 1975 was linked with the rise in private export credits from $2.5 billion to $6.2 billion. The total capital expenditure expected should be related to the capabilities of the developing countries to invest on a large scale in their national economies.

4/ Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany (Federal Republic of), Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom and United States.

5/ World Bank Annual Report 1976, Table No. 3, p.100.

Capital cost and employment created

The direct employment generated by 1 million tons of steel-making capacity may be estimated at 6,500 people. The average figure for capital investment of $600 per ton used in this study implies a figure of $600 million per 1 million ton/year steel-making capacity. With reference to the assumption of 6,500 people employed, this means that $92,300 is required per job. The figure of $600 per ton was applied to all sub-regions and countries, regardless of any specific conditions. This may lead to significant over- or under-estimates of the actual capital needed to establish a job or vacancy under specific circumstances.

Operating costs

Average operating costs have been calculated using data on four 3-million ton capacity steel-making mills, favourably located in the United States, Brazil, Western Europe and Japan, and these are shown below:

	Operating costs (dollars per ton)
BF - Pig iron	98-68
BOF - Raw steel (transfer of pig iron and basic oxygen process)	35.72
CC - Slab (continuous casting, less scrap credit)	8.74
Related general equipment charges (in-plant transportation and general facilities)	9.45
	152.59

In practice, operating costs vary extensively owing to local conditions affecting supplies of energy and raw materials, transport and labour costs, scale of operation, and level of capacity utilization. Costs also vary owing to capital charges. Since the above costs were calculated at the operating level, only depreciation was considered (5.5 per cent of capital investment). Accordingly, an interest rate of 10 per cent would add $21.60 to the operating costs cited above.

Assuming the average figure of $600 per ton used in this study, the capital charges for 1 million tons of installed capacity are shown below. Since the figure of $600 per ton covers various capital requirement components, including working capital, a depreciation rate of only 4 per cent is used instead of 5.5 per cent. Likewise, only 3 per cent (instead of 4 per cent) of the capital investment is calculated for maintenance.

	Per cent	$/ton/year	Millions of dollars
Depreciation	4.0	24	24
Maintenance	3.0	18	18
Return on capital[a]	10.0	60	60
Return on capital	5.0	(30)	(15)
			102 (or 57, if return is 5 per cent)

a/ The return on capital may take on different forms according to the capital structure of the company, but as regards its magnitude, two variants have been calculated.

If this calculation were applied to the investment required to provide a job, annual capital service costs would be $8,770-15,700 per job. The cost structure of steel-making reflects the capital intensity of the industry and its dependence on ore and energy (coke, oil, gas, electricity) prices. The percentual distribution of the inputs in relation to total operating costs is shown below.

Table 10. Cost structure of iron and steel-making at the operating level (BF/BOF)

(Per cent)

	Blast furnace shop	Basic oxygen steel-making	Continuous steel casting
Raw materials and primary energy	84.7	93.0[a]	95.6[a]
Utilities	1.9	1.0	0.3
Labour	5.2	0.8	0.9
Overhead	3.3	0.5	0.5
Maintenance (4 per cent of investment)	2.0	2.9	1.1
Local taxes and insurance	0.1	0.4	0.3
Depreciation (5.5 per cent of investment)	2.8	1.4	1.3
Total costs	100.0	100.0	100.0

Source: Arthur D. Little Steel Report.

a/ Liquid metal from the previous process and transfer costs.

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