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ENHANCED RECUPERATION AND RECYCLING: IMPLICATIONS FOR PRIMARY COMMODITY PRODUCERS IN DEVELOPING COUNTRIES - THE CASE OF FERROUS SCRAP VERSUS IRON ORE

Report by UNCTAD secretariat

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Introduction

1. Within the framework of UNCTAD's work programme on Natural Resources Management and Sustainable Development, the Commodities Division is reviewing the impor-tance of enhanced recuperation and recycling of materials[1] for commodity-producing and manufacturing developing countries. Two studies are being conducted aimed at assessing, respectively, the opportunities and constraints arising from enhanced global recuperation and recycling of materials for commodity producing developing countries, and the pros and cons of increased recuperation and recycling of materials in a given developing country. This paper briefly summarizes some results of this work concerning the use of ferrous scrap in world steel-making and its consequences for iron-ore producing and exporting developing countries.

2. Steel accounts for some 80 per cent of the volume of world metal consumption measured at the level of semi-manufactures.[2] The steel industry is not only very important in most developed countries, it is also the key industry in the process of industrialization in many developing countries. In the latter, including China, iron ore output increased considerably over the past decade, outpacing the growth of world steel production. The question arises as to what extent major producers and exporters of iron ore (for a list of the countries concerned see table A-1 in the annex) have been, or will be, affected by an increasing use of ferrous scrap as raw material for steel production.

3. As figure 1 shows, the share of ferrous scrap in world steel-making has remained virtually unchanged, at about 35 - 38 per cent during the past two decades. However, as will be seen later, these figures reflect important developments in the scrap economy of trends which move in opposite directions and have offset each other. On the one hand, recent technological changes in steel-making have increased flexibility in selecting ferrous inputs:

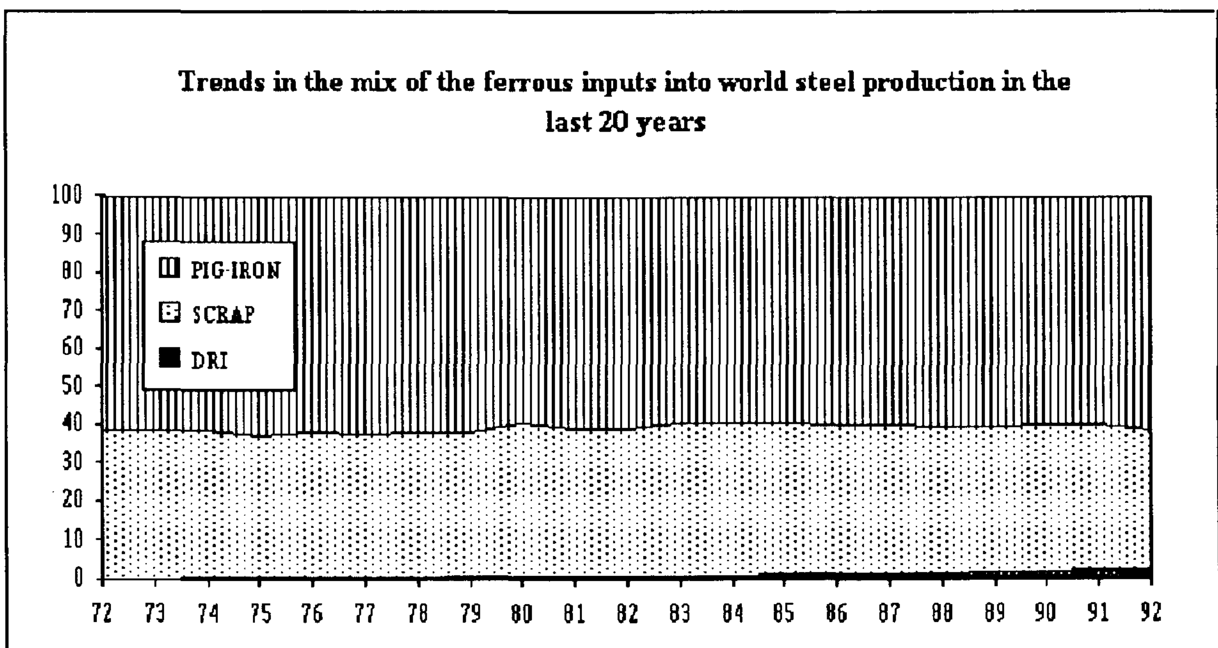


Figure 1 Source: ECE/STEEL/74,UN,New York,1991,p.15; TD/B/CN.1/IRON ORE/8,UNCTAD,Geneva,1993,p.10

pig iron, sponge iron (also called direct reduced iron - DRI[3]) and ferrous scrap. This has encouraged the use of scrap in the input mix of steel production. On the other, there has been a significant change in the sources of scrap and its quality resulting from a technology-induced fall in the availability of home scrap of steel mills which has forceded the steel industry to increase the use of scrap from sources outside its boundries. The supply of clean, top-quality scrap from these sources has, however, not matched demand at a time when cleanness requirements of all charge materials, including scrap, have become more stringent. Furthermore, growing environmental concerns are likely to influence the future pattern of production, consumption and trade of ferrous inputs into steel-making.

4. To review the motives behind the choice between primary and secondary iron, it is necessary to analyze the factors which determine the demand for ferrous scrap for steel-making, notably the desired mix of steel types and grades; changes in the steel-making process; price competition between the ferrous inputs; and environmental considerations. It is also necessary to review the factors which affect the availability of scrap in sufficient quantity and suitable quality.

I. Factors affecting demand

A. Desired mix of steel types and grades

5. The proportions of scrap and iron ore that go into steel-making are a function of the kind of products to be produced. Finished steel products for unspecialized use in general constitute the "mass market" of steel. As quality requirements are not the prime concern, and competitiveness depends principally on cost, these products can be produced on the basis of 100 per cent scrap or a sizeable scrap share, depending on relative prices. This is the case with the so-called mini-mills which, using electric-arc furnaces, make a basic commodity at competitive prices. Conversely, the more important the quality factor is, the greater the tendency to rely on iron ore as the principal ferrous input into steel production. This is typical of conventional large integrated mills, whose production is concentrated on very clean flat and long steel products (for example steel sheets for bodywork in the car industry).

6. From an economic point of view, mini-mills are considered to be very suitable for regions that are beginning to develop and where steel requirements largely comprise mass steel products. The short-process steel-making in mini-mills is also very flexible in its operation (i.e. electric furnaces can be stopped and restarted at will) and is normally a cheap solution, especially in terms of investment (whereas a conventional mill of a capacity of 6 million tons per year requires a unit investment of US$ 1300 per ton of finished steel products, a mini-mill based on scrap needs only about US$ 400 dollars[4]). The problem for most developing countries is, however, that they have only limited scrap resources. With the spread of mini-mills to a good number of these countries, local scrap resources increasingly become insufficient, leading, on the one hand, to increased imports of scrap from developed countries (as can be seen from table A-2 in the annex, developing countries are now the main importers of scrap) and, on the other hand, to enhanced reliance on direct reduced iron ore feeding the larger electric-arc furnaces.

B. Changes in the steel-making process

7. Every steel-making process uses quantities of scrap and iron ore within limits peculiar to itself. Three types of changes in steel-making processes have affected the choice of quantities and qualities of ferrous inputs for crude steel production: (a) changes in the choice of the steel-making reactor, (b) changes in the scrap load of the reactor, and (c) the increased importance of continuous casting.

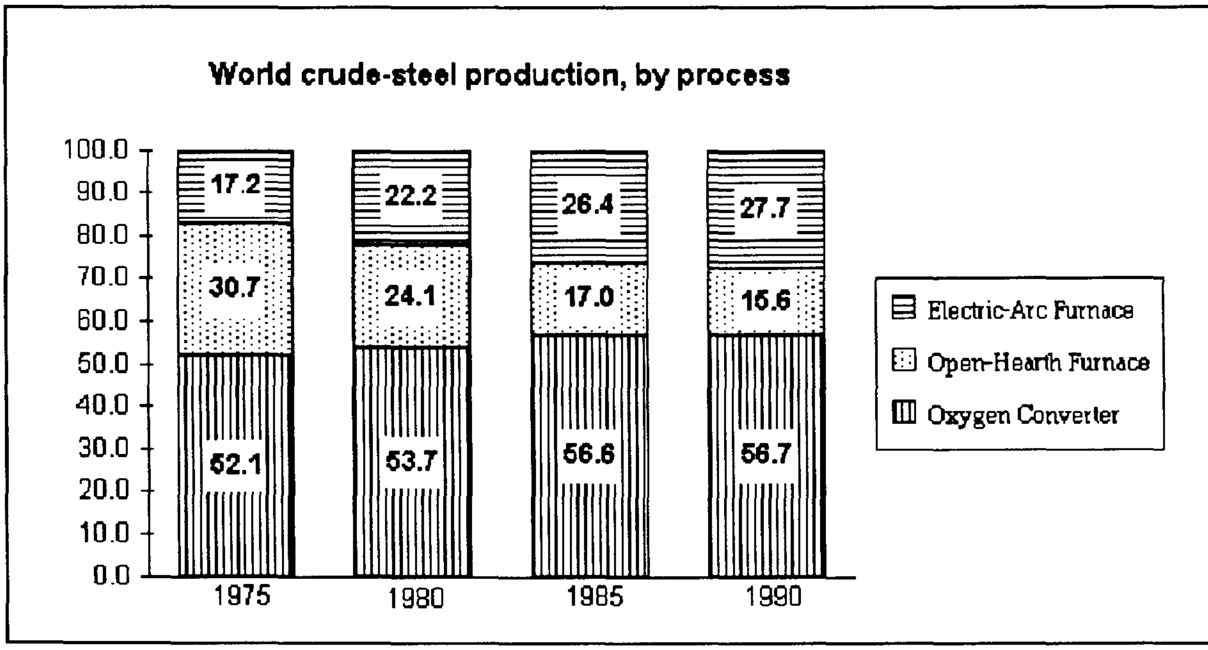


Figure 2 Source: ECE/STEEL/74, United Nations, New York, 1991, p.7

(a) Changes in the choice of the steel-making reactor

8. As can be seen in figure 2, over 15 years there has been a significant shift in the types of converters used for steel-making. At the beginning of the 1990s, about 57 per cent of world crude steel production was made in oxygen converters as against 52 per cent in 1975. In the same period, the share of electric-arc furnaces climbed to almost 30 per cent from 17 per cent while the share of open-hearth furnaces has been halved. The growth in electric-arc furnace steel production has had a significant impact on the volume of scrap utilization in steel-making.

(b) The scrap load of the reactor

9. Electric-arc furnaces can use 100 per cent scrap or DRI with small quantities of pig iron as a possible supplement. In open-hearth furnaces there is a freedom of choice between scrap, pig iron and (up to 30 per cent) DRI; however, a mix of 50 per cent pig iron and 50 per cent scrap is widely used. Basic oxygen converters are mostly charged with pig iron and

some scrap, ranging from 10 per cent (in France and Japan) to almost 40 per cent (in Luxembourg).[5] The trend is for large integrated steel mills based on oxygen converters (and to a certain extent on electric-arc furnaces) to concentrate on flat and heavy products which require top-quality and very clean carbon steel, and therefore (unless scrap can significantly be upgraded) use less and less scrap.

10. New steel-making processes under development permit a far greater flexibility as regards the proportion of scrap in the furnace charge than processes based on oxygen converters. Such new processes would rely on a sort of "modern open-hearth furnace" and the most advanced of them is that involving the Energy Optimizing Furnace (EOF). Various types of the EOF are either in industrial operation or are the subject of trials. Charge-wise, the EOF in operation in Brazil, India and Italy are using approximately 40 per cent scrap in the charge while those on trial are operating with 100 per cent scrap.[6]

(c) Increased importance of continuous casting

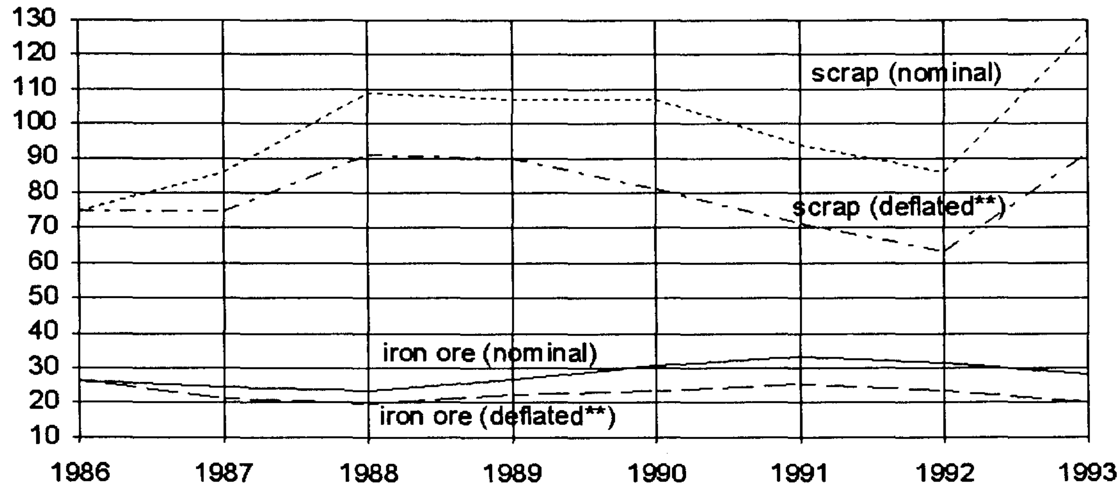
11. Since its introduction in the early 1970s, continuous casting has revolutionized classical steel-making. It replaced ingot manufacturing by integrating blast furnaces, converters, foundries and rolling mills into a continuous process which avoids reheating of the metal. While continuous casting accounted for some 5 per cent of world steel production at the beginning of the 1970s, it is now the characteristic manufacturing route for about 60 per cent of world steel production. As far as scrap is concerned, the rapid introduction of continuous casting has had a twofold effect: on the one hand, continuous casting places much more emphasis on stable steel quality and thus on an almost unchanged chemical composition of steel. This requirement is very difficult to meet as, the higher the share of the scrap load, the more scrap from sources outside the iron and steel industry (with an unknown or unstable quality) is used. On the other hand, the rapid progress in continuous casting has also affected scrap supply. Manufacturing losses have successfully been reduced, leading, in most developed countries, to a decline in circulating scrap per unit of crude steel produced of some 50 per cent during the last two decades (from 200 to 250 kg per ton in 1970 to 80 to 140 kg per ton in 1990[7]). In consequence, both the sources and the quality of available scrap have changed. A decade ago, home scrap (scrap arising in the iron and steel industry with known chemical properties) represented on average about 50 per cent of the total scrap used in steel mills. This share has fallen to about 30 per cent. In this light, scrap verification, preparation and upgrading assume increasing importance; in fact these steps are the essential condition to maintaining or increasing the current position of scrap in the mix of ferrous inputs into steel production.

12. To summarize, the position of scrap in the mix of ferrous inputs into steel-making has remained unchanged so far because counteracting trends have tended to cancel each other out. The rising share of electric-arc furnaces in global steel-making would allow for increased use of scrap, but at the same time the scrap load in conventional oxygen converters has been on the decline, and the availability of consistently clean scrap has become increasingly limited. Scrap upgrading is therefore the key prerequisite to any further significant increase in the share of scrap in the input mix for steel-making.

C. Price competition between ferrous inputs into steel production

13. Price competition between the inputs has to be examined in the light of two sets of variables: the relative prices of the inputs and the overall production costs on the basis of the use of scrap versus iron ore. As far as the latter are concerned, it is cheaper to produce crude steel from scrap, avoiding heavy investments and pollution problems of cokeries and blast furnaces. Furthermore, savings in terms of energy use and waste disposal are substantial. These ecological aspects will be discussed at greater length in section D.

Prices of iron ore versus steel scrap*



*) Iron Ore: Brazil fines, 64.5%, FOB to Europe, US dollars per metric ton / Steel Scrap: annual composite prices in US dollars per long ton for No. 1 heavy melting steel scrap
**) Deflator: unit value of manufactured goods exported by developed countries (1986=100)

Figure 3

Source: American Metal Market; UNCTAD database

14. Price trends of iron ore and ferrous scrap have followed an inverse course during the last few years (figure 3). Evidence suggests that scrap prices have been influenced more by supply constraints than by various factors of demand. The decreasing availability of home scrap and the resulting higher demand for old/purchased scrap from sources outside the iron and steel industry have increased the volatility of scrap prices. As figure 3 illustrates, scrap prices (i.e. prices for shredded steel scrap in the US based on markets in Birmingham, Philadelphia, Chicago, Pittsburgh and Houston) leapt sharply upward on two occasions since the mid-1980s. Moreover, since 1986, real prices for No. 1 steel scrap have increased by some 21 per cent, whereas real iron ore prices fell by 23 per cent.

D. Environmental considerations

15. As more Governments are introducing environmental norms, variables such as waste generation, emission levels and energy savings play an increasingly important role. This has improved the competitive position of scrap inasmuch as its use lowers emissions resulting from steel-making, and leads to raw material and energy savings and lower waste requiring disposal.

16. As far as energy savings are concerned, evidence suggests that electric-arcs melting of 100 per cent scrap generates a net saving of about 65 per cent as compared to oxygen converters based on pig iron[8]. When a conventional oxygen converter is charged with some 20 per cent of scrap, the energy saving as compared to 100 per cent charge of pig iron is estimated at 25 per cent.[9] To put these savings into context, one should add that energy accounts for about 25 - 30 per cent of total operating costs in the major steel producing countries.[10]

17. Turning to raw material savings, the 100 per cent recycling of one ton of flat steel products substitutes for 1.5 tons of iron ore and 0.5 tons of coke. As for emissions, it is estimated that the level associated with the recycling of ferrous scrap is 30 per cent less for air emissions than in the treatment of pig iron and about 60-70 per cent less for water emissions.[11] The recycling of flat steel products produced 1.28 kg less of waste for each kg of steel recycled.[12]

18. In the light of the magnitude of these "ecological" savings, there can be little doubt that as Governments try to internalize environmental externalities and resource costs (i.e. incorporate environmental costs into price formation) the competitive position of ferrous scrap will improve. Internalization might include the compensation for environmental services provided (e.g. relieving the problem of disposal for solid waste) and reduction in expenditures on pollution abatement by adopting ecologically preferable practices.[13]

II. Availability of scrap

19. There are two main types of ferrous scrap: *circulating (or home/revert) scrap* is generated during crude steel production and the transformation of finished into manufactured steel: *old (capital and process or purchased) scrap* is collected outside the iron and steel industries from processing and transforming industries.

A. Quantity factors

20. A constraint to higher scrap usage could be an inadequate availability of scrap. Three variables determine the availability of scrap: the level of generation of scrap; the capacity of the scrap processing industry; and restrictions which limit or distort international trade in scrap.

21. In the second half of the 1980s, between 84 and 93 per cent of annual scrap formation was actually utilized by the industry.[14] This relatively high rate of utilization implies that if scrap demand rises, supply will have to come from scrap contained in the scrap fund (the accumulated unused scrap pile). The margin for an increase in the rate of utilization of scrap emerging every year is thus not very high. The capacity of the scrap processing industry, however, does not restrain a higher scrap utilization. It is generally reckoned that the world scrap-processing industry has an unused capacity of some 30-35 per cent, enough to meet possible increases in demand.[15]

22. The Basel Convention on the Control of Transboundary movements of Hazardous Wastes and their Disposal, the Decision of the OECD Council on the Control of

Transfrontier Movements of Wastes Destined for Recovery Operations and the EU Council Regulation on the Control and Transport of Waste Within and Outside the Union[16] have adopted rules and regulations which also apply to international trade in ferrous scrap. Although these regulations have been adopted on the basis of sound environmental, economic and political reasons (i.e. implementing the self-sufficiency and proximity principles in dealing with waste as well as the attempt to combat trafficking of hazardous waste), as far as waste shipments destined for recovery are concerned, they are sometimes ambiguous or contradictory and have the potential to lead to trade distortions.

23.. For example, under the OECD decision, ferrous scrap is not defined as secondary material but as waste destined for recovery, often difficult to classify according to the three tiers of the OECD waste list (green, amber and red). Although ferrous wastes and scrap in general are recognized as non-hazardous items figuring on the green list of OECD, they may not be shipped as Green Tier wastes for recovery if they are contaminated by other materials or if they are categorized differently by domestic legislation in the exporting or importing country.[17] According to the regulation of the European Union, exports of scrap destined for recovery will only be allowed to countries signatories to the Basel Convention or with which a bilateral agreement on the trade of recyclables has been signed. This constraint, together with the administrative hurdles erected poses the risk of seriously limiting the availability of ferrous scrap in developing countries at just the time when they most need to make use of it for low-cost steel production. As the latter have become the principal market for ferrous scrap (see table A-2) and most of them are net exporters of steel, inadequate supply of ferrous scrap would have to be replaced by DRI inputs.

B. Quality factors

24. As far as the availability of scrap of suitable quality is concerned, the increasing quality demands for end-products of steel are translated into higher steel quality requirements, that is increasingly tighter specifications for steel chemistry. Sophisticated microchip-based CAD/CAM manufacturing processes have also raised the demand for consistently clean steel since even a slight deviation in steel behaviour from the programmed processing pattern can have an adverse effect on production results. Thus improving purity has become a major tool in modern steel metallurgy for tailoring steels with better properties. In this regard, it replaces traditional alloying, enabling substantial improvements of steel performance in a cost-effective way. In this light, one of the preconditions for modern steel-making is the exact knowledge of the chemical composition of all charge materials, including scrap.

25. As mentioned above, the shift in the pattern of scrap formation away from circulating/home scrap and towards purchased scrap has made it more difficult to achieve consistent quality. Purchased scrap often contains contaminating residual elements also known as tramp elements, which cannot currently be completely eliminated in the process of recovery and preparation. Much attention is therefore placed on new scrap-upgrading technologies which can yield high-density uniform size scrap from low-grade feed material. However, technological development in this respect is still at an incipient stage.

26. In the future, quality improvements in purchased scrap can also result from the

campaign "Design for Recycling". It is a systematic approach to management and processing of recyclable structural materials aimed at improving scrap quality and reducing waste. At present, almost all car producers are engaged in the research and development of new processing lines based on design for recycling. It is, however, much too early to draw conclusions concerning its impact on scrap versus iron ore input use.

27. In summary, unless the new regulatory environment for transboundary movement of waste distorts the ferrous scrap trade, the amount of scrap supply is generally sufficient and where shortages occur, in particular in developing countries, imports can meet demand. The far more difficult variable is the availability of ferrous scrap of suitable quality. The reason for the reluctance of producers to increase the scrap load in oxygen converters of integrated steel mills is the fear of uncontrollable steel contamination by tramp residual elements. The higher the steel cleanness standards (like for black plate, deep and extra deep drawing sheet, high strength low-alloyed hot-rolled sheet and plate for critical applications), the greater the reluctance to use scrap in the charge. Therefore, any increase in scrap usage in oxygen converters, particularly as far as the production of flat steel products is concerned, is dependent on improving scrap quality through scrap upgrading.[18]

III. Implications for iron ore producing and exporting countries

28. It has been stated above that, from a metallurgical point of view, modern steel-making technologies have reached a point where producers have almost complete freedom in selecting the mix of input materials as a function of steel quality requirements and price competition between the ferrous inputs (pig iron, sponge iron/direct reduced iron and scrap). For the time being, price competition seems to play a decisive role favouring iron ore use, whose prices fell by about 15 per cent in the period 1991 - 1993, while ferrous scrap prices increased by about 30 per cent. Moreover, scrap prices tend to be very volatile. This conclusion does not take into account, however, mounting international pressure to internalize environmental externalities. Any change in energy prices, amendment of emission norms and/or fees, any mandatory recycling quota, or modifications in taxing products or production based on recuperated inputs will undoubtedly change the competitive edge of ferrous scrap.

29. The major constraint for higher scrap consumption in oxygen converters is the as yet unsatisfactorily resolved problem of scrap quality. Investment in improved scrap preparation and processing procedures is still small and, if investment were to be made in sufficient volume it would most likely increase ferrous scrap prices for some time.

30. As mini-mills and new steel producing processes such as the Energy Optimizing Furnace are increasingly becoming part of integrated steel producing lines (with foundries and rolling mills), quality requirements take priority and thus limit the potential for the use of scrap. Its position is challenged by sponge iron/DRI which, in a good number of developing countries, is readily available at competitive cost (developing countries with chronic scrap deficits, and mainly those well-endowed with natural gas and/or iron ore, are the major sponge iron/DRI producers accounting for about 75 per cent of world output).

31. The new regulatory environment for transboundary movement of waste appears likely to make trade in ferrous scrap administratively more laborious and economically more expensive, if not impossible. This affects, in particular, steel producers in developing countries who might have little choice but to replace scrap by sponge iron/DRI.

32. In the light of the above, producers and exporters of iron ore would only have to reckon with a worsening of the present situation if (a) environmental regulations and, in particular, the internalization of environmental externalities and resources values were to change, (b) significant progress in upgrading of ferrous scrap quality were to be made, and (c) the current relative prices of iron ore and scrap were to change.

Notes

1. Recuperation and recycling comprise the collection and separation of materials from waste and subsequent processing to produce marketable goods.

2. For more details, see: U. Hoffmann and D. Zivkovic, *Demand growth for industrial raw materials and its determinants: an analysis for the period 1965-1988*, UNCTAD discussion papers, No. 50, Geneva, November 1992, p. 9.

3. The reduction of iron ore with a solid or gaseous reductant, usually without producing a liquid product.

4. ECE, *Impact of developments in the reclamation and preparation of scrap on the world steel industry*, Second ad hoc meeting for the study on problems arising from the use of iron and steel scrap (STEEL/AC.14/R.2/Add.1), United Nations Economic Commission for Europe, Geneva, 20 January 1993, p. 3.

5. Ibid.; STEEL/AC.14/R.2, ECE, Geneva, 20 January 1993, p. 12; ECE, *Iron and steel scrap: its significance and influence on further developments in the iron and steel industries* (ECE/STEEL/74), New York, 1991, p. 30; ECE, *Impact of Developments in Scrap Reclamation and Preparation on the World Steel Industry* (ECE/STEEL/84), Geneva, 1993, p. 24.

6. ECE/STEEL/84, p. 21.

7. ECE/STEEL/74, p.23.

8. The specific energy-saving from scrap recycling will depend greatly on the state and quality of the scrap to be recycled.

9. ECE, STEEL/AC.14/R.2, p. 17.

10. UNCTAD, *Impact and effect of energy costs on the consumption of metallics, such as scrap, pig iron and direct reduced iron* (TD/B/IPC/IRON ORE/AC.1/11), Geneva, 1987, p.3.

11. No exact emission data for the various production methods of steel are available.

12. S. M. Ogilvie, *A review of the environmental impact of recycling*, Warren Spring Laboratory, London, 1992, pp. 70-73.

13. Internalization of environmental cost and resource values means that the user pays for preventing harm which might be done to the environment as a result of the production, utilization or disposal of something he demands or, similarly, for the extra benefit (environmental services) that he receives as a by-product of this production.

14. ECE. *Steel product quality and maximum utilization of scrap*, ECE/STEEL/77, New York, 1992, p. 26.

15. *Ibid.*, p. 30.

16. EU Council Regulation 259/93.

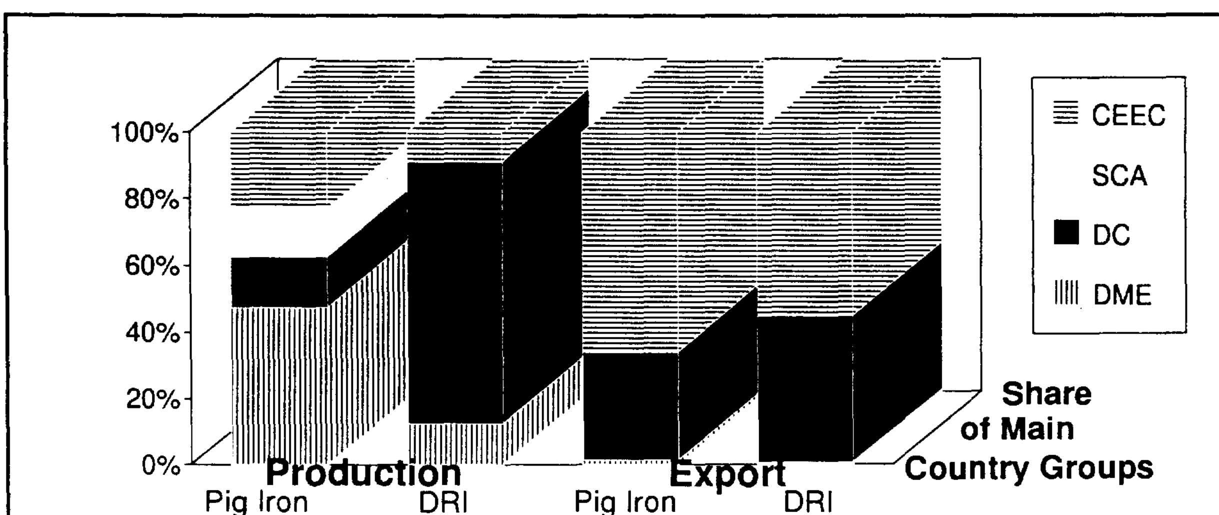
17. OECD, Document C(92)39, Paris, 6 April 1992, p. 6 and 17.
According to OECD data, total trade in metal bearing wastes within the OECD area in 1988 amounted to about 35 million tonnes of ferrous and 4 to 5 million tonnes of non-ferrous metals. Of these, 8 million tonnes of ferrous and roughly 0.6 million tonnes of non-ferrous metal bearing wastes were exported from the OECD area. Thus, in aggregate, about 22 per cent of the metal bearing wastes exported for recovery operations left the OECD area; 78 per cent or about 31 million tonnes remained within the OECD area. Of the roughly 8.6 million tonnes which did leave the OECD area, 93 per cent was ferrous in nature and probably destined for electric arc furnace steel-making in the importing countries.
OECD, Document CE/CG(91)16, Paris, 13 May 1991, pp. 4 -5.

18. Several representatives of the steel industry admit that the general knowledge about scrap as a primary iron source is limited and that the industry should heavily invest in that field. It is suggested that steel producers devise a distinctly new type of relationship with their scrap suppliers. Henri Faure, Usinor's former director of research predicted, for example, that steel mills may strengthen ownership links with scrap processors, especially if they are simultaneously funding technical research into new scrap processing methods. Recent years have indeed witnessed some steel mills buying into scrap processors, but so far they have not derived much benefit by way of price stability.
Metal Bulletin, London, 25 October 1993, p. 15.

Table A-1

Average Annual Production and Export of Iron Ore for the Period 1990-1992*

	Production in 1000 tons		Export in 1000 tons	
	Prig Iron	Sp. Iron DRI	Pig Iron	Sp. Iron DRI
World	**511155**	**18917**	**8879**	**1653**
Developed Market Economies (DME)	**242578**	**2373**	**117**	**10**
Developing Countries (DC)	**77404**	**14887**	**2904**	**734**
Africa	2984	1525		
Algeria	1200			
Libya		712		
Egypt	1107	719		
America	28361	7963		
Argentina	1442	1004		
Brazil	22218	245	2821	
Mexico	3369	2470		
Venezuela	305	3487		734
Asia	44592	5567		
India	13982	1123		
Indonesia		1403		
Iran	1757	531		
Rep. of Korea	17741			
Saudi Arabia		1272		
Taiwan, Prov. of China	5448			
Turkey	4780		83	
Socialist Countries of Asia (SCA)	**73703**			
China	67736			
DPR of Korea	5967			
Central/East European Countries (CEEC)	**117471**	**1657**	**5857**	**909**
Former USSR	92379	1657	5792	909



Source: UNCTAD Secretariat

* The figures for export are rough estimates and should be regarded with extreme caution.

Table A-2

World trade in scrap: main exporting and importing countries in 1990
(in million metric tons)

Exporters		Importers	
United States	11.6	Italy	6.0
Germany	5.0	Spain	4.3
United Kingdom	3.9	Korea	3.9
France	3.7	Turkey	3.8
Former USSR	2.7	India	2.2
		Thailand	1.3
		Taiwan, Province of China	1.3
		Indonesia	0.8
		China	0.5
		Mexico	0.3
		Singapore	0.2
		Philippines	0.1
		Brazil	0.1
Total, including others	34.0	Total, including others	31.0

Source: UNCTAD, ECE, International Iron and Steel Institute