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THE DEMAND FOR SCRAP AND PRIMARY METAL ORES
AFTER A DECLINE IN SECULAR GROWTH

by

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CARL VAN DUYNE 1946 - 1983

My professional colleague and personal friend Carl Van Duyne died at the end of February 1983, as work on the present paper was drawing to a close. Though physically he is not longer with us, his spiritual presence will remain through his valuable contributions in various fields to the academic work of the Institute.

MARIAN RADETZKI

1. Introduction

This study deals with the substitution between scrap and primary metals, the two alternative metallic inputs in metal production. Our objective is to explore what happens to the growth rates of scrap and primary metallic inputs in response to a slowdown in the long-run rate of growth of demand for final metal products.

The issue under scrutiny has acquired great practical relevance as a result of the slowdown in world economic growth that occurred in the mid 1970s. From the perspective of the early 1980s, world economic growth between 1950 and 1974 appears to have been exceptional; economic expansion in the last quarter of the present century is expected to be much slower. This is likely to reduce the rate of growth of demand for raw materials and to result in important shifts in the shares of scrap and primary metallic inputs in metal production.

This issue has been analyzed before. Writing more than 50 years ago, DeGeer (1928) discussed the increasingly important role of iron and steel scrap as an input in steel production resulting from the satiation of steel needs and the consequent deceleration in the growth of steel output. At a more general level, Perbix (1972) noted that depletion must eventually arrest the exponential growth in demand for minerals. With the help of graphical illustrations he depicted the decline of mine production and the expansion of scrap use as growth in the world mineral economy approached zero. More recently, Radetzki and Svensson (1979)

employed a simple model to explore the changes in the steady-state share of scrap when the longevity of products, the share of scrap recovered, and the growth rate of demand are all allowed to vary.

Our study is similar to yet differs in important respects from these studies. Like DeGeer and Perbix, we explore the effects on the demand for primary metal minerals of declining economic growth and increasing scrap use in metal production. A distinguishing feature of our effort is its emphasis on the transition period, during which the economy adjusts from one steady state to another. The rationale for this emphasis is our belief that the transition period is quite prolonged. Following the change in the growth trend that occurred in the mid 1970s, the demand for primary metallic materials through most of the 1980s and 1990s will be governed more by transition dynamics than by steady-state conditions.

A more important feature distinguishing our effort from other works in this area pertains to methodology. Earlier studies commonly considered scrap to be a perfect substitute for primary raw materials and disregarded the relative price movements between these two alternative inputs in production. Our model explicitly considers the case of imperfect substitutability and of shifting relative prices between primary and secondary inputs.

The distinction between new and old scrap is an important one for our analysis. New scrap consists of rejects generated in the production and fabrication of metals. It does not add to total metallic availability, but merely makes the flow of material more roundabout. In contrast, old scrap, originating from products discarded at the end of their useful lives, does constitute an addition to total metallic

supply. In this paper, new scrap is regarded as part of primary supply, so the word "scrap" refers exclusively to old scrap.

Our model is applied to the copper and iron ore/steel industries, using empirically derived parameters for the two industries to obtain steady-state results as well as time paths for the transition period. Our preliminary conclusion is that primary minerals industries like copper and iron ore mining may be severely hurt by the transitional adjustments during this period. No full-fledged empirical tests are undertaken to verify our model because of the absence of appropriate data.¹

The paper proceeds as follows: Our model is presented in section 2. At the end of section 2, we insert plausible, empirically derived values for parameters for copper and iron/steel into the model in order to derive predictions for the steady-state consequences of a change in secular economic growth. Section 3 is devoted to a detailed qualitative analysis of the transition period. This analysis is based on the model as well as on earlier work by the authors concerning a closely related subject (Radetzki and Van Duyne 1983). Section 4 contains a summary of our major conclusions.

2. The Model

In an earlier paper, Radetzki and Svensson (1979) presented a simple formal model of the determinants of the steady-state share of recovered scrap in total metal demand. We begin this section by summarizing the results of that earlier study and by discussing its limitations. In section 2.2, we extend their model to incorporate prices of primary and secondary supplies. The extended model is then used in

sections 2.3 and 2.4 to analyze the steady-state effects of a deceleration in economic growth.

2.1 The Radetzki-Svensson Model

The essential assumptions of the Radetzki-Svensson model are (1) all metal products are used for a fixed number of years, after which they are scrapped; (2) a fixed proportion of the scrap is recovered and supplied to the market; (3) the market for scrap adjusts continually so that scrap demand equals scrap supply; and (4) primary and secondary supplies are perfect substitutes. Although prices are nowhere discussed in the paper, the second assumption implies that scrap supply is price inelastic, and the fourth assumption implies that the relative price between primary and secondary materials is fixed.

To derive the basic Radetzki-Svensson results, consider a steady state in which the demand for primary plus secondary materials is growing at a rate g :

$$M_t = M_t^p + M_t^s = M_0 e^{gt} \quad (1)$$

where M_t^p , M_t^s , and M_t indicate primary, secondary, and total demands. Secondary or scrap supply is given by:

$$M_t^s = \alpha M_{t-d} = \alpha M_0 e^{g(t-d)} \quad (2)$$

where d is the durability of metal products, in years, and α is the share of scrap recovered. If all scrap recovered is utilized in the production of new metal, then from equations (1) and (2) the

steady-state share of recovered scrap in total metal demand, β , is:

$$\beta \equiv M^S / (M^S + M^D) = \alpha e^{-gd} \quad (3)$$

The higher the scrap recovery ratio, the lower the growth rate, and the lower the durability, the higher will be the steady-state share for scrap.

Although Radetzki and Svensson show that β 's calculated using equation (3) are consistent with actual scrap shares for the United States, equation (3) should not be used to analyze the effects of changes in growth rates, longevity, or recovery technology. Primary and secondary supplies are not perfect substitutes, so changes in relative supplies of primary and secondary inputs alter relative prices and hence demands for the two types of material. Furthermore, changes in scrap prices affect the scrap recovery ratio, altering scrap supplies. Our extended model, developed next, incorporates these price responses.

2.2 The Extended Model

Let F be an aggregate, linear homogeneous production function describing the transformation of primary materials (e.g., iron ore), secondary sources of raw materials (e.g., ferrous scrap), capital, labor, and energy into output (e.g., raw steel):

$$Q = F(K, L, E, M^D, M^S) \quad (4)$$

where Q is output, K is capital, L is labor, and E is energy. Primary materials and scrap are assumed to be imperfect substitutes in the

production process. Assume further that the marginal rate of technical substitution between primary materials and scrap is independent of the quantities of capital, labor, and energy employed in the production process, and that the elasticity of substitution between M^P and M^S is constant. Then the production function is homogeneously separable (cf. Van Duyne 1975; Green 1964, pp. 9-32) and can be written as:

$$Q = F(K, L, E, \tilde{M}) \quad (5)$$

where

$$\tilde{M} = \Psi(M^P, M^S) \quad (6)$$

The function Ψ is a C.E.S. quantity index of raw material inputs. The tilde ($\tilde{}$) is used to distinguish the C.E.S. quantity index in equations (5) and (6) from the linear quantity index in equation (1). The assumption of homogeneous separability is admittedly unrealistic, but it allows us to determine the optimum mix of raw materials inputs independently of the choice of other inputs.² In what follows, we go one step further and assume that the marginal rates of technical substitution between $\tilde{M}$ and the other inputs are zero; men may be figuratively "made of steel", but no matter how much labor is added to the production process, it is impossible to make a ton of steel with less than a ton of iron-bearing raw materials.

The demands for primary materials and scrap are derived demands, determined by the demand for output and the prices of the two materials inputs. To simplify the analysis of these derived demands, we make two additional assumptions: (1) the price of primary materials in the long run is constant in real terms, implying that the long-run price

elasticity of supply of primary raw materials is infinite, and (2) the price elasticity of demand for output is zero. Neither of these two assumptions is especially limiting. The first assumption is roughly consistent with historical experience. In the cases of copper and iron ore, improvements in mining technology have tended to offset the higher costs associated with exhaustion of high-grade ore bodies (see Barnett and Morse 1963; Barnett 1979; Radetzki 1975; 1980; Mikesell 1979, chap. 4), and reserves have been sufficiently abundant that scarcity rents have been negligible, so price has approximated extraction cost, at least in the long run (see Dasgupta and Heal 1979, pp. 170-172). The second assumption eliminates any feedback from changes in input prices to changes in the quantity of output demanded, working through the effect of higher input prices on the output price. Presumably this effect is small because primary materials prices are assumed to be constant, because changes in scrap prices are likely to be small (see table 2), and because the demands for industrial raw materials like steel and copper are price inelastic. This assumption, together with the assumptions made above about the marginal rates of technical substitution, implies that $\tilde{M}$ also grows at an exponential rate:

$$\tilde{M}_t = \psi(M_t^D, M_t^S) = \tilde{M}_0 e^{g_0 t} \quad (7)$$

where g_0 is the initial steady-state growth rate.

Given these assumptions about production technology, prices, and elasticities, and assuming that the market for scrap is initially in steady-state equilibrium

$$\beta_0 = \alpha_0 e^{-g_0 d} \quad (8)$$

the demand for scrap at time t_1 , $t_1 > t_0$, is given by:

$$M_1^S = \beta_0 \tilde{M}_1 (P_1/P_0)^{-(1-\beta_0)\sigma} \quad (9)$$

where P is the price of scrap and σ is the elasticity of substitution.³

On the supply side of the market, we assume that the scrap recovery ratio varies positively with scrap prices:

$$\alpha_1 = \alpha_0 (P_1/P_0)^\varepsilon, \quad \varepsilon > 0 \quad (10)$$

where ε is the elasticity of scrap supply. Together, equations (2), (7), and (10) imply that total scrap supply is given by:

$$M_1^S = \alpha_0 (P_1/P_0)^\varepsilon \tilde{M}_0 e^{g(t-d)} \quad (11)$$

2.3 The Comparative Statics of Decelerating Economic Growth

In this section, we explore the effects of a permanent deceleration in economic growth on scrap prices, the recovery ratio, and the scrap share in the steady state. We continue to assume that in the long run primary prices are constant in real terms, but that the scrap price adjusts to equate scrap supply with demand.

Suppose the growth rate decelerates from g_0 to g_1 . Setting scrap supply (equation (11)) equal to scrap demand (equation (9)), substituting equations (7) and (8) for $\tilde{M}$ and β_0 , taking logs, and solving for $\ln(P_1/P_0)$ yields:

$$\% \Delta P \approx \ln(P_1/P_0) = d(g_1 - g_0) / ((1 - \beta_0)\sigma + \varepsilon) \quad (12)$$

Equation (12) gives the percentage change in the steady-state scrap price following a permanent change in economic growth. If growth decelerates, scrap prices fall. The more severe the deceleration in growth, the larger the decline in scrap prices. In addition, the larger the elasticity of substitution and the more price sensitive the scrap recovery ratio, the smaller the decline in scrap prices.

Finally, the effect of decelerating economic growth on the scrap share can be derived from equations (8), (10), and (12):

$$\beta_1 = \alpha_0 (P_1/P_0)^\varepsilon e^{-g_1 d} \quad (13)$$

Equation (13) shows that the increase in the scrap share resulting from a deceleration in economic growth is moderated by any decline in scrap prices caused by the increased relative supplies of scrap. These lower prices reduce the incentive to recycle scrap, thereby reducing the recovery ratio. The larger the price decline, say due to a low elasticity of substitution between primary and secondary supplies, and the larger the elasticity of the scrap recovery ratio, the larger is this moderating effect. Only if the recovery ratio is insensitive to scrap prices ($\varepsilon = 0$) or if scrap prices remain unchanged (because primary and secondary materials are perfect substitutes) can equation (5) be used directly to compare steady states as Radetzki and Svensson do.

2.4 Empirical Illustrations of Alternative Steady States

The above analysis provides us with tools for predicting what will happen to the price of scrap relative to the price of primary metal, the scrap recovery ratio, and the share of scrap in total raw material input in the new steady state that ultimately emerges after a change in the rate of growth in demand for final products. Note that the transition period from one steady state to another is approximately equal to the durability of final products made from the recyclable material. For products like copper, aluminium, and steel, a new steady state will be attained only about the end of the century, if the slower growth rates that emerged in the mid 1970s are maintained.

Table 1: Empirical Parameters for Copper and Iron/Steel

	<u>Symbol</u>	<u>Copper</u>	<u>Iron/ Steel</u>
Durability of final products, years	d	25	20
Initial scrap recovery ratio	α_0	0.65	0.60
Price elasticity of scrap supply, long run	ϵ	0.3	0.3
Price elasticity of primary supply, long run		∞	∞
Elasticity of substitution between scrap and primary, long run	σ	10	5
Growth of final product demand, percent per annum			
historical (1950-1975)	g_0	4.4	5.4
projected (1975-2000)	g_1	2.8	2.6
alternative projected (1975-2000)	g_1	2.0	2.0

1. These estimates were derived from a variety of published studies and from interviews with a number of industry representatives. A detailed appendix listing the sources from which each of the figures was obtained follows the bibliography.

Several kinds of data have to be inserted into the equations in order to derive the predictions. We have succeeded in obtaining reasonably reliable data of this kind for copper and iron/steel. These are summarized in Table 1. Only some of the data contained in the table are needed for the present computations. The remaining data will be employed in the empirical illustrations of the transition period, presented in section 3.

Inserting estimates for d , g_0 , g_1 , σ , ε , and α_0 in equations (8), (10), (12), and (13) yields the following predictions for P , α , and β in the year 2000:

Table 2: Initial and Predicted Final Steady State Values for
Price, Recovery Ratio and Share of Scrap

	Copper		Iron/Steel	
	<u>1975</u>	<u>2000</u>	<u>1975</u>	<u>2000</u>
Relative price of scrap, P_1/P_0	1.00	0.95	1.00	0.88
Scrap recovery ratio, α	0.65	0.64	0.60	0.58
Scrap share, β	0.22	0.32	0.20	0.34

For both metals, our model predicts substantial increases in the shares of scrap in total raw material input. The increase in scrap share is larger in the case of iron and steel because we predict a sharper deceleration in the growth of demand for iron and steel products. This increase in the scrap share for iron and steel is larger than that for copper despite our belief that the long-run elasticity of substitution between primary and secondary materials is noticeably higher in the case of copper.

Our qualitative conclusions are insensitive to the choice of the elasticity of substitution over a wide range of values. In table 3 we present predicted scrap shares for the year 2000 calculated using elasticities of substitution half as large as those used above, and elasticities of substitution equal to infinity, the implicit assumption in the calculations of Radetzki and Svensson (1979). In all cases, substantial increases in the scrap share are indicated.

Table 3: Predicted Scrap Shares in the Year 2000 for
Alternative Values of the Elasticity of Substitution

		Alternative elasticities			
	Initial scrap Share (β_0)	2.5	5	10	∞
Copper	0.22	-	0.30	0.32	0.32
Iron/steel	0.20	0.33	0.34	-	0.36

Our conclusion that the share of scrap in total raw material input will grow from 22 percent to 32 percent for copper, and from 20 percent to 34 percent for iron/steel, coupled with the projected growth rates

for overall final product demand in the 1975-2000 period, permits us to calculate the average rate of growth of demand for primary materials over the entire transition period.⁴ This works out to be 2.2 percent for primary copper and 1.6 percent for iron ore. Some of the industry sources we consulted felt that the projected growth rates for 1975-2000 that we used (2.8 percent for copper and 2.6 percent for iron/steel) were too high. When both growth rates are lowered to 2.0 percent, the predicted share of scrap in 2000 is 39 percent for copper and 38 percent for iron/steel, and the 1975-2000 average rate of growth of demand will be 1.0 percent for primary copper and only 0.7 percent for iron ore.

The transition period requires further analysis, though, since there appear to be several distinct stages through which these markets must pass. The following section tries to tackle this task.

3. The Transition Period

The dynamics of the transition period appear to be extremely complicated, so we make no attempt here to analyze them formally. What follows is an attempt to analyze the transition period qualitatively, integrating the insights of earlier work by the authors with the comparative statics analysis of the preceding sections.

Findings from an earlier paper (Radetzki and Van Duijne 1983) are particularly relevant to the present analysis. In that paper we used control theory to analyze the overshooting of capacity requirements that regularly occurs following a downward shift in the rate of economic growth in industries where investments take long to complete. At the time when the deceleration in economic growth becomes apparent, such industries would have a series of investment projects, at different

states of completion, aimed at expanding capacity for several years at the old growth rate. Our analysis indicated that a large proportion of these investments would be completed on schedule even after it became clear that the growth rate of demand for the industry's products had been permanently reduced. The rationale for such behavior is that for many investment projects in the pipeline, large commitments would already have been made when the new trend in demand growth is perceived, and the remaining cost of completion would be less than the value of their additional output, even when that output is valued at the depressed price level that would result from the anticipated excess capacity. Hence, completing these investments on schedule will increase the present value of the typical firm's profits (or reduce the present value of their losses). Completion of the remaining investment projects under execution would be delayed until market prospects improved. Few projects would be abandoned outright.

The period of excess capacity would consist of two stages. In the first stage, investment projects would be completed on schedule, and excess primary capacity would increase. In the second stage, completion of investment projects would be stretched out, overall investment activity would shrink, and excess capacity would gradually decline to zero. Our numerical solutions of the optimal control problem, using parameters that reflect conditions in the world copper industry but that disregard secondary supply, suggested that the period of excess capacity, encompassing the two stages, could approach eight years, even when all firms are rational profit maximizers and immediately perceive the deceleration in economic growth. The period of excess capacity would be even more extended if a part of the industry is

controlled by state enterprises unwilling to adjust their investment plans or current production to the emerging market conditions.

These findings, along with the analysis of earlier sections of the present paper, lead us to conclude that the transition period from one steady state to the next after a slowdown in the growth of demand for final products will ordinarily consist of three stages, the first two of which would coincide with the two stages of excess capacity just described.

The first stage is characterized by increasing excess supply of primary and secondary output, exerting downward pressure on both prices. The excess supply would be due to the combination of continued expansion of primary and secondary supply at the old, higher growth rate combined with the reduced rate of growth of demand. At each point in time, primary and secondary prices would adjust so as to equilibrate the quantities supplied and demanded.

Primary minerals industries are typically capital intensive, with variable costs constituting a small proportion of total costs. As is common in most base materials firms, the marginal cost schedule is gently upward sloping over a wide range of capacity utilization rates, but rises steeply as capacity is approached (Scherer 1980, p. 207). In ordinary market circumstances, price will intersect the steep portion of the marginal cost curve, the industry will operate close to full capacity, and the price elasticity of supply will be very low. In a profound market depression, however, price will fall towards the variable cost levels of the industry, capacity utilization will be reduced, and the price elasticity of supply will be high.

In the secondary industry, in contrast, fixed costs are low, and there is no clearly defined capacity limit. Marginal costs increase

smoothly as the area of scrap collection is widened and the recovery of material from scrapped products is intensified. Hence, the price elasticity of scrap supply is not likely to undergo any substantial change over a wide price range.

The difference in the shapes of supply curves permits us to draw several conclusions about changes in quantities of the two materials supplied. As the industry is increasingly depressed in the course of the first stage, most of the quantity adjustment will be accounted for by scrap. So long as primary prices remain above variable costs of production, there will be a tendency to maintain full capacity utilization of the old as well as the newly established primary installations. However, if prices fall so low as to intersect the elastic portion of the primary industry supply schedule, the quantity of scrap supplied will continue to shrink, but the quantity of primary supply will shrink even more.

The first stage will last as long as the primary industry continues to implement its old investment plans on schedule. The second stage will begin by a sharp reduction in the rate of primary investment, as the industry enters the period in which its original investment plans are stretched out. This stage will be characterized by a gradual reduction of excess supply, and a slow recovery of price. With secondary supply continuing to expand at approximately the old rate, primary supply growth must be restricted to below the new low rate of overall demand increase to bring about a reduction in total excess supply. Continuation of the old primary investment program at a reduced pace implies positive gross investment, but net investment may well turn negative, reducing primary capacity over time. The investment program will be stretched out

so that its completion coincides with the end of the second phase, at which time there will be no excess supply in the primary industry, and primary prices will have risen back to their steady-state equilibrium.

The pattern of change in the quantities of primary and secondary supply will be opposite to that in the first phase, with scrap ordinarily accounting for a major share of the additions to the quantity supplied. The share of scrap in overall supply will be higher at the end of the second phase as compared to the initial steady state. Given that the elasticity of substitution between scrap and primary is less than infinite, the relative scrap price at the end of stage II will be somewhat lower than in the original steady-state equilibrium.

The investment analysis without scrap contained in Radetzki and Van Duyn (1983) and summarized earlier in this section suggests that on reasonable assumptions, stages I and II, characterized by excess capacity and depressed prices, might extend over periods of up to eight years. The essential consequence of adding scrap to that analysis is that even longer periods may be involved. In the first stage, the addition of scrap implies a more rapid rate of growth of excess supplies, with a sharper and more profound depression in price. Because of the more depressed market, fewer investment projects can be profitably completed on schedule. This shortens stage I. Stage II, however, will be considerably longer as a result, because more investment projects must be stretched out over a longer period before excess capacity in the primary industry has been eliminated.

In extreme cases, it is conceivable that the second stage will not be completed until well beyond the time at which the entire transition period would ordinarily have ended. When the initial share of scrap in

total supply is high, overshooting in primary capacity is sizable and depreciation is slow, excess capacity may continue for a long time, even if gross investment in primary capacity is reduced to zero.

The characteristics of the third stage are the easiest to disentangle. Overall supply will grow at the same (constant) rate as demand. But since the supply of scrap will continue to expand at the old, higher growth rate, it follows that the supply of primary materials will increase at a rate lower than the growth in demand, a rate that may even be negative. While gross investment in the primary sector must be non-negative, net investment may be either positive or negative. The price of primary will remain constant through the third stage, but the relative price of scrap will experience a further decline as the share of scrap in total quantity supplied continues to increase.

Completion of stage III occurs at the end of the transition period when there is a reduction in the growth rate of secondary supply. From then on, overall demand, primary supply, and secondary supply all grow at the same rate.

Figure 1 presents a graphic summary of our discussion of the transition period, using parameters for copper as summarized in table 1 above. Demand for copper metal is taken to grow by 4.4 percent per year in the 1950-1975 period, or from 3.0 to 8.8 million tons. With an average durability of copper products equal to 25 years, and an initial scrap recovery ratio of 65 percent, the quantity of scrap recovered in 1975 is roughly 1.9 million tons, representing 21 percent of total metallic raw materials used in copper production.

After demand growth for copper metal drops to 2.8 percent per year from 1975 onwards, a 25-year transition period follows, with a new

steady state attained only in the year 2000. With a long-run price elasticity of scrap supply equal to 0.3 and an elasticity of substitution between scrap and primary material of 10, recovered scrap in the year 2000 will be 5.5 million tons, equal to 31 percent of total metallic materials employed. The relative price of scrap will be 5 percent lower than in 1975 and the scrap recovery ratio will have fallen to 63 percent. The average rate of growth of the quantity of scrap recovered throughout the transition period will be 4.3 percent per year.

As is already apparent from the earlier discussion, the transition period from initial to final steady state will not be characterized by smooth changes in the growth rates and shares of the two metallic raw materials. The overshooting of primary capacity, illustrated by the dashed line above the demand schedule in figure 1 will cause primary and secondary prices to fall and actual scrap recovery to decline below the dashed portion of the smooth scrap recovery path.

The three stages identified in the earlier analysis are clearly apparent in the figure. The first stage, assumed to last from 1975 until 1978, is characterized by continued growth of primary capacity along the old expansion path, increasing excess supply, and falling prices, leading to stagnant or even declining quantities of scrap recovery. The second stage, stretching from 1978 until 1983 in our figure, starts with a sharp drop in primary investment. Excess capacity is then gradually reduced and prices increase, thereby inducing a fast rise in the quantity of recovered scrap. Primary prices attain their long-run equilibrium at the end of stage II when excess primary capacity has been exhausted. Stage III lasts from 1983 until 2000. In this period primary prices remain at their long-run equilibrium, scrap recovery expands

along the smooth path of 4.3 percent per year, the share of scrap in total raw material input is gradually increased, and scrap prices experience a slow decline.

Given the stagnation or even decline in the quantity of scrap recovered during the first stage of the transition, the average rate of growth of the quantities of scrap used in metal production through the second and third stages has to be substantially higher than the 4.3 percent average for the entire transition. It follows that the market expansion for the primary raw material will be limited in the last two stages of the transition period.

4. Conclusion

In this paper we have analyzed the consequences of a slowdown in long-run economic growth, such as occurred in the mid 1970s, on the demand for old scrap and primary metal ores. For this purpose, we constructed a model in which scrap and primary ores are considered as imperfect substitutes in metal production. Empirically derived parameters for the copper and iron ore/steel industries were incorporated into the model to derive steady-state shares for the two raw materials following a deceleration in rates of growth of final demand.

With a decline in the long-run rate of growth of demand for copper metal from 4.4 percent per year until 1975 to 2.0 percent in the following decades, the share of old scrap in total metallic input is seen to increase from 22 percent when the decline occurred to 39 percent at the end of the century when the new steady state will be attained. A simultaneous decline in the annual growth of demand for steel from 5.4

percent to 2.0 percent leads to an expansion in the share of old scrap from 20 percent in the mid 1970s to 38 percent in the mid 1990s.

The growth of demand for primary metal ores is doubly hit by a deceleration in economic growth. First, demand growth for metal products declines. Second, the share of scrap increases. Insights from earlier work (Radetzki and Van Duyne 1983) along with the comparative statics analysis just described were used to illuminate qualitatively what will happen during the extended transition period that follows a reduction in long-run economic growth.

We found that the transition period is divided into three stages. Our analysis suggests that the first two stages last up to 4-5 years each in industries like copper and iron ore/steel, where investments in primary capacity expansion take long to complete. The third stage would typically be even more protracted, leading to a total transition period of 20-25 years. each in industries like copper and iron ore/steel, where investments take long to complete. The third stage would typically be even more protracted, leading to a total transition period of 20-25 years.

The conclusions derived from our work have far-reaching and pessimistic implications for mining industries and for countries heavily dependent on the mining sector. If the slow economic growth since 1975 continues until the end of the century, there will be very little scope for market expansion in many primary metal ores through the 1980s and 1990s. Some ore markets may even experience absolute declines. The prospect for secondary raw materials is more encouraging, given the anticipated substantial increases in the share of scrap in total raw material inputs.

Footnotes

- 1) One data limitation - but not the only one - is that most statistical series for scrap do not distinguish between old and new scrap.
- 2) In a study that used large-scale, cost-minimizing process analysis models of the steel industry to evaluate the performance of neoclassical models of these technologies, Kopp and Smith concluded that all three standard steel-making technologies "exhibit sufficiently interdependent production activities for the inputs ... that it would not be possible to identify any subset of them as separable from the remainder" (1982, p. 240).
- 3) See Layard and Walters (1978, p. 267) for the derivation.
- 4) The formula for the average growth rate of demand for primary materials (g_p) is given by $g_p = \ln \{ [(1 - \beta_1)/(1 - \beta_0)e^{g_1 d}]^{1/d} \}$.

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DATA APPENDIX FOR

THE DEMAND FOR SCRAP AND PRIMARY METAL ORES AFTER A DECLINE IN SECULAR GROWTH

Marian Radetzki and Carl Van Duyne

The data contained in this appendix have been obtained from a wide search in the literature and from interviews with knowledgeable executives in corporations and other institutions involved with metal scrap in Sweden. The interviews were carried out early in 1982. The list of references at the end of the appendix identifies the literature and the individuals consulted.

Durability of final metal products

Copper:

There is a great variation among products, and no generally accepted average figure has been established. U.S. Bureau of Mines (1974, p. 7) claims that the durability of copper products in the United States is about 17 years. Mikesell (1979, p. 344) criticizes this study

and claims that the average life is considerably longer. The Battelle Study for CIPEC (1971, p. 350) provides disaggregated data from which we have derived a very rough average of about 20-25 years. We have chosen 25 years for our computations. Jerker Stavrén and Magnus Blomqvist felt that we could not be very far off the mark in this choice.

Steel:

Estimates of the durability of steel products range from 15 to 30 years. Wijkander (1950, p. 274) claims 15 years for the United States and 25-30 years for Europe. ECE's (1959) forecasts for the early 1970s were 22 years for Europe, 23 years for Japan, and 17 years for North America. In 1971, ECE claimed about 20 years for the world as a whole (p. 85), but in 1978, revised this downward to about 15 years (ECE 1978, p. 146). Finally, Robert R. Nathan Associates (1977, p. 460), claimed an average durability for steel products in the United States of 22 years. In our interviews, Erik Ruist estimated a durability of 15-20 years, and Sven Verner Carlson estimated 20 years. We have chosen 20 years for our computations.

Share of Old Scrap Recovered

Copper:

Estimates of the share of old copper scrap recovered range from 31 percent to 65 percent. U.S. Bureau of Mines (1974, p. 7) presented the lowest estimate, claiming 31 percent for the United States. Barton (1979, p. 9) estimated 45 percent for the US and 30 percent for the United Kingdom. UNCTAD's estimate for the United Kingdom (1977, para. 33) is 60 percent. Battelle (1971, p. 350) claims the scrap recovery ratio for the Western World is 65 percent. In our interviews, both

Jerker Stavren and Magnus Blomqvist claimed that the recovery ratio was considerably more than 50 percent. For our computations, we have adopted the Battelle Study result of 65 percent.

Steel:

The range of estimates of the scrap recovery ratio for steel is almost as large as that for copper. Wijkander (1950, p. 271) claims 65-80 percent for Sweden, while ECE's 1959 forecasts for the early 1970s were 60 percent for Western Europe, 65 percent for Japan, and 70 percent for Japan. In 1978, ECE revised downward its estimate for Europe to 55 percent (p. 147). For the United States, Jensen (1973) estimated that the scrap recovery ratio was 77 percent in 1950, 1960, and 1970, but would rise to 80 percent in 1980. At the other extreme, Robert R. Nathan Associates (1977, p. 476) claimed it was only 30-40 percent for the United States. In our interviews, Sven Verner Carlson estimated about 50 percent, while Erik Ruist estimated about 65 percent. We have adopted a figure of 60 percent for our computations.

Price Elasticity of Scrap Supply

Copper:

Three sources give the following estimates for the United States:

	<u>Short Run</u>	<u>Long Run</u>
Fisher, Cootner, and Baily (1972)	0.4	0.3
Bonczar and Tilton (1975, p. 66)	0.26	0.26
Charles River Assoc. (1970, p. 310)	0.47	-

The figures appear to be stable over a wide price range.

The explanation of the possibly higher elasticity of scrap supply in the short run than in the long run has been elucidated in our interviews in the following way. Both in the long run and in the short run the price elasticity is due to variations in the share of old scrap recovered at a particular time. In the short run there is an additional elasticity factor resulting from the possibility of recovering from products that were scrapped in earlier periods, but were not recovered at that time. This stock of potential scrap supply (sometimes referred to as "sleeping scrap") is of limited size, since it can be assumed that discarded products will be permanently lost, unless they are recovered within a relatively short time after discarding. In view of the limited size of this stock, its impact on the supply elasticity will be of a short-run nature.

Steel:

We have not found any figures on the price elasticity of supply for old scrap. The interviews we have carried out suggest that the factors behind these elasticities are similar to those for copper. In steel, too, the concept of "sleeping scrap" has some short-run relevance. As in copper, it appears that the elasticities of supply are relatively stable over a wide price range.

In our analysis we have adopted the long-run value of 0.3 for the elasticity of scrap supply of both copper and steel.

Price Elasticity of Primary Raw Material Supply

Copper:

Figure A1, taken from Radetzki and Van Duyne (1983), depicts a short-run marginal cost curve for the non-socialist world primary copper industry (solid line) and the theoretical C.E.S. supply curve (dotted line) used for the numerical solution exercises in that paper.

The latter line has an elasticity of substitution between labor and mine capacity equal to 0.1. Both curves contain a smelting and refining cost of about 10 U.S. cents. Hence the corresponding curves for copper concentrates, the substitute raw material to scrap, will be 10 cents lower at all levels of capacity. Over the price range at which we performed our numerical solution exercises the theoretical curve has a close fit with the empirical one, with a price elasticity of supply of the primary raw material at roughly 0.15.

Iron Ore:

We have not been able to find empirical data to derive a similar curve for iron ore supply, but we assume that the shape of the supply curve is quite similar to that for copper concentrates.

Elasticity of Substitution between Scrap and Primary Ores

Copper:

No data concerning this elasticity have been found in the literature. In our interviews, Didrik Nordmark felt that this elasticity might amount to 5 in the short run (1 year) and to about 20 in the long run (10 years). N.K. Basse felt the figures might even be higher. In discussions with executives at Boliden, Magnus Blomqvist and Jerker

Figure A1: Short-Run Marginal Cost Curves for the Non-Socialist World Copper Industry

Sources: Commodities Research Unit (1978) and authors' calculations.

Stavren, no clear-cut figures emerged, but the persons interviewed were of the opinion that scrap was a very close substitute to copper concentrates. In their opinion, substitutability was much greater than in the case of iron/steel, and the adjustment period was much shorter -- the long run was no more than 4-5 years.

In our analysis we have adopted a value of 10 for the long-run elasticity of substitution. This is a very high figure, and it renders results not substantially different from those obtained with the elasticity of substitution equal to 20. Our choice of a figure somewhat lower than that which emerges from the interviews is motivated by a desire not to exaggerate the substitutability between the two materials.

Steel:

No data concerning this elasticity have been found in the literature, either. Interviews with K.G. Berg, Erik Ruist, and Sven Verner Carlson revealed that substitutability is not as great as in copper, and that the long-run substitution is mainly achieved through changing composition between steel-making processes. The interviews suggest a short-run value for the elasticity of substitution at 3 or less, and a long-run value of about 5. The long run will be attained over a period of up to 15 years after the change in relative prices.

For our analysis, we have adopted the figure of 5 as the long-run elasticity of substitution between ferrous scrap and iron ore.

Growth of Final Product Demand

We have adopted Malenbaum's (1977, pp. 109-116) authoritative world figures, both historical and projected. These work out as follows (in

percent per annum):

	<u>1951-1975</u>	<u>1975-2000</u>
Refined copper	4.4	2.8
Steel	5.4	2.6

These projections tally quite closely with the World Bank's forecasts through 1995 (World Bank 1982).

However, when confronting our interviewees with these projections early in 1982, the reaction we received was a belief that growth of final demand would be lower than projected above. For instance, Erik Ruist indicated that he would have accepted Malenbaum's steel forecast in 1977, but that in 1982 he would lower the figure from 2.6 percent to perhaps 2.0 percent. Staffan Anger likewise felt that world consumption of refined copper between 1980 and 2000 was unlikely to exceed 2 percent per year. These opinions have led us to undertake alternative assessments based on a 2 percent growth rate of demand for both metals.

Share of Old Scrap in Total Raw Material Input

Copper:

U.S. Bureau of Mines (1980) shows that the share of old scrap in the United States in the 1970s was between 20 and 25 percent.

Steel:

For steel, we have been unable to find any data in the literature.

With the technology and prices that prevailed in the 1970s, the feed into steel-making consisted roughly of 45-50 percent scrap and 50-55 percent pig iron (K.G. Berg; U.S. Bureau of Mines 1975, p. 554; International Iron and Steel Institute 1978). Old scrap accounts for about one third of total scrap inputs (U.S. Bureau of Mines 1975, p. 554; ECE 1971, p. 95; Jensen 1973). This permits us to deduce that old scrap provided 15 to 17 percent of the overall steel-making feed requirements.

The initial (1975) steady-state share of old scrap obtained from applying some of the empirical parameters presented in this appendix works out at 21 percent for copper and 20 percent for steel. The copper figure tallies with the above empirical assessment, but the steel figure is somewhat higher than our empirical deduction presented above. However, we feel that the discrepancy is well within the margin of possible error.

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Persons Interviewed

- Staffan Anger, Gränges Metallverken, Västerås, Sweden.
- N.K. Basse, Boliden Bergsö, Landskrona, Sweden.
- K.G. Berg, Research Director, Jernkontoret, Stockholm
- Magnus Blomqvist, Boliden, Stockholm.
- Sven Verner Carlson, Former President of The National Swedish Iron and Steel Scrap Purchasing Corporation, Stockholm.
- Didrik Nordmark, Gränges Metallverken, Västerås, Sweden.
- Erik Ruist, Professor of Statistics, Stockholm School of Economics, Consultant to Jernkontoret, Stockholm.
- Jerker Stavrén, Boliden, Stockholm.

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