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AN ANALYSIS OF THE FACTORS AFFECTING STEEL SCRAP COLLECTION

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PREFACE

The report by the Industry Commission into recycling has pointed out that the last two decades have seen growing community involvement in recycling. This has arisen because of concerns about the environment and resource conservation. As a result, there has been increasing pressure to force the pace of recycling and governments, at all levels, have been keen to respond in a positive way. Yet it is not obvious that government engineering of higher recycling rates would make the community better off, either economically or environmentally.

This paper examines the factors affecting steel scrap collections and develops a model to explain the supply and demand of steel scrap. The analysis suggests that in the case of steel- by far the most recycled material in Australia- recycling has not resulted from environmental or resource scarcity concerns nor from government requirements. In fact, those large amounts have arisen mostly from the technical requirements of steel production and commercial considerations of both steel producers and steel users (who eventually must become potential scrap sources).

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AN ANALYSIS OF THE FACTORS AFFECTING STEEL SCRAP COLLECTIONS

Steel is by far the most recycled material in Australia (by weight). About 1.7 million tonnes of steel scrap were collected in 1988-89. This is more than double the quantity of packaging/industrial paper recovered, the second most recycled material (le, 1991a, Table 2.1). Despite the large amounts of steel collected, up to 4.5 million tonnes of steel could end up as waste each year.' Those large amounts may create disposal problems which recycling could decrease. It is argued that recycling could also help address perceived scarcity and sustainability problems. In particular, a slower depletion of natural resources would seem to be associated with higher recycling rates. However, the impact of steel recycling on such potential problems as waste generation and resource depletion depends on the particular characteristics of scrap supply and demand. This paper examines those characteristics.

SCRAP SUPPLY

Steel scrap is derived from the stock of discarded steel-intensive products such as machinery, vehicles and buildings. Thus, the identification of potential scrap sources involves determining those sectors that are substantial consumers of steel-based products.s

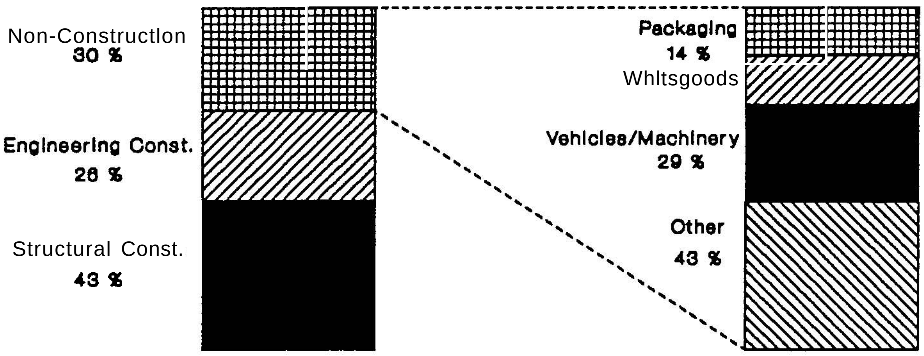
Figure 1 shows the main end-use markets for steel in Australia in 1987 (finished-tonne basis). The figure indicates that the building and engineering construction industries absorb over two-thirds of all steel consumed in Australia. According to McLennan Magasanik, most of that consumption took the form of slab and plates, structural beams and reinforcing rods. Other important sectors such as whitegoods, vehicles and machinery consumed mostly coated products. Packaging represented the only significant non-durable application for steel. Based on this observation, McLennan Magasanik Associates (1989, p 33) concluded that:

> ... overall demand for steel is very sensitive to changes in economic activity - particularly investment in (steel-intensive) buildings and capital goods... steel demand fell by 20% during the 1975 and 1983 recessions as business stopped investing in new plant and equipment. Conversely, the recent boom in

t This quantity corresponds to the difference between the quantities of raw steel production and steel recycled provided in le (1991b). The actual quantity discarded would probably be smaller because finished steel production is about 25 per cent lower than raw production and because the stock of steel-based products is probably increasing.

2 The amount of steel scrap imports is negligible. According to IC (1990b), scrap imports accounted for 0.1 per cent of scrap supplies in 1988-89.

Figure 1. Steel End-uses



Source: (1geg).

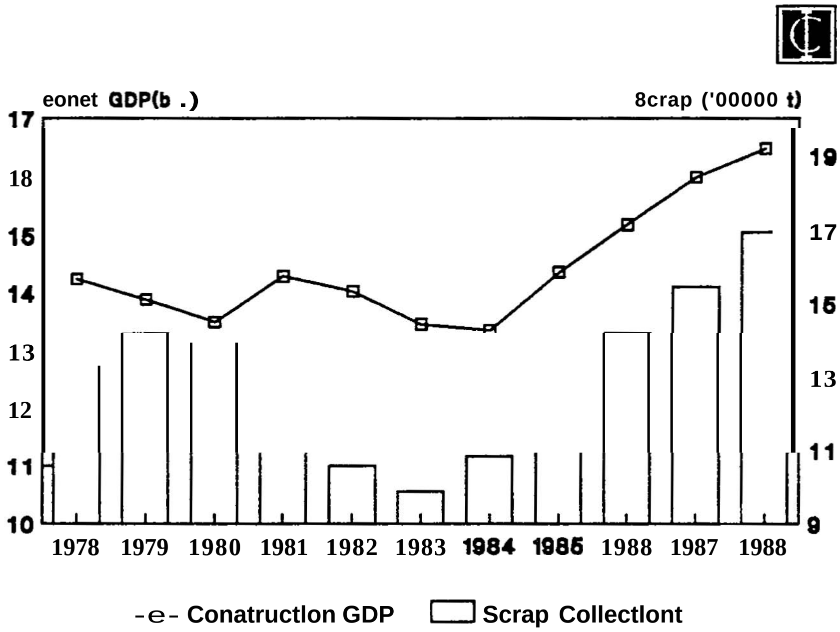
housing and office construction and the recovery of the manufacturing sector has led to a substantial increase in steel demand.

Scrap supply should also be sensitive to the activity level of the construction sector because construction activity often involves demolition. Data on the contribution of the construction sector to (real) total GDP, plotted in Figure 2, is consistent with this claim. Note in particular that an upward trend in construction GDP since 1983 coincides with growing scrap collections while falls in construction GDP accompanied falls in scrap collections during several earlier years.

Economic analysis also suggests that the supply of steel scrap should be directly related to the price of scrap. Figure 3 plots the amount of scrap collected and a scrap price index. (No actual scrap prices were available for this analysis. See appendix for a description of data sources.) Figure 3 shows that scrap collections peaked in 1979 and the scrap price index in 1980. Both the price index and scrap collections fell continuously until 1983. The price index stabilised in later years while scrap collections increased substantially.

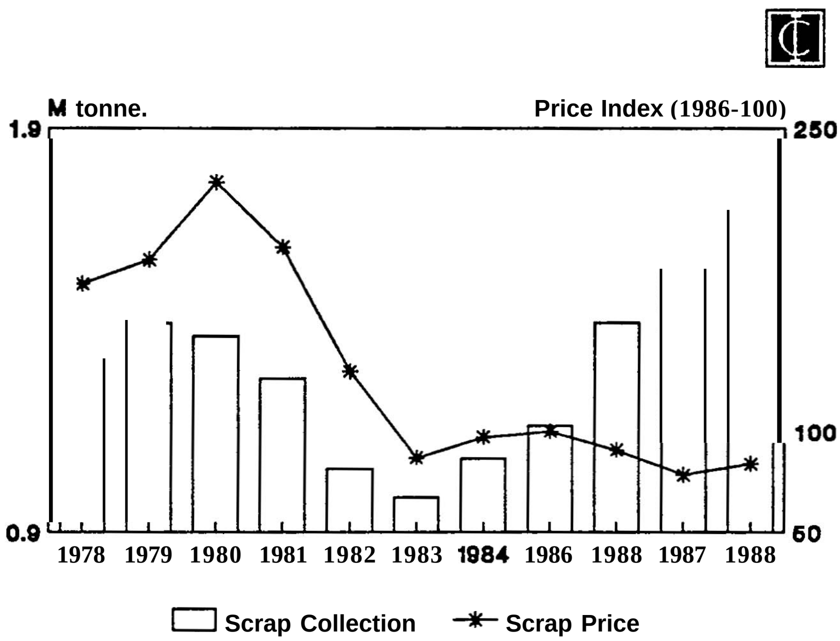
The imperfect correlation between the scrap price and scrap collections shown in Figure 3 is not surprising. Whether observed scrap collections rise or fall as real scrap prices change depends on the interaction of many factors affecting supply and demand. For example, scrap collections would decrease with falling prices - such as during the 1980-1983 period - if demand decreased while supply remains constant. On the other hand, an increase in scrap collections could be associated with lower prices (as in 1986 and

Figure 2. Construction Activity Levels and Scrap Collection



Sources: ABS Cat. No. 5201.0 and BHP (1000).

Figure 3. Real Scrap Price Index and Scrap Collection



Sources: BHP (1000) and The Iron and Steel Industry. OECD.

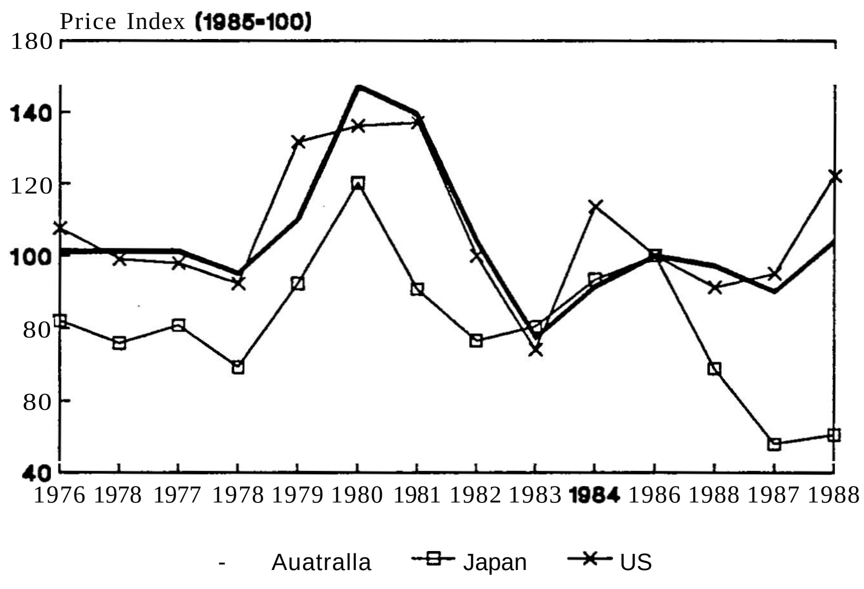
1987) if supply increased while demand remams static. These supply-demand interactions are examined in more detail later.

SCRAP DEMAND

A fundamental issue in modelling scrap demand and supply is to determine whether the domestic scrap price is determined by the interaction between supply and demand in the domestic market or whether that price is linked to the prices observed in foreign steel scrap markets. If price is determined in the domestic market, a bidirectional causality arises because price would be a function of domestic demand and domestic supply which in turn would depend on the prevailing price. On the other hand, if the domestic price responds mostly to developments in foreign markets, then it can be assumed that the causality between price and supply goes from the first to the second but not vice-versa.

According to BHP (1990, p. 28): 'the price of steel scrap in Australia is set, as are the prices of so many other commodities, by the export parity price ruling on the international market.' Further discussions with BHP Steel confirmed that domestic prices are indeed closely linked to foreign scrap prices. Figure 4 validates this view by illustrating the close relationship between scrap price trends in Japan - Australia's largest export scrap market - and, more obviously, the US - the world's largest exporter of steel scrap. On this basis, the demand for domestic steel scrap is assumed to depend (inversely) on the domestic price of scrap but not vice-versa.

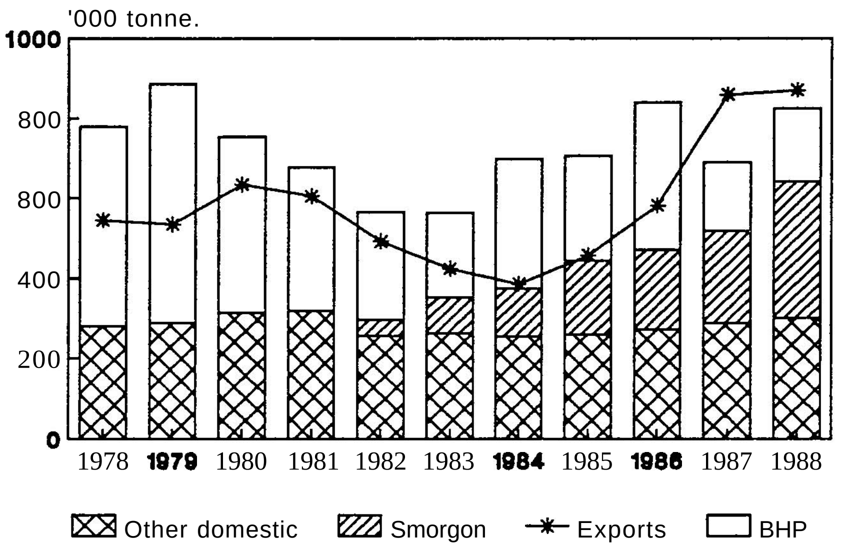
Figure 4. Scrap Price Indexes (Nominal)



Source: The Iron end Steel Industry, OEeD.

Economic theory also indicates that a scrap demand function should include the activity levels of the main scrap users. Those users were identified by using data provided in BHP (1990, p. 20) on scrap allocation within Australia. Part of that information is plotted in Figure 5.[3] The bars in that figure show the annual distribution of collected steel scrap among BHP, Smorgon - a mini-mill in Victoria using electric furnaces to remelt steel scrap - and other domestic users. The solid line on that figure plots scrap exports.

Figure 5. Scrap Allocation



Source: BHP (1990)

Figure 5 shows that much of the total scrap collected is exported. (More than half of the total was exported during 1987 and 1988.) The figure also illustrates the cyclical behaviour of scrap exports and domestic scrap allocations during the 1978 to 1988 period.

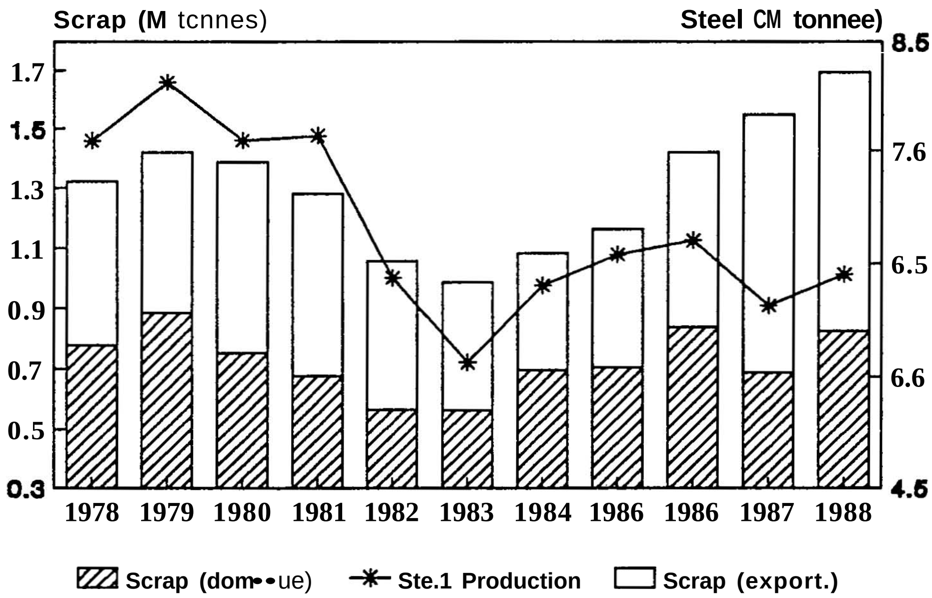
It is important to note in Figure 5 the increasing importance of scrap consumption by Smorgon. This firm was by far the largest single user of scrap, accounting for 41 per cent of total domestic consumption in 1988. The increased consumption by Smorgon is on line with that firm's expanded steel production which grew uninterruptedly between 1983 and 1988. Smorgon's increased consumption of scrap is in sharp contrast with BHP's scrap consumption which after accounting for 64 per cent of domestic scrap consumption in 1978, accounted for only 22 per cent in 1988. BHP's reduced scrap consumption resulted mostly from that firm discarding in the early 1980s the steel-

3 Data provided in BHP (1990) on scrap allocations to Comsteel and foundries is shown as 'Other domestic' in Figure 5.

making open hearth technology which allowed significantly greater flexibility to use scrap than is available currently.

Most of the scrap acquired by domestic users is employed as an input in steel making. Thus, a close relationship is to be expected between domestically used scrap and steel production. Indeed, Figure 6 seems to show such a relationship. In particular the various expansion-contraction stages of steel production seemed to be mirrored by changes in domestic scrap allocations (and by total allocations up to 1986). A more rigourous analysis demonstrates that the statistical relationship between steel production and domestic scrap allocations is relatively strong.'

Figure 6. Scrap Collection and Steel Production



Sources: BHP (1990) and Quarterly MIneral StatIstics. BMR.

MODELLING SUPPLY AND DEMAND

The observed quantities of scrap collected will be the net result of the interaction between scrap supply and demand. Thus, a simple model of the market for steel scrap may be specified along the following lines. Supply depends on the price of scrap and on

4 The following correlation coefficients between steel production and total scrap collection, scrap exports and domestic scrap allocations were found: 0.29, 0.01 and 0.59, respectively.

the activity level of steel-intensive demand sectors - the potential sources of scrap. Demand is also a function of the price of scrap and on the activity level of the scrap-using sectors, namely, the steel industry. This can be formalised in three equations:

Supply:	$SSCRAP_t = f(PSCRAP_t, CONST_t)$	(1a)
Demand:	$DSCRAP_t = g(PSCRAP_t, QSTEEL_t)$	(1b)
Market clearing:	$SSCRAP_t = DSCRAP_t + XSCRAP_t$	(1c)

where $SSCRAP_t$ is total scrap supply during period t, $PSCRAP_t$ is the price of scrap, $CONST_t$ is construction GDP, $DSCRAP_t$ is domestic scrap demand, $QSTEEL_t$ is domestic steel production, and $XSCRAP_t$ is scrap exports.

The following two expressions are obtained by specifying linear functions for equations (1a) and (1b) and replacing the resulting equation (1b) in equation (1C):[5]

Supply:

$$SSCRAP_t = k_1 + k_2 PSCRAP_t + k_4 CONST_t \qquad (2a)$$

Demand:

$$SSCRAP_t = k_5 + k_6 PSCRAP_t + k_8 QSTEEL_t + XSCRAP_t \qquad (2b)$$

The two equations above determine the quantity supplied and demanded when the market is in equilibrium.

An extension to equation (2a) was suggested by the observation in BHP (1990) that steel scrap is supplied through a relatively complex system of collections. This raised the possibility that scrap supply may not respond within one year to price changes as implicitly assumed by equation (2a). Thus, to account for possible delays between price changes and supply responses, a lagged price was added to equation (2a):

$$SSCRAP_t = k_1 + k_2 PSCRAP_t + k_3 PSCRAP_{t-1} + k_4 CONST_t \qquad (3a)$$

Equation (2b) needs to be also modified because Figure 5 strongly suggests that the analysis of scrap demand should take account of Smorgon's 1983 entry in the scrap market. Not only has that firm become the largest domestic user of scrap but its production technology based on electric furnaces currently makes Smorgon - unlike BHP - totally dependent on scrap as a source of iron. Moreover, as mentioned before, BHP's use of open hearth furnaces - which can take more scrap than the basic oxygen furnaces currently in use - was discontinued in the early 80s. This has further limited

5 A linear form was chosen because the market clearing condition (equation 1c) imposes a linear relationship between total supply, domestic demand and exports. On theoretical considerations, a linear form is probably not the most desirable algebraic specification but was nevertheless selected to simplify the estimation procedure.

the substitutability between scrap and other inputs in steel making and potentially changed the characteristics of the demand function.

Thus, the combined effects of Smorgon entry and the discontinuance of the open hearth technology could have affected the sensitivity of scrap demand to price changes (ie, alter k_6 and changed the amount of scrap required in steel production (ie, alter k_8). These potential effects can be examined through the use of a dummy variable, DM_t:

Demand:

$$SSCRAP_t = k_5 + k_6\,PSCRAP_t + k_7\,PSCRAP_t \cdot DM_t$$

$$+ \, kg\,QSTEEL_t + k_9\,QSTEEL_t \cdot DM_t + XSCRAP_t \qquad (3b)$$

where DM_t is equal to zero between 1978 and 1981 and equal to one from 1982 - the year when scrap was first allocated to Smorgon.s

No attempt was made to explain scrap exports which are assumed to be determined outside the model.

PARAMETER ESTIMATION

Equations (3a) and (3b) were used for the statistical analysis of scrap supply and demand. In equation (3a), k_2 should be positive as a direct relationship is expected between scrap supply and the price of scrap during the same period. The nature of the relationship between scrap supply and the price of scrap during the previous period (ie, the sign of k_3) is not so obvious, though. On the one hand, a high price may result in increased supplies the following period, ie, k_3 may be positive. On the other hand, because a high price should lead to an increased supply during the same period, less scrap may be available for the following period, ie, k_3 may be negative. The expected sign of k_4 is much less ambiguous because increases in construction activity should lead to greater generation of scrap. Thus, k_4 should be positive.

In equation (3b), k_6 (and $k_6 + k_7$) should be negative as an inverse relationship should exist between scrap demand and the price of scrap. On the other hand, kg (and $k_8 + k_9$) should be positive as scrap demand should increase with increasing steel production.

Statistical tests were carried out by adding an error term to equation (3a) and (3b).[7] Table 1 shows the computed R-squares, D-W statistics, the estimates for all the k_n

6 Equation (3b) implies that the demand equation for the period 1978 to 1981 is given by:

$$SSCRAP_t = kS + k_6\,PSCRAP_t + k8\,QSTEEL_t + XSCRAP_t$$

whereas the demand equation for the period 1982 to 1988 is given by:

$$SSCRAP_t = kS + (k_6 + k7)\,PSCRAP_t + (kg + k9)\,QSTEEL_t + XSCRAP_t.$$

7 Note that because $PSCRAP_t$ is assumed to be determined outside the model, single equation estimation by ordinary least-squares (OLS) is appropriate. This not only simplifies the estimation procedure but conserves degrees of freedom since at most five parameters need to be estimated for any individual equation.

coefficients, and the corresponding t-ratios. That table also shows the elasticities computed at the sample means.

Table 1 shows that in the supply equation the price coefficient (k_2) has the expected positive sign. All the estimated coefficients are significant at the customary 95 per cent confidence level or higher. The same is true for all the estimates in the demand equation except k_6 (and the constant term). In that equation, the signs of the price and steel production coefficients are as expected for both the 1978-1981 and the 1982-1988 periods.t

TABLE 1: PARAMETER ESTIMATES

Parameter	*Equation*	*Associated Variable* (1)	*Estimated Coefficient* (2)	*Elasticity at Means* (3)
k1	Supply	Constant	-1888.9 (-5.7)	na
k2	Supply	$PSCRAP_t$	4.420 (6.4)	0.44
k3	Supply	$PSCRAP_{t-1}$	-2.687 (-4.0)	-0.29
k4	Supply	$CONST_t$	0.207 (10.1)	2.29
k5	Demand	Constant	-631.9 (-1.9)	na
k_6	Demand	$PSCRAP_t$	-0.662 (-0.5)	-0.07
k7	Demand	$PSCRAP_t \cdot DM_t$	-3.910 (-2.3)	-0.46 (3)
k8	Demand	$QSTEEL_t$	0.198 (4.1)	1.04
k9	Demand	$QSTEEL_t \cdot DM_t$	0.082 (2.1)	1.46 (3)

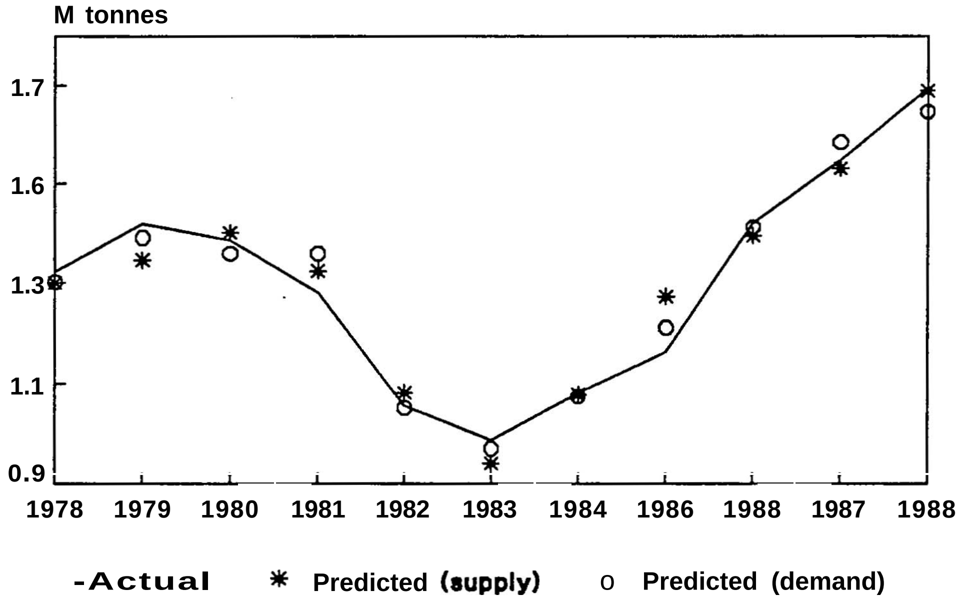
	R-square	*D-W statistic*
Supply	0.95	2.1
Demand	0.97	2.3

Notes: (1) na: Not Applicable.
(2) t-statistics in parenthesis.
(3) Net elasticity after 1981.

8 Estimates for the demand equation were obtained by using equation (3b) and restricting the coefficient of XSCRAPt to be equal to one. Alternatively, those estimated can be obtained by replacing the independent variable in equation (3b) with the value of the domestic scrap demand (ie, total demand minus exports) and deleting the export variable from the right hand side of the equation. This alternate procedure does not change the parameter estimates nor the associated t-statistics shown in Table 1 for the demand equation.

Figure 7 compares the observed amounts of scrap collected with the values predicted by the estimated supply and demand equation. That figure shows that the predicted values track actual scrap collections very well.

Figure 7. Actual and Predicted Scrap Collection.



Sources: BHP (1990) and Commission estimates.

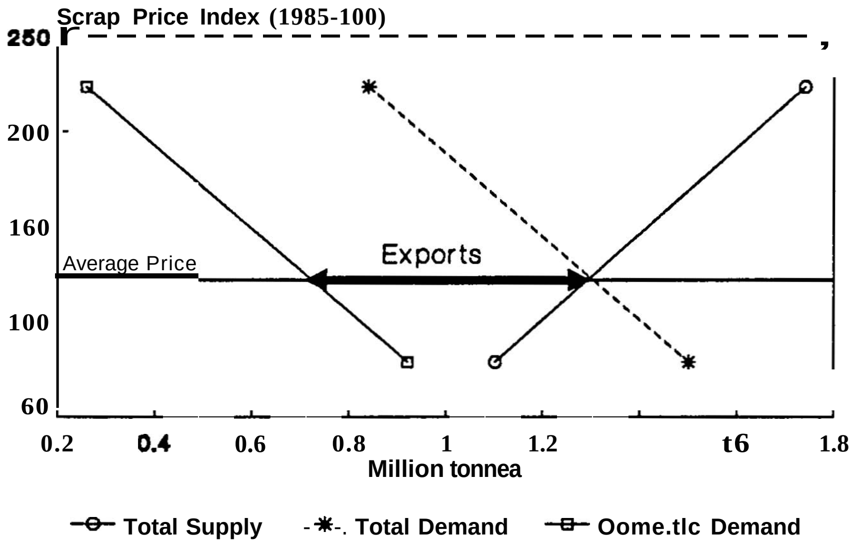
INTERPRETATION OF RESULTS

Scrap Price

The value and t-statistic associated with k_2 clearly indicate that the price of scrap has the expected direct effect on supply. The elasticity at means associated with k_2 corresponds to the own price elasticity of supply. That elasticity indicates that the effect of the scrap price on scrap supply is not large, a one per cent change in prices bringing about a 0.44 per cent change in supply. The sign of k_3 indicates a negative relationship between scrap supply and the scrap price prevailing during the previous period. (Note that the *ceteris paribus* assumption applies in this and following analyses, ie, all variables except the one under consideration are held constant.)

Allowing prices to vary while holding all other variables in the supply function (equation 3a) constant allows plotting the supply curve for scrap. This curve - by assumption a straight line - is plotted in Figure 8. The two points marked on that line correspond (from left to right) to predicted scrap supply values at the minimum and maximum prices observed during the 1978 to 1988 period. Note that despite the low price elasticity of supply, the large scrap price variations observed in practice mean that prices can readily affect the supply of scrap," As plotted in Figure 8, for example, consideration of the price extremes observed during the 1978 to 1988 period result in a supply change of about 640,000 tonnes (or 48 per cent of the average value).

Figure 8. Scrap Supply and Demand Curves.



Souroe: Commission estimates.

The price coefficients in the demand equation imply an extremely low (in fact not statistically different from zero at the 95 per cent confidence level) and negative price elasticity of demand for the period 1978 to 1981. The implicit price elasticity of demand for the 1982 to 1988 period has the expected negative sign and at (minus) 0.46 is in absolute terms as large as the price elasticity of supply.

As in the case of supply, a demand curve can be derived from the demand function (equation 3b) by allowing prices to vary while holding all other variables constant. This curve is plotted in Figure 8 with two points showing total demand values computed at

9 Also note that the price elasticity associated with a linear supply or demand function is not constant. In the case of the supply curve plotted in Figure 8, the price elasticity increases along the supply line from left to right.

the rmrnmum and maximum price observed during the 1978 to 1988 period.'? The possible large scrap price variations mean that prices can have a significant effect on demand despite a low price elasticity. As plotted in Figure 8, for example, total demand would almost double (an increased of about 660,000 tonnes) as a result of the scrap price falling from its observed maximum to its observed minimum.!'

Construction activity

The elasticity associated with the construction activity variable (k_4) indicates that scrap supply is very sensitive to the level of activity in the construction sector. This is especially true when the associated elasticity is compared with those related to other variables. However, although the elasticity of supply with respect to construction GDP is much larger than the price elasticity of supply (or demand), the much smaller variations (in percentage terms) in construction activity compared with price variations means that prices and construction activity can in practice have similar effects on supply.

According to Table 1, a one per cent change in construction GDP would result in a 2.3 per cent change in scrap supply. Thus, growth in that sector would seem to be in itself a powerful incentive for increasing steel recycling. On the other hand, recycling would appear to be one of the first casualties of downturns in the construction sector. As vividly argued in BHP (1990, p. 28), during an economic downturn:

> Everybody pulls his belt in, sales fall and cost reduction becomes the name of business' game. Scrap no longer waits to be collected. It remains locked up in buildings derelict but undemolished, in plant kept operating despite its poor efficiency, in cars still driven when their owners would prefer the newer model, in rails on minor lines forced by tighter budgets to last another season, and in the problem tractor the farmer must put up with for yet another harvest. When the economy turns up and money flows again through aching pockets, all these hidden stores of scrap become available and the collectors travel just that further to gather them. When plants look hungrily for scrap it is available, but in greater quantities than might have been predicted. This is the merchant's bounty, the accumulation of scrap through obsolescence that continues, unrecognised, during periods of downturn.

Steel Production

The demand for scrap is a function of steel production. The steel production coefficients for the 1978-1981 and 1982-1988 periods have the expected sign and are statistically different from zero. The (net) elasticity increases from 1.0 during the first period to 1.4 during the second. The latter value implies that a change in steel production results in a relatively large change in scrap demand. It is not clear why the sensitivity of scrap demand to changes in the amounts of steel produced should increase during the second period for it probably should be expected that the entry of Smorgon and the replacement

10 The line was plotted using the post-1981 coefficient estimates.

11 Adams (1976, p. 215) has observed that a low price responsiveness is to be expected if inferior quality scrap (eg 'obsolete') predominates over more desirable types of scrap (eg 'prompt').

of the open hearth technology by BHP would reduce the flexibility of scrap usage in steel making.

SUPPLV-DEMAND INTERACTIONS

It is instructive to track the changes in scrap collections illustrated in Figure 7 based on the supply-demand interaction represented in Figure 8. This analysis is facilitated if, as Figure 7 graphically suggests, the 1978 to 1988 period is divided in three intervals: one characterised by relatively high scrap collections (1978 to 1981), one of low scrap collections (1982 to 1984), and one of growing scrap collections (1985 to 1988).

The period from 1978 to 1981 was characterised by high scrap collections, scrap prices and scrap exports. This situation resulted from various factors: on the supply side, a relatively low activity level in the construction sector meant that the supply curve was shifted to the left of the average supply line plotted in Figure 8; on the demand side, a booming steel production shifted the domestic demand curve to the right of the average demand line. On their own, these two shifts would have resulted in a drop in scrap exports. However, the prevailing high scrap prices meant that in fact the gap between total domestic demand and total domestic supply increased and so did exports.

The period 1982 to 1984 is characterized by low scrap collections, scrap prices and scrap exports. During this period, construction activity was only slightly lower than during the initial period analyzed. Thus, the supply curve was probably not appreciably shifted. Demand, however, was dramatically affected by the collapse of steel production which shifted the domestic demand curve to the left. Under these conditions, exports would have increased. However, a simultaneous fall in scrap prices meant that in fact scrap exports dropped during this period.

Scrap collections, scrap prices and, especially, scrap exports increased during the 1985 to 1988 period. During this period, construction activity increased significantly and uninterruptedly thus shifting to the right the supply curve. A partial recovery in steel production shifted the demand curve in the same direction. Scrap exports would have remained about constant except that scrap prices increased during the same period thus effectively widening the gap between domestic scrap supply and demand.

CONCLUSIONS

By weight, steel is by far the most recycled material in this country. In the main, the large amounts of steel being recycled have not resulted from environmental or resource scarcity concerns nor from government requirements. In fact, those large amounts have arisen mostly from the technical requirements of steel production and commercial considerations of both steel producers and steel users (who eventually must become potential scrap sources).

As stated in le (1991a), recycling is not an end in itself. Steel recycling in particular is the by-product of a complex interaction of several factors including prices and the activity levels of various economic sectors. demonstrated in this paper, those factors are incessantly changing. Under those conditions, attempting to determine the 'optimal' level of steel recycling is a practical impossibility. Thus, a recycling target would necessarily be arbitrary and, very likely, inappropriate. A misallocation of resources would probably result not only from setting an improper target but also because the flexibility of the market system would be replaced by the invariably sluggish machinery of regulation.

Of course, it is possible that the present allocation of resources to steel using activities and steel making is socially inefficient and has lead to an improper level of steel recycling. If this is the case, however, the proper policy response is not to target steel recycling in itself. Instead, efforts should be directed to ensuring that complete and efficient markets are created so that the variables responsible for recycling (prices and levels of and sectoral economic activity) approach the socially optimal levels.

APPENDIX: DATA

Scrap collection and allocation data was obtained from BHP (1990). It is indicated there that the data is an update of the one originally published as part of the Technical Colloquium on Steel Scrap hosted by BHP Steel in Sydney in September 1988.

Steel production corresponds to production of raw steel (including recovery from scrap) obtained from *Quarterly Mineral Statistics*, BMR, Canberra.

Scrap price indexes were derived from 'Index of Home Scrap Prices (delivered) for Selected Countries', *The Iron and Steel Industry*, OECD, Paris.

Construction and manufacturing GDP in nominal dollars were obtained from 'GDP at factor costs, by industry', *Australian National Accounts, National Income and Expenditure, Summary* (Cat. No. 5201.0), ABS, Canberra.

All dollar values and the scrap price index were transformed to constant (real) values by using the implicit GDP price deflator (Gross Domestic Product, 1985= 100) obtained from the *Australian National Accounts* (Cat. No. 5206.0), ABS, Canberra.

The variables and $XSCRAP_t$ in equations (2a) and (2b) were expressed in thousand tonnes. $CONST_t$ and $MANUF_t$ in those two equations were expressed in (real) million dollars.

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