A TIME SERIES MATERIAL FLOW ANALYSIS OF THE UK STEEL SECTOR

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Abstract

This paper presents a material flow analysis of iron and steel within the economic system of the UK. Information on the amounts of iron and steel going into different groups of goods, together with values for their estimated life times, have enabled modelling of the yearly release of iron and steel from the use phase in the form of end-of-life scrap. By comparing modelled generation of scrap with actual scrap consumption in the UK, we obtain estimates of accumulation/leakage of iron and steel scrap in the UK. The model indicates that as much as 50% of the scrap that was potentially available in 1999 as end-of-life scrap has either been accumulated within the economic system or been lost. The analysis suggests that it is in the smaller consumption groups such as mechanical & electrical engineering and domestic appliances that the largest gains can be made in increasing the recovery.

1 INTRODUCTION

Various sources state recycling rates for different types of iron and steel (I & S) goods. However, many of them do not offer a clear understanding on how the rates have been derived. Furthermore, there is uncertainty over the definition of “recycling rate” in a sector like I & S where the quantity of material entering use varies over time and the service life differs between applications, so that different products available as scrap entered use at quite different past times. In order to obtain better understanding of the flows of steel scrap from end-of-life goods in the UK, a comprehensive compilation of the historical flows of I & S through the economic system of the UK has been performed. The time aspect is taken into account by allowing for the delay of stocks of I & S goods in use. The aim of the study is to estimate how much end-of-life scrap might be lost from the economic system in the UK and from which sectors the largest losses might occur.

2 DESCRIPTION OF THE MODEL

The model that has been used to calculate the generation of prompt scrap (from manufacturing) and end-of-life scrap in the UK is outlined in Figure 1. The analysis covers the major I & S containing flows, i.e. minor products such as dust and slug have been ignored. The system boundary for the analysis is the UK border. The starting point is the production of I & S, which in the UK consumes imported virgin material as well as domestic scrap and a very small portion of imported scrap. The finished I & S products are either exported or consumed by domestic manufacturing industries. The industries also receive I & S from imports. The total flow of I & S into the manufacturing industries is split [6] into different groups of goods, presented in Table 1. In the absence of scientific information, we have assumed this split to be constant over time. We have also assumed that the flow of prompt scrap is 10% of the I & S entering goods manufacture. The goods are then either exported or enter the use phase together with imported goods, where they stay until they reach the end of their service lives. The estimates for the lifetimes of the different goods are shown in Table 1. At the end of their lifetimes the goods are released as end-of-life scrap. Part of the scrap is recovered and either consumed in domestic I & S production or exported and recycled abroad. The recycling rate that we use in this paper is defined as the yearly recovery of prompt and end-of-life scrap divided by the yearly release of prompt and end-of life scrap.

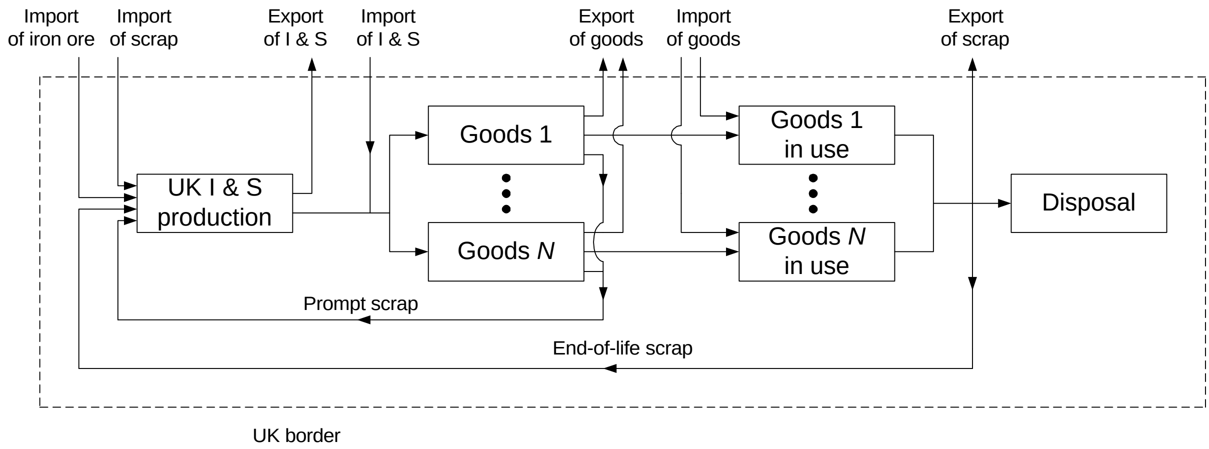

Figure 1 Model of scrap generation and consumption.

Data for production and trade of I & S [4] and consumption and trade of scrap [1,4] have been collected on a yearly basis for the years 1968 to 1999. Data for traded goods [3] have been collected for every five years and then linearly interpolated to yield yearly values. In order to estimate how much I & S the traded goods contain we have assumed a constant average I & S content for each category [8,10].

Table 1 Percentages for UK markets used in the material flow analysis for splitting the flow of iron and steel into different manufacturing sectors in the UK, plus lifetimes.

Groups of goods	**% of UK market**	**Lifetime in years**
Motor vehicles	17	13 [11]
Construction	22	30 [7]
Metal working & engineering tools	9	10 [9]
Industrial and process plant	14	10 [9]
Other mechanical engineering	10	10 [9]
Electrical engineering incl domestic appl.	5	7 [9]
Other metal goods, eg furniture, doors, windows, springs etc.	9	15 [9]
Wire drawing and manufacture	6	10 [9]
Coal, coke, petroleum/electricity, water/chemical/allied industries	3	25 [9]
Packaging	5	1 [9]

3 RESULTS

Estimates for I & S in goods that entered the use phase in the UK over the past thirty years are shown in Figure 2. Up until the most recent ten years, most of the manufactured goods containing I & S were produced domestically. Since then the trend has changed and more and more goods are now being imported instead; in 1999, 71% of the I & S going into use entered use in the UK in the form of imported manufactured goods. The chart also shows that the overall amount of I & S in goods entering use has stayed fairly stable. One explanation for this is that the market for the kind of goods that typically contain I & S is reasonably saturated and that when the goods are bought they are bought to replace an obsolete item or upgrade an item to a newer model; in other words, consumers are not buying goods that they do not already own. Another possible interpretation of the stable input is that consumption of I & S containing products might have increased over the years, but the material intensity per product has decreased, resulting in a reasonably constant input of I & S in the economy.

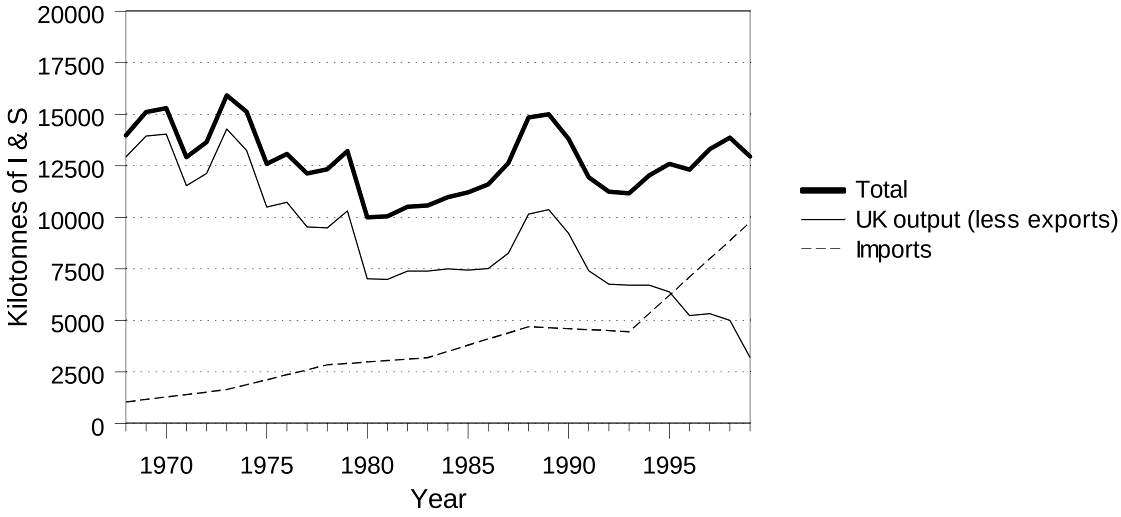

Figure 2 Origin of manufactured goods containing I & S entering use in the UK.

Figure 3 also shows I & S in goods entering use, but subdivided into the different categories of finished goods for the total of UK produced and imported goods. It is clear that automotive and construction are consistently the two largest sectors consuming I & S. Knowing the amount of I & S that goes into each end use together with the values for their estimated life expectancies, we are able to model when the metal will be released from the use phase. Figure 4 shows the estimated release of scrap from the use phase (end-of-life scrap) and from the manufacturing stage (prompt scrap). We cannot estimate scrap release until 30 years from the start of the time series data, this being the lifetime in the sector with the longest use phase. The data series starts in 1968; the scrap release estimates in Figure 4 are therefore only shown for years 1998 and 1999. Figure 4 also shows the amount of scrap that has been exported and the amount that has been received at steel plants and foundries in the UK (not including scrap arising at the plant, so called home scrap). It appears that, in 1999, the inferred amount of scrap available is twice the amount of scrap actually recovered. In other words, the inferred recycling rate in 1999 for scrap arisings is 50%. The model thereby suggests that there is a vast amount of scrap that is not being recovered at present.

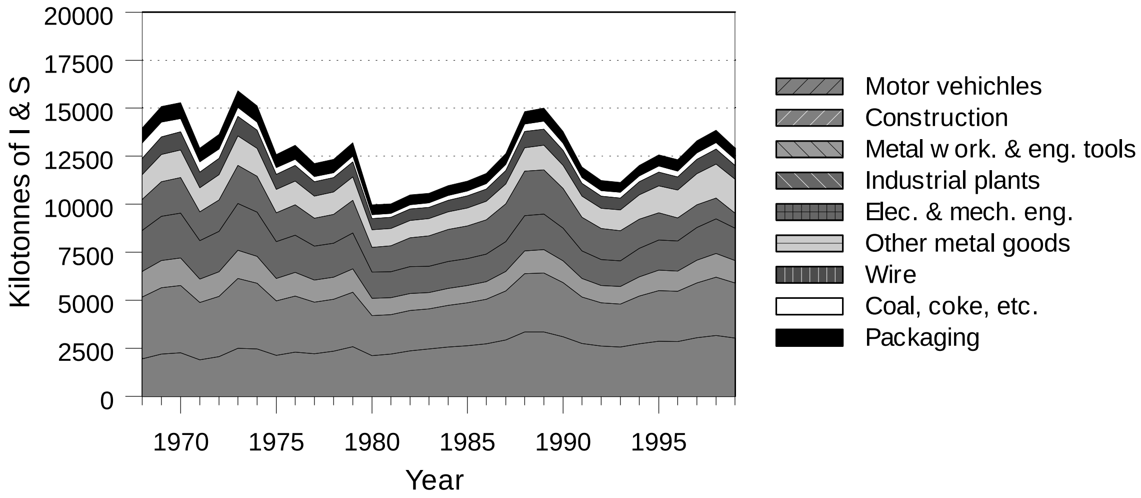

Figure 3 Manufactured goods containing I & S entering use in the UK.

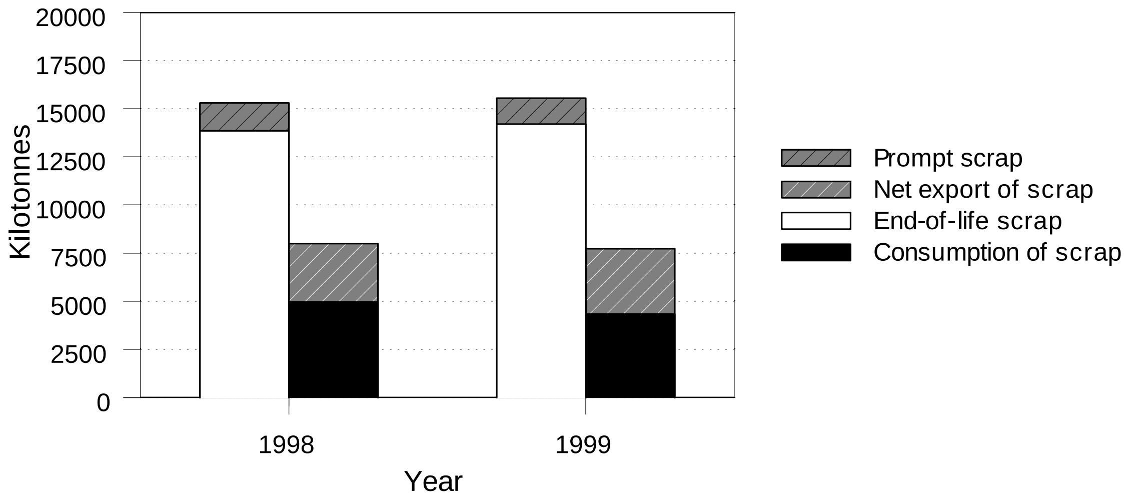

Figure 4 Quantities of end-of-life scrap and prompt scrap leaving the use phase in relation to quantities exported and consumed in UK I & S making.

3.1 Sensitivity analysis of inferred recycling rate

The end-of-life scrap arisings estimated in this model is affected by the key parameters of expected lifetimes, domestic market shares for I & S and I & S contents of traded goods. In order to understand the reliability of the inferred recycling rate, we have examined how changing these parameters influences the predicted amounts of released scrap.

Setting all lifetimes to ten years apart from packaging (1 year) and construction (30 years) gives an increase in released end-of-life scrap in 1999 (Table 2), due to a peak in the amount of steel going into use in the UK around 1989. When the lifetimes are increased or decreased five years this gives a decrease in released amount of scrap. However, all of these quite dramatic changes in lifetimes result in an inferred recycling rate of 46 to 57%, i.e. the rate is in the same range as estimated for the original lifetimes (50%).

The effects of changing the market shares of the I & S going into UK manufacturing sectors can be seen in Table 3. Changing the percentages for UK markets in the model by increasing and decreasing the share for the two major categories (automotive and construction) has only a minor effect on the amount of released end-of-life scrap in 1999.

Estimates of I & S content is only applied to traded goods in the model and changing this parameter radically does not have a significant effect on the amount of released scrap. Setting the steel content to 100 and 0% for all traded goods gives an inferred recycling rate of 48 and 53% respectively. The reason for the low impact of changing the I & S content is that imports and exports of goods have been largely similar in quantity and growth rate over the last 30 years, so that they largely balance each other out.

Table 2 Effects on inferred recycling rate in 1999 of changing the lifetimes of goods.

Lifetimes	**Inferred end-of-life and prompt scrap (Mtonnes)**	**Actual recovery of scrap (Mtonnes)**	**Inferred recycling rate**
Unchanged	15.56	7.72	50%
Increase all by 5 yr. but keep construction at 30 yr.	14.26	7.72	54%
Decrease all by 5 yr. but keep packaging at 1 yr.	13.53	7.72	57%
All 10 yr. except for construction (30 yr.) and packaging (1 yr.)	16.73	7.72	46%

Table 3 Effects on inferred recycling rate in 1999 of changing the market share of UK manufacturing industry.

Market share	Inferred end-of-life and prompt scrap (Mtonnes)	Actual recovery of scrap (Mtonnes)	Inferred recycling rate
Unchanged	15.56	7.72	50%
Increase automotive to 22% Decrease construction to 17%	15.26	7.72	51%
Increase automotive and construction to 22 and 27% respectively Decrease all other groups by 1-2% to satisfy overall balance	15.58	7.72	50%
Decrease automotive and construction to 12 and 17% respectively Increase all other groups by 1-2% to satisfy overall balance	14.18	7.72	54%

3.2 Recycling rates for different sectors

We have created possible scenarios of recovery from each sector in 1999 by applying recycling rates to the modelled amount of released scrap. Recycling rates that have been used for the different scenarios are shown in Table 4. For the sectors automotive [10], construction [5] and packaging [2], recycling rates have been extracted from literature. Information on recycling rates for the remaining sectors has not been found, and rates for these have been chosen to obtain a total scrap recovery equal to the documented scrap recovery in 1999. In scenario 1, the rate 11% is chosen for all sectors other than automotive, construction and packaging. It is however likely that industrial plant equipment has a higher recovery than products such as domestic appliances, smaller engineering tools and metal goods which is represented in scenarios 2 and 3. In all three scenarios, quite low recycling rates had to be chosen for groups 5-9 in order to obtain the documented scrap recovery in 1999. Providing that the recycling rates extracted from literature are accurate, the analysis demonstrates that it is in sectors other than automotive and construction where focus should be put for increased recovery.

Table 4 Scenarios of different recycling rates for the different sectors in 1999 used in the model to generate the amount of recovered scrap that is equal to the documented recovery of scrap in 1999: 7.72 million tonnes.

Sector	Inferred end-of-life and prompt scrap in 1999	Recycling rates in Scenario 1	Recycling rates in Scenario 2	Recycling rates in Scenario 3
1. Motor vehicles	2.731	0.87	0.87	0.87
2. Construction	3.458	0.85	0.85	0.85
3. Metal working & engineering tools	1.216	0.11	0.24	0
4. Industrial and process plant	1.860	0.11	0.24	0.37
5. Other mechanical engineering	1.248	0.11	0	0
6. Electrical engineering incl. domestic appl.	0.841	0.11	0	0
7. Other metal goods, e.g. furniture, doors, windows, springs etc.	0.923	0.11	0	0
8. Wire drawing and manufacture	0.841	0.11	0	0
9. Coal, coke, petroleum/electricity, water/chemical and allied industries	0.427	0.11	0.24	0.37
10. Packaging	0.657	0.33	0.33	0.33
Prompt scrap generation	1.355	1	1	1
Inferred amount of recovered scrap in Mtonnes		7.72	7.72	7.72

4 CONCLUSIONS

Material flow analysis (MFA) for iron and steel (I & S), using historical time series data, provides estimates for how much scrap is released from the use phase in the UK each year. Sensitivity analysis has shown that the model is robust enough to generate reliable results. For 1999, the estimated amount of released end-of-life scrap and prompt scrap greatly exceeds the documented amount of scrap that is consumed within the country or is exported. This indicates either a loss of end-of-life scrap of around 50% or that there is an undocumented accumulation of I & S scrap within the economy. Recovery in the major sectors automotive and construction is reported as working well, and this MFA does not contradict this. Even though these two major sectors are the largest consumers of I & S in the UK, the other sectors together consume more than half of the total domestic consumption and therefore appear to account for the lost end-of-life scrap. Focus therefore needs to be put on recovering scrap not only from the major sectors but also the smaller ones such as packaging, wire, engineering tools and domestic appliances. More detailed MFA of these sectors therefore represents a research need.

The environmental performance and resource efficiency of any sector within an industrial ecology depend on the recovery and re-use or recycling of scrap material emerging from use. Recovered material may be re-used in the same sector, or “downcycled” to another application (usually with lower purity or performance specifications), or sent to landfill. For high re-use and recycling rates to be maintained, it is essential that the demand for scrap be maintained and that scrap quality is assured. These requirements illustrate the function of scrap “agglomerators”, and show the importance of quality assurance in scrap management. Use of the kind of MFA summarised in this paper would therefore support improvements in resource efficiency in this and other material sectors.

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