

Natural Resource Usage in the U.K. - A Preliminary View

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Abstract

This paper presents and discusses two tentative models of the U.K. natural resource usage system.

1. Introduction

It is becoming almost axiomatic in industrial, governmental and academic circles that the world in general, and the United Kingdom in particular, is likely to face more severe problems from the shortage and high cost of all kinds of natural raw materials, especially metals and minerals. A variety of solutions have been suggested, including the development of technology to extract material from reserves which have hitherto been intractable or inaccessible, the development of the technologies of recycling and substitution, and the use of government controls on usage. A consequence of this has been that very large sums of money are being devoted to technological research and to other areas such as demand prediction.

It is perhaps, less axiomatic that there is no single 'resource problem' but, instead there is a whole complex of interactions which we may call the 'resource system'. If money is simply spent broadcast on improving such a system there seems to be at least a prospect that some of it will be wasted, despite the technological merit of the work, simply because the interactions of the system will overcome piecemeal improvements by creating disadvantages elsewhere. Thus, in order to have the most effective technological research programme one must also understand the system and the way in which it will be affected by technological change.

The basic approach of this paper is to use the system dynamics method to construct models of resource usage systems. Two tentative models are presented and briefly discussed.

2. Control Possibilities in the System

The ways in which the system can be controlled may be divided into two broad categories, either technological or governmental.

Technologically there are a number of possible approaches - by causing changes in recycling, substitution, product lifetime, efficiency in the use of material, etc.

The non-technological approaches to the regulation of the system include taxation subsidy, quota and legal restrictions. It is argued that these need to be applied in different ways at different states of the system. A simple example is a tax holiday to get a new mine into operation followed by various restrictions to prolong the project's lifetime.

3. Classes of Model

There are many possible ways of classifying natural resource models- however two important features of any model are a) the time horizon of the model and b) the boundary of the system to be modelled.

It is useful in the present context to consider two classes of model. Firstly, long term global models which are mainly concerned with the ultimate limits of resource availability in the essentially closed world system. Models of this type have been discussed over a prolonged period (1) and have been the subject of recent work by Meadows et al (2) and Inston (3) among others. Secondly, medium term national models, which are concerned with national subsystems and their interaction with the rest of the global resource system, and have a time horizon in which depletion effects are not significant for most non-renewable resources. We shall be principally concerned with the second class of model in this paper.

4. Tentative Models of Resource Systems

In this section we describe tentative models of natural resource usage, clearly these descriptions can do no more than convey the outline of what a finished model would look like.

The models outlined below are concerned with materials which are non-renewable (within the time horizon of the model) but which may be recycled.

4.1. Subsidy Policy Model

There are a number of ways in which the U.K. could reduce the amount of a given material which it imports without reducing its usage of that material. In order not to complicate the influence diagram unduly we will concentrate on two of the more important of these methods.

- a) increasing the recycling of scrap material
- b) using a substitute for the imported material

The later course of action could be effected in at least two ways. Firstly, by replacing imported material by home produced material (e.g. by increasing production of Cornish tin). Secondly, by substituting a cheaper imported material for a more expensive one (e.g. using aluminium in place of copper or plastic coating in place of tin plating). Both of these types of substitution are represented by a single composite substitution loop in the diagram below.

The diagram below shows control being exerted via subsidies, clearly other financial, legal and physical controls are also possible. One of the major advantages of a system dynamics model is that it allows the effects of different control policies to be readily compared.

It can be seen that the upper part of the diagram represents material flows in the system, which must occur so that the quantity of material is conserved. The lower part of the diagram represents possible control loops acting via a subsidy policy. This part of the diagram is not necessarily conservative.

Clearly it would be straightforward to construct a diagram for two or more materials which could be used as substitutes for each. This could be done by linking the diagram for the individual material via the substitution loops.

In the diagram subsidies (both recycling and substitution) are shown as influencing costs. This link can take a number of forms, including a perhaps less obvious mechanism whereby investment in research leads to technological advance which can lead to reduced costs.

"Demand," "World Market Price" and "Energy Cost" are exogenous variables in that they vary as a result of factors external to the system under consideration, showing both short term fluctuations and long term trends. The objection of the modelling exercise might, in this case, be defined as an attempt to find control policies which result in the import bill being well behaved in the face of a wide range of possible changes in the exogenous variables.

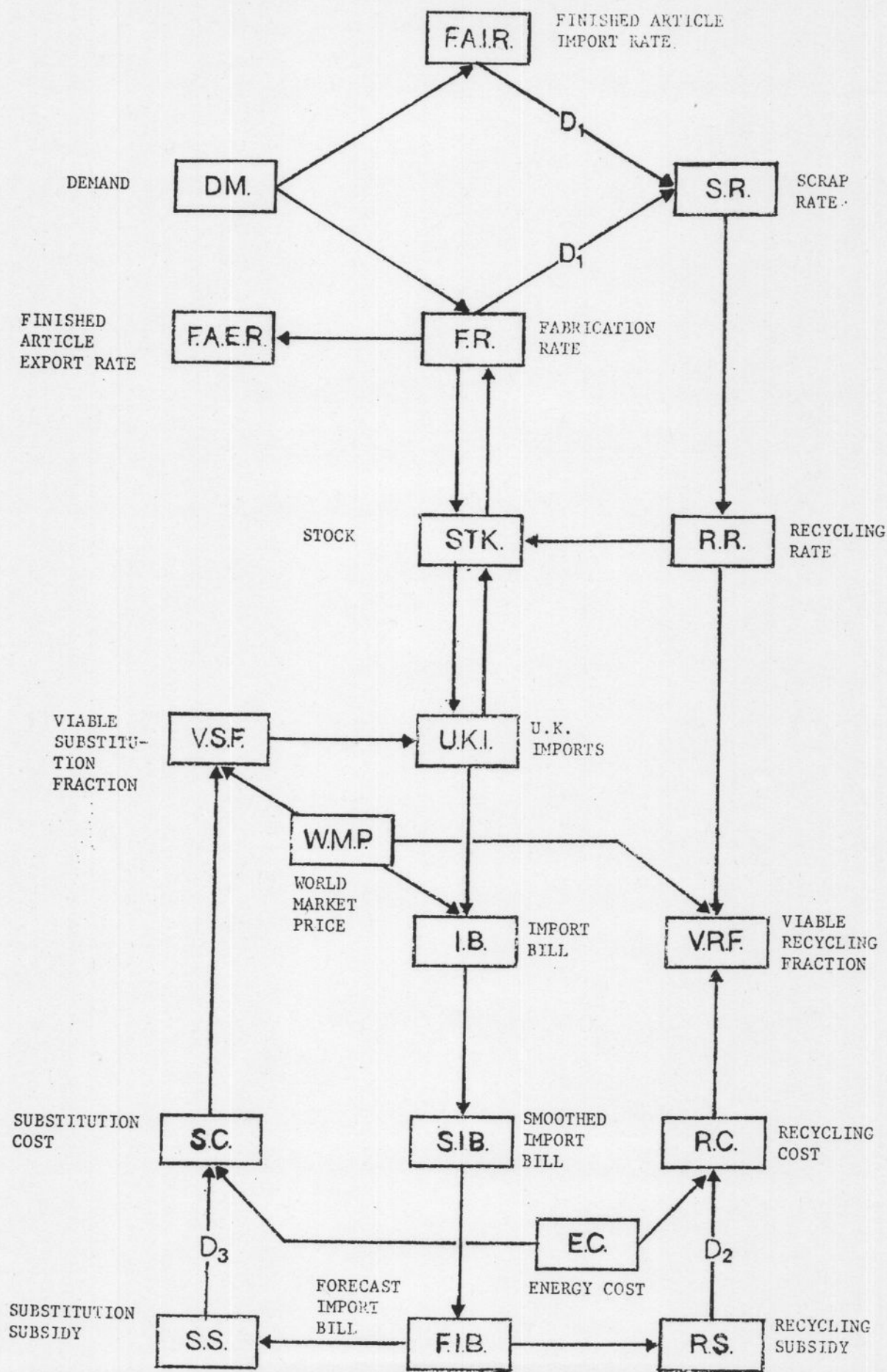


Fig. 1 INFLUENCE DIAGRAM FOR SUBSIDY POLICY MODEL

4.2. More Detailed Recycling Model

The model outlined in the previous subsection is of a fairly general nature, and thus it may be useful to consider a less general but more detailed model.

In order to simplify the problem further, let us consider only the recycling of scrap material, and let us assume that it is possible to control the system via subsidies on the construction of new recycling plant. We further assume that the import and export rates are equal for finished goods containing the material in question.

The model is concerned principally with the medium term effects on the system, and in particular on the import bill of changes in "demand" and "world market price". It is anticipated that both of these would, on average, increase as time proceeds. This would have a twofold effect on the amount of material available to be recycled. Firstly, increases in the "fabrication rate" would be reflected in the scrap rate, after a delay equivalent to the average product lifetime. Secondly, as the "world market price" increased it would become viable to recycle a greater proportion of the scrap. Clearly an increasing requirement for recycling capacity would result. Let us assume that it is desired to recycle at the maximum viable rate, i.e. avoiding capacity limitation of the rate. Then it would be necessary to order capacity in advance of the requirement for it because of the delays involved in acquiring capacity. Thus the object of a policy would be to ensure that the capacity was available when required, i.e. it is a method by which a government with a fairly long time-horizon could persuade industry with a shorter time horizon to anticipate the need for capacity.

In this subsection we have concentrated on the longer term behaviour of the exogenous variables, the control mechanism will of course have to be designed to deal with shorter term fluctuations in these variables. This is done in part by the use of exponential smoothing to reduce the effect of high frequency noise in the system. However, low frequency fluctuations associated for example with the business cycle will remain.

The relation between "viable recycling fraction" and "world market price" is discussed briefly in the appendix.

The magnitude of the average product lifetime i.e. the delay between fabrication and scraping can have a significant effect on the system. Take the example of copper products for which the average lifetime is of the order of 20 years, assuming an exponential growth in fabrication of 4% p.a. for 20 years the scrap rate would be about one half of the fabrication rate. For a material where the product lifetime is much shorter the two rates may be almost equal. Clearly not all the products made of a given material have the same lifetime, the actual distribution of lifetimes is approximated by an exponential delay of appropriate order.

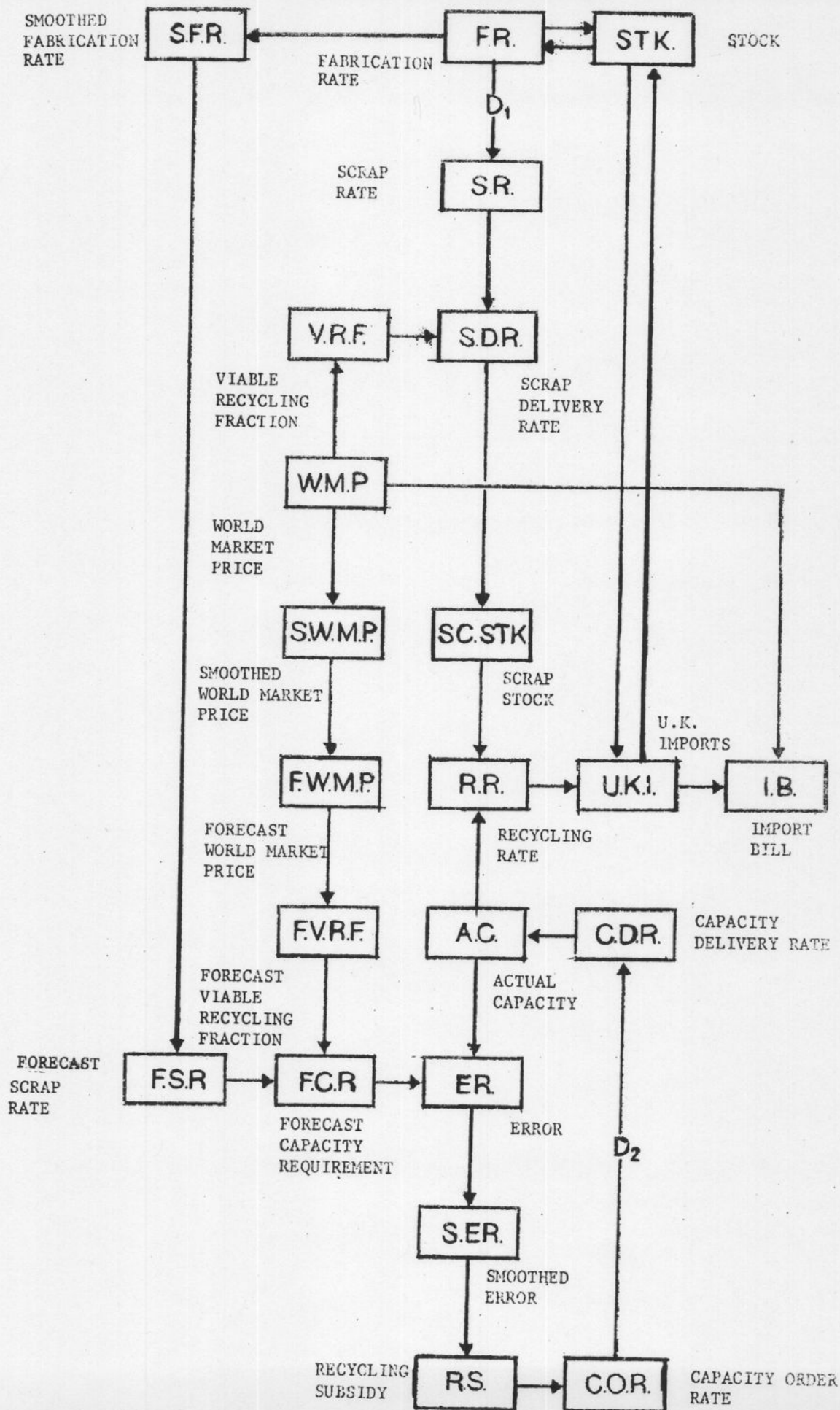


Fig. 2 INFLUENCE DIAGRAM FOR RECYCLING MODEL -22-

5. Possible Developments of the Tentative Models

Clearly there are a considerable number of ways in which the models outlined in the previous section could be developed, three such are mentioned below.

Firstly, the models consider only the cost of imported material, another important factor which could be included is security of supply.

Secondly, the models make no explicit reference to companies operating in the materials supply and usage sector. It would seem very unlikely that such a neglect can be justified in more detailed models than the ones above, because of probable differences in objectives and planning horizons between companies and the government. One might expect the government to be interested in the national import bill whereas companies are more likely to be interested in corporate profitability. In practice the interaction between government and companies might well be one of the more interesting features of more detailed models.

Thirdly, the role of forecasting in the models and in particular the effects of forecasting errors needs careful attention. In this context the work of Sharp (4) should prove useful.

References

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|---|--|
| (1) See for example
BARNETT H.J. and MORSE. C.F. | "Scarcity and Growth" John Hopkins Press
1963 |
| (2) MEADOWS D.L. (Ed) | "Dynamics of Growth in a Finite World"
Wright Allen Press, 1974 |
| (3) INSTON H.H. Conference on | "Conservation of Materials" Harwell, 1974 |
| (4) SHARP J.A. | "DYNAMICA" to be published Spring 1976 |

Acknowledgements

The Author wishes to acknowledge valuable discussions with R.G. Coyle, J.A. Sharp and V. Thillainathan. The first named was responsible for instituting a study of natural resource usage in the System Dynamics Group at Bradford.

APPENDIX

Relation between "Viable Recycling Fraction" and "World Market Price"

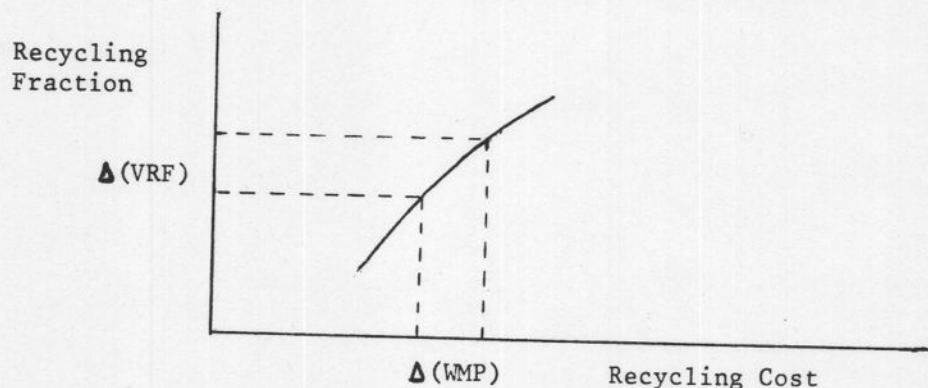
The complex nature of the relationships represented in the influence diagrams and in particular the dynamic behaviour of these relationships is well illustrated by the relation between "viable recycling fraction" and "world market price".

The cost of recycling material varies with the type of scrap. We can illustrate this point by considering three types of copper scrap arranged in increasing cost of recycling.

- a) off-cuts of copper tube and rod
- b) spent electrolyte from a copper plating bath
- c) short lengths of copper wire in redundant electrical machinery

We might expect that the relation between recycling fraction and cost of recycling might look somewhat as below. The precise form of the relation is not important in the present discussion (the current form of the relation can, within limits, be obtained by empirical means). Although the curve is shown as being smooth it may well, of course, contain steps.

Fig. 3 Recycling Fraction v. Recycling Cost



The fraction of the scrap which can be economically recycled is obtained by plotting the world market price of new material on the recycling cost axis and finding the corresponding value of recycling fraction. It can be seen from Fig. 3 that if the world market price increases then the fraction which can be viably recycled increases. The viable recycling fraction will also vary with time because the relation between recycling fraction and recycling cost is not constant. This relation will vary because a) components of the recycling cost, e.g. energy cost, will vary with time and b) technological changes will modify the form of the relation. Thus we see that the relation between world market price and viable recycling fraction will show complex dynamic behaviour exhibiting both short term fluctuations and long term movements.