THE RELATIONSHIP BETWEEN MATERIALS, ECONOMIC STRUCTURE AND PERFORMANCE

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The Relationship Between Materials, Economic Structure and Performance

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SUMMARY

The objective of this work is to contribute to the understanding of the role of the engineering and construction materials industries in the economic performance of the United Kingdom between 1954 and 1974.

This requires the establishment of a framework for the analysis and quantification of the factors affecting materials consumption, and of the influence of developments in materials production technology and consumption trends upon aspects of the national economy.

The change in the output of materials over time is explained in terms of various economic structural and technological factors, and the relationship between materials substitution and changes in the relative price and resource requirements for the production of materials is analysed.

The role of engineering materials in the external trade of the United Kingdom is investigated.

Finally an attempt is made to establish the effect of changes in materials use upon engineering industry productivity and hence overall economic performance. A suitable productivity criterion is devised for this purpose.

The principal conclusions are:

(i) Substitution between materials in the production of engineering goods was the major determinant of the change in the relative level of output of each material. This substitution was partly attributable to changes in relative price, but also to improvements in the manufacturing properties and processes associated with particular materials.

(ii) Efficiency of processing materials in the engineering industries was a potentially more important influence upon the United Kingdom's balance of trade than its dependence upon (non-energy) raw materials imports.

(iii) Whilst there was evidence that there had been substitution in favour of those materials which had shown the most progress in their economy of labour and capital use, more detailed information would be required to estimate the influence of materials use upon the total productivity of an industry.

Materials Resources Economy

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CHAPTER 1

INTRODUCTION

Objective

The objective of this work is to identify and illustrate the relationships between the production of engineering materials and the economic structure and performance of the United Kingdom.

This objective has two components:

(i) The analysis and quantification of the effects of changes in the economic and technological environment upon trends in materials consumption.

(ii) The estimation of the impact of developments in materials production technology and efficiency of use upon aspects of economic performance.

Section 1.1

Background

The most obvious way in which the economic environment influences materials use is through the demand for the output of the engineering or construction industries. Changes in the demand for materials may arise from shifts in the aggregate level of demand in the economy or from changes in the relative requirements of different sectors. For example, the transfer of demand from manufacturing to services would decrease the relative demand for steel and other materials required for manufacturing production without necessarily changing the total output of the economy.

Materials which are intensively used in the faster growing sectors of the economy will tend to grow relatively rapidly as a result.

The demand for a material may also be affected by its price relative to potential substitutes or by technical improvements in its properties which make it appropriate to a particular application.

The first part of the work reported in this thesis is an attempt to explain the absolute and relative growth of materials consumption in the post-war period in terms of these factors. This constitutes the part of the work corresponding to the first component of the objective.

The second part of the objective concerns the estimation of the impact of the efficiency and effectiveness of materials use upon economic performance.

Materials selection, technology and efficiency of use have both microeconomic and macroeconomic implications:

At the level of the firm, the cost of materials inputs is a high proportion of total cost, often significantly greater than labour cost, (1), (2), (3) and thus changes in the efficiency of use could have a substantial impact upon the profitability of the firm (1), (4), (5).

Furthermore, the properties of various materials and the processes associated with them play an important role in determining the quantity and quality of labour and capital required by the firm: the manpower requirements for making a plastic component will differ from those for the manufacture of a corresponding one made from metal. Similarly, the properties of materials determine machining rates, the number of steps in a fabrication process and many other factors which in turn determine the type and volume of machinery required (1).

Yield rates in materials processing are another important determinant of resource requirements, since the higher the proportion of waste, the more labour and capital will be required to achieve a given level of added value.

The macroeconomic impact of materials use arises from the indirect effects of decisions taken within firms or factories. A decision to use one material instead of another in a process, not only influences direct labour and capital requirements, but also affects the output of those commodities which are required as inputs to the materials industries concerned, and thus the labour, capital, energy and other resources required in those industries.

A decision to use aluminium instead of steel will, for example, increase the labour and capital requirements in the aluminium industry, increase either the use of electricity for smelting and the import of alumina or the import of the primary metal. The requirements for labour and capital, coke, energy, iron ore and other materials in the iron and steel industries would be decreased. This would obviously have a net impact upon the aggregate labour and capital required in the economy as a whole and would have further implications for such economic variables as the level of imports and regional employment (7).

The substitution of one material for another would have to be considerable to have a perceptible impact at the level of the national economy but substitution across a broad spectrum of production processes has often occurred within a short space of time, suggesting that the aggregate impact of a number of local decisions may be substantial.

An important macroeconomic implication of materials use is the energy requirement for their production. The materials industries are relatively energy intensive and their importance in the determination of aggregate energy consumption is demonstrated by the work of Pick and Becker (6), (7). They found that the energy embodied in the materials consumed by the engineering and construction industries was approximately double that directly consumed by those engineering industries. This has obvious implications for energy conservation.

The implications of materials waste were also explored by these authors (7), (8). In (7) it was reported that a 10% reduction in process steel scrap produced in engineering in 1968 would save not only £172 million in the iron and steel industry, but £9.2 million of non-ferrous metals, £28 million of energy, £30 million of imports (all at 1968 prices) and 62000 man-years of labour.

In summary, materials have been shown to have an impact at the firm level through their effect upon the 'complementary' inputs which are associated with them. They have an impact at the national level because of their effect upon 'upstream' input requirements. Some of these effects are examined in this thesis.

Section 1.2

What are Materials? - The Problems of Industrial Classification

Before proceeding further, it is necessary to define the term 'materials'.

Materials, for the purposes of this study, are substances whose physical properties make them suitable for fabrication in engineering or structural use in construction.

This definition is not complete in that it fails to delimit the boundary of the set of commodities which may be termed 'materials'. In fact, no definition is universally appropriate, since the process of converting resources into final products is one of continuous application of labour,capital and energy to a set of commodities in order to create 'value'.

This definitional problem requires the making of rational but ultimately arbitrary divisions in the set of all commodities produced in the economy in order to classify them as materials or finished products etc. This classification is essential to the study of the change in the structure of an economy over time.

Carter (9) described the problem thus:

> "Industrial classification is the lens through which all change is observed and measured. Since we cannot see at all without the lens we cannot say whether it 'distorts' the 'true' picture."

The classification system which will be adopted for the purposes of this work is based upon the Standard Industrial Classification published by the Central Statistical Office[1] and the industries which are deemed 'materials producing' are identified in Table 1.1.

Section 1.3

The Importance of Materials in the U.K. Economy

Having defined which constituents of the output of the economy are 'materials' it is possible to present a preliminary picture of their role in the Economy of the U.K.

Figure 1.1 is a representation of the U.K. Economy in 1968 in aggregated form showing the output of and flows between the major industrial sectors of the economy.

It can be seen that materials are responsible for approximately 5% of the net output of the economy and about 70% of the total sales of these industries go to the engineering and construction industries or to other materials industries. Of the remainder, 43% is directly exported.

The input-output technique used in the empirical section of this work is based upon the assumption that the requirements for inputs of commodity 1 to commodity 2 are always proportional to the ratio of commodity 1 inputs to the total inputs of commodity 2.

A crude application of this technique to the data in Figure 1.1 would imply that an increase in the demand for engineering and construction goods of £100 million would increase the output of the materials industries by $\frac{3150}{18100}$ x £100 million = £17.4 million, since £3150 million is the apparent input of materials to engineering and construction and £18100 is the gross output of the latter industries. This in turn, would increase the demand for imported raw materials by $\frac{200}{6400}$ = £0.3 million.

However, this additional materials output would also require additional engineering output and output from other industries and this in turn, would have an effect upon imports, raw materials and the materials industries themselves.

This interdependence means that changes in the demand for materials, directly or indirectly, affect all the other sectors of the economy including imports, and the indirect effects may be greater than the direct effects. The need to take the indirect effects into account is an important consideration in the work.

An additional indication of the importance of the materials industries in the economy is given by Tables 1.2 - 1.4 which show that materials accounted for approximately 16% of manufacturing net output in 1968, 15% of the labour force, 21% of the capital stock employed and 51% of the energy consumed in manufacturing. Thus, as a group, they are averagely capital intensive and very highly energy intensive.[2]

Section 1.4

Identification of Specific Areas for Research

1.4.1 Constraints upon the Quantitative Analysis

The ultimate objective of a study such as this would be to construct a model of an economy in which, firstly, the influences of the factors affecting materials consumption could be quantified and the sensitivity of materials consumption to changes in those factors estimated. Secondly, the effects of various aspects of materials use upon the economy could be determined.

In approaching such a task, two problems immediately arise:

(i) As explained in Section 1.2, the delineation of any commodity group such as 'materials' is ultimately arbitrary, since there are no 'natural' or immutable boundaries within the economy.

(ii) In practice, the determinants of materials consumption are a complex network of interacting factors and it would be impossible to isolate precisely the influence of each factor.

Similarly, materials and their use is only one determinant of economic performance and the contribution of materials alone is difficult to isolate.

These problems, together with those of data availability place the construction of a comprehensive mathematical model beyond the capacity of the present study and impose severe constraints upon the scope of the empirical work and accuracy of the results.

However, with the aid of certain assumptions, it is possible to proceed with the more limited objectives stated in the opening paragraph of this Chapter.

1.4.2 Areas in which it is possible to make a contribution

The first area for analysis corresponds to the first component of the objective for the work, i.e. to explore the effect of economic structural and performance factors upon materials consumption.

This requires firstly, the measurement of the change in the consumption of each of several engineering and construction materials over a period of time and the apportionment of that change across the broad economic or technological influences, such as the rate of national economic growth, changes in the structure of production of engineering goods and materials etc.

Whilst the two problems identified above are encountered, it is possible, using certain assumptions to estimate the contribution of each major factor to the change in consumption of various materials over an 18 year period.

The other part of the objective concerns the investigation of the effect upon economic performance at the industry or national level, of aspects of materials use, such as the quantity of materials required for the production of engineering goods, efficiency of processing etc.

The work of Becker (7) indicated the manner in which materials saving and substitution affect labour, capital and energy requirements, and this suggested that efficiency of materials use may make a substantial impact upon the efficiency or performance of the economy.

The performance of a process, firm, industry or economy is the relationship between some definition of output and some definition of input. At the macroeconomic level, performance relationships fall into two categories:

(i) Productivity (output/unit of input, at industry or economy level)

(ii) Trade (Exports/Imports)

Hence the remainder of the work concerns the influence of materials use upon these two aspects of economic performance. Once again, the problems stated in Section 1.4.1 are encountered, but with the use of assumptions which are discussed in the relevant chapters, it is possible to proceed towards the second component of the objective.

Section 1.5

Summary

In this Chapter, the objectives of the work were stated. The background to the subject and specific areas of analysis were presented.

In Chapter 2, the strategy for achieving these overall objectives is set out.

CHAPTER 2

Plan and Analytical Framework for the Research

Section 2.1

Introduction

As stated in Chapter 1, the objectives of the research were to analyse and, where possible, quantify the effects of changes in the economic environment upon materials consumption and to estimate the impact of developments in materials production structure, price and efficiency of use upon economic performance.

In this Chapter, the plan for the achievement of these objectives is set out.

The components of the plan are:

(i) The exposition of the analytical framework within which the research was to be conducted.

(ii) An outline of the methodology and data sources used, including an indication of the constraints imposed by the data.

(iii) The way in which the subsequent chapters present the work undertaken.

Section 2.2

The Analytical Framework

This section sets out the theoretical framework within which the research was undertaken. It classifies the factors affecting and affected by the production and consumption of materials, and demonstrates the nature of their interdependence.

The consumption of a material is governed, as for any commodity, by the supply and demand schedules for that material. It is the determinants of supply and demand which therefore determine materials consumption.

2.2.1 The factors affecting the demand for materials

The principal determinants of the demand for materials are:

(i) The price of the material $(P_m)^1$, or more precisely, the price relative to substitutes (P_m/P_s).

It is the price per unit of property rather than the conventionally measured price per unit of weight which is the criterion for consumption decisions, and an improvement in the manufacturing properties of the material or development of a more economical fabrication process which does not increase price, is an effective decrease in price.
Hence the price which is critical in substitution or demand movements is the "quality adjusted price". The index of quality adjusted price would deviate from the nominal price index of the material to the extent that the latter does not reflect quality improvements.

(ii) The demand for the end-products which use the material (D_{ep}). It is clear that the demand for end-products generates a derived demand for materials. Whilst cyclical fluctuations in materials inventories distort the short-term relationship between actual downstream consumption and the apparent demand for materials, this is a self-correcting factor in longer term comparisons.

(iii) The production structure of the end product (PS_{ep}) i.e. the quantity of a material required per unit of output of that end-use product.

If the requirement of a material increases per unit output of the end-product, the demand for the material will increase. (All other factors remaining constant).

This production structural change may occur for various reasons:

(a) There may be a change in the efficiency of use of the material through a change in work practices or design of the component.

(b) The material may be substituted for another on the basis of price or the fact that the process associated with the material requires less labour or other complementary or joint inputs per unit or output. If quality adjusted price is used, these amount to the same thing.

(c) There may have been an innovation which has led to new production possibilities, involving the increased use of the material. This is known as a change in the production function of the end-product PF_{ep}. The difference between the production function and the production structure is that the former is determined by purely technical or engineering considerations and represents the most efficient output which may be obtained from a given combination of inputs, whereas the production structure is the combination of inputs actually used[2]. One production function may be consistent with several different production structures since there may be the possibility of substitution between inputs to produce the same output, but it is probable that most production structures will not be the most efficient possible since most production processes have a degree of slack in them.

For example, the adoption of the 'best-practice' technology is not instantaneous. It is a process of gradual diffusion. Different rates of diffusion in different countries or regions will lead to differences in the intensiveness of use of certain processes and materials. This difference in the rate of adoption of new processes may be referred to as the 'inertia factor' and often explains differences in materials use when price and technological conditions are similar.

The occurrence of this factor is commented on, but is not part of the classification scheme since it is considered to be a short-term phenomenon resulting from incomplete adjustment to relative price conditions. In the long-term, substitution trends are determined by trends in (quality adjusted) price per unit of property.

It should be noted that these factors are not independent. Substitution and thus production structures depend upon relative prices. This interdependence complicates any classification of the change in consumption.

2.2.2 The Factors affecting the supply of materials

The supply factors affecting the output of a material are:

(i) The price of the material (P_m).

(ii) The price of the major inputs α, β, γ etc., to the production process of the material (P_α, P_β, ...), since these will determine the costs of production.

(iii) The production structure of the material (PS_m) is also important in that it represents the proportions in which the inputs are combined and may have a dramatic effect upon P_m if one of the inputs (e.g. energy) increases sharply in price.

Other factors affecting supply are:

(a) The relative natural abundance or scarcity of the raw material.

(b) Capacity factors which may cause bottlenecks or over-supply in the short term but will usually tend towards a long run equilibrium.

(c) Market structural factors: a few producers may affect supply schedules by forming a cartel or by other forms of oligopolistic behaviour.

These latter factors do not yet appear to have had a long term effect upon the consumption of the major materials.[3]

Thus demand factors may be represented by the expression:

$D_m = f\ (P_m,\ P_s,\ D_{ep},\ PS_{ep})$ 2.1

and supply factors by:

$S_m = f\ (P_m,\ P_\alpha,\ P_\beta,\ P_\gamma,\ ....\ PS_m)$ 2.2

All of these factors affect the intercept of the demand and supply schedules and thus the quantity of the material consumed (see Appendix 2.1).

2.2.3 Diagrammatic representation of the system

The interaction between the factors affecting the demand for or supply of materials is represented in Figure 2.1

This assumes that there are only 2 engineering industries, E_1 and E_2 and 2 materials industries M_1 and M_2, and that E_1 uses M_1 and M_2 whilst E_2 uses only M_2. The principle may be extended to any number of industries.

Figure 2.1 shows that the economic environment influences the aggregate level of demand which in turn affects the demand for engineering good E_1 and E_2 and thus the demand for materials M_1 and M_2. However, a change in the ratio of the demand for E_1 to the demand for E_2 will (cet.. par.) also change the relative requirements for M_1 and M_2, since E_1 consumes both M_1 and M_2 whilst E_2 only consumes M_2.

These changes all come under the heading 'end-use product demand' or D_{ep}.

Similarly the production structure of E_1, (PS_{e1}) ie., the proportion in which it combines inputs of M_1 and M_2, will affect the demand for M_1 and M_2, and this is partly determined by the technological possibilities summarised by the production function of E_1 (PF_{e1}). The other factors affecting PS_{e1} are the relative price of M_1 and M_2 and the efficiency of use of these materials.

Thus D_{ep} and PS_{e1} determine the change in the consumption of M_1.

Similarly, the production of M_1 requires the supply of labour, capital, energy, imports and other inputs. Again, the production structure PS_{m1} will determine the exact quantities and this is in turn determined by the production function PF_{m1}, relative input prices, and efficiency of use. Finally, the price of these inputs together with the combinations in which they are required by materials M_1 and M_2, affects the relative prices of M_1 and M_2 and thus the production structure of both the materials and the engineering goods.

The importance of each of these factors in determining materials consumption is discussed in Chapters 3 and 4.

In addition, it may be seen that additional consumption of M_1 or M_2 requires additional inputs. Hence an improvement in the efficiency of industry E_2 engendering a change in PS_{e2} such that the unit requirements for material M_2 decrease, will lead to a decrease in primary inputs including imports. The extent to which imports may be decreased by such a change is explored in Chapter 5.

Similarly, if the labour efficiency of M_2 improves and a higher quality good is produced for the same quantity of labour, then less labour will be used by the engineering industries indirectly via M_2. In addition, the production structure of E_1 will probably change such that there is an increase in the consumption of M_2 relative to M_1. This is a simplified representation of the relationships investigated in Chapter 6.

The total work undertaken may thus be expressed in terms of this framework.

Section 2.3

Outline of Methodology and Data Sources

For reasons of time and data availability, the research is restricted to the United Kingdom and to the period from 1954 to 1974[4].

2.3.1 Factors affecting materials consumption

2.3.1.1 Methodology and data availability

In attempting to apportion the change in materials consumption across the various explanatory factors, sources of published literature and data are used in order to demonstrate the extent to which such an analysis may be undertaken without the use of econometric techniques. This is an attempt to demonstrate the value of a systematic approach to the classification of factors determining materials consumption.

As indicated in Section 2.2 and Figure 2.1, such an approach would require information on the production structure of engineering goods and materials. The only sources of such information for the UK Economy are the Input-Output Tables compiled by the Central Statistical Office (CSO). Since the analysis was dependent upon the use of these Tables, it was necessary to adopt the same industrial classification system as that used by the CSO in constructing them. This leads to a very high level of aggregation in the classification employed and this constitutes one of the major problems of the empirical analysis. However, since this study is limited to the relatively low cost, high volume throughput materials, the implications are not as serious as they might have been had the work been principally concerned with the minor materials.[5]

These tables are constructed from information collected in the Census of Production. Since a full Census is undertaken at intervals of five years or more, it is not possible to construct an annual time series for input-output information,[6] and so comparisons must be made of production structures at discrete intervals.

The years for which tables are available were 1954, 1963, 1968 and 1972, though the first and last of these were considered to be less reliable than those for the other two years, (as discussed in Chapter 4). They are included in order to compare apparent longer term trends with the information emerging from the comparison of data for 1963 and 1968.

Having adapted these tables to make them comparable, it is possible firstly to estimate the total change in the consumption of a material over a period, and then to use input-output techniques[7] to apportion the explanation of this total change across changes in the production structures of, and changes in the demand for the goods which consume materials. It is also attempted, using simple correlation techniques, to infer whether there is any relationship between changes in the unit labour or capital requirements of a material and changes in its price or consumption. The results would indicate the degree to which increased efficiency in the use of inputs in the manufacture of materials led to increased use of that material and substitution for other materials.

2.3.1.2 The influence of the business cycle upon comparisons

One drawback of using four discrete points in time instead of a complete annual time series is that observed production structures are critically affected by the point in the business cycle at which the information is recorded. For example, in times of low capacity utilisation, output per unit of labour is usually below its long-term trend level. This may tend to distort comparisons between years of different levels of capacity utilisation.

It would thus be an advantage if the four years for which tables are available represented similar stages of the business cycle.

One indicator of the position of the economy in relation to the business cycle is "Cyclical Indicators for the UK Economy" published by the Central Statistical Office (117).

This is a composite index of indicators which are related to the business cycle. The index of coincident indicators includes Gross domestic product and manufacturing output. A five-year moving average is used to eliminate the trend from the series leaving an indicator of the cyclical pattern of the economy.

Figure 2.2 shows that 1963, 1968 and 1972 were all years of upswing in activity and that the trough of a cycle occurred at or near the beginning of each year.

The CSO index series goes back only as far as 1957, but a similar technique applied to the output measure of real GDP using a centralised five-year moving average trend, suggests that 1954 was also an upswing year, with the preceeding trough occurring in mid-1953. Table 2.1 indicates that activity in 1954 was, on average, 1.1% above the long-term trend whilst in 1963 it was 1.2% below. In 1968 it was 0.6% above and in 1972, 1.1% below.

These figures are greatly influenced by the amplitude of the particular cycle. The upswings of 1963-64 and 1972-73 were much steeper than those of 1953-55 and 1967-69, and as a result, the trend value against which the years 1963 and 1972 are compared is relatively higher than for 1954 and 1968. Nevertheless, none of the four years deviated by more than 1.2% from its trend value, whilst years at the extremities of cycles, such as 1958 and 1973, deviated by 2.5% and 4.2% respectively.

A more specific indicator of capacity utilisation is given in the "CBI Industrial Trends Survey" (118). This records the percentage of firms in the sample reporting below capacity working. Whilst the results are weighted according to the size of the respondent firm, there is no attempt to estimate how far below capacity firms are working.

Table 2.2 indicates that the aggregate CBI data confirms the evidence of the cyclical indicators in that the percentage of firms reporting below capacity working declined during the course of each of the years 1963, 1968 and 1972. Once again, 1968 appeared to have a slightly higher average level of capacity utilisation, though the figures for all three years were similar.

Information on individual sectors is complicated by a change in classification between 1963 and 1968, but it appears that the average percentage of firms reporting below capacity working in engineering and metals production was about 70% in 1963 and 65% in 1968. For 1972 the proportion was somewhat higher (75%).

Whilst a further disaggregation may reveal large discrepancies in the levels of capacity utilisation and may affect intersectoral comparisons, it is not possible, using this published information to compare activity in small industrial categories. This is a problem which is dealt with in Chapter 6 and the methodology used explained in Appendix 6.5.

In terms of aggregate levels of activity, it may be concluded from the CSO and CBI data that the years chosen, and in particular 1963 and 1968, were sufficiently similar for useful comparisons of output and productivity to be made.

2.3.2 Materials and External Trade

In the analysis of the role of materials in external trade, it is attempted to demonstrate and compare the two main ways in which the processing of materials affects performance.

Firstly, there is a materials component of imports and exports, such that materials are a constituent of the export/import performance ratio. This may be termed the "direct" effect. The magnitude of this direct effect may be observed from the analysis of the commodity composition of UK external trade which is undertaken in this study.

Secondly, there is an indirect influence of materials processing upon external trade. The export of engineering and other goods requires the use of materials in the production of those goods. Similarly, the efficiency of use of materials in engineering affects the quantity of both materials and non-materials imports required for a given level of output.

The relationships are analysed in order to test the relative importance to trade performance of the long-term or 'structural' deficit in the United Kingdom's direct trade in materials, arising from international differences in resource endowment and historical factors, and the efficiency of the domestic processing of materials. The practical significance of such a comparison is that, whilst resource endowment is fixed, processing efficiency is to a large degree, controllable.

The data for this section came mainly from Overseas Trade Statistics of the United Kingdom (36), OECD Commodity Trade Statistics (76) and Input-Output Tables for the United Kingdom for the year 1972 (10).

2.3.3 Materials and Productivity

The final part of the work is concerned with the role of materials processing in the determination of the productivity of UK industry.

Since materials and non-primary inputs are usually netted out in productivity measurement studies, the first objective is to construct a productivity measure which includes both intermediate inputs and intermediate outputs, whilst being appropriate to the measurement of the output of an industry in relation to the resource inputs consumed.

Once such an index is constructed, it is used to measure the contribution of materials processing to the productivity performance of each industry. The overall change in the productivity of each engineering industry between 1963 and 1968 is estimated by comparing the total input and gross output of each industry for the two years.

In addition to this direct affect of materials processing upon productivity, there is an indirect effect. This may occur where the processing properties associated with a material afford the saving of other inputs such as labour. This is difficult to measure, but an attempt is made to identify any evidence of such 'materials related' productivity change in engineering industries, using simple econometric techniques.

The data for this section came mainly from input-output tables and Reports on the Census of Production for 1963 and 1968 (10) (11). Most of the work required to make these tables comparable was undertaken in order to quantify the determinants of materials consumption, the results of which had been reported in an earlier section. The results of the two sections are complementary in that it is possible to estimate the extent to which the productivity performance of a materials industry has led to changes in the intensity of use of that material in engineering industries.

As in the other section where input-output tables for different years were compared, the relative stage in the business cycle of the two years 1963 and 1968 is very important. As indicated in Section 2.3.1.2, these were years with similar levels of capacity utilisation. However, certain sectors appeared to be working at a substantially lower level of capacity in 1968 than in 1963. This has an effect upon productivity comparisons and an attempt is made to quantify the impact of this factor.

Section 2.4

Structure of the Report

This Chapter has specified the aims of the work, the analytical framework for the research, and given a brief account of the methodology and data involved.

This section indicates the way in which the work is reported in the following chapters.

Chapter 3 contains the first stage of the analysis of the factors affecting materials consumption. It gives a brief account of the information which may be obtained from the literature concerning the recent history of four major materials and classifies the factors identified according to the system described in Section 2.2.

The second stage of the analysis is reported in Chapter 4 which describes the application of input-output techniques to the same problem of explaining materials consumption in terms of the factors listed in Section 2.2. This is a more systematic approach than that of Chapter 3 and, where possible, comparison is made of the results obtained using the two methods.

A brief introduction to input-output analysis is included in Chapter 4 together with an account of the methods adopted to obtain input-output tables appropriate for the work of this Chapter and Chapter 6. A more comprehensive account of input-output analysis and the construction of tables is given in Appendix 4.1.

Chapter 5 is concerned with the role of materials in external trade and the relative importance of comparative advantage and the efficiency of materials conversion, as explained in section 2.3.2.

In Chapter 6, the role of materials substitution and efficiency of use in the productivity performance of UK engineering industries is investigated.

Finally, Chapter 7 summarises the conclusions which may be drawn from the analysis and makes some suggestions for refinements to the methodology and further work which would be possible given more resources of time and data.

CHAPTER 3

The Determinants of Recent Trends in the Consumption of Four Major Engineering Materials in the UK

Section 3.1

Introduction

The objective of this chapter is to quantify the relative contribution of the factors listed in Section 2.2 to the determination of trends in materials consumption between 1954 and 1974, using published statistics and literature.

This is presented as both an illustration of the use of the classification framework set out in Section 2.2, and as an introduction to the work of Chapter 4 which attempts the same objective using a different method.

Whilst the input-output approach of Chapter 4 is more systematic and comprehensive, the work reported in the current chapter shows the extent to which the contribution of each of the determinants of change may be quantified without the computation and transformation of data required for input-output analysis. The methodology of this chapter also allows the use of more disaggregated and qualitative data than that of Chapter 4 and thus provides a degree of explanation of changes in addition to the simple quantification of the contribution of each factor.

In Chapter 4, the results are, where possible, compared with those of Chapter 3. Agreement between the results of the two methods would allow stronger conclusions to be drawn, whilst discrepancies may illustrate the relative merits of the two approaches.

The materials studied in this chapter are iron and steel, aluminium, copper and plastics, since these are materials with a large number of applications and which compete with one another in various markets. Demand, technology and price factors have all had an important influence upon their development.

In accordance with the analytical framework, the discussion is divided into four parts, the first of which concerns the total change in consumption over the period 1954-74[1] and the trends within that period. The other three parts are the groups of factors listed in Section 2.2 which have determined these changes.

Thus, the four sections of the discussion for each material are:

1. Consumption trends 1954-74.
2. Demand factors: The growth of end-use sectors (D_{ep} of Section 2.2)
3. Structural change in end-use sectors and the role of relative prices and substitution in that change (PS_{ep} and P_m/P_s of Section 2.2).
4. Costs of production and resource intensiveness (P_α, P_β.... and PS_m of Section 2.2).

Section 3.2

Iron and Steel

3.2.1 Consumption trends

The growth of steel consumption progressed at a rate somewhat slower than manufacturing output as a whole (Figure 3.1). The increase in consumption was greater than for copper, but not as great as for aluminium and plastics.

UK production of steel increased by 35% between 1953 and 1973, whilst the production of manufactured goods increased by approximately 80%. (Figure 3.2).

Steel has a higher intensity of use in the economy than any other material. A measure of intensiveness is specific consumption which relates the weight of the material concerned to the output of the economy or individual sectors.[2] Table 3.1 indicates that the specific consumption of steel in manufacturing and construction is far greater than the other materials, although plastics were beginning to challenge the dominance of steel by 1972.

The specific consumption of steel showed a steady decline between 1954 and 1972. This indicates that the UK economy was using less steel per unit of output in 1972 than in 1954.

3.2.2 Demand factors

Steel is used in almost every sector of the economy, the major consumers being transport equipment, mechanical engineering and miscellaneous metal goods.

Table 3.3 gives an indication of the output structure of the iron and steel industry.[3]

The motor vehicles industry is an important consumer of steel, and this sector grew significantly faster than the economy over the period considered. The growth of the mechanical engineering sector was slightly faster than the economy as a whole but growth in construction, shipbuilding and metal goods, (with the exception of cans), was less than average.

The weighted average growth of the end-use sectors (weighted by steel consumption in 1963) is 70% compared to 71% for manufacturing and construction as a whole.[4] (See Table 3.2)

Thus there has been no dramatic impact upon steel demand via the pattern of growth of end-use sectors.

3.2.3 Structural change in end-use sectors and relative prices

The principal advantages of steel are its strength, weldability and low cost per tonne. These have been the major factors in the dominance of steel in many applications.

Table 3.3 does not reveal a clear trend in the specific consumption of steel in construction. Its principal competitors in this sector are timber and concrete. The latter is challenging steel in terms of cost/unit strength (13), but the greater versatility of steel ensured that there was no long run decline in its intensity of use in construction.

The specific consumption of steel in motor vehicles declined throughout the period due mainly to design changes leading to weight reduction. Substitution has only been an important factor in the peripheral components for passenger vehicles, where, for example, aluminium pressure die castings were often found to be more economical than iron castings (1).

The market for container vehicle bodies and rolling stock has been largely lost to aluminium where running costs are particularly important (19).

In shipbuilding, steel was again substituted by aluminium in superstructures and glass reinforced plastics in smaller craft (20).

The properties of steel are particularly suited to many mechanical engineering applications. This is reflected in the specific consumption figures of Table 3.3 although specific consumption in this sector has been declining since 1963. In electrical engineering, the fast growth of the sector has led to decreased specific consumption after 1963 in spite of increased absolute consumption.

In the making of cans, there was a very large shift towards the all aluminium can in the United States and aluminium was substituted for steel in can-ends in the UK. However the reduction of the quantity of steel strip required per can during the 1970's meant that by the middle of the decade, competition in this market was finely balanced (21).

In summary there has been a degree of substitution against steel in some applications, and this has led to a decrease in the intensiveness with which it is used in the economy. Most production structural change has, however, been of the form of reducing the input of steel required per unit output of the engineering good.

3.2.4 Costs of production and resource intensiveness

The price of steel increased at a similar rate to the total wholesale price index (Figure 3.3), much faster than plastics, slightly faster than aluminium but much slower than Copper. It is interesting to note that the ranking of these four materials in terms of price increase is exactly the reverse of the ranking in terms of consumption growth. This may be evidence of the effect of relative price upon substitution trends.

The principal inputs to the iron and steel industry, apart from labour and capital, are energy, iron ore and coke.

The prices of the primary inputs, labour and capital, are similar for all material industries and it is the change in the quantity or volume of these inputs required per unit of output which has been a more important determinant of the cost of the finished material.

Labour productivity has been improved by the economies of scale in steel making which took place during the period of study. The increase in net output per unit of labour was less than for aluminium or plastics, but greater than for copper (Table 3.7). However, since labour only accounted for 22% of total costs of the industry in 1968, it is unlikely that the relative 'productivity' figures shown in Table 3.7 had much impact upon the competitiveness of steel with other materials.

Energy is possibly a more important cost determinant than labour in steelmaking. It was equal to about 70% of labour cost in 1968 (10) (and has increased sharply since 1973).

Chapman (22) provides an indication of the energy requirements per tonne for a number of materials. He included not only that energy consumed directly in the production process, but also that required to produce the inputs to the process. (Table 3.5)[5] It appears that crude steel has a fairly low ranking in terms of energy intensiveness at 13000 kWh/ton. However, since steel is relatively cheap per unit of weight, the energy intensiveness in value terms is greater relative to other materials than Table 3.8 would suggest.

Three major factors have affected the energy intensiveness of steel:

Firstly, with the introduction of large bulk marine carriers, imported ores have replaced domestic ones. Between 1954 and 1974, the domestic share of iron ore consumption fell from 59% to 18% (17). Since the imported ores are superior in quality (around 60% iron content by weight compared with about 30% for domestic ores), this development has improved the energy efficiency of the reduction of the ore. (24)

Secondly, there have been economies of scale realised through changes in blast furnace technology. Modern blast furnaces are bigger and more heat resistant than older ones and thus can operate at higher temperatures (25), (Figure 3.4). This, together with the gradual development of techniques for sintering and the recycling of heat have led to substantial energy saving.

Thirdly, the more energy efficient basic oxygen process is gradually replacing the open hearth process in steelmaking.

The increased use of continuous casting, which obviates the need for reheating the ingot, has improved the energy efficiency of fabrication.

The price of coke rose steeply after 1970, but prior to this date it had risen at about the same rate as the aggregate of wholesale prices. It is unlikely that this was a major factor leading to a decline in the competitiveness of steel over the period under consideration.

Another input structure factor affecting the price of steel is the high proportion of scrap which is recycled, (about 55% according to one estimate for the UK (26). About 50% of the total iron input to blast furnaces and foundries is provided by scrap.

Depletion is not a problem for the UK industry. Although there has been an increasing need worldwide to use lower ore grades, developments concerning the UK led to higher rather than lower grades being used. This relative abundance has probably had a positive effect upon the growth of steel consumption.

3.2.5 Iron and Steel - Summary

Overall, it appears that demand effects (D_{ep}) were fairly neutral in that the end-use sectors grew only slightly faster than industrial production as a whole. Production structural change of the material itself was favourable (PS_m positive), although certain raw material costs increased by more than the average for wholesale prices (P_{α}... negative).

Thus the most important factor in the gradual decline of steel intensiveness in the economy was production structural change in the end-use industries. (PS_{ep}) The evidence suggests that weight reduction has been more important than the substitution of other materials, although it is not possible to quantify the relative importance of these two factors.

Section 3.3

Aluminium

3.3.1 Consumption Trends

Consideration of Figure 3.1 indicates that the rate of growth of aggregate aluminium consumption between 1954 and 1974 in the UK was less than that of plastics, but greater than that of steel, copper and manufacturing and construction as a whole.

Specific consumption increased between 1954 and 1963, but showed no sign of a trend after that date.

3.3.2 Demand factors

Table 3.4 indicates the end-use distribution of primary and secondary aluminium and shows transport equipment to have consistently the largest share with about 30% of total consumption. Electrical applications were second most important, and machinery, packaging and construction were also important consumers.

Motor vehicles and electrical engineering were both relatively fast growth sectors, with an increase in production of 125% and 203% respectively between 1954 and 1974. Packaging was another sector which grew more quickly than average, whilst metal goods (holloware etc.) and construction grew at less than the average rate for manufacturing and construction together.

The weighted average of end-use sector growth however was 84% compared to 71% for manufacturing and construction as a whole and thus in this case, demand factors could be said to have had a substantial positive impact.

3.3.3 Structural change in end-use sectors and relative prices

Aluminium has the advantage of the combination of lightness, strength, corrosion resistance and electrical conductivity.

Table 3.4 shows the trend in the specific consumption of aluminium in its various end-uses. Electrical engineering was a sector in which the specific consumption of aluminium increased considerably in the UK between 1954 and 1968. It has substantially penetrated the market for long distance transmission line and cable sheathing, taking over from copper and lead respectively, and this has been mainly due to its cost/unit conductivity advantage over the other metals, in addition to its lightness.

Transport equipment absorbs a high proportion of secondary aluminium and is the sector in which the specific consumption of primary and secondary aluminium together is the highest. Cast aluminium has been substituted on a small scale for iron castings in motor engine heads (21).

In construction, the specific consumption of aluminium fell slightly during the 1960's. After 1970, however, aluminium rapidly increased its share in the market for window frames and cladding, due to its corrosion resistance and finish properties.

As for the non engineering and construction uses of aluminium, the most important is packaging, where there was fast growth in consumption, resulting from the suitability of aluminium for foil rolling, and the properties of the material which are advantageous in packaging applications.

Thus the net effect of production structural change was positive over the period but there is evidence to suggest that the adaption of UK production structures to aluminium was slower than for other industrial countries (27). This may be evidence of the 'inertia factor' mentioned in Section 2.2.

3.3.4 Costs of production and resource intensiveness

There was relatively little change in the technology of production over the period, except for improvements in the techniques of pressure die casting (14), and alloying techniques which have improved the strength and processability of aluminium products. There was no great energy, labour or raw material saving innovation. Although new smelting processes were developed, they were not used on a large scale. Aluminium production is not particularly labour intensive and changes in labour requirements have not been a major factor in the competition between aluminium and other materials. The apparent improvement in net output per unit of labour between 1968 and 1972 indicated in Table 3.7 was the result of the investment in smelting capacity in this period. UK production increased from 40000 tonnes in 1970 to 250000 tonnes in 1973. This has radically changed the capital/labour ratio of the UK industry as a whole.

Energy is an important cost determinant. Chapman (22) estimated that 90000 kWh of energy was required per ton of primary metal in 1968. Over the period in question, this large energy requirement did not have a particularly detrimental effect upon the growth of the material, since cheap sources of energy were exploited and the world price of oil was such that it was economical to use this form of energy for smelting when others were not available.

However, aside from the primary metal stage, aluminium has some energy advantages: Lower casting and forging temperatures mean that aluminium requires less heat input than steel for these processes and both energy requirements and capital depreciation are consequently less than for iron and steel.

The secondary metal is less than 5% as energy intensive as the primary metal (22), and some 46% of old scrap[6] is recovered in the UK (22).

However, the secondary metal is used mainly for castings and is not suitable for many of the applications in which the primary metal is used. This reduces the extent to which the availability of the secondary material increases total supply and moderates price.

There is no depletion problem for the raw material, bauxite, though its geographical concentration is more of a problem. It is unlikely that bauxite costs had a great impact upon the competitiveness of the material over the period. The data in Table 3.9 suggest that a 100% increase in the cost of bauxite at 1963 relative prices, would produce only a 4% increase in the price of primary aluminium.

3.3.5 Aluminium - Summary

In summary, the relative growth of aluminium over the period was due both to relatively fast growth in the end-use sectors (D_{ep} positive) and to increased specific consumption in those sectors (PS_{ep} positive).

Since there were no major innovations in the production of the material (PS_m neutral), it must be concluded that it was the development of applications for exploiting the price per unit property advantages of the material which led to its substitution for other materials in the earlier period.

Section 3.4

Copper

3.4.1 Consumption trends

Copper consumption in the UK has been characterised by cyclical fluctuations around a trend which has been declining since the end of the 1950's. (Figure 3.1).

Specific consumption decreased by 33% over the period 1954-74 indicating a decline in the intensiveness of copper in the economy.

3.4.2 Demand factors

The principal end-uses of copper are given in Table 3.5 and it can be seen that electrical machinery, domestic appliances and electronics together represent about 47% of the total consumption of the refined metal. The next most important sectors are construction and metal goods, each representing about 10% of consumption, with transport equipment approximately 8%.

Electronics and telecommunications is a particularly fast growth industry, but construction and general metal goods grew at a rate slower than manufacturing and construction as a whole.

The weighted average growth of end-use sectors was 125% over the period, relative to 71% for manufacturing and construction. Thus, the pattern of end-use tended to have a much more positive effect upon consumption than for the other metals.

3.4.3 Structural change in end-use sectors and relative prices

The advantage of copper in electrical applications is its conductivity, and in construction, corrosion resistance. Thermal conductivity is also an important property, particularly in mechanical applications.

Figure 3.3 shows that the fluctuations in price have been relatively greater than for other materials. This is because a large proportion of total transactions are conducted via the London Metal Exchange, which is subject to short-term speculatory pressures.

Price is certainly an important factor in the electrical markets where copper competes with aluminium, since the latter would not be preferred on purely technical grounds.

Some markets have been retained by copper because of this superior conductivity, and some, such as domestic wiring, because of ease of jointing.

In construction, specific consumption declined because of competition from aluminium in cladding and roofing, and plastics in pipes. The UK was atypical in its high use of copper in building (14). For example, copper pipes were used for 90% of plumbing in the UK in 1975, whereas in

Austria it was used in only 10% of drainage applications (29). Nevertheless, even in the UK, there was a substitution trend against copper in construction.

The use of copper in transport equipment declined with the emphasis upon weight reduction. Car radiators were made mainly from copper because of its corrosion resistance properties, and not much impact was made by other materials over the period.

Dowsing (29) apportioned the total loss of markets by copper to the following materials:

aluminium 54%
Plastics 8%
stainless steel 5%
other ferrous 18%

The remaining 15% was attributed to design changes involving straightforward economy rather than substitution.

An example of the latter is the reduction in the thickness of the wall of copper tube in order to keep copper competitive with other materials (30).

Thus there is much evidence of substitution trends against copper mainly for reasons of changes in relative (quality adjusted) price.

3.4.4 Costs of production and resource intensiveness

There have been few major technical developments in the production of copper, this together with the gradually declining ore grade led to a relatively unfavourable price trend.

Once again, labour costs are not very important (Tables 1.2 and 3.7) but energy and extraction costs are.

Chapman (22) estimated that only 20000 kWh/tonne of copper were required, less than 25% of the energy requirement of primary aluminium. However, this energy intensiveness has been steadily increasing because of the use of lower grade ores.

Unlike aluminium and iron, there is a resource constraint problem for copper and deposits are concentrated in unsettled areas of the world. An organisation of copper producers was formed (CIPEC) but was ineffective in raising prices above the level dictated by the "free market".

About 38% of copper is recycled (24) and a relatively high proportion of total consumption, and the majority of domestic production, is based on secondary material. The latter is a very good substitute for the primary metal and this increases the effective supply of the material.

3.4.5 Copper - Summary

The distribution of end-use industries and especially the advantage in the electronics market tended to have a positive effect upon the trend in copper consumption (D_{ep} positive). There was some input structural change in end-use industries, involving weight-saving and substitution, both having the net effect of reducing copper consumption. (PS_{ep} negative).

Section 3.5

Plastics

3.5.1 Consumption trends

Plastics were the growth materials of the period, easily outperforming the others. (Figures 3.1 and 3.2). UK production of thermoplastics increased from 0.12 million tonnes in 1954 to 1.22 million tonnes in 1972.

Specific consumption of all plastics grew by 375%. (Table 3.1).

3.5.2 Demand factors

The end-use distribution for 1968 is given in Table 3.6. The largest user was the construction industry, accounting for 24% of plastics consumption, followed by packaging which used 22%. The third largest user was the electrical industry, mainly for insulation and domestic appliances. Transport equipment is also a substantial plastics user.

The packaging and electrical markets grew relatively rapidly over the period, whilst the construction sector was fairly sluggish. The weighted average growth of end-use sectors was 85% relative to 71% for manufacturing and construction as a whole.

Thus demand distribution factors were favourable.

3.5.3 Structural change in end-use sectors and relative prices

Plastics, have the advantage of lightness, ease of fabrication, corrosion resistance and electrical insulation. Their main technical disadvantages are poor resistance to heat and lack of strength. Though it is now technically possible by fibre reinforcement and other means, to make plastics with high tensile strength, they are at a natural disadvantage to the metals in applications which require a combination of strength and other properties.

The principal reason for the dramatic growth of plastics materials has undoubtedly been price. The price of synthetic resins declined in absolute terms between 1954 and 1968 and fell precipitously in real terms. This led to across-the-board substitution of plastics for other materials.

In construction, they have been substituted for copper in pipes, for wood and aluminium in windows and for lead and other materials in insulation. The growth of prefabricated building techniques has also been a source of increased plastics use, because of ease of working and cheapness of transportation.

In the electrical markets plastics have been substituted for natural rubber, and lead in insulation and for other materials in domestic appliances.

The labour and capital economy and low waste of the moulding process has led to plastics being used for manufacturing components formerly made from metal, though they have not the performance characteristics for engines.

The advantages of transparency, barrier properties and relative price competitiveness were the source of the dramatic growth in the use of plastics in packaging.

The main end-use production structural source of reduction in plastics use was the advance of fabrication technology giving rise to lower material requirements, but this was not thought to have had a major impact upon consumption.

Freeman (31) reports the relatively rapid adoption of plastics technology in Germany and Japan. This may be more evidence of the 'inertia factor' when the performance of the UK is considered (27).

3.5.4 Costs of production and resource intensiveness

The dramatic real price decrease of plastics in the 20 years from 1954 were achieved through economies of scale (31) via increasing plant size which facilitated the saving of labour and energy, technical progress in general and the stable price of feedstock. The relatively low labour intensiveness in 1968 is indicated by Table 1.2 and the increasing economy of use of labour in Table 3.7.

PVC required an average 19000 kWh/ton of energy in 1968 (22), which was greater than for most of the metals, about the same as copper and much less than aluminium. Thus plastics are fairly energy intensive, but stable prices meant that this was not a problem during the period under study.

Collecting and sorting problems and the relative cheapness of the primary material, precluded the large scale recycling of plastics over the period.

Nevertheless, technology and input price effects were very favourable.

3.5.5 Summary - Plastics

If improvements in materials properties which do not increase price are regarded as 'quality adjusted' decreases in price, then the dramatic growth of plastics may be attributed almost totally to relative price advantage (P_m/P_s). The basis for the price advantage originated in such technological factors as innovation and economies of scale as well as favourable trends in some resource input prices. $(P_\alpha, P_\beta \ldots)$

Section 3.6

Summary

The objective of this chapter has been to illustrate the way in which reported developments in materials consumption patterns can be classified according to the framework of Section 2.2. It has not been an attempt to provide a comprehensive report of changes in materials technology over the period concerned.

It has illustrated the advantage of using such a classification system in that the evidence may be collated in order to assess the relative importance of the various factors affecting the consumption of materials.

It has also indicated the principal limitation of the approach:- The difficulty of quantifying precisely the contribution of each factor.

In Chapter 4 an attempt is made, using input-output analysis, to apportion more precisely the changes in the consumption of certain materials across the set of demand and supply factors listed in Section 2.2. It will be possible to judge whether the results of comparing the economic structures of individual years, reported in Chapter 4, accord or conflict with the more qualitative analysis of Chapter 3.

CHAPTER 4

A Quantitative Analysis of the Role of Economic Growth and Structural Change in the Determination of Trends in the Consumption of Materials

Section 4.1

Introduction

Chapter 3 showed that many authors have made reference to particular changes in materials use such as trends in substitution or a reduction in requirements through design changes etc. (13) (14). This information was combined with published statistics in order to determine the extent to which changes in the total consumption of materials over time may be explained in terms of the causal factors listed in Section 2.2.

Whilst speculation concerning substitution or other changes in the production structures of materials-using products was possible, the quantification of the effect of these changes upon materials consumption was not possible. The latter requires quantitative information relating to those production structures at different points in time.

Input-output tables provide such structural information and the current chapter makes use of these tables in order to estimate the contribution of the various causal factors to the change in the absolute and relative consumption of materials over the period 1954 - 72.

4.1.1. Recapitulation of Analytical Framework

As explained in Section 2.2, the determinants of materials consumption may be classified into two groups - demand and supply factors:

The demand factors are

(i) Price of the material relative to substitutes (P_m/P_s)

(ii) Demand for end-products which use the material (D_{ep})

(iii) Production structure of the end-product (PS_{ep})

The supply factors are

(i) Price of the material (P_m)

(ii) Price of inputs (P_α, P_β)

(iii) Production structure of the material (PS_m)

These causal factors are, of course, interactive and the current chapter includes an investigation of the relationships between the various factors.

4.1.2. Plan of the Chapter

Section 4.2 provides a brief introduction to input-output analysis and describes how it will be applied to the work of the chapter. (A more detailed introduction to input-output analysis appears as Appendix 4.1).

This section also explains the derivation of the specific tables used in this work.

Section 4.3 examines the supply parameters of materials output. In particular it estimates the labour, capital and energy and natural resource intensiveness of each of the materials and the relationship between relative resource intensiveness on the one hand and price and output changes on the other.

Section 4.4 explains the change in the output of materials in terms of the two main demand parameters referred to above. This procedure is applied to the short period of 1963 to 1968 for which relatively good data exist and the results compared with those obtained using the longer time span 1954-72.

Finally, in Section 4.5, the relationship between the various supply and demand determinants of output is analysed in order to assess the role of interaction between such factors as end-use demand, price, substitution and efficiency of resource use in the determination of trends in materials use over time.

Section 4.2

The Application of Input-Output Analysis to the Work of This Chapter

4.2.1 A Brief Outline of Input-Output Analysis

Readers unfamiliar with input-output tables and analysis are referred to Appendix 4.1 and references (32) (33) (34). This section will, very briefly, outline the input-output approach and its relevance to the work of this chapter.

An input-output table is a record of the total purchases by each industry in the economy from every other industry. If the purchase from industry i by industry j is divided by the total output of industry j, the result is a coefficient of the output of industry i required, on average; to produce a unit (£) of industry j output. Repetition of this process for each industry i would give a total input structure for the production of a unit of industry j output.

Thus if industry i was a materials industry and industry j was an engineering industry, this coefficient a_{ij} of the matrix A would indicate the requirement of material i for the production of a unit of engineering good j.

It is changes in these coefficients over time which reflect the structural change (i.e. substitution and changes in efficiency) which is an important determinant of the change in materials requirements over time.

In addition if material i is required by industry j and the output of industry j is used in the production of k, then changes in the output of industry k will have an effect upon the requirements for industry i, even if the material i is not used directly in the production process of k. If the total effect of economic structural change upon the requirement for materials is to be measured, these indirect effects must be taken into account. Input-output analysis makes this possible, as shown in Appendix 4.1, and thus, in order to measure structural change, it is necessary to produce comparable tables for different points in time. The construction of these tables was a substantial project and the methodology and data sources are reported below.

The basic information for input output tables is obtained from the Reports on the Census of Production (11) which record the purchases of commodities by production units and then allocate those production units to industries. The information is then assembled into a set of three square matrices.

(i) The 'make' matrix which shows the production of each commodity by each industry.

(ii) The 'absorption' matrix which shows the consumption of each commodity by each industry.

(iii) The imports matrix which shows the purchase of imports by each industry.

These tables must then be converted into commodity x commodity or industry x industry tables so that it is possible to trace the direct and indirect impact upon all other commodities of d change in the demand for one commodity, and similarly for industries. Some theoretical aspects of this conversion process are discussed in Appendix 4.1.

4.2.2. Data Sources

At the time the research was undertaken, the only published input-output tables for the U.K., were those for the Census of Production years of 1954, 1963 and 1968, (11) and of non-Census years 1970 to 1972. The latter tables were updated from 1968, mainly by the RAS method (42).

Two major problems preclude the direct use of these tables for the comparison of economic structure:

(i) The tables for all three years were based upon different industrial classifications and different levels of aggregation. For example, the 1954 tables are on a 1948 SIC basis, and identify 45 sectors. The 1968 table is on a 1968 SIC basis and identifies 90 sectors.

(ii) All the tables express value at current prices and thus changing relative prices will distort the analysis of economic structure.

Some additional tables were obtained from the C.S.O. in order to facilitate the derivation of comparable tables.

These were:

(i) A 70 order 'make' (M) matrix for 1954 on a 1963 SIC basis at 1954 prices [1](M_{54}^{54}).[2]

(ii) A 70 order 'absorption' (X) matrix for 1954 on a 1963 SIC basis at 1954 prices [1](X_{54}^{54}).

(iii) A 69 order M matrix for 1963 on a 1968 SIC basis at 1963 prices[3] (M_{63}^{63}).

(iv) A 69 order X matrix for 1963 on a 1968 SIC basis at 1963 prices[3] (X^{63}_{63}).

(v) A 70 order commodity x industry imports matrix for 1963 on a 1968 SIC basis at 1963 prices[3] (X_{m63}^{63}).

(vi) A 69 order industry x industry matrix for 1963 on a 1968 SIC basis at 1963 prices[3] (H^{63}_{63}).

(vii) A 69 order X matrix for 1968 on a 1968 SIC basis, but at 1963 prices[3] (X^{63}_{68}). (See Appendix 4.2).

(viii) A 70 order commodity x industry imports matrix for 1968 on a 1968 SIC basis at 1963 prices[3] (X_{m68}^{63}).

It is immediately obvious from the distribution of available data that comparison of the years 1963 and 1968 must form the core of the study.

The 1954 and 1972 data may be manipulated to provide a very approximate comparison with that for 1963 and 1968, from which some conclusions concerning general trends may be made.

4.2.3 The Commodity x Commodity Tables at 1968 Prices

It was decided to use 1968 as the base year for the commodity tables, since the commodity matrix W^{68}_{68} $(= A^{68}_{68}\,\hat{q}^{68}_{68})$ could be taken directly from the C.S.O. tables. It was necessary to construct the matrix W^{68}_{63} for comparison and this was undertaken by first obtaining the matrix W^{63}_{63} from the make and absorption matrices for 1963 and then deflating this matrix to a 1968 base.

The first step in constructing the matrix W_{63}^{63} was to divide M_{63}^{63} into M_1 and M_2 according to the technology assumption upon which elements of M_{63}^{63} were to be treated. This was undertaken on the basis outlined by the C.S.O. in the notes to (10) and the classification of cells to each of the technology assumptions given in Appendix 4.3.

The matrix R and the coefficient matrix A_{63}^{63} were estimated from equation 22 in Appendix 4.1 (see page 117)

Some negative entries appeared in the consequent commodity x commodity matrix, resulting from the use of the commodity technology assumption for some of the cells of the make matrix.

An element w_{ij} of the commodity x commodity flow table W is equal to x_{ij} of the absorption matrix X plus those inputs of i required to make commodity j in industries other than j minus the value of commodity i required to make commodities other than j in industry j.

The commodity technology assumption states that commodity k has the same input structure in whichever industry it is made. If, in reality, a negligible quantity of commodity i is required to make commodity k in industry j, whilst a substantial quantity of commodity i is required to make commodity k in industries other than j, w_{ij} may well be negative, if derived from x_{ij} under the commodity technology assumption.

The treatment of negative entries is a difficult problem requiring considerable judgement (39). The purpose and limitations of the present work, deemed it necessary to adopt the simplest approach, which was to set negative entries to zero following the approach of Stone (41) and make an adjustment to another element of the same row, such that the row totals remained constant, since these are constrained by the commodity totals of the absorption matrix[4].

Details of these adjustments are given in Appendix 4.4.

Deflation of the table was effected using a 69-order matrix P of price deflators, obtained by dividing X_{68}^{68} by X_{68}^{63}. Each element p_{ij} of P is the deflator for the commodity i purchased by industry j.

Some of the elements of P were very large or very small. These usually corresponded to small volume transactions and probably arose out of data errors. As a result, deflators for each commodity were not allowed to deviate by more than 10% from the mean for the relevant commodity row, calculated from the respective intermediate row totals of X_{68}^{68} and X_{68}^{63} . (The deflators implied by the ratio of these row totals are shown in Table 4.1).

The matrix W_{63}^{68} was then obtained by multiplying each element of W_{63}^{63} by the corresponding element of P.

The matrix P is a set of implicit Laspeyre price indices for the conversion of a table of 1968 values to 1963 prices. To use the inverse of this ratio to adjust a 1963 matrix to 1968 prices is to apply 1968 volume weights to 1963 values, thus engendering an index number problem. The magnitude of the resultant errors involved depend upon the change in the volume composition of each element x_{ij} of the absorption matrix over the five year period. Certain heterogeneous sectors (of which the non-ferrous metals sector is of particular interest in the context of this study), may have changed in structure over the period. However, it was thought a reasonable assumption that the errors resulting from this intra-commodity group structural change would not be of greater magnitude than those intrinsic in the data.

There are unfortunately no fixed row totals to act as constraints upon the deflated matrix and thus the identity between inputs and outputs is not preserved. The row and column sums were checked for any large discrepancies, but no adjustments were thought necessary.

No attempt was made to reallocate primary inputs to a commodity basis, since this was not required for the work involving this table.

The matrix was then aggregated to 48 sectors, using the classification given in Apendix 4.5.

The 48 order table W_{63}^{68} is shown in Appendix 4.6.

The final demand vectors for 1963 at 1968 prices were also estimated by applying the price deflators implicit from the final demand data accompanying the 1968 absorption matrices in current and 1963 prices, to the current price final demand matrix for 1963. Again the index number problem was ignored. The final demand vectors were then aggregated to the 48-order level and appear in Table 4.2.

4.2.4 The Industry x Industry Tables at 1963 prices.

Since a 1963 industry x industry table was available in a fairly disaggregated form on a 1968 SIC basis, the first task was to obtain a comparable table for 1968 in 1963 prices.

One method of constructing such a table would be to obtain a make matrix for 1968 at 1963 prices, M_{68}^{63}, and then apply the hybrid technology assumption to X_{68}^{63}. Unfortunately, the only deflators which exist for the level of aggregation required are those derived implicitly from the ratio of the intermediate row totals of X_{68}^{63} and the current price absorption matrix for 1968 aggregated from 90 to 69 sectors (X_{68}^{68}). This may not be appropriate to the cells of the make matrix, and in particular, the value of the large diagonal cells would be very sensitive to a small change in a deflator. A more serious problem in the deflation of the make matrix is that the industry and commodity totals for M_{68}^{63} will not necessarily be consistent with those of X_{68}^{63}.

In view of these problems and the time and resource consuming nature of this method, it was decided to use an alternative method to produce the industry x industry table, using the matrix P of deflators obtained as in the previous section:

If P^* is the matrix of reciprocals of the elements of P, then P^* would be a matrix of deflators to convert a table at 1968 prices into one at 1963 prices.

If each element h_{ij} of the industry matrix H_{68}^{68} can be decomposed into the purchase of 69 commodities k produced in industry i purchased by industry j, then a column of P* would provide the appropriate deflator for each commodity k. (For many of the values of k, the output by industry i would be zero).

Assuming that the output mix of industries is the same for each industrial purchaser (the proportional output purchase assumption (7)), the product mix matrix C would provide the commodity weights for the output of each industry i, where c_{ij} is the proportion of commodity i in the output of industry j. The weighted average of price deflators of all the commodities k purchased by industry j from industry i is given by:

$$p_{ij}^{**} = \sum_{k} c_{ki}\ p_{kj} \text{ or } P^{**} = C'P^{*} \text{.... 4.1.}$$

C may be obtained from the 1963 current price make matrix and H_{68}^{63} may then be obtained by dividing the elements of H_{68}^{68} by those of P^{**}.

The control totals are given by the vector of total intermediate inputs to industries, since these should be the same as in X_{68}^{63}, minus the diagonal elements. Since the primary inputs were also estimated by the C.S.O., the gross industry inputs were known and thus the gross outputs could also be estimated.

The final demand matrix was again obtained by the implicit deflator method, and whilst the deflators referred to commodities rather than industries, this was thought to be of negligible importance.

Final demand was not adjusted and so the intermediate row totals were also fixed. It remained to reallocate values in order that the row and column totals should conform to their control totals. This was done on a judgemental basis, using those cells which were very large and those for which the deflator was suspect in deviating substantially from that implied by its commodity row total.

4.2.5 The Imports Tables

The 1968 commodity x commodity imports table appears as Table M of (10) and there was no requirement for an industry x industry imports table.

Hence the only imports table required which had not already been published was a 1963 commodity x commodity table at 1968 prices.

The 1963 table at current prices was obtained using the same multiplier R via the relation

$$A_{m63}^{63} = B_{m63}^{63} R$$

where

$$B_{m63}^{63} = X_{m63}^{63} \hat{g}_{63}^{63-1}$$

Again, negative entries were set equal to zero and slight adjustments made to preserve row totals. This was then adjusted to 1968 prices using the implicit deflators from the ratio of tables X_{m68}^{68} (Table M of (10) aggregated to 69 sectors) and X_{m68}^{63}, (also aggregated to 69 sectors). This resultant matrix is denoted by P_m.

Once again, there are index number problems, but these were tolerated for the same reasons as were those encountered in the deflation of the domestic commodity flow matrix.

The existence of a large number of zero entries in the imports matrices, leads to the occurrence of several infinitely large values in P_m. These are set equal to the weighted row mean. Each individual cell of P_m was not allowed to deviate by more than 10% from its row mean. Appendix 4.6 contains a 48 order commodity x commodity import matrix for 1963 at 1968 prices.

4.2.6. Complementary and competitive imports

For the purpose of the structural comparisons which are reported in this chapter, it is necessary to separate imported commodities into those which compete with similar domestic products and those which are complementary and have no domestic counterpart. This is largely an arbitrary decision (52).

The Department of Applied Economics, Cambridge (53) identified 7 complementary import categories and isolated them from the aggregated domestic plus imported intercommodity matrix.

Since the current study is concerned with engineering materials and goods, it was decided that certain of the agricultural imports deemed complementary in (53) could be safely subsumed in the competitive imports category.

Certain commodities which were largely imported were deemed to be complementary, such as crude mineral oil, and metal ores, all of which were isolated from the "other mining and quarrying" sector. Since a large proportion of the import of "paper and board" is pulp, this whole commodity group was deemed to be complementary. The case of timber and wood products was more marginal: A large proportion of the imports in this category is timber, which could safely be termed a complementary import, and as a result, the whole of this category was deemed complementary. It was considered that the implications of the error arising from the exclusion from the commodity matrix, of certain wood products which were decidedly competitive, would be less than those of mis-specifying the technology of production of a material by assuming it could be produced using only domestic resources.

In addition, the purchases of imported agricultural goods by the tobacco and rubber industries consisted mainly of tobacco and natural rubber respectively and thus were included as complementary imports.

4.2.7. Final demand and gross output vectors for other years

The major problem encountered in the use of a period as short as five years for comparative purposes, is that the trends during that period may be obscured by cyclical factors. Furthermore, the method of deflation of commodities which are volatile in price, such as non-ferrous metals, can have a major impact upon the results, especially over a short time period. The longer the period under study, the more relatively important the trend becomes in explaining changes in coefficients and consumption.

For this reason, the 1954 and 1972 data were used to provide a longer period perspective, notwithstanding the lower accuracy of the results using the data for these years. Deflation of the 1954 and 1972 interindustry matrices would have been a major project and so the objective was limited to obtaining a vector of final demand and gross output for 1954 and 1972 at 1968 prices.

The 1972 final demand matrix was deflated to 1968 prices with the help of a set of commodity deflators provided by the C.S.O.[5] The deflators were on the same commodity basis as the 59-order 1972 tables. However, they did not differentiate between final and intermediate demand, and in particular, specific export deflators were not identified. As a result, the general commodity deflator was used for the whole of final and gross output, though a comparison was made, where possible with the implied price deflator given by the Annual Abstract of Statistics (15) in its Table of of unit export values.

Certain commodity categories are missing from the series of C.S.O. deflators, and for these, surrogate deflators were found using the wholesale price indices provided in (15) and those for current cost accounting in (54).

The 1954 vectors proved more problematic, since the original tables were on a 1948 SIC basis. The expanded version derived by Woodward (55), was on the 1958 SIC basis and identified 70 categories. Deflation was effected largely on the basis of deflators provided in (53), and where suitable categories were not identified, the Board of Trade wholesale price indices were used, as published in the Annual Abstract of Statistics

(15). Unfortunately, the commodity detail in (54) and (15) was not appropriate for the deflation of the price of engineering goods, and so an aggregated approach was used in the computations involving the 1954 data. Since the Cambridge study (53) aggregated the engineering industries it seemed sensible to do likewise.

Both the 1968 and 1963 matrices and the 1954 and 1972 final demand vectors were aggregated to 23 sectors, since the results must of necessity be more approximate (classification given in Appendix 4.7).

More detail of this deflation process is given in Appendix 4.8.

Aluminium is unfortunately not separated from other non-ferrous metals in the 1954 table. Gross output was allocated on the basis of the Report on the Census of Production for 1954 (11) and imports and exports from the Trade and Navigation Accounts of the UK (36).[6]

Deflation problems overshadow those of industrial classification, especially at this aggregated level, and hence the problem of the different SIC bases for the 1954 and 1968 tables is ignored.

The 23 order final demand and imports vectors for 1954 and 1972 are given in Tables 4.3 and 4.4 respectively.

Finally, a 1972 industry matrix at 1963 prices was estimated using simple row deflators obtained from information supplied by the C.S.O. and from the wholesale price indices reported in the Annual Abstract of Statistics (15). This was then aggregated to 23 sectors according to the same classification as the 1972 final demand and gross output vectors. This table was not considered suitable for use in the analysis of coefficient change, but adequate for the purposes of Section 4.3.

Section 4.3

Resource Intensiveness of Materials

This section uses the industry x industry tables[7] obtained as described in Section 4.2 to investigate the supply factors affecting materials output. It analyses the relationship between the intensiveness of resources in materials production on the one hand and relative prices and output growth on the other.

4.3.1 Labour and Capital intensiveness of materials

In Section 1.3 it was shown that materials industries required a large direct input of capital relative to output, compared with the average for other industries in the economy.

The work of Becker (7) suggested that materials industries as a whole, directly and indirectly required less labour per unit of output than the weighted average for either engineering or 'other' industries, and were more capital intensive than the engineering industries.

Estimates of the direct labour required to produce a tonne of material were presented in Table 3.7. However, weight is not the most appropriate measure of output for comparative purposes and this type of measure does not take into account the value of the resources and primary inputs required for the production of the intermediate inputs which enter the production process of the materials.

With the use of input-output analysis it is possible to estimate the total requirements of labour and capital to produce a given constant price value of output, both directly in the production of the material and indirectly, generated via other inputs.

From equation 26 of Appendix 4.1 it follows that the total labour and capital requirements per unit of output may be obtained by evaluating the expression:

$$v\ (I-A)^{-1}$$

where v is a vector of primary input coefficients and A the industry coefficient matrix.

Imports also contain embodied labour and capital. Using the domestic matrix only, would fail to allow for the labour and capital content of imports and thus a change in purchasing patterns from domestic output to imports would arbitrarily affect the labour and capital intensiveness of goods. In order to overcome this problem, the matrix of import coefficients was added to the matrix of domestic output and the inverse derived from the resultant matrix. The algebraic expression is:

$$v\ (I-(A_h + A_m))^{-1} \qquad \ldots\ldots\ldots\ 4.2$$

where A_h and A_m are the domestic and competitive import coefficient matrices respectively.

To use the above expression for the analysis of resource requirements implies the assumption that the labour and capital content of the imported commodities are in the same proportion as for the domestically produced equivalent. This may cause discrepancies in certain instances, but is more likely to lead to a representative estimate of resource intensiveness than the use of the domestic matrix alone.

Table 4.5a shows the direct requirement of labour and capital per one 1963 £'s worth of output of each material in both 1963 and 1968. This is compared with the total direct plus indirect requirements for the same output. The figures for labour were obtained from the Report of the Census of Production for 1968 (11) and the capital stock figures from the estimates of Armstrong (12).[8]

It may be seen that the inclusion of indirect requirements substantially increases the labour and capital coefficients for non-ferrous metals. This is entirely explained by the very high import content of this category. (In a similar exercise, using only domestic matrices, the ranking of materials by labour and capital intensiveness was almost the same for direct and total requirements).

For the other materials, there is little difference in the ranking, either between the set of direct and total coefficients or between the sets of coefficients for 1963 and 1968, the only notable changes being the decrease in the relative capital and labour intensiveness of rubber in 1968 on the inclusion of indirect requirements.

These estimates and the ones obtained from the 1972 tables suggest the existence of a trend of declining labour and capital intensiveness of synthetic resins through the period 1963-72.

Non-ferrous metals appear to have increased in both labour and capital intensiveness over the period, from being halfway down the ranking in 1963 to being the most labour and capital intensive by 1972.

This is possibly attributable to distortions in the deflation of the output values of this category, discussed further in Section 4.4 below and Appendix 4.8.

In summary, synthetic resins are the least labour intensive engineering material by any criterion and non-ferrous metals and timber are the most labour intensive. Timber is the least capital intensive and metals are the most.

4.3.2 The Relationship Between Price, Output and Factor Intensiveness

It was anticipated that there should be a positive correlation between changes in primary factor intensiveness and price movements. Indeed, changes in price reflect a combination of changes in the quantities of primary inputs per unit of output and rates of return to primary inputs. Hence if the latter is assumed to be constant, the change in labour and capital intensiveness should be reflected in the change in price of each material. In competitive equilibrium there would be exact correspondence between the ratio of prices of materials in different years and constant price primary input intensiveness, but product and labour market imperfections distort the pattern of relative price change.

The relative price of materials is also likely to be related to relative output growth, since the latter is determined by both the total demand for industrial output and the intensiveness of use of the material in industrial production, which in turn is largely the result of price factors. The tendency to substitute a less factor intensive material for a more factor intensive one is what Carter termed 'adaptive structural change'(9).

It is a plausible hypothesis, therefore, that there should be a positive relationship between factor intensiveness and relative prices and a negative relationship between the former and relative output growth.

This is supported by the results reported here. The rank correlation[9] between the ratios of the increase in labour and capital intensiveness over the period 1963-68 with output price ratios for the two years was very high. (Spearman's rank correlation coefficients of 0.83 and 0.69 respectively, significant at the 5% level). See Table 4.5b and Figure 4.1.

There was a negative but insignificant correlation between the growth of gross output and primary factor intensiveness between 1963 and 1968. However, the correlation between the growth of net output and both labour and capital intensiveness was significantly negative (rank correlation coefficients of -0.98 and -0.90 respectively, Figure 4.2).

There was no evidence to support the hypothesis that the substitution of capital for labour is related to the rapid growth of output per unit of factor use.

It must be emphasised here that materials substitution usually results from long-run price changes arising from changes in the production function of the material and of materials-using commodities. Short-term price fluctuations have relatively little effect and in the five year period of study, cyclical factors may have obscured underlying trends. The 1972 figures were unfortunately considered insufficiently reliable to provide more than a cursory comparison with the 1963-68 results.

Thus, this section provides some superficial evidence of a relationship between the efficiency of factor use and relative prices, which in turn is related to the substitution of materials. The degree to which substitution has taken place may be judged from the results of Section 4.4., in which the determinants of materials demand are analysed.

4.3.3. Energy Intensiveness of Materials

4.3.3.1 The problem of measuring energy intensiveness

Several attempts have been made to estimate the total energy requirements to produce a unit of material. Some, based upon technical assessment of the processes of production were presented in Chapter 3 (see Table 3.8). Some of these studies, in addition to assessing the energy requirements for all the processes in the direct chain of production, also attempt to include the processes which are peripheral to the production of the material, and estimate energy used in those processes, together with the energy content of the capital "expended" in the process.

However, these process-based studies do not trace through the total energy requirements for each intermediate input used in the production of the material, whether directly or indirectly via other inputs, since this would be an infinite process.

Input-output analysis, in principle, allows the estimation of the total requirements of energy both directly and indirectly required for the production of a material.

In a climate of increasing energy scarcity, the estimation of the total energy requirements to produce a unit of a material becomes a very important calculation. Unfortunately, no study has yet overcome all the problems involved.

The major difficulties are:

(i) Input-output tables are expressed in terms of £'s of input required per £ of output. Since different users pay different rates for the same type of energy, and different types of energy have differing costs per therm, the straightforward energy intensiveness coefficient suggested by the input-output inverse may not be a true indicator of physical energy requirements.

(ii) The coefficients of total requirements for the various types of energy are not additive, since there is likely to be duplication. For example part of the total coal requirement is used in the production of the electricity requirement.

(iii) Imported goods also have an energy content which must be allowed for if the total energy requirement for the production of a good is to be estimated.

Certain alternatives have been suggested in an attempt to surmount these difficulties: Wright (57) firstly estimated the total value of energy required per £ of output of each commodity, estimated the energy content of imports by an iterative method and then expressed energy requirements in kilowatt-hours (kWh), via a simple kWh/£ conversion for each type of energy input. He then aggregated the total kWh requirements for each commodity. The problem of duplication is minimised by only including primary energy (i.e. coal, crude oil, nuclear and hydro-electricity, and natural gas).

He made no attempt, however, to adjust for the different prices paid by different users. The results for materials were as in Table 4.6. It must be remembered that Table 4.6 is expressed in current £'s which would tend to reduce the 1968 requirements relative to those of 1963.

NEDO (58) also undertook a study to estimate the impact upon the final prices of commodities of a postulated change in the price of the output of various types of fuel. Their approach was to work backwards from a postulated first-round price increase of the output of a fuel commodity forming one of the rows of the input-output matrix, to obtain the increase in the price of the primary inputs to that commodity required to produce such a price change.

The result was then combined with the Leontief inverse to obtain the change in the final prices of all commodities consequent upon such a change in primary input prices.

The equation used to obtain the vector of resultant price increase was:

$$p = r\hat{v}(I - A)^{-1} \qquad \ldots\ldots 4.3.$$

where p is the vector of price indices of final demand by commodity (base = 1), r is the vector of price indices of primary inputs. $\hat{v}$ is the diagonal matrix formed from the primary input coefficients. A, in this instance, is the result of the aggregation of the domestic and imported coefficient matrix. The latter is included in order to take account of the energy content of imports. The derivation of 4.3 is shown in Appendix 4.1 and represents the conventional method of estimating the final price implications of changes in primary input prices. (See Equation 26 , Page 120).

The total energy intensiveness was obtained by simply adding the intensiveness coefficients for primary fuels (coal and oil). Whilst elements of the Leontief inverse are not strictly additive, in this case, the total use of oil via coal and vice -versa in 1968 was insufficiently great to lead to substantial double counting (This of course would not be the case if coal intensiveness was added to that of, for example, electricity).

The energy intensiveness of various materials in 1968, estimated by NEDO, is also shown in Table 4.6.

Pick & Becker (6) made allowance for the different price paid for energy by different users, by approximating the total physical consumption of each type of energy by each industrial user, using the United Kingdom Energy Statistics (59). The classification in the latter was not sufficiently detailed for input-output applications, but at least industrial consumption could be separated from domestic consumption, thus eliminating a significant source of bias arising from differential pricing. It was necessary to use input-output coefficients to disaggregate the totals given in (59). They then obtained direct plus indirect energy use in £ of energy per £ of materials output, taking care to remove double counting,[10] and provided an approximate translation into heat equivalents, though acknowledging the difficulty of identifying the appropriate conversion factors in an aggregative analysis.

They showed that materials were generally more energy intensive than engineering and other commodities, and that engineering industries, (in 1968), required more energy indirectly, embodied in the materials they consumed, than directly in their production processes. This result has obvious implications in the area of energy conservation, and for materials substitution, as energy intensiveness becomes an increasingly important factor in materials competition.

Carter (60) reported the work of Brandeis University using the US Department of Commerce input-output tables which analysed the inputs of natural gas, electricity and petroleum in terms of British thermal units (B.t.u's), as well as in dollars. A column of coefficients for an energy industry would thus be expressed in terms of dollars of non-energy inputs and B.t.u's of energy inputs per B.t.u. output of the energy industry.

This appears to be as close as possible to the ideal method of estimating energy intensiveness in that the estimates are not distorted by price-discrimination amongst users and take into account the indirect energy used (i.e. coal and oil via electricity etc.) without double-counting.[11] This would allow the estimation of total (direct plus indirect) energy requirements in physical terms of a fairly homogeneous material such as primary aluminium.

A further refinement to reduce duplication would be to set all elements in the primary energy columns equal to zero such that no further energy is deemed to be required in order to produce this energy, effectively treating energy as a primary input. This appears to have been suggested by Wright (57).

4.3.3.2 A Simple input-output approach

The work involved in isolating the physical flows underlying the monetary values and setting up an input-output table designed to estimate the kWh or B.t.u. per unit volume requirements for materials would be a major project.

For the purposes of this Chapter, an estimate of the relative magnitudes of energy requirements by materials may be obtained by a simple £/£ analysis for the years 1963, 1968 and 1972. In order to avoid double counting, all energy categories, primary and secondary, were aggregated in the flow matrix, and the imports matrix aggregated with the domestic table, making the implicit assumption that the technology of production for an imported commodity is similar to that for the output of the corresponding domestic commodity. All non-energy diagonal elements of the domestic coefficient matrix were set at zero.

Imports of "other mining and quarrying" by the domestic "mineral oil refining" industry was assumed to be crude oil and this figure was included as a separate row and column of the matrix, with all other elements zero, thus treating this cell as a primary input.

The coefficient matrix was then inverted in the normal way, and the total energy coefficients per £ of output estimated.

It was thought justified to add the resultant crude oil coefficients to the other energy coefficients, since double counting should be avoided by the process described.

If the prices of the various forms of energy always represented their relative energy content, this aggregation of different energy forms would not distort the estimate of total energy used by each commodity. In fact, it has already been stated that conversion factors vary for different forms of energy and for different purchasing industries, and so the results of this method are very approximate indeed. Nevertheless, they provide a useful comparison with those of Wright and others.

Total energy requirements to deliver £1 of each material to final demand in 1963 and 1968 is shown in Table 4.6. The results are compared with those of Wright and NEDO.

There is perfect correspondence in the ranking of the results of Wright and NEDO. There is also almost perfect correspondence between the results for 1963 and 1968 in the current study. Between this approach and those of NEDO and Wright, however, some differences are revealed. The aggregative method employed here leads to estimates of energy intensiveness of a greater order of magnitude than the other studies and there is some difference in the ordering.

One reason for this may be that the price of one kWh via the electricity industry is greater than via the oil industry for example, since the cost of conversion to energy via electricity exceeds that of the direct conversion of oil. This means that industries which purchase a large proportion of their energy in the form of electricity appear to be relatively more energy intensive in monetary terms.

The results for the remaining materials appear to be consistent with NEDO and Wright, with cement by far the most energy intensive per £ of output, followed by iron and steel or building materials (refractory products) which were similarly energy intensive. Timber and wood manufactures was the least energy intensive category in each case. There was also agreement over the positioning of synthetic resins and aluminium in the ordering.

Marked differences may be seen between the "total" requirements of energy and the direct (plus quasi-direct) requirements estimated from technical data. For example, Chapman (22), Roberts (23) and Bravard and Portal (62) found aluminium to be highly energy intensive, whilst the input-output approach estimated its energy intensiveness to be less than that of steel or synthetic resins. This is mainly owing to the inclusion of secondary aluminium, as stated above.

The results for 1963 and 1968 gave no indication of a trend in total energy intensiveness, except that unit requirements tended to decline very slightly for each material.

There is significant rank correlation between the total energy coefficients and total capital requirements per unit of output (rank correlation coefficients of 0.90 for 1963 and 0.86 for 1968), and there is evidence of correlation between capital (per unit of labour) intensity and energy intensiveness.

However, it is not possible to draw conclusions, from the evidence of this section, concerning the implications of relative energy intensiveness for factor requirements and materials substitution.

4.3.4 The Impact of natural resource prices

One other factor which may be thought to be an important cost and relative price determinant is the trend in prices of the natural resources required for the production of the materials.

For example, differences in the trend rate of growth of iron ore, bauxite and crude oil may have been an important determinant of the differential rate of price increases of steel, aluminium and plastics respectively.

Table 4.7a shows that there was a positive rank correlation between the price changes in the materials and the price of their respective raw material inputs, though this correlation was on the borderline of statistical significance.

The importance of these price differentials depends upon the proportion of the cost of the final material represented by the cost of extraction or other cost of obtaining the crude material.

Table 4.7b shows that only for non-ferrous metals and timber was the raw material intensiveness greater than 10% of the cost of the material. In all but two cases, energy was a more important cost determinant than non-energy raw materials, and without exception, wages were a more important cost component than both energy and raw materials.

However, since the variation in wages intensiveness was much smaller than that of energy or raw materials intensiveness, the latter may have been more important than labour 'productivity' in determining relative materials prices.

The raw material price was probably an important factor in the price trend of non-ferrous metals and timber, since not only were these the materials with the highest proportion of natural resources in total cost, they were also the ones for which raw materials prices increased the most.

For the other materials, this factor is probably not very important, since a massive change in relative primary product price (of the order of the 1973-74 oil price increase) would be necessary to make a perceptible impression upon the price of the material relative to its competitors.

Section 4.4

The Identification of the Effects of Changes in End-Product Demand and Production Structures upon the Consumption of Materials

4.4.1 Theory

In Chapter 2 the three important parameters for the determination of the demand for materials were listed as:

(i) Price relative to those of substitutes. (P_m/P_s).

(ii) The demand for end-products using the material (D_{ep})

(iii) The production structure of those end-products (PS_{ep})

Relative prices are partly determined by technological factors such as innovation and economies of scale which change the unit requirements for primary inputs. The price of inputs to materials production also influences relative prices.

Since relative prices affect PS_{ep}, and their total impact upon consumption is via this medium, (ii) and (iii) above completely explain the change in the consumption of a material over time.

The input-output terms, these two factors may be identified with changes in the magnitude of intermediate and final demand for the output of those sectors which use the material on the one hand, and changes in the technical coefficients of materials inputs to those sectors on the other.

There is a standard technique employed by Vaccara and Simon (63), Armstrong (53) and Bezdek and Wendling (64) amongst others, to explain changes in sectoral output in terms of final demand and technical coefficient change. This separation is obtained by post-multiplying the Leontief inverse matrix for one year by the final demand vector for another, and comparing the resultant vector of gross outputs with the actual gross output for the two years.

I.e. if $q_o = (I - A_o)^{-1} (f_o - m_o)$ ...... 4.4[12]

Where q_o is the vector of gross outputs for year 0.

A_o is the matrix of domestic plus competitive import coefficients for year 0.

f_o is the vector of total final demand for year 0.

and m_o is the vector of competitive imports for year 0

and $q_1 = (I - A_o)^{-1} (f_1 - m_1)$

then $q_1' = (I - A_o)^{-1} (f_1 - m_1)$ 4.5

and $q_o' = (I - A_1)^{-1} (f_o - m_o)$ 4.6

are the gross output vectors obtained by combining the 'technology' of year 0 with the final demand for year 1 (4.5) and vice-versa (4.6). (All expressed at year 0 prices).

The total difference in output between the two years is $q_1 - q_o$, but this may be subdivided into $(q_1 - q_1^{\dagger}) + (q_1^{\dagger} - q_o)$ ..... 4.7 or

$(q_1 - q_o^{\dagger}) + (q_o^{\dagger} - q_o)$ 4.8

The component of total gross output change ascribed to final demand would be $(q_1^{\dagger} - q_o)$ or $(q_1 - q_o^{\dagger})$.

The component ascribed to coefficient change would be $(q_1 - q_1^+)$ or $(q_o^+ - q_o)$. The two produce different divisions of the total change in output because of the "interaction effect" (63) and a common practice is to average the results of the two estimates, though this is not theoretically ideal (65).

If the appropriate final demand vector is deducted from the estimate of gross output in each case, it is possible to apportion the change in intermediate output in the same way. With the objective of analysing changes in materials requirements it is preferable to concentrate upon intermediate demand.

The problems of interpretation of these technical coefficient changes are described by Carter (9) and outlined in Appendix 4.1. Changes in a coefficient may occur as a result of a change in the production function i.e. changes in the technological possibilities, substitution within the same production function, or intra-commodity group changes in product composition.

The last of these is a serious drawback to this type of methodology, but the inability of input-output analysis to separate the first two influences is not considered important within the framework of the current study: This work has the objective of quantifying the extent of and effects of substitution, rather than analysing the technical reasons for its occurrence.

4.4.2 Adaption of this procedure for the purpose of this study.

The classification proposed does not completely isolate the effect of production structural change upon materials consumption. The total change in consumption attributed to changes in coefficients is the outcome of a set of many, sometimes conflicting influences, even in the absence of product mix and data problems. For example, if coefficient change appears to have increased the consumption of a material, then this may be attributed to a combination of increases in the direct use of the material by other industries and increases in the coefficients of industries or commodities which are users of the material.

In this study then, it was decided to undertake a further refinement and to estimate the ceteris paribus effect of changes in materials coefficients alone and to compare this with the remainder of the total change implied by coefficients plus that implied by final demand. This would approximate to the change attributable in PS_{ep} as opposed to that attributable to D_{ep}.

The interdependence of these two factors may be clearly observed when such a dichotomy is attempted.

The direct effect of changes in, for example, plastics coefficients alone upon plastics consumption, may be estimated by summing the products of the change in each coefficient and the value of the corresponding gross output for the base year.

However, such coefficient changes would have further implications for the output of all commodities, including plastics, since an increase in plastics use would require an increase in all the commodities required for the production of a unit of plastics output. Thus, without any change in coefficients outside the plastics row, the demand for products which use plastics would have changed, which, in turn, would influence the consumption of plastics.

This problem was resolved by deeming that the change in the consumption of plastics originating from a change in plastics coefficients, but effected indirectly via increases in the requirements of other commodities to produce plastics, may be attributed to changes in the demand for the end-product (D_{ep}) rather than change in the production structure of the commodities using plastics (PS_{ep}).

Thus the only change attributable to the latter should be that caused by the direct impact of changes in plastics coefficients upon plastics consumptio obtained by multiplying the change in each plastics coefficient by the base year value of the gross output of the purchasing industry. (The base year will be that which was used for final demand in the calculation).

The change in plastics consumption attributable to D_{ep}, may thus originate from three sources:

(i) Changes in Final Demand.

(ii) Changes in non-plastics coefficients.

(iii) Changes in plastics coefficients which affect plastics consumption indirectly via the demand for other commodities.

The change attributable to PS_{ep} originates from:

(iv) Changes in plastics coefficients which directly affect plastics consumption.

Interdependence between these four factors precludes the unique quantification of the influence of each factor upon plastics consumption. Indeed, there is little value in separating (ii) and (iii) given the theoretical framework set out in Section 2.2

The methodology adopted was to firstly separate (i) from (ii), (iii) and (iv), using the conventional method for factoring total consumption change into that caused by final demand and that caused by coefficient change. The further refinement of separating (iv) from (ii) and (iii) was then undertaken for the materials industries by estimating (iv) as described above and allocating the residual change to (ii) and (iii).

This was undertaken using both 1963 and 1968 bases and the results compared.[13]

In the context of 4.7 and 4.8, the change in output ascribed to coefficient change: $q_1 - q_1^{\dagger}$ or $q_o^{\dagger} - q_o$, would be subdivided into:

$(q_1 - q_1^*) + (q_1^* - q_1^{\dagger})$ or

$(q_o^{\dagger} - q_o^*) + (q_o^* - q_o)$ where

$q_1^* = A_1^* q_1 + f_1 - m_1$ and

$q_o^* = A_o^* q_1 + f_o - m_o$ and

A_o^* is A_o with the specific row replaced by the corresponding row of A_1. Similarly for A_1^*.

That part of output attributed to the change in direct materials coefficients alone (PS_{ep}) would be $(q_1 - q_1^*)$ or $(q_o^* - q_o)$ respectively.

The above algebra refers to gross outputs, but since the final demand component is the same for q_1 and $q_1{}^*$ or q_o and $q_o{}^*$, the change in intermediate output resulting from this factor is the same as the change in gross output.

In addition to estimating the change in materials output resulting from all production structural changes involving that material, an estimate was made of the change in materials output induced by structural changes in individual engineering and construction sectors alone. This was done by multiplying the coefficients of materials requirements in, for example, the mechanical engineering industry, in year 1, by the gross outputs of that industry in the base year and comparing the result with the actual purchases of materials by the mechanical engineering industry in the base year. This was repeated for electrical engineering, transport equipment and construction.

4.4.3 Results of Comparison of 1963 and 1968 commodity tables

Synthetic Resins

Using both 1963 and 1968 bases, it appears that both final demand and technical coefficients were positive factors in their influence upon the growth of demand for synthetic resins.

Tables 4.8 a & b indicate that between 46% and 49% of the total change in intermediate demand for this material could be attributed to changes in the synthetic resins row of the input-output matrix. It could thus be inferred that much of the increase in output was due to favourable change in the production structure of end-use commodities, involving the substitution for other materials and new uses for plastics. About 40% of the increase in output was attributable to changes in final demand.

However, much of this favourable production structure change occurred outside the engineering and construction industries. The subdivision of PS_{ep} in Tables 4.8 suggests that the net effect of changes in coefficients of direct synthetic resins requirements in engineering and construction, was only just positive. Only in electrical engineering was there an appreciable increase in synthetic resins requirements.

The large direct coefficient increase was in the category 'other manufacturing', over half of which is the 'plastics products' industry. The growth of this latter industry, over 50% in the 5 year period, possibly explains the major proportion of the increase in output due to indirect intermediate demand factors.

It is interesting that only a negligible quantity of synthetic resins is purchased directly by the construction industry in spite of the increasing use of plastics in building reported in Section 3.5. This is possibly because the construction industry purchases its plastics indirectly via the 'plastics products' or other intermediate industries. The coefficient of direct plus indirect plastics use in construction grew by 19% over the period.

There was also a 16% increase in the synthetic resins coefficient in the 'packaging and other paper products' commodity, suggesting the increased use of plastics in packaging, although the latter category was diluted by the inclusion of 'other paper and board products'. The growth in intermediate output implied by final demand alone was about 25% and since the growth in final demand volume was 16%, this suggests that the composition of final demand favoured the growth of synthetic resins output.

Iron and Steel

The production structure and demand influences were both positive. There was a remarkable degree of consistency between the 1963 based and the 1968 based estimates. Only about 10% of the increase in demand could be attributed to changes in PS_{ep}.

The net increase in consumption resulting from coefficient change in the engineering and construction industries was greater than the net increase due to all direct coefficient change suggesting that coefficient changes outside the engineering and construction industries had a negative net effect upon consumption.

Within the engineering industries, there was a decrease in consumption implied by mechanical engineering coefficients, but increases in the other sectors. General metal goods and construction were sectors where coefficient effects were strongly positive.

Final demand accounted for about 75% of the change in output and on its own, would have given rise to a 16% increase in the intermediate demand in iron and steel between 1963 and 1968. Since the volume increase in final demand over the period was also 16%, it may be concluded that the composition of final demand was neutral in its effect.

Aluminium

For aluminium, final demand has the opposite effect to coefficient change, the net effect being a slight increase in output.

Within the engineering and construction industries, the results were indecisive for three sectors, the change being either zero or differing in sign between the two base years. There was a decided increase in the transport equipment coefficient and a marked decrease in construction coefficients. This is consistent with the apparent decline in the intensity of use of aluminium in the building industry during this period, reported in Chapter 3.

The total direct coefficient effect was much greater in absolute terms than that of engineering and construction alone, suggesting that non-engineering coefficients had a negative effect upon output.

The growth implied by final demand alone was approximately 17%, again very similar to the growth in final demand itself.

Non-ferrous metals

In the case of other non-ferrous metals categories, of which copper forms a large proportion of the value (about 60% in 1968), the negative coefficient effect exceeded the positive final demand effect, leading to an overall negative change in consumption.

Most of the negative direct coefficient effect could be attributed to production structure change in the engineering and construction industries.

The effect of PS_{ep} was negative in all sectors and the impact was particularly adverse in electrical engineering and other metal goods. This is consistent with the trends reported in Chapter 3.

Final demand growth alone would have led to an increase in non-ferrous metals consumption of 12%, somewhat less than the increase in final demand volume itself and so possibly the composition of demand also had an unfavourable effect upon output.

Cement

Cement is consumed almost exclusively in construction where the coefficient change had a negative effect upon output. This was outweighed by the final demand effect which produced a net increase in output of 18%.

Building Materials

Both PS_{ep} and D_{ep} influences were positive. The construction sector is obviously the dominant one and the output increase implied by the coefficient change in this sector was substantially positive.

Final and indirect intermediate demand accounted for over 80% of the total output change.

Timber

The final demand and coefficient changes were opposite in their effects upon output, and their share in the total output change differed between the estimates using the two base years. The effect of PS_{ep} was approximately the same in both cases, implying a negative output change of around £40 million, but the final demand effect is much greater for the 1968 output based estimate, and the negative effect due to coefficients other than the direct timber coefficients correspondingly larger.

The net effect was to increase output by 7%.

Rubber

The effect of direct coefficient change was positive, due to increases implied by coefficients in the mechanical engineering and construction industries. The production structural effects outside engineering were negative.

Final demand explained 80% of the total change in output and alone would have induced a growth in intermediate demand of 16%, similar to the growth in final demand itself.

Summary - Comparison of 1963 and 1968 commodity structure

In summary, for synthetic resins, iron and steel, building materials, and rubber both PS_{ep} and D_{ep} had a positive impact. In all four areas D_{ep} had a greater impact than PS_{ep}, but only marginally in the case of synthetic resins.

In the case of aluminium and timber, the direct coefficient (PS_{ep}) effects were negative but the positive effect of D_{ep} outweighed this to produce a positive net growth.

For other non-ferrous metals, the overall change was negative with coefficient change in all sectors having a negative effect.

Changes in the production structures of the engineering and construction industries were a very important component of total change for iron and steel but were not so significant for synthetic resins.

4.4.4 Checking the stability of the results using industry x industry tables

The same process was repeated using industry x industry matrices at 1963 prices and the results confirmed the general findings of Section 4.4.3 (see Table 4.8 c and d). The only difference in the procedure was the omission of the sector breakdown of coefficient change. The aggregate effects of PS_{ep} and D_{ep} were again quantified.

For synthetic resins, the major difference was the increased impact of intermediate demand changes which accounted for about 20% of the total increase in consumption relative to between 8% and 14% using the commodity matrices. The share of direct coefficient change (PS_{ep}) was correspondingly reduced, especially in the case of the 1963 based estimate which was 28% compared with nearly 50% of total change accounted for by direct commodity coefficient changes.

The pattern for iron and steel, aluminium and other non-ferrous metals was consistent with the commodity based estimates, though the total decline in non-ferrous metals output is much less using the industry tables than using the commodity tables.[14]

The comparison for cement was unremarkable and for building materials the industry estimates showed a much higher proportion of the total change in output explained by PS_{ep} changes (about 29% compared with 16%). The effect of final demand is reduced accordingly.

For timber, the industry estimates showed a much greater indirect coefficient effect and relatively smaller final demand effect. All the estimates for timber differ substantially in the proportions of the change in output allocated to each causal factor.

All four estimates for rubber were very similar in pattern.

Overall, there was no major inconsistency in the estimates, although they were not sufficiently similar to afford total confidence in their accuracy. The evidence from the industry tables does not contradict the principal conclusions drawn from the commodity estimates, these being that end-product input structures tended to change in an adverse manner for non-ferrous metals and timber and favourably for synthetic resins and to a certain extent, iron and steel and miscellaneous building materials.

4.4.5 Pattern of direct coefficient change

A more detailed analysis of changes in the direct coefficients between the two years may cast more light upon the origin of the structural changes which underly observed differential changes in materials consumption.

The coefficients corresponding to the metals and plastics rows of the commodity and industry matrices for 1963 and 1968 are shown in Table 4.9 (commodity) and 4.10 (industry). (These coefficients are for domestic and competitive import purchases combined.)

Following the practice of the D.A.E. Cambridge project (53), the weighted average change of coefficients was computed for each of the seven materials[15] and the number of coefficient changes conforming to the sign of the weighted average change was recorded. This provides an indicator of the consistency of changes in output. An 'across-the-board' increase in the consumption of a material would indicate a decided substitution trend, whereas inconsistency of sign may indicate that data errors and aggregation problems were of more importance in explaining the results than actual changes in technology.

The D.A.E. (53), studying the period 1954-63 for the UK and Vaccara (66) the period 1947 to 1958 for the US, found that for many commodities, there were a number of coefficients which moved in the opposite direction to the overall trend. Vaccara referred to the "unpatterned behaviour of coefficients" (66).

In the current study, the weighted average of direct materials requirements was found by first calculating the percentage change in each coefficient for each "materials" row of the direct coefficient matrices, using both the industry x industry tables at 1963 prices and the commodity x commodity tables at 1968 prices. Before summing, each coefficient change was weighted by the value of the total transaction registered in the corresponding cell of the input-output matrix in 1963, relative to the intermediate row total. Coefficients of less than 1 per 1000 were ignored, as were those corresponding to a transaction of less than £1 million in 1963 (current prices). This was because coefficients relating to very low monetary values would in general be subject to greater deflation and transformation error, in percentage terms, than those corresponding to larger values.

This procedure was repeated for coefficients of materials inputs to the engineering and construction industries alone.

Tables 4.11 and 4.12 indicate that the results of the current study are consistent with the findings of (53) and (66) with respect to the apparent lack of pattern in the behaviour of coefficients. All seven materials had a significant minority of coefficients moving in the opposite direction to that suggested by the weighted average. Only for timber and non-ferrous metals could the trend be said to be unequivocal.

One of the reasons for this disparity cited by Armstrong was that each commodity classification was in fact an aggregate of a number of commodities and thus mix problems would lead to disparate results. This problem is perhaps less great for materials sectors than other sectors since materials may be considered to be more homogeneous in output than most commodities.

There is little sign of any consistency between the weighted average coefficient changes reported in (53) for the period 1954-63 and those of this study for 1963-68. (See Table 4.13 - a reproduction of Table III.4 of (53)). For example Table 4.11 shows a weighted average increase in iron and steel coefficients between 1963 and 1968 of 10.3%, whereas

Table 4.13 shows a decrease of 6.9% between 1954 and 1963.

Estimates derived from the volume figures of the Iron and Steel Annual Statistics (17), reported in Chapter 3 (Tables 3.1 and 3.3) tend to corroborate the results of the D.A.E rather than this study, in that the specific consumption of steel appeared to decline steadily throughout the period 1954 to 1968, although the decline was less steep between 1963 and 1968, possibly owing to the pattern of the business cycle.

Synthetic Resins

Most surprising, perhaps, about the results shown in Tables 4.11 and 4.12 is that although plastics showed the greatest increase in use over the period according to the weighted average coefficient change (almost 30%), only a small majority of coefficient changes conformed to the sign of the weighted average, and in engineering in particular, the performance was very mediocre, with as many coefficients declining as increasing. This was possibly the result of the relatively high ratio of indirect to direct purchases of synthetic resins by the engineering industry, particularly via the "plastics products" category which, in the tables provided by the C.S.O., was unfortunately aggregated with "other manufacturing", tending to dampen the apparent increase in the output of this sector. In fact the "other manufacturing" category was responsible for by far the largest absolute increase in terms of value of plastics consumption, and the second largest increase in terms of coefficient percentage change. This category too had declining coefficients in certain engineering industries, but large increases in the heavily weighted electronics and motor vehicle sectors resulted in a substantial increase in average consumption.

Other sectors which significantly increased their unit requirements of synthetic resins were chemicals, insulated wires and cables, and textiles. In contrast, direct synthetic resins use per unit of output of instrument engineering, electrical machinery, and furniture declined substantially. Overall, the increase in plastics use was much greater in non-engineering than in engineering applications.

The value of input-output analysis in quantifying indirect linkages is exemplified by the difference between the increase in the output of synthetic resins implied by the total change in all coefficients reported in Section 4.4.3 and the observed changes in direct coefficients of consumption of the materials in engineering and construction industries, which were, in many cases, negligible or negative.

Iron and Steel

Iron and steel registered the second largest increase in its weighted average coefficient, about 10%. The largest increases were in transport equipment except shipbuilding, metal goods and construction. The decreases of note were in machine tools, industrial plant and steelwork, shipbuilding and road and rail transport. These results do not accord very well with the estimates of Table 3.3. which showed the specific consumption of steel decreasing in transport equipment and construction. The specific consumption data is probably more reliable since the deflation problems involved are less.

Once again there were a large number of coefficients moving in the oppositve direction to the general trend. In fact there were more coefficients declining than increasing, in the economy as a whole, though in engineering, more coefficients rose than fell.

Aluminium

Aluminium coefficients showed a slight decline on average and the individual coefficient changes were evenly distributed between increases and decreases. Substantial increases occurred in chemicals, insulated wires and cables, electronics, motor vehicles and cans and metal boxes. Decreases occurred in construction equipment, industrial plant and steelwork, electrical machinery, domestic and general electrical appliances, and construction. These results are fairly consistent with the specific consumption estimates of Table 3.4 in as much as the sectors identified are compatible.

Non-ferrous metals

Non-ferrous metals showed a dramatic decline in coefficients, with a weighted average decrease of about 20%. The largest decreases were in electrical machinery, shipbuilding and motor vehicles. The only sectors which moved against the trend were chemicals, aerospace and other vehicles.

Building Materials

There was a relatively small increase in the weighted average coefficient for building materials, though more coefficients declined than increased. However, the weighted average was dominated by the construction sector for which the coefficient increased by about 8%. There was no discernible trend in the coefficients for non-construction sectors.

Timber

The construction sector also dominated the demand for timber, though the applications of the latter are more varied than those of the building materials category. The coefficient change for timber into construction was similar to the weighted average, (about −25%). Large decreases in coefficients also occurred in the coal, motor vehicles, furniture and distribution sectors.

Rubber

The weighted average coefficient increase for rubber and rubber goods was about 10%, but the increase was mainly concentrated in the non-engineering sectors. The largest increases were in chemicals, domestic electrical goods, textiles, other manufacturing and services. Decreases were in insulated wires and cables, road and rail transport and distribution. Coefficient changes were evenly distributed between increases and decreases.

Engineering and Construction relative to the economy as a whole

For all materials except iron and steel the weighted average coefficient change was lower (i.e. less positive or more negative) in engineering and construction than for the economy as a whole, suggesting a decreasing unit throughput of materials in engineering relative to the rest of the economy. However, for all materials except synthetic resins and rubber, the difference between the total weighted average and that for engineering and construction alone was fairly small.

Substitution Indicators

For the four groups of engineering materials, (plastics, iron and steel, aluminium and non-ferrous metal) the industries in which the coefficient of one material had increased by more than (the arbitrary figure of) 10%, whilst that of another had decreased by at least 10%, were identified. This is a possible indicator of the occurrence of substitution between materials. The sectors in which substitution appears to have occurred according to both the industry and commodity tables are recorded in Table 4.14, together with the average percentage changes for each material.

Unfortunately, comment on the evidence of Table 4.14 would not be appropriate in the absence of a major study of the processes of each engineering industry. The reader is left to judge whether this evidence accords with his experience and knowledge.

4.4.6 Comparison with 1954 and 1972 estimates

The object of extending the procedure to use 1954 and 1972 data was to investigate whether the results of the main 1963/1968 comparison are consistent with either a longer-term trend or with the evidence of previous work on the subject, appertaining to the period 1954-63. This was thought necessary in view of the problems caused by cyclical fluctuations in short-period comparisons.

The final demand vectors for 1954 and 1972, obtained as described in Section 4.2 and Appendix 4.8, were premultiplied by the inverse matrix of domestic plus competitive import commodity coefficients for 1968, aggregated to 23 sectors. The 1954 final demand vector was also premultiplied by the 1963 commodity inverse. The resultant intermediate outputs of materials implied by these calculations were compared with the actual intermediate output for 1954, 1963, 1968 and 1972, in order to factor the changes in total output into those due to changes in final demand and those due to changes in intermediate coefficients.

E.g. $(I - A_{63})^{-1} (f_{54} - m_{54}) - (q_{54} + m_{54} - f_{54})$
gives the change in intermediate output implied by coefficient change between 1954 and 1963.

It is not possible, without the construction of 1954 and 1972 tables at 1968 prices to obtain an estimate of that change in materials output which is solely attributable to the input structure change of the material-using product PS_{ep}. However, the results provide an indication of the relative importance of production structural change and changes in demand and may be compared with the results obtained using the 48 order matrices of 1963 and 1968.

4.4.6.1 Changes in output between 1954 and 1972

Tables 4.15 a,b, and c show the total change in intermediate output of the major materials between 1954 and 1972 and the breakdown into technical coefficient and final demand induced change.

Synthetic resins

Synthetic resins consumption grew substantially throughout the period 1954-72, though the rate of growth was slowing towards the end of the period.

The period 1954-63 was that of the most rapid growth in consumption. This was partly due to the low base level of consumption at the beginning of the period and partly to the rapid decline in the real cost of the materials (see Figure 3.3). A very large proportion (71%) of the growth in this period originated from coefficient change, suggesting that the influence of substitution was stronger than that of end-product demand. Final demand alone would have produced an increase in output of 95% which, since final demand itself increased by only 30% in real terms, suggests that the composition of demand was very much in favour of plastics-consuming products.

Unfortunately, synthetic resins are subsumed in the much larger "chemicals" category in (53) and comparison is not possible.

Growth between 1963 and 1968 was less rapid though still substantial, and in the period 1968-72 there was a further slowing of growth, with production structural changes now less important than final demand. This reflects the 'maturing' of the material over the 18 year period though the growth in consumption between 1968 and 1972 was still well above that of total industrial production.

These results are consistent with the estimates of Table 3.1 which show the specific consumption of synthetic resins increasing in eadh sub-period, with the annual rate of increase the highest in the period 1954-63 and declining slightly in each sub-period.

It appears then, that the 1963-68 comparisons were, in this case, consistent with the longer term pattern of synthetic resins growth.

Iron and Steel

This commodity did not display the same consistency of growth as synthetic resins. The growth due to coefficient change was negative in the period 1954-63, positive between 1963 and 1968 and negative again between 1968 and 1972. This suggests that markets were lost to other materials during the 1954-63 period, but this negative substitution effect had peaked by 1963, and then commenced again towards the end of the decade.

Whilst there is some evidence that steel became more competitive during the 1960's, through the reduction of energy requirements etc. (Section 3.2.4), most of the evidence, including the specific consumption estimates of Table 3.1, suggest a continuous decline in the intensity of use of steel. The most likely explanation is that business cycle factors tended to depress steel consumption below trend level in 1963 and increase it above trend in 1968. This is supported by the information shown in

Figure 3.1

It was estimated that the 21% change in gross output could be apportioned -7% to coefficient change and 27% to change in final demand. Results differ from (53) (see Table 4.16) in that the negative impact of coefficients is much less than in (53) and the positive impact of final demand slightly less. The signs and orders of magnitude are, however, consistent.

Aluminium

The overall growth in the consumption of aluminium was very rapid in the period 1954-63 and progressively slowed in the later periods.

The decided slowing of growth after 1963 was due to the absence of the contribution of the strongly positive coefficient effect which influenced the period up to 1963. From then on, the influence of coefficient change was negative, suggesting perhaps, that the metal had attained an equilibrium position in some markets. This is consistent with the data presented in Section 3.3.3 and in particular Tables 3.1 and 3.4 which show that the intensiveness of use of aluminium grew rapidly in most applications between 1954 and 1963 and thereafter stabilised.

It was noticeable that throughout the period, the final demand effect was greater than the growth in final demand itself, suggesting that the change in the composition of demand had favoured aluminium intensive products. Developments in the packaging and electrical markets probably accounted for this.

Non-ferrous metals

This heterogeneous category consists of those metals which are commonly regarded as 'traditional' and those for which applications have been discovered relatively recently. This latter group of metals is relatively small and the category is dominated by such metals as copper, lead and zinc. As explained above the results for this category will very much reflect the growth performance of copper.

In 1954, as indicated in Chapter 3, copper was used in nearly all applications requiring electrical wire. Since then it has lost markets to aluminium in electrical engineering and transport applications and to plastics in construction and other applications. Design changes were made to reduce the unit consumption of copper required in fabrication.

Another major non-ferrous metal, lead,declined in consumption over the period 1963-72 and much of this was due to substitution particularly in cable sheathing and roofing. Where lead consumption increased it was not through substitution, but in demand led areas such as batteries for motor vehicles.

All this is consistent with the performance of the non-ferrous metals sector as suggested by the results of Tables 4.15 a b and c.

Aggregate use of non-ferrous metals grew between 1954 and 1963, but this was totally attributable to the growth of the economy in general. The coefficient change during that period had a negative influence upon consumption, suggesting that non-ferrous metals were being substituted by other materials. During the period 1963-68, total output fell and rose slightly again between 1968 and 1972. However, the coefficient effect was negative throughout. Thus although the total consumption of non-ferrous metals was influenced by the performance of the economy, the coefficient effect was consistent throughout the period.

As previously stated, deflation is very difficult for this category and may have a significant impact upon the results. However, as far as possible the deflators were checked using sources other than the tables provided by the C.S.O ((15), (18), Appendix 4.8).

For comparison with the estimates of (53), an approximation of non-ferrous metal gross output including aluminium had to be made, since (53) did not identify the latter as a separate commodity.

The results obtained show a coefficient effect of -9% and final demand effect of 40%, compared to Armstrong's 0% and 25% respectively. Again, there is substantial disagreement, as with the iron and steel category, and this again casts doubt upon the accuracy of the deflation carried out here.

Building Materials (including cement, pottery and glass)

The trend here was fairly consistent. Overall growth was positive in each period and the effect of technical coefficients was fairly small and generally positive. The heterogeneity of the category meant that intra-category substitution is probably of more importance than inter-commodity structural change.

The demand for the output of this category derives very much from the activity of the construction industry the demand for which, in turn, is much more dependent upon the level of final demand than upon coefficient changes. Thus final demand was the dominating influence and the effect of coefficients was negligible.

Armstrong (53) separates pottery and glass from this sector and a comparison for the aggregate of the two sectors would give the following results for 1954-63:

	Change in gross output implied by coefficient change	Change in gross output implied by final demand change
D.A.E.	3%	30%
This study	5%	30%

These figures are somewhat more consistent than those relating to iron and steel and non-ferrous metals.

Timber

The consumption of this material did not show much sign of a trend through the period 1954-72, but the influence of coefficient change was always negative, suggesting that substitution had an unfavourable impact throughout the period.

Timber is of course mainly used in construction and furniture. In the former application it has been replaced in many instances by other building materials in structures, plastics in floor covering and metal or plastic sheeting in low pitched roofings (67).

It is difficult to explain the slight recovery of consumption between 1968 and 1972 except in terms of cyclical factors, although the relative price of many woods did improve with respect to the metals over this period. (Figure 3.3).

Again, comparison with (53) is obscured by the aggregation in the latter publication, of timber with furniture. Armstrong (53) estimated a growth in gross output of this aggregated category of 5% between 1954 and 1963, 23% implied by final demand and -18% implied by technical coefficients. The figures for this study are 28% and -19% for final demand and coefficients respectively, not inconsistent with (53).

Rubber

This is a category of commodity for which derived demand was by far the strongest influence upon consumption. Substitution appeared to be of little importance, at least until 1968. Since a very large proportion of the output of the category consists of tyres for vehicles, and there was no other material for this purpose, (given that some goods made from synthetic rubber are also included in this category), this result is to be expected.

After 1968, coefficient change began to have a negative effect, possibly due to the increased use of synthetic materials in cable insulation and footwear, resulting in the transfer of some of the demand derived from these goods from rubber to 'plastics products'.

Armstrong (53) estimated that the total change in gross output between 1954 and 1968 was 29%, 28% implied by final demand and 1% implied by coefficient change. The estimates reported here suggest a total change of 21%, 20% implied by final demand and 1% implied by coefficient change.

4.4.6.2 Summary of results for 1954-72

In three cases, synthetic resins, non-ferrous metals and timber, the results of 1963-68 conform to the apparent long term trend suggested by the results using the 1954 and 1972 data.

The results for aluminium suggested a turning point at about the middle of the 1960's, when, in many cases the market share of the metal had attained approximate equilibrium.

Rubber moved very much in line with final demand until 1968 when there seemed to be some substitution by other materials.

For iron and steel the 1963-68 results conflict with both the longer term comparisons and the specific consumption estimates. This is probably due to an aberration caused by the relative position of the two years in the business cycle.

Where comparison with the published results of (53) was possible, it showed an acceptable degree of consistency for building materials, timber and rubber, whilst the results for iron and steel and non-ferrous metals were cause for concern. The results of both studies would lead, however, to similar broad conclusions.

Section 4.5

The interrelationship between the influences of final demand, structural change and resource intensiveness upon materials output

One of the observations made by both Armstrong (53) and Vaccara (66) was the tendency of the contributions of final demand and coefficient change to the differences in the output of commodities, to be complementary rather than offsetting. The commodities for which the growth of final demand had the greatest positive impact were also those for which the coefficient was above average.

This is possibly the result of the interaction between the growth of demand for the material and development in the production technology and the use of that material. For example, increased demand for a material via growth in a downstream industry may lead to economies of scale in the production of the material, full utilisation of capacity and an increase in the use of best-practice technology, which, in turn, will decrease the unit resource requirements of that material and thus reduce or moderate its unit price. This may then lead to further increases in demand via substitution for more expensive materials and so on.

The extent to which the complementarity between final demand and coefficient change exists may be observed from the results of this study. It is also possible to ascertain the degree to which substitution trends are determined by changes in the observed price of materials.

Table 4.17 shows that there is a high degree of rank correlation between the coefficient and final demand effects for the 1954-63 period (r_s = 75%, significant at the 5% level). This correlation is positive but not statistically significant for the period 1963-68 and there is no perceptible correlation at all for the period 1968-72.

There seems only a little evidence to support the hypothesis that the materials which are forward linked to high growth final demand categories are also those for which intensiveness of use has increased the most. Thus the interaction between these factors is not well established.

With respect to the relationship between prices and resource intensiveness on the one hand and substitution or coefficient change on the other, the evidence for 1963-68 shows a very strong negative correlation between direct input structural change (PS_{ep}) and the change in relative prices over the period (r_s = -81%) and between PS_{ep} and the ratio of unit labour requirements for 1968 relative to 1963 (r_s = -90%) (Table 4.18). There is also significant negative correlation between the total coefficient effect and the price ratio for this period (r_s = -92%).

Changes in 'quality adjusted' price probably account for the main proportion of the change in materials' market share not explained by observed relative price changes.

There is also a significant negative correlation between relative price changes and output changes due to coefficients over the period 1954-63, (Table 4.19a), whilst the data for the period 1968-72 show no correlation.

It was considered that this may be due to short-term deviations from trend in price producing an unrepresentative price ratio for individual years. For this reason, a five period moving average trend price index was calculated for each material and the trend values substituted for the individual year values. This improved the correlation for 1954-63 but the figures for 1968-72 remained unpatterned (Table 4.19b). Price instability in this latter period was the most probable cause of this result.

It must be noted that not only was the sample size small, but any errors in deflation would not be unbiased: An overestimate in the price change of a material would lead to an underestimate of the volume change and would thus accentuate the observed negative relationship between price and volume.

However, it may be stated with some confidence that the evidence indicates the existence of a relationship between prices and intensity of use and substitution trends. This is consistent with the assertion in Chapter 2, that relative price is the main factor underlying substitution activity.

However, it is also the case that the change in observed price is not a true reflection of the change in price per unit property or 'quality adjusted' price. The degree to which technical developments such as reinforcing, alloying, special processing etc., which improve the properties of materials and extend their application, are not reflected in the observed price determines the deviation between the latter and the 'quality adjusted' price.

Finally, relative raw material input prices did not appear to be strongly correlated with the relative price of the corresponding processed materials over the period 1954-68 (Table 4.20). Once again, the materials which are most natural resource intensive (timber and non-ferrous metals) were also those for which the price rose most. For the other materials, the impact of raw material price and technology change upon final prices was slight because of the generally low intensiveness of the resource in the total cost of the material.

Section 4.6

Conclusions

The results for individual materials have been discussed at length in the foregoing text and this section will be confined to general conclusions.

Firstly, the level of aggregate demand in the economy is by far the dominant force in determining the absolute level of materials consumption For each material in each sub-period, with the exception of synthetic resins, the effect upon output of final demand was more positive than that of coefficient change.

In the determination of relative output growth, however, coefficient change was more important. The change in output associated with the latter ranged from +34% to -19% between 1963 and 1968, whereas for final demand this range was +24% to +12% and there was a similar pattern for all subperiods. Clearly, if the growth of final demand slows, as it did between 1968 and 1972, coefficient change becomes relatively more important in the determination of the absolute level of output of the material..

The results for 1963-68 showed that a large proportion, (usually greater than 50%) of the effect of total coefficient change upon the output of a material is attributable to changes in the coefficients of the row of the input-output matrix referring to the material in question and may thus be associated with design changes or substitution (PS_{ep})

The input-output matrices for 1963 and 1968 did not display any across the board substitution trends, and many coefficients within a single row changed in an opposite direction to the average change for the row.

In one particular case, that of synthetic resins, the matrix of direct coefficients revealed no trend toward increased use in engineering and construction, whilst the direct plus indirect requirements, as estimated using the input-output inverse matrices, increased substantially.

Concerning the inputs to materials production, wages were a more important component of costs than energy or raw materials, but the variation in wages intensiveness was very small. The wide variation in energy intensiveness might have made this a more important relative price determinant, had energy prices not been as relatively stable as they were in the period considered.

The materials may be classified into two groups with respect to the importance of natural resources (excluding energy) in costs. For non-ferrous metals, timber and rubber, they were a considerable cost component, whilst for others, they were of minor significance.

The strength of the relationship between observed materials prices and coefficient changes suggests that much of the impetus for substitution originated in relative price change. 'Quality adjusted' price changes determined by the relative efficiency of fabrication processes associated with materials, probably explains the major proportion of the residual changes in the intensiveness of use.

The results of Chapter 4 confirm the conclusions of the previous chapter in the case of aluminium, other non-ferrous metals and synthetic resins. In the case of iron and steel, the effect of structural change in end-use sectors was more equivocal.

A greater degree of disaggregation,and thus more accurate data and a larger sample of materials categories, would be necessary in order to obtain a clear picture of the mechanism underlying materials output. If such data were available it would then be possible to construct a model of materials demand.

However, this chapter has demonstrated the way in which the various sources of change may be traced and has given an indication of their relative importance. This information is an important input to the discussion of the role of materials in the economy, which follows in Chapters 5 and 6.

CHAPTER 5

The Role of Engineering Materials in U.K. External Trade

Introduction

The object of this chapter is to quantify the role of engineering and construction materials in U.K. external trade. This involves the examination of trends in the relative importance of materials in total imports and exports, the contribution of the U.K. materials industries to the overall trade performance and the analysis of the implications for the balance of trade of certain changes in materials supply and production technology.

Firstly, the commodity structure of U.K. imports and exports was examined with reference to trends in the share of different materials in each and to the output of materials required indirectly to produce the set of imports and the set of exports for the year 1972. Comparison was made with the commodity composition of West German trade in order to test certain hypotheses concerning comparative advantage in the production of materials and engineering goods and to discuss the implications thereof.

Secondly, simple input-output formulations were used to provide a comparison of the impact upon the balance of trade of certain developments in materials technology and supply conditions. The conclusions of this latter section suggest the appropriate areas for emphasis in the discussion of materials related policies to improve the trade performance of the U.K.

Section 5.1 analyses the historical structure of U.K. imports and exports in relation to the changing proportion of materials and manufactures in each and the net trade in each material . A disaggregation of certain materials categories was made, in an attempt to test the hypothesis that the U.K. developed a comparative advantage in products of a relatively low unit value, within the materials categories, over the period 1962-1976.

Section 5.2 examines the relationship between the value of a commodity exported directly and that exported indirectly. Total direct plus indirect exports is known as "export-related output"[1](69). The structure of West German exports are compared with those for the U.K., and the results suggest the degree to which a country has a comparative advantage in any particular material or engineering good.

Section 5.3 is also concerned with the concept of comparative advantage; there is a test of the hypothesis that U.K. imports are more engineering materials intensive than exports, when considered both in total or in terms of bilateral trade with West Germany.

Finally Section 5.4 quantifies the effects upon the balance of trade of certain changes in materials prices and technology. There is discussion of some possible implications for the balance of trade of:

(1) Domestic substitution for imported materials.

(2) Changes in the price of certain imported raw materials.

(3) An improvement in the efficiency of use of materials in engineering.

The principal conclusions are that imported raw materials for engineering are of relatively little significance in terms of the balance of trade (less than 5% of the total value of imports of goods in both 1968 and 1976), and a change in the price of these would have a relatively small impact upon prices of final goods or upon the balance of trade.

There is a suggestion that recent trends have been for the performance of the U.K. to decline more markedly in the higher unit value categories of material.

Efficiency of use of materials in engineering emerges as a more dominant factor in determining trade performance than the availability of materials production capacity or of the relative prices of materials and final manufactures.

Section 5.1

Materials and the Structure of Imports and Exports

The structure of a nation's external trade is largely the result of comparative advantage in different commodities, arising from international geological, technological or social differences. This intuitively plausible hypothesis was first advanced by Ricardo and stated that under free trade a nation would specialise in those commodities for which production costs were relatively low. Extending this theory Heckscher (70) and Ohlin (71), contended that the commodity structure of a nation's trade reflects its relative factor endowments . Davies (72) provided evidence to suggest that this hypothesis was broadly appropriate for the U.K.

Hence a relatively low direct or indirect contribution to exports or high requirement for imports does not, in itself provide an indication of the relative "merit" of an industry. However, the diffusion of technology has lessened the importance of natural resource endowment in the determination of trade structure, and for developed countries, comparative advantage is determined by a complex interdependent set of influences. Some of these are relative growth rate, affording the embodiment of new technology in capital, the skill of labour, the effectiveness of R & D and managerial and governmental choice with respect to the allocation of resources. In other words, technology affords an institutional dimension with respect to commodity specialisation and comparative advantage is not, at least in the long run, predetermined. There is the possibility that a nation may have a "structural disequilibrium" between its demand for and supply of commodities (73). Some writers have attempted to use the composition of trade as an explanatory variable in the analysis of trade performance. There is no attempt here to evaluate the relative merits of specialisation in different products. Instead, it is assumed that an observed relative dominance in a commodity "reveals" comparative advantage and there is an attempt to test the hypothesis that the U.K., for whatever reason, has a comparative advantage in low unit cost goods within the engineering/materials sector.

5.1.1 The Structure of Imports and Exports

The significance of materials in imports and exports may be seen from Figure 1.1 which indicates that the value of crude materials[2] imported into the U.K. in 1968, just exceeded the value of domestically produced crude materials and constituted only about 3% of total imports of goods and services. The value of imported processed materials, £1100 million, was less than the output of the domestic materials industries, £6450 million, but greater than the exports of materials, £850 million.

Tables 5.1 to 5.4 give more detail for a period of 22 years. The most striking feature of Tables 5.1 and 5.2[3], showing the import structure of the U.K. from 1953-76 in value and volume terms, is the decline in the relative importance of primary and semi-processed commodities, although engineering materials have maintained a fairly constant proportion in value terms and only a slightly declining proportion in terms of volume.

The share of machinery and other manufactured goods has increased dramatically in relation to foods and non-engineering materials. This is partly a reflection of the sharp increase in world trade in finished manufactures over the period, owing to successive rounds of tariff reductions and partly due to the increasing propensity for the U.K. to import finished goods (73) (74). The degree to which the change in structure of imports within the engineering goods/materials category can be attributed to tariff reductions is discussed below.

From Table 5.3 & 5.4 it may be seen that the export structure for the U.K. has been more stable than that for imports. The share of materials was only just less than that in imports. Manufactures constitute the major proportion of exports, though, with the exclusion of chemicals, this proportion has not increased, in spite of the increase in importance of manufactures in world trade as a whole[4].

Table 5.5 shows the U.K. trade balance for each commodity for 1972 & 1976 and indicates that, though there was an overall trade deficit in engineering materials, most had a significant compensating export trade, either directly, as in synthetic resins and building materials or after a degree of processing, as in the case of rubber. The trade surplus in finished manufactures more than offset the deficit in materials.

The concept of the industrialised nation with a relatively small resource endowment importing relatively low unit value materials and exporting them after processing in the form of higher unit-value manufactures is one to which the U.K. is generally believed to conform. Although the former is valid as a general statement, the actual structure of trade is much more complex and it is one of the purposes of this chapter to examine the pattern of trade to see how closely the U.K. approximates to the above model relative to other industrial nations.

Panic & Rajan(75) for example classified commodities into five categories according to the growth of world trade in each. They then used this breakdown to test whether part of the explanation for poor U.K. performance lay in the specialisation upon relatively slow growth industries. In the current study, a slightly different approach is used to test the hypothesis (hypothesis I) that, in recent years, the U.K. has tended to have a growing comparative advantage in relatively upstream or intermediate industries, within the engineering sector, as opposed to those concerned with finished manufactures.

An alternative hypothesis (II) that will be examined is that within specific materials categories, the U.K. has developed a comparative advantage in the lower unit value materials. There is no attempt to compare factor intensities in order to test these hypothesese. Instead observations of actual performance in different commodities are used.

In considering hypothesis I, it was noted above that the U.K. experienced a significant export trade in materials, and rapid growth in the import of finished manufactures. It is firstly necessary to determine whether the pattern of structural change in imports and exports is peculiar to the U.K. and not typical of industrialised nations over this period. Hence, the trade structures in engineering materials and goods for Germany and France were compared with those for the U.K.

Tables 5.6a, b and c compare trade in materials and engineering goods as a proportion of total imports and exports for the U.K., France and West Germany (in U.S.$ terms) for three years 1962, 1972 and 1976 .

In fact the trend toward an increasing proportion of engineering goods in imports is reflected in both West Germany and France, which both had strong growth in the imports of SITC categories 7 and 8 over the period 1962-72. From then on, this proportion appeared to stabilise, possibly owing to the increased weight of fuel in value terms. In all three countries, the proportion of materials in imports has declined, but that decline has been concentrated in wood, ores and non-ferrous metals. The proportion of synthetic resins slightly increased in all cases, whereas iron and steel imports have strongly increased for the U.K. whilst showing no trend in other countries. This may reflect the relative vulnerability of the U.K. in those commodities for which there is worldwide overcapacity (a hypothesis not tested here).

For exports, only France showed a significant trend in the export of finished manufactures categories 7 and 8 increasing their share in exports from 36% to 46%. For the U.K. the decline in the proportion of machinery and transport equipment in exports was somewhat offset by the increase in other manufactures and there was no discernible trend in the total for finished manufactures.

All countries showed a decline of materials in exports, but this decline was not as marked as that for imports. Within the total, wood and iron and steel fell significantly, whereas synthetic resins increased for all countries.

Although there are one or two indications in Tables 5.6 that U.K. performance has suffered more in finished engineering markets than materials markets, particularly the behaviour of category 7, there is little at this level of commodity group to suggest significant differences in trade structure between the U.K. and, for example West Germany, for which the change in the proportions of materials in imports and exports was very similar to that for the U.K.

Though the work of Panic and Rajan(75) did strongly suggest that the specialisation pattern for U.K. trade was further from "optimum" with respect to world commodity trade growth rates, than some of her competitors, they concluded that further disaggregation would be necessary to establish whether the U.K. has a decidedly unfavourable trade structure.

Similarly, an unpublished NEDO study(74) recognised that the broad product structure of exports cannot account for a significant part of the decline in the U.K's share of world exports, and instead of examining the favourability of commodity trade structures, investigated the relative unit values of imports and exports within commodity groups. It demonstrated that the U.K. showed a marked tendency to import goods of a higher unit value than it exported within the engineering categories.

It is perhaps necessary then to disaggregate the materials categories according to the degree of processing in order to obtain any firm evidence of trends in comparative advantage.

5.1.2 Disaggregated Trade in Metals

Tables 5.7 a,b and c indicate the trend in the volume trade balance for certain worked or fabricated materials. These tables reveal that the U.K's net balance has tended to decline in all these materials.

A disturbing trend is evident in aluminium semi-manufactures, for which there was relatively rapid growth in consumption and trade. The performance of the U.K. was best in copper where world trade grew relatively slowly.

Tables 5.7 a, b and c also show that in the case of copper and aluminium, the trend in relative performance of the U.K. has been better in the unwrought metal than in the worked metal. In iron and steel, the effect of worldwide overcapacity and the competition from developing and newly industrialised countries, has been evident across the board, and if anything, appears to have been more damaging to U.K. trade in primary forms than in semi-manufactures.

A more detailed examination of trends is given in Tables 5.8 a,b and c which indicates the volume of imports and exports of metals by the U.K. and West Germany according to the degree of processing. Bilateral trade between the two countries is also shown.

If the U.K. has experienced a better trade performance in the higher unit value categories of metal, it would be expected that the worked to unwrought ratio for U.K. imports $(W/U)_m$ would tend to grow more slowly than that for U.K. exports $(W/U)_x$ and than $(W/U)_m$ for West Germany. The reverse would be the case for exports. The bilateral figures show whether the W/U ratios for trade with Germany are significantly different to those for overall trade. If W/U for U.K. exports to Germany is less than W/U for total U.K. exports, this would be evidence for the existence of a comparative advantage for unwrought metal in U.K. trade with Germany. (See Appendix 5.3 for further explanation).

For iron and steel, the growth of imports of unwrought metal was similar for the two countries. German exports of worked metal grew at more than twice the rate of those of the U.K., but since the latter's performance in the unwrought metal was so poor, $(W/U)_x$ has grown faster in the U.K. than in Germany. The bilateral figures for 1976 also tend to refute the hypothesis, in that W/U for W. German exports to the U.K. was less than that for trade in the opposite direction and less than $(W/U)_x$ for West German iron and steel as a whole.

A similar situation prevailed in copper where both U.K. and German import of worked metal increased very rapidly between 1962 and 1976. German export of worked metal almost doubled between 1962 and 1972 whilst those of the U.K. increased by 50%. Exports of unwrought metal by the U.K. halved in this period and the ratio $(W/U)_x$ increased more for the U.K. than for W. Germany. Between 1972 and 1976, exports of unwrought metal declined further for each country, whilst exports of worked metal approximately doubled for Germany but were stagnant for the U.K. The especially rapid decline in unwrought exports for the U.K. tends to contradict the hypothesis. However, W/U for U.K. imports from West Germany increased between 1972 and 1976, whilst it was approximately constant for U.K. exports. W/U for U.K. imports from West Germany was also greater in absolute terms than that for trade in the opposite direction and for $(W/U)_m$ for overall U.K. copper imports.

The evidence for copper is thus inconclusive.

For nickel, the rates of growth of worked and unwrought metal imports have been similar for the two countries. German exports of worked metal trebled between 1962 and 1976, whilst its exports of unwrought metal was negligible throughout. The rate of growth of U.K. exports of worked and unwrought metal was similar, leaving $(W/U)_x$ unchanged. Again, W/U for U.K. bilateral exports was less than $(W/U)_x$ and vice versa for imports. In fact W/U for U.K. bilateral imports is greater than unity, whilst $(W/U)_m < 1$. This again suggests that the U.K. is relatively less competitive in the worked metal category.

For aluminium U.K. imports of unwrought metal grew very little over the period, owing to the increase in domestic smelting capacity, whilst those for West Germany increased by nearly 300%. Imports of worked metal grew very rapidly, but more rapidly in West Germany than in the U.K. Between 1972 and 1976, U.K. imports of unwrought metal fell, whilst those of worked metal increased by 38%. In the same period, West Germany increased its unwrought imports by 17% and its worked imports by about 43%.

In exports, the U.K. doubled its volume of both worked and unwrought metals whilst West Germany increased its export of unwrought metal by about 230%. The overall W/U ratios for aluminium do not support the hypothesis, but bilateral trade figures again show that W/U for West German exports to the U.K. was greater than for total $(W/U)_x$ for Germany in both 1972 and 1976 and was substantially greater than unity. W/U for U.K. bilateral exports was less than unity and less than $(W/U)_m$ for overall U.K. aluminium imports. This strongly suggest a relative comparative advantage for the U.K. in the unwrought category.

Performances in tin, lead and zinc were very similar for the two countries with insufficient trade in worked metals to provide any evidence relevant to the hypothesis.

In summary then, for the four major metals, the overall W/U ratios do not provide convincing evidence relating to hypothesis II, and if anything tend to refute it. However, for bilateral trade, West Germany had a higher W/U in exports for all four metals in 1972 and all but iron and steel in 1976, suggesting a general comparative advantage for the U.K. in unwrought metals, in trade with West Germany.

One further test was applied to these data: The corresponding values for the worked and unwrought metals were obtained and the implicit price of imports and exports calculated in \$/tonne. At perfectly competitive valuation, this price should be a reflection of product mix, though in the real world, there is the problem of incomplete adjustment to exchange rates. This may particularly influence the figures for 1976, where the sterling exchange rate fell so rapidly that U.K. exporters would not have adjusted to the gain in competitiveness. Nevertheless, in all three years there appears to be a tendency for U.K. exports to be of lower unit value than U.K. imports and West German exports. Only part of this cheapness is probably explained by exchange rate changes, especially since, making the same calculations in sterling terms for copper and aluminium imports of semis for all the years between 1970 and 1976, only on two occasions (one for each metal) did the unit value of exports exceeds that of imports (Tables 5.9 a and b).

Thus there is a tentative suggestion that the product mix of U.K. exports of metals tended to contain lower unit value material than that of imports.

Further research is obviously required to adequately test this hypothesis, and this would include applying regression techniques to the various time-series and the further disaggregation of the metals categories according to degree of processing embodied. A priori, a function for bilateral trade such as

$$\frac{W}{U} = AT^{a}S^{b}g(t)u \qquad \text{.........} \; 5.1$$

could be specified for imports and exports where

A is a constant

T is relative average tariff levels for worked and unwrought metals

S is the relative level of subsidies, direct and indirect for worked and unwrought metals.

t is a time trend.

u is a disturbance term

The coefficient on t would represent that growth in the $\frac{W}{U}$ ratio unexplained by government policy and would thus approximate to the trend in comparative advantage. (Though would provide no indication of the underlying influences upon this trend.)

5.1.3 Possible Distortions Via Institutional Factors

5.1.3.1 The Influence of Tariffs and Subsidies

The full tariff on UK imports of worked steel fell from an average of about 10% in 1962 to 8% in 1972, via the Kennedy Round etc. The Commonwealth Preference rate fell from 7% to zero. The Common Customs Tariff (CCT) thereafter applied to imports from outside the EEC, whilst for trade with the Community, tariffs fell progressively to zero by 1977.

Imports of pig iron and primary forms were largely tariff free throughout the period.

For sheet, strip and tube of aluminium, the full rate fell from 12½% in 1962 to 8% in 1972. The Common Customs Tariff then became about 11%, whilst for imports from the Community, from where a large majority of metal imports originate, the rate fell to zero by 1977.

For sheet and strip of copper the full rate fell from 15% in 1962 to 10% in 1972 and for tubes, containers and wire, from 20% to 10%.

Once again, tariffs on ores and unwrought metal were negligible throughout the period, and there has thus been a substantial reduction in the tariff differential between worked and unwrought metal. How much this has affected W/U ratios is difficult to estimate in the absence of a statistical test such as that represented by 5.1. However, since a similar trade liberalisation has applied to exports, any differences in the trends in imports and exports to and from West Germany for example, are unlikely to be explained by tariff reductions alone, though statistical tests may indicate the size of tariff (if any) required to achieve a given balance between worked and unwrought metals.

Though it is possible to have a degree of confidence in the statement that tariffs are not the explanation for differences in W/U trends for imports and exports, the same cannot be said of subsidies. In the case of iron and steel, for example, the effective subsidies deemed necessary by social policy in the U.K. (and elsewhere), were so great in the mid-seventies, as to completely distort any data relating to comparative advantage.

With respect to tariffs on finished goods, there was a more pronounced closing of the gap, over the period 1962-76 between the latter and semi-manufactures. This must have had some effect upon the relative growth of imports, but Panic (73), for example, does not believe that trade liberalisation was solely responsible either for the apparent high marginal propensity to import or the increasing average propensity to import finished manufactures. He postulates a permanent structural disequilibrium between the supply and demand for commodities, owing to the sluggish response to changes in taste, income and technology.

This would be consistent with hypotheses I and II

5.1.31 Multinational Companies

Though it is probable that the policies of vertically integrated multinational companies influence the international flow of metals, it is unlikely that they will tend to act in a way which is totally contrary to the theory of comparative advantage. Economic theory would predict that activities within the firm will be optimised in some way as is international trading between firms. Distortions, of course occur via monopoly, government grants and subsidies, but these would occur whether companies were national or international. Hence it is these distortions which would tend to detract from the strength of the conclusions on comparative advantage and not the international integration of firms.

The conclusion from this section must be that more data on trade especially at a disaggregated level, plus the explicit introduction of tariffs and subsidies into the analysis, is necessary before any confident statement on trends in comparative advantage may be made.

Section 5.2

Exports and Export-Related Output

The previous section provided evidence concerning the hypothesis that the U.K. tends to specialise in relatively low unit value materials. In this section, there is a return to aggregate commodity categories for the purpose of the input-output analysis of U.K. exports. The investigation will be concerned with testing the hypothesis I (that the U.K. has a comparative advantage in engineering materials relative to finished engineering goods) by means of analysing the commodity composition of U.K. exports and in particular the direct and indirect output from each industry required to produce the vector of U.K. exports.

It will be considered that the proportion of the output of an industry which is exported directly rather than indirectly reflects:

(i) Comparative (cost) advantage either owing to resource endowment or the relative efficiency of production of a commodity.

(ii) The development of downstream export industries which use that commodity as an input.

If the value of commodity B is mainly exported indirectly rather than directly and vice versa for commodity A, and A is a significant purchaser of B and is of a higher unit value, it would suggest that the low unit value good is being used to support the export performance of the high unit value good, rather than as a direct export and that the country has a comparative advantage in the high unit value good relative to the low unit value good. Thus the typical primary producer will tend to export directly,low unit value goods, whilst industrialised nations will tend to export them indirectly, embodied in higher unit value goods.

Of course, some of the materials categories cover a wide range of products, some embodying sophisticated technology, but, in general it could be agreed that the unit value of most materials would be less than the unit value of most finished engineering goods.

One concept of "indirect exports" is that of "Export-related output" used by Stäglin et.al in the DIW project(69). This was deemed to be the gross output of each industry generated by the total export of goods and services in a year. The resultant figure corresponds to the value of direct exports by an industry, plus the value of the total output generated in that industry in order to produce the goods and services exported by other industries.

Thus, to use the nomenclature set out on Page 98

$$q = A_H q + h \qquad \ldots\ldots\ 5.2$$

$$\text{and } q_x = (I-A_H)^{-1}x \qquad \ldots\ldots\ 5.3$$

where q_x is the vector of domestic gross output requirements in order to produce the vector of exports, A_H is the matrix of domestic input-output coefficients, and x is the vector of exports.

One drawback to this approach is that this export-related output, by definition, exceeds the total value of exports, and thus, in the context of national accounting, contains an element of duplication which is arbitrary in magnitude, since it depends upon the pattern of aggregation of the input-output matrix.

Nevertheless, an indication is given of the relative proportion of output of each industry which is exported via other commodities.

A problem occurs with respect to the inclusion of imports in the interindustry matrix. It could be argued that to aggregate competitive imports with domestic production would obscure the evidence relating to comparative advantage. However, since the magnitude of the import of a commodity required indirectly for export (imports for re-export are set equal to zero), is a reflection of comparative disadvantage in that commodity, it would be consistent to include competitive imports in the interindustry matrix.

Thus if m is the vector of competitive imports,

$$q_m = (A_h + A_m)\ q_m + m + h_m + x_m \quad \ldots\ 5.4$$

where q_m is the total gross output generated, by the production of the import vector.

A_h is the matrix of domestic intermediate coefficients

A_m is the matrix of imported intermediate coefficients

h_m = direct imports into domestic final demand

x_m = re-exports.

If it is assumed that: $h_m = x_m = 0$, aggregating 5.2 and 5.4:

$$q + q_m = A_h q + A_h q_m + A_m q_m + m + h \quad = \quad A_h q + A_h q_m + A_m q_m + A_m q + h$$
$$= (A_h + A_m)(q + q_m) + h$$
$$\Rightarrow q + q_m = \{I-(A_h + A_m)\}^{-1} h$$
$$= \{I - (A_h + A_m)\}^{-1}(h-m) + (I - (A_h + A_m) \ )^{-1} m$$

Analogous to 5.3.

$$q_x + q_{mx} = \{I-(A_h + A_m)\}^{-1} x \qquad \ldots . \ 5.5$$

where q_{mx} is the gross output generated abroad in order to produce the export vector x .

The ratio of direct to indirect exports for commodity i is thus

$$\frac{x_i}{q_{xi} + q_{mxi} - x_i} \qquad \ldots . \ 5.6$$

The approach was to calculate $q_x + q_{mx}$ for the U.K. for the year 1972 and compare the results using aggregated versions of Tables K and M with those using the vector of West German exports for 1972 [5]. Bilateral exports were also tested in this way.

Owing to their diversity of content and only peripheral relevance to the present discussion, the transport, distribution, agriculture, food and services components of imports and exports were set equal to zero. A very serious flaw in this methodology, apart from the level of aggregation, is the assumption that West German production structure is the same as that of the U.K. It would be preferable to use German input-output tables, but given the problems of relative prices and appropriate exchange rates, there was insufficient time to construct a compatible German table for computation. The greater the level of aggregation (a 24 - commodity table is used here), the less additional information is provided by studying indirect exports as opposed to the simple comparison of direct export structure. Nevertheless, this exercise should at least differentiate between comparative and absolute advantage in commodities. For example, Germany may have performed better in both semi and finished manufactures, but the direct/indirect export ratio should indicate where comparative advantage lay.

Tables 5.10 a and b show that the information on direct/indirect ratios broadly conforms with the relative shares of commodities in direct exports. However, some interesting observations concerning individual materials may be made.

For both countries, total direct export of synthetic resins exceeded indirect, though in bilateral trade, the comparative disadvantage of the U.K. was reflected in the excess of indirect over direct exports. In iron and steel, Germany's direct/indirect export ratio was higher than that for the U.K., but in bilateral trade, the ratio was similar.

For aluminium, the direct/indirect ratios in bilateral trade are the reverse of those in total trade, thus reflecting a possible U.K. comparative advantage in trade with Germany, but not with other countries. The U.K. appears to have a strong comparative advantage in other non-ferrous metals, building materials and rubber, with substantially higher direct/indirect ratios, especially in bilateral trade, whilst Germany has a comparative advantage in timber and wood products a category which is effectively a complementary import to the U.K.

The ratio of direct to indirect exports for materials in total was lower for the U.K. than Germany for total trade, but higher for bilateral trade, from which it could be concluded that the U.K. had a comparative advantage in most materials in its trade with Germany in 1972, but probably not in its trade with the rest of the world.

An interesting variant of this exercise is the calculation of the import requirements for each vector of final demand. It could be argued that imports which are subsequently domestically processed and ultimately embodied in export goods do not detract from the balance of trade, except to the extent that domestic substitution would have reduced the import requirement. However, this domestic substitution if technically possible, would have both a current and a capital cost attached, in terms of additional import requirements.

Thus the implicit destination of imports which may be approximately estimated by input-output techniques, is relevant for isolating those categories of imports for which subsequent domestic processing most offsets the original negative impact upon the balance of trade.

The final destinations of imports are calculated from the expression:

$$m_{fj} = A_m(I-A_h)^{-1}h_j \qquad \ldots\ldots \quad 5.7$$

where m_{fj} = the vector of intermediate import requirements for the final demand vector j. h_j = jth vector of final demand.

Table 5.11c quantifies the direct plus indirect requirements for each type of imported commodity by each branch of final demand. From Tables 5.11b and 5.11c it may be seen, for example, that although non-ferrous metals was the materials category with the second largest value of imports, 44% of this value was required for exports. This is a reflection of the link between the U.K. non-ferrous metals industry and industries with a high propensity to export. On the other hand, of imported timber, only 10% was ultimately exported, partly reflecting the "complementary" nature of this category.

Thus there is a strong link, via domestic processing between most engineering materials imports and U.K. exports, and thus, from an overall balance of trade perspective, it is suggested that improved efficiency in converting these materials into final products would be more effective than attempting to limit directly the inflow of these imports. (See Section 5.4)

The evidence presented in this section then, strongly suggests that, with respect to bilateral trade with West Germany, the U.K. has a comparative advantage in non-ferrous metals, building materials and rubber, whilst Germany has a comparative advantage in synthetic resins and timber. For iron and steel the evidence is ambiguous. On the whole, the U.K. tended to have a comparative advantage in materials in its trade with Germany which did not appear to be the case for its total trade.

Section 5.3

Materials Intensiveness of Imports and Exports

Sections 5.1 and 5.2 have shown that the U.K. is a considerable materials exporter and that a considerable proportion of materials gross output is directly exported.

In this section, there is an attempt to estimate the total materials intensiveness of exports and imports, in order to further test the comparative advantage hypothesis.

The methodology is broadly based upon Leontief's work on factor proportions in U.S. trade (78) (79). In common with Leontief, this study employs the expedient of using the domestic input structure of one country to test the factor or input intensity of both imports and exports. Also, as in (78), complementary and competitive imports are separated, but this study departs from Leontief's approach in the following ways:

Firstly, the imports coefficient matrix, excluding complementary imports, is added to the domestic matrix before the inverse is computed, in an attempt to obtain a more appropriate representation of input structure. Secondly the entire value of complementary materials imports was added to the value of imports required for the imports vector, whilst complementary non-engineering materials imports are excluded altogether from the calculations. The complementary materials requirements for exports are estimated using the product of a matrix of total complementary materials import coefficients and the export vector. It would be preferable to use net output rather than gross output requirements, since the latter are not strictly additive. However, the problem of attributing a value added content to complementary imports precluded this approach, and instead, the materials categories were aggregated so that the total materials intensiveness of imports could be compared with that of exports.

Thus the materials requirements for exports is calculated from:

$$q_x \doteq (I-A)^{-1}\,x + M_2\,\hat{q}^{-1}\,(I-A)^{-1}\,x \qquad .....5.8$$

and materials requirements for imports from

$$q_m = (I-A)^{-1}\,(m_1 + h_m) + M_2 i \qquad .....5.9$$

where the nomenclature is as in Section 5.2, and $A = A_h + A_m$, where :

A_m is the matrix of competitive import coefficients.

q_x = vector of output requirements for export vector (including indirect complementary imports requirements)

q_m = vector of output requirements for import vector (including complementary imports)

m_1 = vector of competitive intermediate imports.

M_2 = matrix of complementary imports.

h_m = vector of competitive imports direct to domestic final demand.

$\hat{q}$ = diagonal matrix of gross outputs.

The results show that the vector of exports required £2804 million worth of engineering and construction materials for its production, or £349 for every £1000 of direct exports (excluding transport,services and food).

The imports vector required £2279 million of materials output or £294 for every £1000 of direct imports. Thus the import vector requires less direct plus indirect materials output per unit, than the export vector.

Restricting the analysis to bilateral trade with West Germany increases the materials intensiveness of both U.K. imports and exports, but the relatively greater materials intensiveness of U.K. exports is preserved.

This is consistent with the hypothesis that the U.K. has a comparative advantage in materials in its trade with West Germany, though not as great as that with the rest of the world.

Three major objections to this methodology may be:

(i) The pattern of aggregation of the matrix may influence the observed materials intensities.

(ii) Though transport and agriculture, food and services etc. are omitted from the import and export vector, the large agriculture/service category in the domestic matrix may bias the calculations.

(iii) Imports are of necessity measured on a c.i.f. basis and exports f.o.b.

For these reasons, the procedure was repeated, excluding the aggregated agriculture/food/services row from the domestic and import matrix. Since a large proportion of the difference between imports on a c.i.f. and f.o.b. basis is allocated to the transport category, this row was also excluded from the matrices.

Under these circumstances, the materials intensiveness in total export requirements was £337 per £1000 relative to £281 for imports, a very similar result to the first calculation.

For bilateral exports, materials intensities were £346 per £1000 for exports relative to £322 for imports.

Thus making an adjustment for agriculture etc., does not alter the conclusion that the materials intensiveness of U.K. exports to West

Germany is similar to that of U.K. exports in total, whereas imports from West Germany are less materials intensive than U.K. exports to West Germany. Again, a slight comparative advantage in materials in trade with West Germany is suggested, though greater disaggregation of commodities and more bilateral comparisons are obviously necessary in order to make stronger conclusions about the structure of U.K. trade.

Section 5.4

The Balance of Trade Effects of Changes in Materials Processing Capacity, Prices and Efficiency of Use

In this final section, the input-output representation of the structure of the U.K. economy is combined with certain assumptions concerning the elasticity of demand for commodities with respect to changes in the price of, and demand for other commodities, in order to examine the impact upon the balance of trade of changes in certain aspects of materials production and utilisation.

The objective was to test the relative importance of the dependence of the U.K. upon imported materials, in terms of their quantity and price, and the efficiency of use of those materials within the domestic economy, with respect to the marginal impact upon the balance of trade of changes in each of these.

This was undertaken by estimating the magnitude of the initial change required to effect the same net import saving in each of the following cases:

(1) Domestic substitution for competitive materials imports.

(2) A change in the price of "complementary" imported materials.

(3) A change in the efficiency of use of materials in domestic engineering.

Some fairly strong assumptions were employed, but it was felt that little bias across the three experiments was introduced as a result. The most critical assumption was probably that marginal import contents can be approximated by the average contents given in the input-output tables.

Barker and Lecomber (80) attempted to quantify the difference between average and marginal import contents for different groups of commodities and branches of final demand. The marginal propensities to import were estimated using log-linear regression formulations to estimate the demand and price elasticities of each imported commodity (81).

In general, marginal import contents were greater than the corresponding average contents, but the differences for food, fuel, raw materials and semi-manufactures were not very large - less than a percentage point in most cases.

However, the differences for finished manufactures were significant and so there is a high probability of error being introduced as a result of using average components. However, it must be remembered that the objective of the current exercise is to approximately estimate the short-term ceteris paribus effects of different developments in materials trade and not to provide a forecast of imports within a planning model of the economy. Thus the proportionality assumption of input-output analysis was used and the incidence of errors as a result, discussed below.

5.4.1 Domestic Substitution

The criteria for selecting a category of material appropriate for this exercise were that the imported and domestic product should have a similar input structure and should be readily substitutable. The only materials which even approximately satisfy these conditions are steel, aluminium and synthetic resins, though in each case it could be argued that the imported product in some respect differs qualitatively from the domestic product.

However, since a large quantity of both the domestic and imported material are relatively standard products, it was thought to be a reasonable assumption that they are substitutes.

The following assumptions were thus applied:

(i) The input structure of the additional domestically produced material is identical to that already produced and thus the product mix should also be identical. This implies that there are no economies of scale through using existing capacity more intensively, nor are there productivity gains from using newly installed capacity. It also means that marginal import requirements for other commodities are equal to average requirements as discussed above.

(ii) The unit value of the imported materials is assumed to be equal to that for domestic output.

Assumptions (i) and (ii) probably understate the value of domestic output required to substitute for a given value of imports, whereas the use of c.i.f. values for imports rather than f.o.b. imposes an opposite bias and it is hoped that the effects approximately offset each other.

(iii) Final demand (including exports) for all commodities remains unchanged.

There was no attempt to estimate the import content of the capital equipment required since capital coefficients are unreliable, and the estimate of requirements on a technical basis did not appear profitable given the approximate nature of the exercise.

The methodology combines these assumptions with the formulae of Becker (7) designed to estimate the primary input changes resulting from a change in the domestic demand for materials. The import row vector for the material is added to the vector of domestic output, and the resultant change in the imports of other commodities calculated from the formula.

$$\Delta g_i = \sum_m v_{i,m} t_m + \frac{\sum_m \varepsilon_m t_m}{1-\sigma_p} \left(\gamma_{i,p} + \sum_m v_{i,m} \delta_{m,p} \right) \qquad \ldots\ 5.10$$ [6]

where g = demand for primary input i by all industries (in this case i = the row vector of total intermediate imports)

$v_{i,m}$ = change in coefficient of primary input i in the output of industry m.

t_m = Gross output of industry m.

ε_m = Change in the direct coefficient of material p in industry m.

$\sigma_p = \sum_m \varepsilon_m \delta_{m,p}$ where:

$\delta_{m,p}$ = direct plus indirect (inverse) coefficient of industry m in material p.

$\gamma_{i,p}$ = Direct and indirect requirement of primary input i (imports) per unit of output of material p.

Since imports of the selected materials going direct to domestic final demand are negligible and exports are assumed unchanged, the net import saving is deemed to be equal to the difference between the original value of the total intermediate imports of the material and the marginal requirements for other imports resulting from the additional domestic output.

In 5.10., since it is assumed that domestic output exactly substitutes for imports:

$$\sum_m v_{i,m} t_m = -\sum_m \varepsilon_m t_m = \text{Total value of substituted imports.}$$

$$\text{Thus } \Delta g = \text{Value of substituted imports } \{1 - \frac{(\gamma_{i,p} + \sum_m v_{i,m} \delta_{m,p})}{1 - \sum_m \varepsilon_m \delta_{m,p}}\}$$

which term estimates the additional imports of all commodities required for the incremental domestic output.

Table 5.12 sets out the changes in input requirements resulting from such a substitution. In the case of aluminium, the direct saving in the imported material is £97 million, but this is partly offset by increases in the requirements for other imports, principally energy and other non-ferrous metals. The net saving is about £83 million. In fact, the marginal energy requirements would be greater if this additional value of primary aluminium were domestically produced, since the recorded value of energy does not reflect the marginal cost of energy imported and the subsequent processing of aluminium is less energy intensive than smelting. It would be interesting to disaggregate the requirements for primary aluminium from census and engineering data and make a similar calculation. Unfortunately this was deemed beyond the scope of the current work.

For steel, the saving would be much greater: £209 million of iron and steel imports would be directly saved, partly offset by large increases in the import of energy, (£11 million) iron ore (£12 million) and non-ferrous metals (£5 million). The net saving in this case would be £172 million.

For synthetic resins, the original materials import saving is £150 million, offset by increases in the import of chemicals (£18 million), and energy (£5 million). The overall net saving is £115 million.

Thus £172 million is the greatest estimated net import saving from the total domestic substitution for a material. The following subsections estimate the change in price or efficiency of materials use required to make a similar impact upon the balance of trade.

5.4.2 Change in Price of Complementary Materials Imports

The U.K. is dependent upon certain complementary imported commodities, and it was decided to examine the sensitivity of the trade balance to changes in the price of the imported raw materials used mainly in engineering and construction.

Dramatic changes in the terms of trade may arise from exchange rate changes or changes in market conditions for a certain product. This study is not concerned with the general price and demand shifts brought about by exchange rate adjustment, but with the effect of changes in price of certain essential materials imports.

The analysis was confined to complementary imports since in order to apply the input-output assumptions, demand for these products must be price inelastic, and any autonomous change in price must originate in the inputs which are primary to the system. Competitive imports would probably be more price elastic[7], and an autonomous change in the price of these would lead to a change in domestic profitability, or to substitution between domestic output and imports, and thus input-output assumptions would not be tenable.

The materials selected were the products of the mining and quarrying industry (excluding petroleum) and timber[8], which constitute all the engineering or construction materials which may be considered complementary.

Since the comparison is between the positive effects upon the trade balance of the different contingencies, a reduction rather than an increase in the price of these materials is considered, although, owing to the linearity of the input-output system, the effect is symmetrical.

Five assumptions were made:

(i) The demand for the complementary imports is totally price inelastic, i.e. there is no substitution or income effect upon demand via a change in price.

(ii) There is no corresponding domestic demand effect via the shift in real incomes.

(iii) The input structures for domestically produced commodities are representative of those for imports and there is no substitution between competitive imports and domestic products as a result of this price change.

(iv) The price of complementary imports, other than those deemed to be the subject of the autonomous price change, is assumed to be unresponsive to that price change.

(v)(a) The products of all countries are affected similarly and so any reduction in the cost of production of exports arising from the initial change in import prices will be reflected in export price changes with volume remaining constant.

(b) Alternatively, the exercise may be undertaken assuming export demand is price inelastic downwards and thus export price may remain constant with no reduction in volume. The implications of both (a) and (b) are tested.

Assumption (i) is believed to be reasonable for a complementary input in the short run. For assumption (ii), there is bound to be a second round income effect, but this is simply ignored for the purposes of this comparison.

Assumption (iii) is feasible if other countries are similarly dependent upon the original commodity and their production technologies are also similar. Assumption (iv) is considered to be unrealistic but not important in terms of influence upon the results.

Assumption (v) implies that $\frac{\Delta p_f}{p_f} = \frac{\Delta p_x}{p_x}$ in Barker's expression for export forecasting (52):

$$x = c_o \, (\theta^{-1} p_f{}^{-1} p_x)^{c_1} \qquad \ldots\ldots \quad 5.11$$

where θ is the exchange rate

p_f is the price of competing foreign products

p_x is the price of exports

c_o and c_1 are parameters.

Thus there is no change in export volume. This is acceptable provided all competitors are affected in the same way by the initial price change.

(b) implies that $c_1 = 0$ in 5.11 for any p_x below the current level and thus there is no change in price or export volume.

In order to find the final price effect the methodology employed was that of Becker (7). The input-output price dual is used to estimate the affect upon the final price of each commodity of an autonomous change in the price of a primary input.

The equation used was:

$$\Delta p_i = \sum_j \delta_{j,i}\Delta\theta_j + \frac{\sigma_i}{1-\sigma_p}\left(1 + \sum_j \delta_{j,p}\ \Delta\theta_j\ \right) \qquad \ldots\ldots.\ 5.12$$

where p_i = change in the price index (base = 1) of final demand for commodity i.

$\delta_{j,i}$ is the direct and indirect requirement of commodity j per unit of final demand of commodity i.

$\Delta\theta_j$ is the change in the primary input coefficient to commodity j (in this case equal to the change in the complementary import coefficient).

$$\sigma_i = \sum_m \varepsilon_m \delta_{m,i}$$

$$\sigma_p = \sum_m \varepsilon_m \delta_{m,p}$$

where ε_m = change in the direct coefficient of material p in industry m. In this case $\varepsilon_m = 0$ and so 5.13 reduces to $\Delta p_i = \sum_j \delta_{j,i}\Delta\theta_j$ 5.13

Since a crucial part of the exercise is to estimate the effect of the autonomous price change upon competitive imports, the latter must be included in the inverse matrix of which $\delta_{j,i}$ is an element.

Thus, employing assumptions (iii) and (iv) the matrix of competitive import coefficients is added to the domestic coefficient matrix and the Leontief inverse is computed from the resulting matrix. This was the technique employed by NEDO (58) in their study of the implications of the increased cost of energy [9].

$\Delta\theta_j$ is calculated by multiplying the existing coefficients for the complementary imports rows of the imports matrix by the ratio of the new to old price and subtracting the original coefficient. 5.14 gives the resultant price changes for each commodity.

The change in import value is given by:

$$\Delta\theta_j t_j + \sum_i\sum_j m_{ij} q_j (p_i - 1)$$

where m_{ij} is an element of M, the matrix of competitive import coefficients.

q_j = gross output of commodity j.

p_i is the price index (base 1) of commodity i.

The change in export value is given by:

$$\sum_i x_i (p_i - 1)$$

The latter expression is equal to zero under assumption (v) (b).

It was found that a decrease in the price of these materials of about 27.5% was required to equal the maximum net import value saving from the domestic substitution for an imported material; (£172 million) and only 20% under assumption (v) (b). If the import value reduction was to originate in mining and quarrying products alone, a 67% decrease in price would be required to achieve the £172 million saving. (40% under assumption (v) (b)).

Since raw materials have fluctuated quite substantially in price in a short time, it appears that the balance of trade is more dependent upon the price of complementary materials imports than upon the international location of processing capacity.

It remains to compare the importance of relative prices with the efficiency of use of materials in engineering.

5.4.3 The Efficiency of Materials Use

In Chapter 1, evidence was quoted suggesting that substantial savings could be made in U.K. materials utilisation, via improved design, machining and quality control, purchasing research etc. This saving would not only, ceteris paribus, increase the value added of materials using firms, but would also lead to indirect savings of the intermediate inputs, labour, capital and imports, required to manufacture the materials.

In particular, since most materials have a high energy component, this would lead to significant savings in energy imports.

In this subsection, the efficiency improvement required to achieve a direct plus indirect import saving for the U.K. equivalent to the net trade effect of domestic substitution and raw material price changes is estimated.

Once again, the methodology is from Becker (7) and the equation used is 5.10. Once again the proportionality of marginal import requirements to average requirements was assumed, and equation 5.10 was applied with ε_m referring to the arbitrary proportional change in the elements $d_{p,m}$ (where $d_{p,m}$ is the purchase of material p by the industry m, and m in this case covers the engineering and construction industries). Thus a 10% saving in material p would mean that $\varepsilon_m = \Delta d_{p,m} = -0.1.\ d_{p,m}$.

Since a reduction in the use of materials would also involve a reduction in those materials directly imported by the engineering industries, $v_{i,m} - t_m$ is equal to -10% of the value of material p directly imported by industry m. All materials p were aggregated into one category to take account of the interaction effect of savings in different materials[10].

It was found that the requisite percentage improvement in efficiency required to achieve the £172 million of the first exercise was 12.4%, a figure which appears to be within the bounds of engineering possibility, according to the evidence of Bahiri (4) and Rawicz-Scerbo (3), and unlike the case of domestic substitution for materials, there would be relatively little labour cost and negligible capital cost involved in achieving savings of this magnitude. Furthermore, the input-output technique takes no account of all the complementary inputs, primary and intermediate, required to process a given unit of material within the using industries, which are not recorded as direct inputs to the production of the material. In addition, this method takes no account of the possible reduction in price and gain in competitiveness of U.K. products resulting from such a materials saving. If this were measured, it would add further to the positive impact upon the trade balance.

It appears that a one per cent materials saving in engineering would approximately offset an 8% increase in the price of imported minerals or a 6% increase in the price of all complementary engineering materials imports. Thus, although the relative prices of raw materials and manufactures are undoubtedly important in determining the terms of trade and thus the value of imports and exports, the efficiency with which materials are used is possibly equally if not more important.

Section 5.5
Conclusions

In this chapter, it was attempted to portray the structure of U.K. trade in relation to direct exports and imports, and the indirect requirements for materials associated with each. Much of the analysis was simple observation of structural aspects of trade, though certain conclusions were also drawn.

Section 5.1 showed that the U.K. is a considerable materials exporter, but that the relative shares of materials and finished engineering goods in imports and exports was not substantially different to that of West Germany. The same applied to the relative growth of these shares.

Disaggregation of the metals categories did not allow strong conclusions to be made concerning overall comparative advantage in low or high unit value materials, especially since tariff structures may have an influence upon the pattern of commodity trade. There was a suggestion of a comparative advantage for the UK in the unworked metals when just bilateral trade with West Germany was considered.

Section 5.2 showed that the ratio of direct materials exports by the U.K. to the export-related output required from the materials industries was similar to that for Germany, but substantially higher when bilateral trade was considered, again suggesting a comparative advantage in materials for the U.K. in trade with West Germany.

This was consistent with the findings of Section 5.3 which showed that U.K. exports were more materials intensive than imports and that exports to West Germany were more materials intensive than trade in the reverse direction.

Section 5.4 showed that a relatively low cost policy of materials saving could have greater positive effects upon the balance of trade than those involving substantial capital cost, such as the domestic substitution for imported materials. It is also suggested that the vulnerability of the U.K. to raw (engineering) material price changes via the impact of natural resource deficiencies, though important, may be offset by efficient processing. This together with the lack of evidence of any comparative disadvantage in materials in general, leads to the overall conclusion that the problem of the U.K. is not one of high materials imports but of efficiency of the subsequent conversion of those materials into finished engineering goods. Much attention has been given to poor labour productivity, but it is possibly not widely recognised that such policy targets as the trade balance may be substantially influenced by savings in the materials area, without any necessity for direct labour, capital or energy saving.

CHAPTER 6

Materials and Productivity Analysis

Introduction

The purpose of this chapter is to examine the role of materials in the determination of relative productivity performance in the U.K. engineering industries. This involves an examination of the concept of industry productivity and in particular, the role of economic structural change in productivity measurement.

The shortcomings of some of the productivity measures suggested in the literature are discussed and an attempt made to derive suitable criteria for the purpose of measuring both industrial productivity performance and the contribution of materials utilisation and selection to that performance.

The results of Chapter 4 are used in an attempt to explain the differences in the observed productivity performance of various engineering industries.

It is concluded that the conceptual treatment of intermediate inputs in productivity studies has often been inadequate. However, no aggregate measure is capable of isolating the impact of changes in the properties, or use of materials from other influences upon the productivity of engineering industries. Some inference relating to the role of materials may be drawn from the attempt to explain differential productivity growth, which is reported in this chapter.

Section 6.1

What is Productivity?

6.1.1 The need for definition

Whilst productivity is generally accepted as being an indicator of the relationship between the output of a process/firm/industry/economy and the inputs thereto, most writers assume the definition of productivity is self-evident and simply concentrate upon its measurement. This frequent oversight has led to conflicts in the discussion of productivity, some of which may have been avoided were rigorous definitions and statements of objectives always given.

The measurement of productivity as Gold (50) observed has no meaning except in relation to the objectives of the economic unit. A measure should thus be chosen according to the objectives which are deemed to be appropriate. Since the current work is concerned with the contribution to national economic performance of the materials and engineering industries, an appropriate performance criterion would be the contribution to national output of a given industry relative to the resource cost of the activities of that industry.

Before defining productivity, it must firstly be emphasised that some inputs have productive potential and some do not. This could also be termed "creative" potential, where the creative inputs are those from which all other inputs and outputs originate. In other words, the "factors of production", (which for the purposes of this study shall be restricted to labour and capital[1]), are the only creative or productive inputs whilst all intermediate or other inputs are simply an embodiment of these factors.

Thus a production sequence should, as stated in Chapter 1 be viewed as a continuum with the categorisation of intermediate inputs into product groups simply a necessary expedient to allow the study of economic structural change. However, individual product groups so defined may have particular properties which change over time and alter the marginal rate of substitution between one product group and another. These properties give the product group "chracteristics" which differentiate it from other products, but not the autonomy of a primary factor, i.e. All properties of intermediate inputs are ultimately attributable to the work of the primary factors.

Thus, under conditions of competitive equilibrium, it is impossible for intermediate inputs to contribute to output a value greater than their input cost. They do not have a productivity. This statement is valid, in spite of the fact that in certain instances, the marginal value product resulting from the purchase of an incremental intermediate input may exceed the cost of that input. This may occur via under-pricing of the input (by accepting a lower return on capital than in the production of other goods[2]), or a temporary deviation of the input mix from its most efficient combination. A similar point was made by Fenske (82) who stated that only energy sources, effectors or directors could have a productivity. The term marginal productivity applied to an intermediate input is thus misleading.

The earnings of factors have a degree of independence from the real cost of those inputs and the divergence of the two provides the motivation for economic activity. Hence the term "creativity".

Thus the productivity of a factor input may be defined as the value of output created by that input relative to the value of the input, both measured at some constant unit price. Productivity change may be defined as that part of a change in output which is not explained by quantitative changes in inputs or changes in input mix. It may thus be identified with the "residual growth" in output after the quantitative change in inputs has been allowed for.

Allowance for the qualitative change in inputs and change in the environment should depend upon the objectives of the study. For example, if it is wished to compare the performance of managements, then all factors deemed to be outside managerial control should be compensated for. In the current study, the productivity index is designed to measure differences in the ratio of output to quantitative input, from whatever source these differences have originated. The explanation of productivity differentials across industries, in terms of qualitative and environmental factors is considered as a separate issue.

6.1.2 Productivity, Efficiency and Technological Change

At this stage it should be explained that productivity and efficiency are not synonymous, since the efficiency associated with an input is simply the actual input-output ratio relative to a hypothetical or potential optimum, dictated by technology and relative prices. Efficiency criteria may be applied to any input, whilst productivity criteria should be applied only to factors of production or resources. Thus, (if the natural resource dimension is ignored), the term "materials efficiency" is meaningful, whilst "materials productivity" is not.[3]

The relationship between productivity and efficiency is crystallised by Simon (83):

> "For an engineer, both output and input are measured in terms of energy. Hence arises a concept of 'perfect efficiency' that is a situation where output equals input. In the social sciences there is not a 'law of conservation of energy' which prevents output from exceeding input."

Finally, there are also two distinct types of efficiency which it is necessary to introduce:

(i) Technical efficiency is a physical or engineering measure and is the relationship of actual to potential output, using given inputs in a given environment[4], the potential output being determined by the production function. Technical efficiency is always less than unity, since physical output cannot be greater than the physical sum of inputs.

(ii) Price efficiency relates to the distribution of productive inputs across the various potential uses. An economically efficient allocation would be one where the marginal product of the input in the manufacture of one good was the same as its marginal product in the production of any other good and thus no overall output gain could be achieved by transferring some of the input from one application to another. Under perfect competition, it follows that the ratio of marginal products of two inputs into an industry should equal the ratio of their prices.

In order to demonstrate the difference between productivity and efficiency, it is instructive to adopt an approach similar to Farrell (84) and Stigler (85). The former constructed a graph using the labour/output and capital employed/output ratios as axes and empirically estimated what he called an "efficiency frontier". This was obtained by plotting the positions of all firms in an industry and drawing a line convex to the origin, enveloping the points and intersecting the line between each point and the origin. Assuming the environment to be similar for all firms and constant returns to scale, the level of efficiency of individual firms was deemed to be reflected by their relative distance from this efficiency frontier.

This approach may also be used in a theoretical sense for the purpose of conceptualising productivity and efficiency.

In Figure 6.1, OA/OB = the technical efficiency of industry B, where OB = actual factor cost per unit output and OA is minimum factor cost per unit of output, given the factor proportions of industry B. A move towards the efficiency frontier, accomplished via reducing the wastage of capital and labour inputs in equal proportions would increase OA/OB and thus the technical efficiency of the industry.

Alternatively, the factors may not be combined in such a way as to lead to a minimum total cost per unit of output. If the ratio of factor costs are represented by the price line CC', the price optimal ratio is represented by point H on the efficiency frontier. The extent to which point A is not price optimal is represented by the ratio OD/OA.

Finally, the efficiency frontier may itself shift towards the origin, representing technological change, change in the quality of factors, changed market conditions, or any factor associated with the environment of the industry.

Any observed movement of a firm or industry towards one axis which does not involve a movement away from the other, represents an increase in productivity.[5] This may occur as a result of a change in technical efficiency or a change in technological possibilities represented by a shift in the efficiency frontier.

Thus, any change in efficiency at the firm or industry level is a change in factor productivity (at that level), but the reverse is not the case.

6.1.3 Ways in Which Materials Influence Productivity

The influence of materials upon the productivity of a firm or an industry may be discussed in terms of Figure 6.1.

Firstly, the utilisation of materials in terms of machining, yield, storage, quality control, design specification etc., places a direct constraint upon the technical efficiency of the factors (ratio OA/OB), since some of the working time of the latter will be wasted by processing materials which finish as scrap or are inefficiently stocked.

Secondly, the environment of the industry is also affected by materials and process technology, in that developments in the properties of materials will influence the position of the efficiency frontier.

Pick (1) explains that the potential capacity of capital equipment, especially machine tools, is dependent upon the manufacturing properties of the material used, in terms of feeds and speeds, setting times etc. The number of machine tools necessary then determines floor space requirements.

This influence of materials upon direct factor productivity may be factor neutral, i.e. a change in materials technology may not change the optimal combination of labour and capital.

Alternatively a new material/process combination may allow a more price efficient capital/labour combination. This type of shift has been common in the expansion of plastics use. The processing properties of plastics typically allow the substitution of capital for labour in engineering, in that whole components may be moulded in one process, which reduces the need for machining and welding etc.

This demonstrates how materials may influence the productivity of factors directly, by shifting the efficiency frontier, via changes in materials technology, and indirectly via the technical and allocative efficiency associated with their use. Materials also influence the productivity of resources used indirectly by an industry as outlined above.

Whilst this diagrammatic analysis helps illustrate the definitional framework and the impact of materials upon the productivity of labour and capital, it does not explain the qualitative difference between materials and factors of production in the context of productivity analysis - An analogous diagram may be drawn with materials/output ratios on the axes and changes in efficiency and technological possibilities would have the same interpretation as for factor/output ratios. However, in the case of materials, changes in efficiency or technology would not constitute productivity change since all developments in both the efficiency of use and the technical properties of materials originate in the application of labour and capital, as explained in Section 6.1.1.

In summary, materials are often the mechanism through which factor productivity changes may be achieved, but they are never the origin of that change. This distinction has important implications for the treatment of materials and intermediate inputs in the measurement of productivity as will be discussed in the following sections.

Section 6.2

Some Conventional Measures of Productivity

Most early contributions to productivity analysis concentrated upon the output/labour ratio. This remains useful for the purpose of international comparisons or long-term national comparisons of output and employment trends, but has little meaning in relation to short period interindustry comparisons because of the dependence of the observations upon the quantity and quality of capital employed.

Hence most studies of industry productivity have been concerned with "total factor productivity" and have generally proceeded by weighting the factor inputs together to form an index of total factor input. This weighting is achieved by specifying (explicitly or implicitly) a production function which is the technical relationship between the output and the factors of production. That proportion of growth in output not explained by the growth of factor inputs is ascribed to productivity change or more circumspectly, residual growth.

Examples of studies employing the "total factor input" concept are those of Schmookler (86), Abramovitz (87), Solow (88), Kendrick (89), Denison (90), Reddaway and Smith (91), Jorgenson and Griliches (92), Armstrong (53).

Some assume an additive production function of the form:

$$q = A(t)\ (wL + rK) \qquad \ldots\ 6.1$$

where q = output of the industry/nation

L = quantity of labour employed

K = quantity of capital stock employed

w and r are rates of return to each factor, representing base year factor prices.

Making the assumption that entrepreneurs strive to minimise cost and thus make the ratio of the marginal product of factors proportional to the ratio of marginal costs, these weights adequately reflect each factor's contribution to the growth of output.

An index of the form

$$\frac{q_1/q_o}{(wL_1 + rK_1)/(wL_o + rK_o)} \qquad \ldots\ 6.2$$

is then derived.

Other writers assume a Cobb Douglas production function of the form:

$$q = A\,L^{\alpha}\,K^{\beta}$$

where α and β are the shares of labour and capital in national income and $\alpha + \beta = 1$ (i.e. constant returns to scale are assumed).

From this the expression for productivity or residual change: $\dot{A} = \dot{q} - (\alpha\dot{L} + \beta\dot{K})$ may be derived, where $\dot{A}$ is the annual proportional rate of residual growth, etc.

An alternative approach, employed by Arrow et al (93) is to estimate the marginal product of factors directly by regression techniques.

These studies were mainly designed to apportion observed growth in economies to the increase in factor input on the one hand, and the increase in productivity (or the residual, including input productivity as one of its components) on the other. A common factor of all of those studies mentioned above is that they are concerned only with the factors of production (assumed to be restricted to labour and capital). Other writers have discussed the role of materials or intermediate inputs in determining productivity growth, but there is not an accepted theory of this role. Indeed, it is by no means generally accepted that any account need be taken in productivity studies, of the quantity, quality and composition of materials.

This thesis does not purport to provide a theory of the role of materials or intermediate inputs in general, in productivity change. However the following contributions are made:

(i) The importance of the consideration of materials and intermediate inputs in studies of comparative productivity is discussed and the problems arising from failure to do so are indicated.

(ii) The literature on the subject and the various productivity criteria suggested are examined critically.

(iii) Suggestions are provided as to possible theoretical and empirical approaches to the study of the role of materials in industry productivity.

Section 6.3

The Role of Intermediate Inputs in Productivity Analysis

Materials are a subset of the intermediate inputs purchased by a firm or industry and therefore a discussion of the role of materials in productivity analysis should be accompanied by a general exposition of the role of intermediate inputs in the productivity of the firm or industry.

The role of intermediate structural change in the understanding of productivity trends was expressed by Carter (9):

> "New technology involves new products and new ways of combining old products. Many of these new products are sold industrially, and some never reach the ultimate consumer .... they are indispensable in bridging the gap between engineering and technical information on the one hand, and economic description on the other .... it is clear that long run changes in labour productivity are rooted in changes in the organisation of production, that new materials, components, communications, as well as new type of capital goods, have been prerequisite to continued rises in primary factor efficiency".

There are three main reasons why intermediate inputs should not be simply ignored or netted out:

(i) Intermediate inputs and engineering materials in particular have an influence upon the productivity performance of the factors of production, via their properties and technological complementarity.

(ii) The total resource productivity implications of the activities of an industry are not totally accounted for, even in theory, by the ratio of net output to factor input. As Gossling (49) (page 64) noted:

> "If they (net-value-added indices) are related to a net-value-added production function they do not seem to belong to economic theory - for the industry is ... making one (principal) output and unmaking all the items used as intermediate inputs".

Apart from the theoretical inconsistency, there may be problems through the existence of externalities, and more significantly in the context of the current study, the fact that the indirect generation of output and use of factors via intermediate inputs may not be in proportion to that arising directly.

In addition, intermediate inputs may, under certain circumstances be substituted for labour.

Thus the total unit resource cost of the total sales of an industry should be measured in addition to the net output per unit of direct factor input.

(iii) There may be actual distortions in the measurement of factor productivity in various industries if the embodied properties of materials are not correctly valued by the market.

Analogous to the argument of Jorgenson and Griliches (92), who suggested that price indices make insufficient allowance for quality change in capital, it is possible that conventional deflation techniques make insufficient allowance for the quality change in intermediate inputs. As indicated below, consideration of intermediate purchasing patterns may ameliorate the bias engendered by inaccurate deflation.

Gold (50) has noted that changes in physical productivity on the one hand and factor and product prices on the other are interdependent in that some innovations occur in response to factor price changes and some improvements in physical productivity have the effect of lowering product prices and increasing demand.

Thus measuring productivity at base period prices obscures the adjustment to the changed relative resource cost of inputs.

Furthermore, it is possible that cross-price elasticities between competing materials are greater than those between engineering goods owing to greater relative substitutability. This implies that the purchase of materials would be in a strong market position, in that downward pressure on materials prices could be applied in order to appropriate the value of the quality improvement of the purchased material to the net output of their own industry.

Thus an index should not overstate the productivity gain of a materials-using industry by attributing the improvement in the quality of the material to the using industry.

Thus, some attributes of a productivity index which was to be both consistent with economic theory and useful in its quantification of the contribution to productivity of intermediate inputs would be:

(i) It would give appropriate weighting to intermediate inputs relative to factor inputs for the purpose of the estimation of total input. This weight would reflect the resource cost of producing that intermediate input.

(ii) It would not be subject to error resulting from the inaccurate price deflation of the outputs of non-principal[6] industries.

(iii) It would allow the estimation of the impact at the margin, of changes in the use of materials upon productivity in downstream industries.

The extent to which any index proposed in the literature possesses these attributes is discussed in Section 6.4.

Section 6.4
Materials and Productivity - The Literature

In this section, the principal contributions to the theory of productivity analysis with respect to intermediate inputs are discussed. The many variants of the "net output per unit of direct factor" approach of Schmookler, Solow, Kendrick etc. will be generically referred to as the "VA/direct factor" approach in order to distinguish them from those measures which explicitly take account of intermediate inputs.

6.4.1 Materials and Firm Level Productivity

Many writers have drawn attention to the influence of materials use upon productivity (3) (4) (5) (see Chapter 1), and some have derived measures to integrate materials utilisation into a system of productivity measurement for the firm. For example, Gold (50) drew attention to the interrelationship between the various technical and financial ratios for a firm and the possibility of misinterpreting a single ratio by viewing it in isolation.

E.g. $$\frac{\text{output}}{\text{labour}} = \frac{\text{Capacity}}{\text{Fixed Investment}} \times \frac{\text{Fixed Investment} \times \text{Output/Capacity}}{\text{Labour}}$$

and thus it may be the intensiveness of use of capacity which was the source of the productivity gain, and not labour as may have been suggested by the interpretation of the partial index output/labour as an indicator of labour productivity.

Gold devised a system of such equations as a framework for empirical productivity analysis, which was applied, for example, in Gold, Eilon and Soesan (48).

Bahiri (4) also recognised the importance of materials utilisation and calculated the potential improvement in value added per unit of total resources used, through quality and waste control, value analysis, and better purchasing and storage methods.

6.4.2 Materials and Industry Productivity

This chapter is concerned with productivity measurement at a level more aggregative than that of the firm.

One of the first pieces of theoretical work on industry productivity to explicitly include materials was that of Domar (94). He noted that materials are usually excluded from both sides of the production equation. " .... presumably to avoid double-counting".

He attempted to construct an index which would provide a measure for individual industries but would also be additive, such that it would be invariant to the degree of aggregation or integration. Thus the weighted sum of the indices for the individual industries would be a measure of residual growth for the economy.

He postulated a Cobb-Douglas production function $Y = A\, L^{\alpha} K^{\beta} R^{\gamma}$... 6.3 with Y, A, L, K, α and β defined as before, and R representing raw material input and γ the weight ascribed to raw materials in input. $\alpha + \beta + \gamma = 1$, implying the assumption of constant returns to scale.

If, as is usually the case, the function $Y' = A' L^{\alpha'} K^{\beta'}$ is estimated, we have $\alpha' = \frac{\alpha}{1-\gamma}$ and $\beta' = \frac{\beta}{1-\gamma}$

Thus R is given a weight of zero and its former weight assigned to labour and capital in proportion to their former weights.

As an alternative he shows that if two industries are to be aggregated into one sector, the growth of productivity or the 'residual' for the aggregated sector should be the weighted sum of the residual growth of the component industries, with the weights being the ratio of the value of product of each compenent industry to the value of that output of the integrated industry which is final or external to the industry, i.e. not consumed by any component industry.

Thus if two industries can be represented by the production functions:

$$Y_1 = A_1 L_1^{\alpha_1} K_1^{\beta_1} Y_{21}^{\gamma_1}$$

$$Y_2 = A_2 L_2^{\alpha_2} K_2^{\beta_2} Y_{12}^{\gamma_2}$$

(where Y_1 is the total output of industry 1, Y_{21} is the input of industry 2 to industry 1 and y_1 represents the external output of industry 1 in the base period).

the rate of growth of the residual

$$\dot{A} = \frac{y_1 \dot{A}_1 + y_2 \dot{A}_2}{y_1 - y_{12} + y_2 - y_{21}}$$

gives the appropriate growth rate for the composite residual.

This is a useful criterion for aggregation when the objective is to measure the contribution of the growth of the residual to the growth of national product, since it is important in that case, to ensure that the pattern of aggregation does not influence the overall result for the economy as a whole. However, if the objective is the comparison of industries within an economy, the criterion of sensitivity to aggregation, though still important, becomes a lower priority than the accuracy of measurement of the relative performance of industries.

Thus Domar's treatment of raw materials only extends as far as the aggregation and integration of industries. It does not address the problem of choosing a weight for the input of industry 2 into the production of industry 1, for the purpose of measuring the productivity growth of the latter industry. To use Domar's weighting of

$$\frac{y_2}{y_1 - y_{12} + y_2 - y_{21}}$$

would not be appropriate for this purpose, since the total output of industry 2 (less its input to industry 1) is included in the denominator. For the purpose of measuring the productivity growth of industry 1, only that proportion of industry 2's output which is required to support the output of industry 1 should enter the expression. If this is not the case, industry 1's observed productivity would be arbitrarily influenced by the scale of industry 2's activity.

The use of Domar's "geometric value added" index does not avoid the problem of estimating γ_1.

Hence, an index constructed in this way does not possess attribute (i) of Section 6.3.

Similarly, Star (95) estimated the error due to the exclusion of materials from the index to be:

$$V_1 \left(\frac{\dot{Y}}{Y} - \frac{\dot{M}}{M}\right) + V_2 \left(\frac{\dot{X}}{X} - \frac{\dot{M}}{M}\right)$$

where $\frac{\dot{X}}{X}$ = a divisia or continuous index of all non-intermediate inputs.

M = outside materials (i.e. those bought-in from outside the industry).

$V_1 = \frac{-M}{Y-M}$ and $V_2 = (1 - \beta)$ where $(1 - \beta)$ is the (average over the period) share of outside materials in gross output.

Similarly to Domar, Star suggests the aggregation rule:

$$\frac{\dot{A}'}{A} = \delta_1 \frac{\dot{A}_1}{A_1} + \delta_2 \frac{\dot{A}_2}{A_2} \quad \text{where} \quad \delta_1 = \frac{Y_1}{Y_1 + M_2}$$

$$\delta_2 = \frac{M_2}{Y_1 + M_2}$$

where $$\frac{\dot{A}_1}{A_1} = \frac{\dot{Y}_1}{Y_1} - \alpha_1 \frac{\dot{K}_1}{K_1} - \beta_1 \frac{\dot{L}_1}{L_1} - \gamma_1 \frac{\dot{M}_2}{M_2}$$

and $$\frac{\dot{A}_2}{A_2} = \frac{\dot{M}_2}{M_2} - \alpha_1 \frac{\dot{K}_2}{K_2} - \beta_1 \frac{\dot{L}_2}{L_2}$$

which Domar showed would produce an aggregate $\frac{\dot{A}'}{A'} < \frac{\dot{A}}{A}$ where $\frac{\dot{A}}{A}$ is calculated by the VA/direct factor method. In other words, observed residual growth is dampened by the inclusion of materials.

However, it may be seen once again that this index assigns a weight to M_2 corresponding to its average total input coefficient in the output of industry 1, and identical problems occur to those resulting from the Domar weighting system.

This problem of weighting intermediate inputs is central to the construction of a "total" productivity index, and serious errors of interpretation may result if an inappropriate weighting concept is used.

For example, Thomson (96) assumed materials to be a factor of production and attached to them, a weight equivalent to their full cost in aggregating them with labour and capital inputs to obtain a total factor input for manufacturing in Australia. The weights used were thus (for total manufacturing) 27.7% for labour, 1.9% for capital and 70.2% for materials. For individual industries, the materials weight was at least 50% in each case. This procedure gives a very heavy weight to the growth in intermediate inputs and since these inputs increased as a percentage of gross output over the period of study, Thomson was led to the conclusion that productivity or residual growth made only a small contribution (about 10%) to the growth in manufacturing output over the period.

This type of weighting has many theoretical flaws:

First, it requires the concept of the "productivity of materials", which is inconsistent with the definitions of Section 6.1.

Secondly, it implies an index of the form:

$$\frac{\dot{A}}{A} = \alpha \left(\frac{\dot{Y}}{L}\right) + \beta \left(\frac{\dot{Y}}{K}\right) + \gamma \left(\frac{\dot{Y}}{R}\right) \qquad \ldots\ldots 6.4$$

where R is the input of materials to an industry

Y is the value added of an industry, and thus

Y = q - R where q is the gross output of an industry

$\left(\frac{\dot{Y}}{L}\right)$ = Rate of growth of the output-labour ratio.

If an industry purchases an increased quantity of an intermediate input as a substitute for direct labour and $\gamma > \alpha$, then its productivity performance according to 6.4 will decline. If the increase in the ratio of intermediate inputs to gross output is exactly compensated by a fall in the direct labour coefficient, then a "VA/direct factor" productivity index will indicate no change, whilst the "Thomson" index will tend to fall.

Consider example 6.1, Table 6.1, where in period 0, industry 1 has a gross output of £20, an intermediate input of £10, and an input of labour (the only factor of production) of 10 units, each receiving a wage rate of £1.

In period 1, prices and wage rates have not changed but it is found that the output of industry 2 is a perfect substitute for labour in the process of production of industry 1, and as a result, industry 1 purchases an additional £2.5 of the output of industry 2[7] and consequently reduces its own labour input to 7.5 units, with no change in gross output.

Applying 6.4, using base period weights, $\alpha = 0.5$, $\beta = 0$ and $\gamma = 0.5$, the index for period 1 would be:

$$0.5 \left(\frac{7.5}{7.5} \div \frac{10}{10}\right) + 0.5 \left(\frac{7.5}{12.5} \div \frac{10}{10}\right) = 0.8 < 1$$

Thus the observed productivity of industry 1 has declined, whilst nowhere in the economy has the output per unit of labour decreased. A VA/direct factor index would indeed show no change. For the economy as a whole, Thomson's index would show a decline simply because intermediate inputs have become a larger proportion of gross output[8].

This index clearly does not possess attribute (i) of section 6.3 and indicates the need to attach appropriate weights to intermediate inputs.

It should be emphasised here that an increase in intermediate input coefficients does not necessarily imply a decrease in productivity either at the industry or national level. Gossling (49) noted that growth in the economy has occurred both when the aggregate intermediate input/gross output coefficient has been rising and when it has been falling. He reports the input-output coefficient (excluding imports) for the UK to have been 0.425 in 1963, 0.422 in 1968 and 0.435 in 1970. Simultaneously, capital coefficients were falling slightly and labour coefficients were in general falling rapidly. Gossling reported a downward trend in this coefficient for the U.S. over the period 1947-67 (0.491 for 1947, 0.483 for 1958 and 0.466 for 1967). Carter (9) however reported an increase in the "roundaboutness" of the U.S. economy between 1947 and 1958 in constant prices and suggested that this does not imply a decline in efficiency owing to the simultaneous reduction of labour coefficients.

Thus materials should be given a weight in estimating total input, but this weight should reflect the resource cost of producing that materials input.

6.4.2.1. Gross Output Measures

Most authors who have included intermediate inputs in a productivity system have done so as part of a "gross" measure, i.e. one that has gross output or something closely related, rather than value added as the numerator.

Kendrick (89) in addition to his net productivity index, proposed an index of the form:

$$\frac{q_1/q_0}{w\ (L_1/L_0) + r\ (K_1/K_0)}$$

where q_1 and q_0 are gross output in periods 1 and 0 respectively, excluding intraindustry output. w is the average wage rate of labour and r is the base period return to capital. (Other symbols as before.)

This index compares gross output with direct factor input, and suffers from the drawback that a switch from "make to buy" would arbitrarily increase observed productivity by reducing labour and capital coefficients per unit of gross output.

Kendrick's index does not directly apply a weight to intermediate inputs and therefore does not satisfactorily deal with the case where one intermediate input is substituted for another, or for a direct factor input.

Returning to Example 1, Kendrick's index for industry 1 is:

$$\frac{20/20}{1 \times \frac{(7.5)}{10}} = 1.33$$

i.e. the index would register a gain in industry 1's productivity when in fact there has been no improvement in productivity in any of the industries. Thus Kendrick's index attributes all factor saving, wherever it occurs to the industry in which the factors are displaced. It thus performs poorly according to attribute (i).

Since the only deflation involved is that of the output of industry 1 itself, Kendrick's index performs well according to attribute (ii).

An improvement on Kendrick's index was that proposed by Stone et al in the U.N. System of National Accounts (47) (S.N.A.). The numerator of this productivity index is, once again, gross output. The (Laspeyre) gross output index for a vector of industries is:

$$\Lambda^* = \frac{q_1' \,(I-A_0')^{-1}\, F_0'\, r_0}{q_0' \,(I-A_0')^{-1}\, F_0'\, r_0} \qquad \ldots\ldots\ldots\ldots\ 6.5$$

where q is a vector of gross outputs of industries

A_0 is the intermediate input coefficient matrix in the base year.

F_0 is a matrix relating the quantity of each primary input to the gross output of each industry in the base year.

r_0 is the matrix of rates of return to each factor in the base year.

The prime symbol represents the transpose of a matrix.

Since $(I-A_0')^{-1}$ is the well known input-output price matrix, the expression $(I-A_0')^{-1} F_0' r_0$ produces a vector of price indices for the output of each industry.[9] Λ^* is thus simply the ratio of gross output in period 1 to that in period 0, valued at period 0 prices.

The index of inputs is given by:

$$\Lambda^{**} = \frac{q_1' \,(A_1' \,(I-A_0')^{-1} F_0' + F_1')\, r_0}{q_0' \,(I-A_0')^{-1}\, F_0'\, r_0} \qquad \ldots\ldots\ldots\ldots\ 6.6$$

and the resultant productivity index by:

$$\Lambda^{***} = \frac{\Lambda^{*}}{\Lambda^{**}} \quad \frac{q_1'\,(I-A_0')^{-1}\,F_0'\,r_0}{q_1'\left(A_1'\,(I-A_0')^{-1}F_0' + F_1'\right)r_0} \qquad \ldots\ldots\ldots \quad 6.7$$

and thus represents the growth of gross output in base year prices relative to the growth of intermediate inputs plus primary inputs, also in base year prices.

For a single industry, the S.N.A. index is an improvement upon that of Kendrick since if applied to Example 1 , it would register no change in the productivity of any industry, since the gross input of industry remains equal to its gross output.

However, if a change in productivity has occurred somewhere in the economy, the S.N.A. index does not always reflect the degree to which an industry has improved its overall resource efficiency.

Consider Example 2, Table 6.2, where the initial conditions are identical to Example 1, but this time the factor input to industry 2 becomes more productive, and £7.5 worth of output is produced in that industry for the use of only 5 units of labour. As a result, the output of industry 2 is substituted for the output of industry 3 in the production of the output of industry 1. Direct factor input productivity in industry 1 remains unchanged.

The S.N.A. index would show a productivity ratio for industry 1 in period 1 relative to period 0 of $\frac{10}{10} = 1$, and so there is no reflection of the decreased use of resources per unit of output of industry 1. This occurs because the index is insensitive as to whether the intermediate inputs purchased have increased or decreased in factor intensiveness.

Hence, if an industry has economised on an input with a relatively high real cost, this will not be reflected. The index is thus useful in establishing where a productivity gain has originated , (industry 2's productivity index would have been 1.5 relative to a base of 1), but not in the comparison of the rate of change of output of an activity with that of total resource use.

Thus by weighting intermediate inputs by their full cost (at base year prices) and not by their resource intensiveness, the S.N.A. index cannot be said to possess attribute (i).

As for sensitivity to deflation, consider Example 3, Table 6.3, where this time, the quality of industry 2's output has improved, allowing the reduction in the input of industry 3 to the production of industry 1. However, unlike Examples 1 and 2, the deflation technique is not assumed to be perfect. In fact it does not allow for the quality improvement in industry 2, and thus the gain in productivity is ascribed to the direct factors in industry 1, which are shown as earning a real return (obtained by double deflation) of 12.5 units for the input of only 10 units of labour.

In this case the S.N.A. index would show a productivity increase for industry 1 of: $\frac{20/20}{17.5/20} > 1$,

whereas if correct deflation had taken place the input from industry 2 to industry 1 would be £7.5, net output would be reduced to £10, and no productivity gain would be registered.

Since the price deflators of all industries influence the determinants of the S.N.A. index, the latter is subject to error via inaccurate deflation and thus does not possess attribute (ii).

All the shortcomings of the S.N.A. index apply to the related ones suggested by Loomis and Barton (97) and West (98). Both attach full cost weights to intermediate inputs and thus do not possess attribute (i). The only significant difference between these latter indices and that of the S.N.A. is that both Loomis and Barton and West specify a Cobb-Douglas production function, whilst the S.N.A. approach implicitly assumes a linear production function.

An alternative approach was suggested by Dovring (99) who compared the total output of an industry (in this case agriculture), with the current direct plus indirect labour (or accumulated labour) required for that industry's output (excluding intraindustry output). The indirect labour was approximated by estimating labour's share of the non-agricultrual national income, multiplying the sum of non-agricultural inputs to agriculture by this proportion, and dividing by the average hourly wage in manufacturing to obtain an estimate of the number of man-hours indirectly required to produce the total agricultural output. This assumes that wage rates are constant throughout the non-agricultural sector of the economy, or at least that the effects of differential wage rates are averaged out in the aggregation of the intermediate inputs.

Dovring's index for industry 1 in a 3-industry economy would be:

$$\frac{(q_1 - d_{11})}{(\sum_{i=2}^{n} d_{i1} \sum_{i=2}^{n} l_i \, w_i / \sum_{i=2}^{n} (q_i - \sum_{k=1}^{3} d_{ki}) \times w)} \qquad \ldots\ldots\ldots \; 6.8$$ [10]

where l_i = employment in industry i. (man-hours)

d_{ij} = the input from industry i to industry j(in flow form).

w_i = the wage rate in industry i.

w = the average hourly wage rate per man in manufacturing (assuming each unit of labour input to be one man hour).

In the case of examples 1, 2, and 3, this index gives the "correct" result in that it reflects in each case the gross output of industry 1 relative to the total labour embodied in the output of industry 1.

This index will possess attribute (i) provided there is only one-way dependence between the principal industry and its suppliers, and the condition $\frac{d_{m1}}{d_{n1}} = \frac{w_m l_m}{w_n l_n}$ ...... 6.9 holds.

In an interdependent system, Dovring's approximation will give an unbiased estimator of total first round or current labour requirements, provided 6.9 holds. (See Appendix 6.1 for proof), where l_2 is total labour used in industry 2, whether required for the production of output destined for other industries or final demand.

Thus Dovring's index implies the assumption that the relative contribution of any industry to the total input of the principal industry, is proportional to its relative contribution to the total net output of the economy (excluding industry 1), and thus that all input structures are linearly dependent (a very strong assumption). Unless this condition holds, it does not possess attribute (i).

With respect to deflation; provided the estimated real sum of intermediate inputs is correct, the Dovring index is invariant to the accuracy of the deflation of these inputs. However, if the deflation is such that the total intermediate coefficient differs from its "real" value, then the estimated labour contribution will be correspondingly misvalued.

This proportionality technique is less appropriate to capital, since the vastly different rates of return in different industries would exacerbate the problems mentioned above[11]. Aggregation of capital and labour into a total factor productivity index, or alternatively estimation of the labour embodiment in capital is not practical within this approach.

6.4.3 Subsystems

A more disaggregated approach with some theoretical similarities was that of Gossling (49). His analysis proceeds by means of constructing a "gross output subsystem" for an industry (in this case agriculture), which measures the proportion of the total output from each industry in the remainder of the economy required to support the "external" output of the principal industry, where the external output of an industry is that which is not required either directly (intra-industry output) or indirectly (via other industries) to support its own output. In other words, the subsystem eliminates interdependence with respect to the principal industry.

The subsystem is constructed by dividing all elements of an input-output table by the corresponding row total to obtain market share coefficients for each industry.

Thus $u_{ij} = \dfrac{d_{ij}}{q_i}$

where u_{ij} = the proportion of industry i's output required for the production of the gross output of industry j.

To each u_{ij} is added the proportion of industry i's output required by industry k multiplied by the proportion of industry k's output required by industry j. In turn, the proportion of industry k's output required by industry j includes the proportion of industry i's output required for industry j multiplied by the proportion of industry k's output required for industry i. This is an infinite process and the ultimate proportions p_{ij} of the output of industry i required directly and indirectly by industry j are the limiting values of the sum of the series of such iterations (See (49) page 22 for the properties of (I+P) the matrix of proportions p_{ij} with the main diagonal elements equal to unity).

The estimate of total output for the productivity index is obtained by deflating the gross output or sales of industry 1, (if industry 1 is the principal activity or industry of the subsystem), by a given price to obtain the total physical output of the industry. From this gross physical output the following are netted out:

(i) The proportion of industry 1's output which is intra-industry output generated within industry 1.

and (ii) The proportion of industry 1's output which is indirectly required for industry 1's output, via the other industries in the economy.

By netting out the circular flow from industry 1 to itself, the interdependence between industry 1 and the rest of the economy is eliminated and the remaining output of industry 1 may be considered as being "external".

The denominator of the productivity index is the "current" labour required for the production of this external output. This is deemed to be equal to the labour used directly by industry 1, plus the proportion of the output of each other industry required directly or indirectly to support the output of industry 1, multiplied by the total labour requirement for each industry. This denominator is net of that labour required by other industries to support the internal output of industry 1 (i.e. that output required directly or indirectly by industry 1 for the production of its own output).

Algebraically, the Gossling index may be expressed as:

$$\frac{(q_1/p_1'')(1-{}'u_{11})(1-\theta_{11})}{l_1 + \sum_{i=2}^{n} p_{i1}\, l_i} \quad \ldots\ldots\ldots \quad 6.10$$

where p_1'' is the price level for industry 1.

$'u_{ij}$ is the share of industry i gross output directly required for the output of industry j. (Pre-prime notation indicates that, the intra-industry output has been netted out.)

$$\theta_{11} = {}'u_{12}\, p_{21} + {}'u_{13}\, p_{31} + \ldots\ldots + u_{1n}\, p_{n1}$$

θ_{11} is the proportion of industry 1 output indirectly required to support the gross output of industry 1 itself.

All other notation is as before.

Thus the subsystem benefits from netting out "circular" output, which is not a net contribution to the output of the economy.

In terms of the criteria established in section 6.3, this index possesses attribute (i), provided it is assumed that the proportion of the labour used directly and indirectly by industry 2 in providing its input for industry 1, is the appropriate weight for this input in the aggregation of the inputs of industry 1 to provide the denominator of the productivity index.

In practice, this weight attributed to each intermediate input is little different to that accorded by the direct plus indirect "labour embodiment" using the Leontief system, discussed below.

The subsystem index clearly possesses attribute (ii) since it is invariant to uniform industry price changes (49).

Examples 1, 2 and 3 are in fact trivial gross output subsystems, and because of the properties of subsystems, the Gossling index would always show the "current" change in total labour use per unit of output.

A problem with this approach occurs if the system is open to international trade. Imports may be treated in an analogous fashion to labour and their entrance into the subsystems of which various industries are the principal activity computed by a corresponding apportionment process.

An industry with a high proportion of imports in gross outlay may register a correspondingly high gross output by adding a relatively small value to these imports. The resulting productivity index would thus show a greater external output per unit labour, than if the corresponding intermediate inputs had been purchased from domestic industries, since the corresponding proportion of that domestic industry's labour requirement would be ascribed to the input of the principal industry:- There is no mechanism for computing the labour content of imports, as there is with the Leontief system.

A similar problem occurs with capital. Gossling noted the problems involved in weighting together different factor inputs, such as factor price changes. He thus limits his analysis to partial productivity measures (External output per unit of capital is measured separately from external output per unit of labour). This avoidance of a "total factor productivity index" is likely to engender bias when comparing industries with differential capital intensities.

Section 6.5
The "Intensiveness" Index

An alternative to the subsystem approach, allowing the estimation of "total factor productivity" change would be the use of a simple static Leontief system to calculate the total labour and capital requirements for the gross output of each industry. It would be possible to obtain an analogous index to the VA/direct factor measure, using gross output and direct plus indirect factor input.

Base period factor prices could be used to weight together the labour and capital input to each industry and the base year price Leontief inverse used to estimate factor requirements.

The equation for a Laspeyre index of gross output analogous to 6.5 would be:

$$\Lambda^* = \frac{q_1 \hat{p}_o - \hat{q}_1 \hat{p}_o \{ t_1' \hat{p}_o (I - \hat{p}_o A_1 \hat{p}_o^{-1})\}^{-1}}{q_o - \hat{q}_o \{ t_o' (I - A_o)^{-1}\}} \quad \text{........ 6.11}$$

where p_o is the diagonal matrix of commodity price deflators.

t_o is the vector of total non-factor primary inputs in the base period, per unit of gross output.

Comparison with 6.5. shows that different algebra is used to express essentially the same concept as the S.N.A. gross output index. However, the algebra of 6.11 reflects the fact that the price indices are independent of the input-output system and are not estimated from the input-output dual. The latter (the expression $(I - A_o)^{-1} F_o' r_o$ in 6.5) may only be used to obtain the change in output price resulting from a change in one or more of the primary input coefficients, with A_o remaining constant. It may not be used to obtain a vector of implicit deflators for the matrix A_1 since any change in the rate of return to primary inputs occurring between period 0 and period 1 cannot be apportioned between productivity change on the one hand and the arbitrary change in the nominal rate of return, on the other, in the absence of independent deflators for product outputs, which in turn allow the estimation of the change in real rate of return to the factors. In fact, the expression

$$(I - A_o)^{-1} F_o' r_o$$

must by definition always be equal to the unit vector, provided all elements of gross value added are included in $F_o' r_o$.

In 6.11, the premultiplication of the current price A_1 by the matrix p_o and its postmultiplication by the inverse of this matrix reflects the mode of deflation of this matrix[12]: Each coefficient must be multiplied by the ratio of its corresponding row deflator to the deflator for the gross output of the industry corresponding to the column of the coefficient. This is explained further in Appendix 6.2.

The gross output of an industry may be decomposed into the total factor input in all industries required to produce the gross output of that industry, and the total non-factor primary inputs (indirect taxes etc.) required for that gross output. Since it is preferable to net out the effects of transfer payments, the latter component of gross output should be subtracted from the total. Hence the expression

$$t_1' \hat{p}_o \, (I - \hat{p}_o A_1 \hat{p}_o^{-1})^{-1}$$

in the numerator of 6.11.

The index 6.11 thus expresses the gross output of an industry as the total net output required from all industries in order to produce the gross output of a given industry, which is equal to the total real value of primary inputs required for the output of an industry, less the real value of all non-factor primary inputs required for that output[13].

The input index would be given by:

$$\Lambda^{**} = \frac{(\hat{q}_1 \hat{p}_o)\,(F_1' r_o)\,(I - \hat{p}_o A_1 \hat{p}_o^{-1})^{-1}}{\hat{q}_o F_o' r_o \,(I - A_o)^{-1}} \qquad \ldots\ldots\; 6.12$$

giving a productivity index of

$$\Lambda^{***} = \frac{\Lambda^{*}}{\Lambda^{**}} = \frac{q_1 \hat{p}_o - \hat{q}_1 \hat{p}_o \,\{t_1' \hat{p}_o (I - \hat{p}_o A_1 \hat{p}_o^{-1})^{-1}\}}{(\hat{q}_1 \hat{p}_o)\,(F_1' r_o)\,(I - \hat{p}_o A_1 \hat{p}_o^{-1})^{-1}} \qquad \ldots\ldots\; 6.13$$

since $q_o - \hat{q}_o \{t_o' (I - A_o)^{-1}\} = \hat{q}_o F_o' r_o (I - A_o)^{-1}$

The direct plus indirect factor inputs index (6.12) differs from the S.N.A. index (6.6) not only because of the treatment of price deflation, but also since the denominator is the direct plus indirect primary input requirements, whereas the S.N.A. denominator is the vector of gross inputs including total labour, capital and intermediate inputs, all valued at base year prices. This is the essential theoretical difference between the method proposed here and the S.N.A., Loomis and Barton, West etc. approach. Instead of treating intermediate inputs as qualitatively identical to factor inputs, possessing a productivity, as implied by the S.N.A. index, intermediate inputs are here, simply considered as embodied labour and capital.

As with the S.N.A. index, it is possible to derive two partial indices measuring the change in productivity, had primary technology or intermediate technology remained constant. Since, also as with the S.N.A. index, the product of the two partial indices does not give the total index, this process is of little empirical value.

The index 6.13 differs from Gossling's in that it includes capital and labour within one measure, risking the problems of factor price weighting, and it does not net out the interdependence between the principal industry and the remainder of the economy.

There appears to be no valid objection to the non-elimination of the effect of interdependence upon the productivity index, except that output from the principal industry required indirectly for itself is not a net contribution to the economy. In practice, since the primary input requirement for this "internal" output is included in the denominator, there will be very little difference between a "gross" labour index using this system and the Gossling external output/unit labour input index. Both numerator and denominator would be more "gross" and the resultant difference would be slight.

The gross index has most of the advantages over the other indices that the subsystemic index has, i.e. it weights intermediate inputs according to factor content and is not biased by arbitrary changes in interdependence such as increased specialisation or the results of "make or buy" decisions.

The "intensiveness" index is also invariant with respect to the accuracy of the price deflators of the output of non-principal industries (see Appendix 6.3).

Thus the index possesses attributes (i) and (ii).

Although the index has the disadvantages of interdependence and index number problems concerned with the weighting together of factors, it also has some advantages over the Gossling system.

Firstly, imports may be included in the interindustry matrix and the corresponding factor requirements estimated (on the assumption that foreign input structures are similar to that of the UK). As stated above, there are problems in using a subsystemic approach where the economy is substantially open to trade. Alternatively, if it is the ratio of domestic output to domestic resource use which it is required to estimate, imports may be simply deducted from the index by including them in the vector t of non-factor primary inputs.

Secondly, there is ease of computation. There is no need for an iterative method to obtain the $(I - A)^{-1}$ matrix, and the results of such computations are often published (e.g. the C.S.O's Input-output Tables for the United Kingdom, 1968 - Table E (10)). The impact upon the productivity index of a given change in technology could be estimated using the linear approximations of Becker (7), without recourse to the re-computation of the inverse matrix.

Lastly, the effect upon observed productivity of each of the intermediate inputs to an industry may be estimated, since 6.13 may be decomposed into its direct component plus an indirect component relating to each industry. However it must be stressed that productivity thus estimated is average and not marginal and regression and other techniques would have to be used to estimate the contribution of materials substitution to factor productivity.

The empirical estimation of such a productivity index for U.K. engineering industries was attempted, and the contribution of materials substitution to the explanation of the variance in performance, was examined. The results are reported in Section 6.7.

Section 6.6
The Empirical Study

This section describes the empirical problems involved in constructing an index of the type represented by 6.13. It also provides a discussion of the results of the application of such an index to data for U.K. engineering industries and compares these with the results given by an S.N.A. type index (6.7) and a VA/direct factor index, corresponding to the expression:

$$\Lambda^{***} = \frac{q_1 \hat{p}_o (I - \hat{p}_o A_1 \hat{p}_o^{-1} - \hat{t}_1 \hat{p}_o)}{\hat{q}_1 \hat{p}_o F_1' r_o} \quad .... \quad 6.14$$

6.6.1 The Measurement of Inputs

In addition to the obvious data problems, there is the theoretical question of what should be included in the measure of inputs. From Section 6.1 it would seem that the productivity performance of an industry depends upon the interdependent influences of its environment, the quality of it inputs, and the technical and price efficiency with which these inputs are used. The controversy concerning the contribution of productivity to economic growth has hinged upon the degree to which each of the above factors is captured in the measure of inputs and how much is ascribed to the residual. If all the determinants of productivity growth are taken into account in the measure of inputs, the observed productivity growth would be zero, and so it is to be expected that there would be a positive correlation between the degree of refinement of the input measurement and the proximity of the estimated growth of productivity to zero. In practice, it is not possible to accurately measure these factors and so there always exists a "measure of ignorance" (87).

Of the above mentioned determinants of productivity growth, technical and price efficiency are two for which, consistently, no adjustment has been made in the measure of inputs. However, researchers vary in the degree to which they adjust for changes in the environment and input qualities in their measures of productivity and hence the disparity of the results.

Kendrick (89) for example, concluded that a large proportion of economic growth (about 50%) could be explained by the increase in factor productivity.

Denison (90) refined the measure of labour by subdividing the labour force according to age, sex and education, and thus reduced the contribution of the residual somewhat.

By refining the measure of capital services, Jorgenson and Griliches (92) reduced the observed contribution of productivity growth to virtually zero, though a later revision (100) placed their estimate closer to Denison's than previously.

As indicated in Section 6.1, the objective here is not to estimate relative contributions to economic growth, but to estimate the relative growth in output per unit of resource use in certain industries, and the question of adjustment of inputs for various quality changes thus becomes less important (though not insignificant).

For interindustry productivity comparison, it is preferable to assign to the residual most of the growth due to input quality change and the environment, since identifying the sources of productivity differentials is not as important at this stage, as determining their magnitudes. Statistical techniques may then be used to obtain an ex-post explanation of observed productivity change.

Within the context of the present study, the important criteria with respect to allowance for quality change in inputs, are whether this change is reversible, and whether the cost of the quality improvement is directly imposed upon the beneficiary industry.

In other words, the effects of education and research <u>in general</u> may be ascribed to productivity change, since the effects tend to be cumulative and irreversible, and the link between the financing body and the resultant increase in earnings, if any, is often very indirect, especially if all the contributions to knowledge through time which have increased the current value of the factors of production are considered.

On the other hand, the cost of training or of improving the education mix of a particular workforce is solely a current cost and could be easily reversed by abandoning a training course or employing relatively less educated labour. The latter is a factor for which allowance should be made in the measurement of inputs.

In short, in this type of study, the only quality changes that should be corrected for are those which both:

(a) have a direct, reversible cost attached

(b) whose influence is likely to be industry specific or differential across industries.

It was decided to divide labour input into two broad categories: Operatives and administrative/technical/clerical staff. This was firstly because the figures are readily available in the Census of Production Reports, secondly because trends in the employment of these two groups have differed, and lastly, because there is a significant differential in the mean incomes of these groups. Labour input was also weighted according to hours worked per week.

All employment related figures were obtained from the summary Tables of the Census of Production for 1968 (11) and appear in Table 6.4.

The measurement of capital presents an even greater problem and no totally satisfactory solution has been found.

Kendrick assumed that the flow of capital services was proportional to the value of the net capital stock in existence in a given year and used the prices of capital goods as weights to provide a deflator to convert current capital values into those representing the contribution to input in the base period. He used net rather than gross capital stock to allow for diminishing productive capacity over the life of the capital good.

Denison (90) used a weighted average of gross and net capital stock since he believed that the productivity of capital does not diminish significantly over its lifetime, and certainly not by as much as would be indicated by the book value of depreciation.

There is also the aforementioned problem of allowing for the quality change in capital.

Other problems in measuring capital are listed by Creamer (101), some of the most important being the level of industry aggregation and assumptions concerning vintages, embodiment and length of life.

It is preferred here to use estimates of gross rather than net capital stock to approximate the flow of capital services to each industry, since it is believed that it is more appropriate to assume that the quality of each unit of capital stock remains fairly constant over its lifetime. When it is scrapped it is more likely to be for technological reasons than because it has reached the end of its physically productive life. As a result, any estimate of gross capital stock engenders an assumption concerning the length of profitable life of a piece of capital of a certain vintage. These assumptions are embodied in the estimate of gross capital stock used . (See Appendix 6.4 for further explanation and Table 6.5 for capital stock figures at 1970 replacement cost).

No additional allowance is made for the quality change in capital, for reasons similar to those for excluding education and other quality improvements from the measure of labour input: Although technical progress has a cost, and often a directly traceable one, it represents an irreversible change in the nation's ability to create wealth, and thus the output change brought about by it should be ascribed to productivity change. The improvement in the quality of capital inputs should only be included in the inputs index to the extent that the new capital is of a higher real cost to the user. Any surplus potential product over and above the value of this real cost should be attributed to productivity change.

Owing to the cyclical nature of output, the degree of utilisation of this capital stock, (and to an extent the labour force), will fluctuate, and thus the flow of services from these inputs will not always be proportional to their total employment. It is always preferable to calculate a trend rate of productivity over a fairly long period, than to compare two single years, especially if they are close together in time (as in this study). If a long enough time period is used, the problem may be ameliorated by taking observations only from peak years of the trade cycle (e.g. Kendrick (89)). In the absence of a time series of output data, capacity utilisation must be introduced as part of the ex-post explanation of productivity differentials. The merits of the various indicators of capacity utilisation and their success in explaining relative productivity growth is discussed in Section 6.8.

6.6.2 Weights for the Aggregation of Inputs

Having assembled the data for capital and labour inputs, it is necessary to combine them into a single index, since exclusion of one factor would subject the resultant productivity comparisons to bias, in that industries consumed different relative quantities of the omitted input.

Some writers have indicated the drawbacks of using base year shares as weights for the aggregation of labour and capital in the presence of externalities, public enterprise and disequilibrium (e.g. Nadiri (102)), and others have indicated that the index number problems engendered may obscure the efficiency of firms or industries in adjusting to the least-cost factor ratio.

In the absence of a readily constructable alternative, and since the period under consideration was too short for significant differential factor substitution amongst industries this method was considered adequate.

The weights used to aggregate the input of the two types of labour and capital were the total wages and salaries of each labour category, and gross profits and trading income, all obtained from the Census of Production for 1968 (which includes the figures for 1963). Thus the weights are the shares in the gross rather than net national product at factor cost.

This index is appropriate for the VA/direct factor approach. For the gross or total output index, total resource use was estimated by premultiplying the Leontief inverse by the matrix of 1968 primary input requirements weighted at 1963 prices, as reflected in equation 6.13. The matrix for 1968 was an industry x industry 48-level matrix at 1963 prices.

Imports were included in the interindustry matrix (See Chapter 4, Section 4.2.6).

6.6.3 The Measurement of Outputs

The indicator most commonly used is net output, since it should represent the real return to the direct factors and is neutral with respect to the distribution of income between the factors.

It should be noted, however, that net output is the result of a combination of factors such as the level of demand, market structure, price elasticity of demand etc., as well as productivity.

As stated previously, it is not necessary, for the purpose of this study to compensate for the effect of these 'environmental' factors upon real output. However, what must be taken into account is the influence of the above environmental factors upon the prices of input and output, for this may produce a distortion in the measure of output.

For example, it is possible for all aspects of the real economy to remain unchanged, whilst the wage and price level doubles. It is clear that every increase in the nominal return to a factor of production is not necessarily an increase in productivity. Furthermore, industries differ in the bargaining strength of their labour force and the elasticity of demand for their product, and so it is possible that the relative level of earnings may be simply attributable to different levels of unionisation and concentration (103). Thus there is an arbitrary rent component in the earnings of both labour and capital, which is divorced from productivity considerations. At any one time, the bias resulting from this is unavoidable, but in intertemporal comparisons, it is possible, at least theoretically, to eliminate the rent component via the technique of double deflation.

This was developed by Geary (104) and Fabricant (105), and the methodology is to obtain independent measures of gross output and total non-factor input, corrected for that component of price increase not associated with quality improvement. This should eliminate this rent component and produce an estimate of the "real" rate of return to the factors.

This estimate of real return was used in the application of a 'VA/direct factor' index to the engineering industries for the years 1963 and 1968. The estimates of real net output were drawn from the absorption matrices for 1963 and 1968 at 1963 prices, on a 1968 SIC basis.

The use of the double deflation method makes this index very sensitive to the accuracy of deflation of the output of the non-principal industries. No such problem exists when gross output is used as the numerator of the productivity indices, as explained in Appendix 6.3.

The values of q_0 and q_1 were obtained from the absorption matrices at 1963 prices and are shown in Table 6.6.

Section 6.7

Results

6.7.1. General Observations

The results of the application of the conventional net output productivity index (6.14) to data for the UK engineering industries are shown in Table 6.7.

The constituents of a change in the productivity of an industry are the change in the unit requirements of labour and capital (factor inputs), and changes in the unit requirements of intermediate inputs (non-factor inputs). The latter represent the measure of success in the indirect saving of labour and capital since intermediate inputs require factor inputs for their production.

It appears that the change in the productivity of engineering industries between 1963 and 1968 may be completely ascribed to the change in output per unit of factor input since the contribution of changes in intermediate coefficients appeared to be negative.

A similar result was obtained in (53) which suggests that industries in the UK did not, in general, improve their total productivity by economising on intermediate inputs.

In general, electrical engineering industries tended to show slightly more productivity improvement than mechanical engineering and vehicles industries. Of the materials industries, synthetic resins experienced by far the greatest improvement in productivity (50% between 1963 and 1968). Iron and steel and building materials were about average for the economy, and aluminium, non-ferrous metals and cement appeared to have performed poorly. The average productivity growth for materials was less than the weighted average for all industries.

There is almost perfect correlation between the ordering of materials according to productivity growth and to structural change induced growth over this period (see Table 4.8). This indicates a positive relationship between the resource economy of the production of a material, and the intensiveness of use of that material. This appears to be evidence of adaptive structural change in the consumption of materials, that is, the indirect saving of labour and capital via the substitution of materials.

For the whole economy, net factor productivity appeared to have grown by 1.75% per year. Growth in real product was 18% or 3.2% per year.

6.7.2 Comparison of Results

The results of applying the intensiveness index of the type 6.13 and the SNA gross output index 6.7 are shown in Tables 6.8 and 6.9 respectively.

Tables 6.7 and 6.8 indicate that the ranking of engineering industries was very similar between the VA/direct factor index and the intensiveness index (equation 6.13). The range of variation is reduced using the gross output index, a result which would be anticipated since the introduction of interdependence dampens the extremes of observed performance.

The comparison between the results obtained using the SNA index and those using the intensiveness index (6.13) reveals considerable differences between the two measures. The average increase in productivity was much lower using the SNA index, owing to a generally higher input increase estimated by the latter. This arises from the high weight attached to intermediate inputs coupled with the use of intermediate outputs rather than inputs as the criterion for the measurement of this factor. This imposes a penalty on those industries with relatively high intermediate input growth, which is a source of bias when used in the measurement of the relationship of total output to total input, as explained in Section 6.4.2.

The assertion of Section 6.4.2 is supported by the positive correlation between the ratio of the productivity growth measured according to 6.13 (Table 6.8) to that measured by the SNA index (Table 6.9) and the increase in the intermediate proportion of gross output (see Table 6.10).

In summary, the intensiveness index developed here does not give substantially different results from the conventional VA/direct factor index, using the data available. The differences between the results using the intensiveness index and the SNA index are considerable. It has been argued here that the former index is more appropriate than either of the other two for the purpose of monitoring the rate of change in the ratio of total output to total input.

Section 6.8

The Contribution of Materials Use to Industry Productivity

The two ways in which materials influence the overall productivity of an industry's activity are the effect upon upstream requirements and the direct effect upon the productivity of factor use within the industry itself via the labour and capital requirements associated with different processes. These two influences are measured separately.

6.8.1 The Effect of Materials Use upon Upstream Input Requirements for Industries

This may be measured by allocating total (direct plus indirect) output and total input to the industry of origin.

The contribution of industry i to the gross output of industry j is:-

$$f_i \; r_i \; x_{ij} \qquad \ldots .6.15$$

where f_i is an element of the primary input matrix F' of 6.13

r_i is an element of the rate of return vector r and

x_{ij} is an element of $(I-A)^{-1}$

A similar breakdown may be undertaken for total input. This will provide estimates of the industrial origin of the value added and the resource costs of the total input and output of each industry.

Since 1963 is the base year, the contribution of each industry to input and output is, by definition, equal, and the sum across all industries i of 6.15 is equal to unity. This is not the case in 1968, since F and r are in this case estimated independently of $(I-A)^{-1}$. If each of the industrial constituents of the 1968 gross input and output are multiplied by the ratio of 1968 to 1963 gross output (and input) total, this will give an indication of the contribution to productivity change by each industry.

The percentage contribution of each materials industry to the output of each engineering industry in 1963 is shown in Table 6.11, with the contribution of the principal industry to itself shown for comparison. The contribution of an industry to its own gross output is the net output required directly for that industry plus that value originating in the principal industry, but embodied in the output of other industries which comprise the gross output of the principal industry.

The contribution of the materials industries to engineering output in 1968 is shown in Table 6.12a and to engineering input in Table 6.12b.

As these tables show, in the majority of cases, over 50% of the contribution to input and output originated in the principal industry itself and in most cases, only a relatively small percentage in the materials industries.

The contribution of the materials industries to the total productivity of the industry may be estimated from the expression:

$$\frac{q_{63} - mo_{63} + mo_{68}}{q_{63} - mi_{63} + mi_{68}} \qquad \ldots.6.16$$

where q_{63} gross output 1963 = gross input 1963

mo_{68} = materials industries' contribution to gross output 1968

mi_{68} = materials industries' contribution to gross input 1968

and $mo_{63} = mi_{63}$

6.16 gives the productivity index resulting if the contribution of all industries except the materials industries had remained as in 1963.

As can be seen from Table 6.13, only the case of motor vehicles and cans and metal boxes was this contribution in excess of one per cent and the rank correlation between the materials productivity index and the total index for each engineering industry is negligible.

It must be concluded from this evidence that, over the period in question, the "upstream" contribution of materials to industry productivity was not an important factor in overall productivity growth.

6.8.2 The Direct Effect of Materials Use Upon the Productivity of Industry

This is probably more important but more difficult to measure than the "upstream" effect discussed above. At firm level there have been attempts to measure the impact of the efficiency of materials use upon a measure of productivity defined in various ways (4), (48).

As suggested in (50) the ratio of output to total primary inputs does not identify the origin of any observed change in productivity. This ratio is in fact, the product of a number of 'sub-ratios' and these sub-ratios are more likely to indicate the nature of the productivity change.

For example, the ratio

$$\frac{\text{output}}{\text{total factor input}} = \overset{(1)}{\frac{\text{output}}{\text{utilised capacity}}} \times \overset{(2)}{\frac{\text{utilised capacity}}{\text{total capital stock}}} \times \overset{(3)}{\frac{\text{total capital stock}}{\text{total factor input}}}$$

and, if, for example, ratios (1) and (3) were stable, whilst (2) showed considerable variation, it might be concluded that capacity utilisation was the main explanation for productivity change. In practice, the breakdown would need to be much finer than this, and each of the above ratios may be further subdivided:

$$\text{E.g.} \quad \frac{\text{output}}{\text{utilised capacity}} = \frac{\text{output}}{\text{materials}} \times \frac{\text{materials}}{\text{labour}} \times \frac{\text{labour}}{\text{utilised capacity}}$$

This process is clearly infinite and any number of combinations are possible. It is difficult to apply such ratios in sufficiently refined detail to empirical data for industries, but this process does identify some of the major categories of productivity determinants, such as capacity utilisation, the capital/labour ratio, the education mix of labour etc.

In order to adopt a cross-section multiple regression approach to the estimation of the effect of materials use upon productivity, it is necessary to include these other groups of variables in the specification. The various explanatory variables were grouped into four catergoes:

(a) Capacity Utilisation

It is probable that over this short period, business cycle factors were an important influence upon observed productivity and a variable was introduced to allow for this. Cyclical indicators are abundant, but it is not easy to obtain differential indicators for different engineering industries.

There were three possible indicators of the difference in capacity utilisation between the two years:

(i) A measure based upon the accumulation or run-down of inventories during the year.

(ii) The percentage unemployment in the workforce ascribed to each industry, in both years.

(iii) The ratio of output to capital stock in the two years.

The accumulation of inventories is an ambiguous indicator of capacity utilisation, since a voluntary stock-build may indicate high sales expectations and full capacity utilisation whilst an involuntary stock accumulation may indicate declining demand. Similarly, a voluntary run-down in inventories may be a reflection of underutilised capacity whilst an unplanned run-down may indicate very high demand.

The unemployment indicator was unfortunately more a reflection of long-term structural disequilibrium than an indicator of capacity utilisation.

Finally to use the third indicator requires the very strong assumption that the ratio of gross output to capital actually employed (or the services of capital consumed) remained constant.

The estimation of an indicator based upon all three types of measure is explained in Appendix 6.5.

(b) Scale

The number of employees in each industry was divided by the number of establishments, using Census of Production figures, in order to obtain an estimate of average establishment size for the two years. If any economies of scale had occurred, presumably they would be reflected in the partial correlation between observed productivity and this scale variable. (See Appendix 6.5).

(c) Factor Ratios

The change in the ratio of capital to labour and of administrative, technical and clerical staff to operatives was included to test whether any impact from mechanisation or 'education' could be detected. (See Appendix 6.5).

(d) Materials

The percentage change in the direct coefficients of the four engineering materials and the changes in the ratio of inputs of one material to another, were used to approximate the efficiency of materials use and the effect of substitution respectively. (See Appendix 6.5).

The dependent variable used was the VA/direct factor productivity index, since the object of this sub-section is to measure the effect of materials use upon direct rather than total productivity.

The results showed that neither the inventory measure nor the unemployment measure of capacity utilisation was significantly correlated with value added productivity.

The output-capital ratio was a significant independent variable and was used in order to allow for capacity utilisation changes notwithstanding the other factors contained within this variable which tend to artificially increase its observed correlation with productivity.

The scale variable was negative in all equations and thus if there were any economies of scale, they were not reflected in this measure.

The capital/labour ratio was highly correlated with observed productivity, with a simple correlation coefficient of 0.32 and a significant coefficient in multiple regression equations. The 'education' ratio attracted a positive coefficient but was not significant.

There was a tendency for the direct coefficient ratios of materials to attract a negative coefficient. This suggests that industries which experienced the greatest productivity growth were those which reduced unit material requirement the most. However, the coefficients were invariably insignificant and the negative correlation between productivity and materials requirements possibly reflected the impact of an omitted variable.

A typical equation was:

$$\text{VAPROD} - \underset{(0.856)}{1.675} + \underset{(0.302)}{1.120}\,q/K - \underset{(0.024)}{0.020}\ \text{SIZE} + \underset{(0.223)}{0.728}\ K/L$$

$$- \underset{(0.458)}{1.019}\ \text{EDUC} - \underset{(0.023)}{0.018}\ \text{PLRATIO} - \underset{(0.148)}{0.063}\ \text{NFMRATIO}$$

(standard errors in brackets)

where VAPROD = Value added productivity

q/K = Gross output/capital stock ratio (1968/1963)

SIZE = Average establishment size (1968/1963)

K/L = Capital/labour ratio (1968/1963)

EDUC = Administrative, Technical and Clerical staff to operatives ratio (1968/1963)

PLRATIO = 'Synthetic Resins' + 'other manufacturing' direct coefficients (1968/1963)

NFMRATIO = 'Non-ferrous metals' direct coefficients (1968/1963)

In general 60% of the total sum of squares was explained by this type of equation.

The use of ratios of the coefficients of one material to another were even less successful, with no combination of materials attaining statistical significance.

Once again it appears that the level of aggregation of the data has obscured any relationship between materials and factor productivity.

Finally, as an adjunct to Chapter 4, the effect of final demand and technical coefficient induced output change upon the observed productivity of industries was tested by regressing the productivity index upon the percentage intermediate output change implied by these two factors. The purpose was to test for the occurrence of 'adaptive structural change'.

The result was:

$$\begin{array}{lcccccccc} \text{GOPROD} & = & 119.9 & + & 0.962.\text{F} & - & 0.110.\text{C} & + & 18.21.\text{CU} \\ & & (0.161) & & (0.245) & & (0.052) & & (30.90) \end{array}$$

where GOPROD = 'Intensiveness' measure of productivity (base = 100)

F = percentage change in intermediate output implied by final demand

C = percentage change in intermediate output implied by coefficient change.

CU = Inventory measure of capacity utilisation.

The negative coefficient on C is evidence against any adaptive structural change amongst engineering industries, though as shown earlier, this mechanism appears to have been important in determining the trends in materials consumption.[14]

Section 6.9

Conclusions

The discussion of the contribution of materials to the productivity of industry requires an exposition of the role of intermediate productivity analysis. The absence of an explicit definitional framework may lead to an erroneous interpretation of the results of any empirical work.

In particular, interdependence in the economy makes the consideration of productivity in terms of discrete sectors a misleading exercise. The input to each industry should be considered as the sum of the resources required, both directly and indirectly, to produce the output of that sector. In addition, intermediate inputs in general and materials in particular, often embody technical progress and thus this mechanism of productivity growth should be investigated in the same way as the embodiment of technology in capital.

This chapter reported the attempt to construct a coherent framework for the measurement of the contribution of intermediate inputs to productivity change. It specified the properties required of an index which would correctly integrate intermediate inputs into a measure of the productivity of primary factors, and would also measure the specific materials contribution to total productivity.

Having constructed such an index, it was applied to the engineering industries for the period 1963-68.

The contribution of materials use, both to the direct productivity of the labour and capital used by the industry and to the productivity of 'upstream' inputs, appeared to be small. There was, however, evidence of adaptive structural change in the use of materials, i.e. the materials which had shown the greatest improvement in labour and capital economy in their production, were those whose consumption increased the most and vice-versa.

The potential for materials economy within the firm, as reported in the literature, suggests that the economic impact of the efficiency of materials use could be substantial. The disappointing nature of the results reported here almost certainly reflect the level of aggregation of the data used in the empirical work.

It is at the wider economic level where further work is required, involving the investigation of the role of materials efficiency and of substitution between materials and processes, in economic performance.

The first step would be the acquisition of much more refined commodity data.

CHAPTER 7

Conclusions and Suggestions for Further Work

Section 7.1

Objectives and Approach

The objective of this work was to examine and quantify the interdependent relationships between economic performance and developments in the production and consumption of materials.

The two components of this objective were:

(i) The explanation of changes in the consumption of materials over the period 1954 - 74, in terms of economic and technological factors.

(ii) The estimation of the impact upon economic structures and performance of developments in materials price, structure of production and efficiency of use.

The framework for the analysis undertaken in attempting to achieve these objectives was described in Section 2.2. This showed the way in which materials consumption is linked to the economic environment via the demand and supply influences upon materials output. Figure 2.1 was a simplified representation of the interaction between materials and the economy showing the main determinants of materials output.

The demand influences derive from the aggregate rate of growth of final demand which determines the demand for engineering and finished goods, which in turn determines the rate of growth of materials (D_{ep}).

However the relationship between demand for end products and materials is variable over time and depends upon relative materials prices and the efficiency of materials processing. Thus the demand for a material is also dependent upon the production structure of the end-product (PS_{ep}).

The price of the material is partly dependent upon the prices of inputs (P_{α} etc.) and the proportions in which these inputs are combined (The production structure of the material PS_m).

Chapters 3 and 4 were concerned with quantifying the effect of each of these factors and examining the relationships between them, in an attempt to explain, in broad economic terms, the differences in the rates of growth of different materials over a recent period of time.

Chapter 5 examines the impact of the economic structure of UK engineering and materials industries upon trade performance. In particular it estimates the relative impact upon the balance of trade of, on the one hand, the trade deficit in materials resulting from the economic and resource structure of the UK, and on the other, changes in the production structure of engineering goods arising from the efficiency of processing materials.

In Chapter 6, the role of materials in determining the production structure of engineering goods is again examined, in order to estimate the effect of materials substitution and efficiency of use upon the aggregate productivity of industries.

Input-output analysis was used in the work of Chapters 4, 5 and 6 since this allows the quantification of the interdependence between industries, from which it was possible to estimate the resources required directly and indirectly for the production of the output of an industry. It was possible, for example, to estimate the total labour requirements in all industries required to produce a unit of output of a material and thus the relationship between labour intensiveness and relative materials demand could be analysed.

Section 7.2

Conclusions

7.2.1 The Determinants of Trends in Materials Consumption

The evidence suggests that the absolute level of consumption of all materials in the period concerned was primarily dependent upon the level of economic activity, represented by the level of aggregate final demand.

However, variations in the rates of growth of different materials were determined more by production structural change in end products (PS_{ep} , i.e. intensity of use of the material in its various applications) than by changes in the composition of final demand (D_{ep}). Thus, structural change, involving both substitution and improvements in efficiency, was more important than final demand in determining the relative consumption of materials.

In Section 2.2 it was stated that the principal determinant of structural change in materials-using industries involving changes in unit materials consumption is the relative price of materials (P_m/P_s). This in turn is dependent upon the relative efficiency of input use in the production of materials (PS_m) and the price of those inputs ($P_{\alpha}.....$)

This was confirmed by the evidence of Chapter 4 which showed that there was a strong relationship between changes in the intensiveness of materials use and relative (observed) price. Nevertheless, it is probable that price deflators do not adequately take account of new fabricating properties of materials, or processes associated with materials which change the effective or 'quality adjusted' price. Many authors have quoted examples of such non-price factors being important in the substitution between materials and they probably account for the major proportion of the change in relative materials use not explained by changes in relative observed price.

On the supply side, whilst wage and salary intensiveness was greater for all materials than energy or natural resource intensiveness, the low variation in unit labour requirements probably made this factor less important in determining relative costs than the other two. Only for non-ferrous metals and timber, however, did crude or unprocessed materials constitute greater than 10% of the total cost of the processed material.

Individual materials differed in the importance of each factor listed in Section 2.2 in the determination of consumption trends. Synthetic resins output was positively influenced by both final demand and structural change. In the early period, 1954-63, the growth of plastics materials was far in excess of that of the economy reflecting a high level of substitution and the emergence of new applications. Structural change was still important between 1963 and 1968, but for the period 1968-72, final demand appeared to have taken over as the most important determinant of growth, an indication that the material was 'maturing' and that its rate of growth was approaching that of the economy.

Synthetic resins outperformed other materials in terms of increased economy of resource use per unit of output and this largely explains their dramatic growth over the period.

Structural change had a mainly negative effect for the metals, particularly non-ferrous metals, for which the cost of raw materials did appear to be an important factor in the increase in relative price and therefore the reduction in demand.

There was substitution against timber, whilst the consumption of other building materials and rubber was in almost constant proportion to the level of final demand, suggesting that these latter products were subject to relatively little technological change and final demand was the overwhelming important factor.

7.2.2 The Role of Materials in External Trade and Industry Productivity

Chapter 5 started from the common assumption (often implicit) that the need for the UK to import a large proportion of its raw materials has led to a high materials component of imports and a low materials component of exports relative to other industrialised countries.

This may be restated as the hypothesis that the UK has a comparative disadvantage in materials.

The work reported in Chapter 5 reveals no evidence for this hypothesis: the composition of UK trade did not exhibit a comparative disadvantage in materials in relation to West Germany and France. A more disaggregated approach suggested that there was no evidence that the UK tended to export relatively high unit value materials and import low unit value materials relative to West Germany.

Any conclusions which could be drawn would tend to refute the hypothesis.

The relative importance of the materials component of imports to trade performance was further tested by comparing the impact of the domestic substitution of certain imported materials, changes in the price of complementary materials imports (those for which there is no domestic substitute) and the efficiency with which materials are processed within the domestic engineering industries.

It was demonstrated that a relatively modest and technically feasible improvement in processing efficiency would have the same impact upon trade performance as a relatively large decrease in the price of non-energy raw materials imports or the domestic substitution of competitive materials imports. It thus appears that the role of materials in the efficiency of engineering production is a more important influence upon trade performance than the structural dependence upon imported raw materials. Since the processing efficiency of materials is partly controllable, this conclusion has practical significance.

Finally, the contribution of the materials industries to productivity in engineering was discussed. Once again, it was concluded that the proper perspective for the study of the role of materials was as an influence upon the 'output to resource input' ratio, rather than as a direct component of input and output.

The effect of materials use upon the overall productivity of an engineering industry may be in three forms:

(i) The efficiency of use of resources within the materials industries which are indirectly consumed by the engineering industry.

(ii) The effect of the efficiency of use of materials within firms upon the efficiency of the firm.

(iii) The embodiment of new technology in materials or new processes associated with materials which improves the factor efficiency of the engineering firm or industry.

The first of these may be measured by a variant of the productivity index devised in Chapter 6, whilst the last two influences can only be measured by the expost explanation of productivity change.

The two most common flaws in conventional industry productivity measures were:

(i) The treatment of the economy as a set of discrete sectors and thus ignoring the role of interdependence between sectors in the determination of resource productivity.

(ii) The productivity measures which had been designed to incorporate the contribution of intermediate inputs were often not appropriate to the purpose of measuring the full input-output implications of the activity of an industry and the contribution of materials to total productivity change.

Having devised a measure which was considered to be more appropriate to this purpose, it was found that the proportion of materials in the total resource input and the total value of output of most engineering industries was relatively small. The contribution of materials to total productivity was correspondingly small.

However, combining the results of Chapter 6 with those of Chapter 4 produced evidence that the relative productivity performance of a materials industry was related to the growth in its consumption by engineering industries. Thus it appears that firms have substituted those materials which have most improved their economy of resource use for those which have been less successful in increasing output per unit of input. (This process was recognised in the U.S. economy by Carter (9) and termed 'adaptive structural change')

There was no evidence of methods of materials use directly contributing to the productivity performance of the engineering industries. This result was probably due to data inadequacies.

In summary, this work has given an indication of the forward and backward linkage between the output of materials and other economic variables and has estimated the changes in these relationships over time. It has also demonstrated the implications for economic performance of these relationships.

The level of aggregation in the available data was a considerable constraint on the reliability and usefulness of the results. This problem could be circumvented if improved data could be obtained at a much more disaggregated commodity level.

Section 7.3

Suggestions for further work

These fall into two categories: refinement and extension.

The collection of more disaggregated data would be the most obvious refinement. Since this type of information is expensive to collect, the researcher would be unable to rely on published statistics to perform such a disaggregation and would have to acquire technical knowledge in order to estimate input structures.

Deflation of materials categories would also have to be undertaken at a disaggregated level on the basis of technical information.

Having obtained accurate price and quantity data, substitution activity would be easier to detect and the role of process technology in the economic development of materials would be easier to isolate.

The accurate estimation of the resource intensiveness of materials would require much more sophisticated input-output information, particularly with respect to energy, as explained in Chapter 4, but would repay this effort by providing an aid to planning for the optimisation of energy and natural resource use, since a large proportion of the energy (and the natural resources) required by industry is embodied in the materials it consumes.

A refinement to the study of the role of materials in external trade would be the acquisition of more data on the intra-commodity group trade structure of metals and materials for a continuous period, rather than at single points in time, and to apply statistical techniques to this data in order to test hypotheses concerning comparative advantage.

The role of tariffs and subsidies also must be more rigorously investigated in order to obtain an accurate estimate of the 'economic or technological' as opposed to the institutional determinants of trade structure.

For the accurate assessment of the impact of the domestic substitution of imported materials and the effect of price and processing efficiency changes upon trade performance, it would be necessary to estimate the marginal rather than the average impact of such changes. It would thus be necessary to introduce the non-linearities of import and export demand using technical data and to make estimates of the price elasticity of the demand for various materials and products.

In the examination of the role of materials in industry productivity, once again, more disaggregated information would be required to accurately estimate the 'progress' in the use of resources by industries and performance would have to be measured over a longer period than five years.

In cross-section estimates of the determinants of productivity, the other factors, such as capacity utilisation, the technology embodied in capital and the skill of the labour force must be accurately measured before there could be a good possibility of identifying any impact of materials-related factors.

Interesting extensions to this work, assuming that more precise, and detailed price and quantity data had been obtained, would be to formalise the analytical framework of Section 2.2 into a multi-equation 'materials model' with an algebraic specification of the relationships between each material and the economic variables. It would be possible under these circumstances to estimate long term income and cross-price elasticities of materials. This would only be possible at a very disaggregated level.

A further extension would be to obtain comparable input-output tables for different countries and perform an international cross-section analysis analogous to that of Chapter 4. The difference between countries in the use of each material could then be apportioned across the following factors:

(i) The absolute value of national product.
(ii) The commodity composition of national product.
(iii) The output of industrial product groups using the material.
(iv) The intensity of use of the material in each of its applications.

The latter would give an indication of the different states of materials technology in different countries and perhaps, the degree to which best practice technology was being used.

In the analysis of the relative implications for the balance of trade of different materials related developments, it might be feasible to specify a dynamic input-output system to estimate the long term current and capital import cost of domestic substitution of a particular imported material such as primary aluminium.

Finally, more detailed information would allow the estimation of the impact upon productivity in engineering of the embodied technology in materials and associated processes. This is a relationship which observations at firm level suggest to be important, but which, as yet has not been identified at the level of the industry.

Epilogue

The pace of change in technologies and wants,makes it essential that production relationships are understood in order to anticipate the ability of an economy to adapt to changing demand structures and resource availabilities.

Whilst this work has only provided a grossly simplified picture of relationship between materials technology and macro-economic developments, it is possible that more work in this direction with improved data could provide a much greater contribution to the understanding of the workings of the economy.