LABOUR PRODUCTIVITY AND PRODUCT QUALITY: THEIR GROWTH AND INTER-INDUSTRY TRANSMISSION IN THE U.K. 1979 TO 1990.

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ABSTRACT

A search for key sectors in the UK economy is undertaken, in terms of those generating labour cost saving and product improvements, the effects from which spill over into the remainder of the economy. To do this the complete accounting framework provided by the input-output statistics published for 1979, 1985 and 1990 is matched by sector to data for R&D. A technique is then developed which enables productivity and product quality improvements generated within the sector to be compared with those transmitted to and from it.

Every sector economised in labour use over the period. In the case of Manufactures this was reinforced by a trend towards input-saving more widely. Services on the other hand became markedly more input-intensive, the job-creating effects from this providing a significant offset. All sectors greatly expanded their use of Business Services. This, in conjunction with its high rate of productivity growth, made it much the most influential sector for employment and productivity change throughout the economy.

The R&D analysis, tracking contributions to rising product quality, reveals closer similarities between high tech. manufacturing and service providers than between high and low tech. manufacturing. Although low R&D spenders, Services emerge as important R&D purchasers through capital and intermediate goods, and through this transmitters of improved outputs. Again Business Services have a particularly significant role.

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The Motivation and Framework for this Study

The record on labour productivity growth in the UK in the 1980s is now acknowledged to have been respectable rather than spectacular; better than the 1970s but inferior to the immediate post-war decades, and well short of the ‘miracle’ claimed for it towards the end of the Thatcher years (Muellbauer, 1991; Bean and Crafts, 1996). Our own earlier work on output and employment change between 1979 and 1990 indicates that economies in labour use almost exactly counterbalanced the employment-creating effects of the growth of output (Gregory and Greenhalgh, 1997). This process of productivity growth/labour-saving has encompassed several different developments. Job-shedding has became a major feature of the UK economy as corporate Britain has ‘down-sized’ and restructured. In part this reflects process innovation and the accompanying reorganisation at the workplace. A further part, however, reflects the move towards contracting-out of activities previously conducted in-house. Out-sourcing in the search for efficiency gains brings increased specialisation and thus creates, destroys and reallocates jobs. The emphasis on down-sizing has been accompanied by a growing awareness that cost-saving alone is not sufficient, and that competitive success increasingly involves the development of new products and services, incorporating innovations and continuous quality improvement. These various dimensions of productivity growth are the focus of our analysis.

Labour productivity growth is most commonly analysed in the context of multi- or total factor productivity growth. Building on the seminal contribution of Solow (1957) the standard vehicle for this type of analysis is the neo-classical production function, often Cobb-Douglas in empirical implementation. Recent examples include Bernard and Jones (1996), Wolff (1996), Hall and Mairesse (1995) and Oulton and O’Mahoney (1994). Hart (1996), developing insights from Jorgenson and Griliches(1967) and Griliches (1990), has recently re-emphasised that many of the results on total factor productivity can be derived directly from an accounting framework, without invoking underpinnings from neo-classical factor pricing. Our approach is similarly largely empirical and broadly in the growth accounting tradition, but differs in several key aspects. Our dual focus is on labour productivity and product quality. We view changes in labour productivity as rooted in changes in the organisation of production and in the development of new products rather than in primary factor efficiency (Carter, 1970). This is not to deny the importance of skill acquisition, which is currently being widely addressed in studies of economic growth, but to sharpen the focus on structural change. This twin emphasis is based on the view that, in an open trading economy, labour endowment and the stock of technology underpin comparative advantage, as firms aim to combine capital with raw materials and intermediate goods to minimise costs and raise product quality; this approach echoes both new growth theory and modern trade analysis (Grossman and Helpman, 1996) .

We look at a single economy, the UK, at a sectoral level, with the sectors encompassing the whole economy. This disaggregated perspective recognises not only that labour productivity growth proceeds at varying rates in different sectors but that its transmission across sectors is an intrinsic part of the growth process. This approach echoes an earlier debate in the growth accounting literature on the appropriate methods for analysis of productivity growth in an economy with intermediate products, in which the whole is more than the simple sum of the parts due to inter-sectoral impacts of technical change (Hulten, 1978). As our results will show, services play a key role both as sources of labour productivity growth and as major elements in its transmission. An exclusive focus on manufacturing, for example, would fail to capture these aspects.

We look at labour productivity growth in parallel with the generation and diffusion of R&D. As with labour cost-saving, the outcomes of R&D can be viewed as embodied in sectoral outputs and transmitted through the economy by inter-industry sales and purchases. The same analytical framework can thus be applied to these two dimensions of productivity gains and their transmission through the economy. Finally, our analysis is based on gross output in place of the more familiar value-added production function. This is the appropriate approach at the sectoral level (Jorgenson, Gollop and Fraumeni, 1987) and reflects our view that the emphasis on labour cost-saving over the 1980s has been part of a much wider cost-saving approach, including contracting-out and just-in-time delivery of materials and other inputs. Similarly, the role of intermediate goods in embodying R&D and product innovations which are then 'bought in' by other sectors is widely recognised. To capture these aspects requires the full range of purchased inputs in addition to primary factors.

Our first objective is to analyse the sources and transmission of labour-saving innovation and technical change in the UK economy, identifying sectors where labour productivity growth has been particularly strong and/or which have had a significant effect, through inter-industry purchases and sales, on other areas of the economy. In parallel with this analysis of the transmission of labour cost saving, we examine the direct and indirect R&D intensity of production and the inter-industry transmission of the outcomes of R&D expenditure. Taking business R&D as a proxy measure of changes in product quality gives the transmission of product quality improvement between sectors. We can then examine how far the sectors characterised by high growth rates and/or large spillovers of productivity are also sources of high rates of innovation arising from business R&D. By using input-output relationships from different dates we gain indicators of the role of contracting-out. In this way our analysis encompasses three broad sources of productivity growth: process innovation at the workplace, which is frequently job-destroying; product innovation to improve product quality, often seen as employment-creating; and restructuring and the contracting-out of work between sectors, bringing efficiency gains through specialisation.

Our empirical framework is based on the input-output tables for the UK for 1979, 1985 and 1990. These provide coverage of the economy as a whole combined with extensive sectoral disaggregation. The input-output framework has been extensively used to analyse the economy-wide linkages in industry outputs. We extend this methodology to examine the transmission of labour cost-saving and R&D across sectors. The articulation of inter-industry transactions in intermediate goods allows linkages to be traced from final use backwards along supply chains and forwards from suppliers to purchasers. These are channels through which producers may seek cost-savings and quality improvements from their suppliers. A further feature of our analysis is the treatment of purchases of capital goods. These contribute to labour cost savings by acting both as complements to some and substitutes for other workers; at the same time product quality improvements from business R&D are often embodied in new capital goods. We therefore treat capital goods as purchased inputs, analogous to intermediate goods, with purchases and sales between their sectors of origin and destination contributing to the transmission of labour productivity improvement and product innovation.

The focus of this paper is thus on the use of domestic labour and on product improvement via own R&D. We abstract from the changes in the level of final demand in order to focus on the changing efficiency of supply. Elsewhere we have undertaken the full accounting of changes in output growth, including an assessment of the respective roles of domestic demand, technological change and the pattern of net trade (see Gregory and Greenhalgh, 1997) and we shall refer to these results where they bear on the present study.

Direct and Indirect Input-Output Labour Intensity of Sectoral Outputs

Our first focus is on labour productivity and its transmission through the economy. In the input-output framework economy-wide labour use can be expressed as:

$$\begin{aligned} \mathrm{L} &= \ell'\mathbf{X} \\ &= \ell'(\mathbf{I}-\mathbf{A})^{-1}\mathbf{F} \end{aligned} \tag{1}$$

where L is total labour use (scalar), **X** and **F** are column vectors of gross output and final demand for domestic output by sector, $(\mathbf{I}-\mathbf{A})^{-1}$ is the Leontief inverse matrix, and ℓ is the vector of labour requirements per unit of sectoral gross output. For each *i*-th sector ℓ_i is therefore the inverse of labour productivity, measured as gross output per unit of labour input. The first line of equation (1) expresses total labour use in terms of sectoral gross outputs and their associated employment requirements. This focuses on the sector where the output and employment are located. However, much of sectoral output is sold on to other sectors before reaching its final use, a process which the input-output approach is designed to encapsulate. The second line of (1) uses the standard input-output relationship, $\mathbf{X}=(\mathbf{I}-\mathbf{A})^{-1}\mathbf{F}$, to express total employment as a function of sectoral final demands for domestic goods and services. Final demand in sector *i*, F_i, gives rise to gross output in (all) other sectors, through the intermediate output requirements encapsulated in the Leontief inverse, and therefore to employment in (all) other sectors.

To capture this concept of the employment generated economy-wide to meet final demand in any sector we define 'input-output labour intensity' λ as:

$$\lambda' = \ell'(\mathbf{I}-\mathbf{A})^{-1} \tag{2}$$

where ℓ will now be referred to as 'direct' labour productivity within each sector and $(\mathbf{I}-\mathbf{A})^{-1}$ gives the inter-industry transmission of output requirements. Total employment in (1) can correspondingly be written more compactly as:

$$\mathrm{L} = \lambda'\mathbf{F} \tag{3}$$

Expanding this to the vector of input-output labour use across sectors gives:

$$\lambda'\hat{\mathbf{F}} = \ell'(\mathbf{I}-\mathbf{A})^{-1}\hat{\mathbf{F}} \qquad (4)$$

where the circumflex denotes the diagonal matrix formed from the vector. Each *i*-th element of the employment vector on the left hand side of (4) gives the labour use, economy-wide, required to produce sectoral final demand F_i ; summing the elements of this vector gives the scalar L on the left hand side of (3). Input-output labour intensity λ in (2) evaluates economy-wide employment generated per unit of sectoral final demand, while labour use $\lambda'\hat{F}$ in (4) scales this by the level of sectoral final demand to give the total level of employment generated.

Changes in labour intensity and labour use can be examined by differencing (2) and (4) over time. From (2):

$$\Delta\lambda' = \Delta\ell'(\mathbf{I}-\mathbf{A})^{-1} + \ell'\{\Delta(\mathbf{I}-\mathbf{A})^{-1}\} \qquad (5)$$

This divides the change in labour intensity (labour cost-saving) between direct labour-saving $\Delta\ell$ and labour-saving through changes in the structure of inter-industry purchases, $\Delta(\mathbf{I}-\mathbf{A})^{-1}$, for example through contracting-out.

The time-difference of (4) contains two components, a difference term in λ and one in $\hat{\mathbf{F}}$. However, for the investigation of productivity change we abstract from changes in final demand and focus on the change in labour intensity, evaluated at actual levels of final demand:

$$\Delta\lambda'\hat{\mathbf{F}} = \Delta\ell'(\mathbf{I}-\mathbf{A})^{-1}\hat{\mathbf{F}} + \ell'\{\Delta(\mathbf{I}-\mathbf{A})^{-1}\}\hat{\mathbf{F}} \qquad (6)$$

The Transmission of Productivity Change

We now extend the framework above to examine the transmission of labour cost-saving across sectors, distinguishing productivity gains originating with decisions by the sector itself from those derived through inter-industry purchases. This latter part, the transmission of productivity gains across sectors, or backward linkages, will be denoted ‘input effects’ (Postner and Wesa, 1983). It is also possible, and in terms of key sectors particularly illuminating, to look at this process from the other direction, following the sector's productivity-enhancing improvements forward in the supply chain, through its sales to further intermediate and final users ('forward' effects).

To examine the contribution of these various effects we decompose (5) and (6) in two ways. Using the expression:

$$(\mathbf{I}-\mathbf{A})^{-1} = \mathbf{I}+\mathbf{A}+\mathbf{A}^2+\mathbf{A}^3+\ldots = \mathbf{I}+\mathbf{A}+\tilde{\mathbf{A}} \tag{7}$$

and noting that $\mathbf{A} = \hat{\mathbf{A}} + (\mathbf{A}-\hat{\mathbf{A}})$ where $\hat{\mathbf{A}}$ is the diagonal matrix formed from the principal diagonal of $\mathbf{A}$, (5) can be expressed as:

$$\begin{aligned} \Delta\lambda' &= \Delta\ell'(\mathbf{I}+\mathbf{A}+\tilde{\mathbf{A}}) + \ell'(\Delta\mathbf{A}+\Delta\tilde{\mathbf{A}}) \\ &= \Delta\ell'(\mathbf{I}+\hat{\mathbf{A}}) + \ell'(\Delta\mathbf{A}) + \Delta\ell'(\mathbf{A}-\hat{\mathbf{A}}+\tilde{\mathbf{A}}) + \ell'(\Delta\tilde{\mathbf{A}}) \end{aligned} \tag{8}$$

Combining the first and second pairs of terms, equation (8) can be summarised as:

$$\Delta\lambda' = \Delta\lambda'_{\text{own}} + \Delta\lambda'_{\text{input}} \tag{9}$$

where:

$$\Delta\lambda'_{\text{own}} = \Delta\ell'(\mathbf{I}+\hat{\mathbf{A}}) + \ell'\Delta\mathbf{A}$$

$$\Delta\lambda'_{\text{input}} = \Delta\ell'(\mathbf{A}-\hat{\mathbf{A}}+\tilde{\mathbf{A}}) + \ell'\Delta\tilde{\mathbf{A}}$$

This divides the change in total labour requirements per unit of final demand between 'own effects', $\Delta\lambda'_{\text{own}}$, and 'input effects', $\Delta\lambda'_{\text{input}}$. The 'own effects' comprise the change in the sector's direct labour use $\Delta\ell'$ for the production of its own output, $(\mathbf{I}+\hat{\mathbf{A}})$, and the labour requirements associated with changes in its own use of intermediate inputs, $\Delta\mathbf{A}$. The elements in the 'own effects' reflect decisions concerning factor proportions, the organisation of production, and intermediate purchases which are under the direct control of the firms in the sector. The 'input effects' comprise the change in labour requirements involved in the input use pattern of supplier industries $(\mathbf{A}-\hat{\mathbf{A}})$, plus the changes in labour requirements further back in the supply chain, encapsulated in $\tilde{\mathbf{A}}$.

Applying the same decomposition to equation (6) gives analogous terms in 'own' and 'input' labour use

$$\Delta\lambda'\hat{\mathbf{F}} = \Delta\lambda'_{\text{own}}\hat{\mathbf{F}} + \Delta\lambda'_{\text{input}}\hat{\mathbf{F}} \qquad (10)$$

where $\Delta\lambda'_{\text{own}}\hat{\mathbf{F}} = \Delta\ell'(\mathbf{I} + \hat{\mathbf{A}})\hat{\mathbf{F}} + \ell'(\Delta\mathbf{A})\hat{\mathbf{F}}$

and $\Delta\lambda'_{\text{input}}\hat{\mathbf{F}} = \Delta\ell'(\mathbf{A} - \hat{\mathbf{A}} + \tilde{\mathbf{A}})\hat{\mathbf{F}} + \ell'(\Delta\tilde{\mathbf{A}})\hat{\mathbf{F}}$

An equivalent, and perhaps more revealing, way of assessing the transmission of labour cost-saving through the economy is by following the supply chain in the opposite direction, forward from the industry originating the productivity change to the industries purchasing its output. This inverts the 'input effects' into 'forward effects':

$$\Delta\hat{\lambda}_{\text{fwd}}\mathbf{F} = \Delta\hat{\ell}(\mathbf{A} - \hat{\mathbf{A}} + \tilde{\mathbf{A}})\mathbf{F} + \hat{\ell}(\Delta\tilde{\mathbf{A}})\mathbf{F} \qquad (11)$$

Equation (11) evaluates the economy-wide labour-saving embodied in each sector's sales to intermediate users and to final demand. Implied in this is fact that the demand-weighted sum across sectors of input use effects must be identically equal to the sum of all forward use effects. The parallel 'forward' effect for labour intensity, corresponding to a one-unit increase in final demand in all sectors simultaneously, gives little insight and will not be presented.

Endogenising investment

Purchases of new capital goods are classified on National Accounts conventions as an element of final demand - investment. Given that we want to trace the impact of labour productivity and product improvements through the forward and backward linkages it would be arbitrary and inappropriate to classify investment as a final demand. The more relevant perspective is that capital goods are analogous to intermediate goods, purchased from their sector of origin in order to contribute to further production. (A full discussion of the accounting principles in the input-output framework is given in Leontief, 1951, part I). Endogenising the demand for capital goods, the augmented input-output model in flow terms becomes:

$$\mathbf{X = AX + JX + C} \qquad (12)$$

where $\mathbf{J} = [j_{ij}] = J_{ij} / X_j$ is the coefficient matrix of capital goods (GDFCF) purchases J_{ij} per unit of sectoral gross output, and **C** is the vector of final consumption (final demand less investment). In a dynamic Leontief framework **J** would represent requirements for maintaining a steady-state capital/output ratio given depreciation and the trend growth of output. Since our approach is purely a descriptive exercise in growth accounting, **J** represents actual purchases of capital goods. With capital goods purchases treated in this way, accounting consistency requires profits to be defined on a cash flow rather than a trading basis. Profits on this measure may become negative as borrowing occurs or assets are run down to finance the investment. Total purchases may then exceed the value of gross output.

From (12):

$$\mathbf{X} = (\mathbf{I} - \mathbf{A} - \mathbf{J})^{-1}\mathbf{C} \;=\; (\mathbf{I} - \mathbf{A}^{*})^{-1}\,\mathbf{C} \qquad (13)$$

where $\mathbf{A}^{*} = (\mathbf{A} + \mathbf{J})$ and the extended Leontief inverse $(\mathbf{I} - \mathbf{A}^{*})^{-1}$ includes the coefficient matrix of capital purchases; gross output becomes a function of the consumption element of final demand only (private and public consumption of domestic output, plus exports).

With capital requirements endogenous, the change in input-output labour intensity (9) becomes:

$$\Delta\lambda' = \Delta\lambda'_{\text{own}} + \Delta\lambda'_{\text{input}} \qquad (14)$$

where:

$$\Delta\lambda'_{\text{own}} = \Delta\ell'(\mathbf{I} + \hat{\mathbf{A}}^{*}) + \ell'\Delta\mathbf{A}^{*}$$

and

$$\Delta\lambda'_{\text{input}} = \Delta\ell'(\mathbf{A}^{*} - \hat{\mathbf{A}}^{*} + \tilde{\mathbf{A}}^{*}) + \ell'\Delta\tilde{\mathbf{A}}^{*}$$

Similarly, the change in input-output labour use (10) becomes:

$$\Delta\lambda'\hat{\mathbf{C}} = \Delta\lambda'_{\text{own}}\hat{\mathbf{C}} + \Delta\lambda'_{\text{input}}\hat{\mathbf{C}} \qquad (15)$$

where:

$$\Delta\lambda'_{\text{own}}\hat{\mathbf{C}} = \Delta\ell'(\mathbf{I} + \hat{\mathbf{A}}^{*})\hat{\mathbf{C}} + \ell'(\Delta\mathbf{A}^{*})\hat{\mathbf{C}}$$

and

$$\Delta\lambda'_{\text{input}}\hat{\mathbf{C}} = \Delta\ell'(\mathbf{A}^{*} - \hat{\mathbf{A}}^{*} + \tilde{\mathbf{A}}^{*})\hat{\mathbf{C}} + \ell'(\Delta\tilde{\mathbf{A}}^{*})\hat{\mathbf{C}}$$

The ‘forward’ effects on labour use, corresponding to (11), are given by:

$$\Delta\lambda'_{\text{fwd}}\mathbf{C} = \Delta\hat{\ell}(\mathbf{A}^* - \hat{\mathbf{A}}^* + \tilde{\mathbf{A}}^*)\mathbf{C} + \hat{\ell}(\Delta\tilde{\mathbf{A}}^*)\mathbf{C} \qquad (16)$$

(14), (15) and (16) will be the main expressions used in the empirical evaluation of the transmission of labour productivity change. While this deals explicitly with the possibility of capital-labour substitution in production, the method does not adjust for the possibility that some producers may be importing more labour intensive intermediate goods. We have evidence on this point from our other study (Gregory and Greenhalgh, 1997) and we shall comment on these research findings below.

R&D Intensity and the Transmission of Improved Product Quality

A further major dimension of productivity growth is product innovation and enhanced product quality. The direct identification and measurement of changes in product quality poses many difficulties, but the framework developed above gives a way of examining the transmission of these changes across sectors. In what follows we posit that the flow of product improvements generated in any sector can be proxied by its level of current business R&D expenditure. By regarding these as embodied in the sector’s outputs, of intermediate goods, new capital goods or commodities for final consumption, we trace their transmission through the economy via these market transactions (Griliches and Lichtenberg, 1984).

This transmission mechanism may also be regarded as proxying the spillover process in the dissemination of the improvements generated by R&D (Griliches, 1979). In the absence of an economy-wide set of hedonic price indices, the conventional methods of measuring real inter-industry purchases by deflating nominal output are unlikely to give full representation of quality improvements. For example, where unit price stays constant following product improvement, without hedonic adjustment the observed market prices of improved products will be too high relative to products of unchanged quality. The real volume of improving products may be persistently understated, in proportion to the extent of transactions. The analysis can also be viewed as tracing the social effects of R&D or perhaps even the ‘knowledge spillover’. The full return to R&D is rarely captured by the spender, as the public good aspect of innovation brings imitation, the resulting competition forcing prices down, such that the purchaser pays less than the full user value of the embodied improvements. This additional social return can be assumed to be proportional to the value of transactions. The direction and scale of pure knowledge spillovers, the disembodied transfer of ideas across sectors, are difficult to infer on a systematic basis; if they are assumed to be proportional to the volume of market transactions between the sectors our transmission mechanism also covers this interpretation. Each of these effects is a plausible part of the diffusion process; our data do not allow us to distinguish among them.

The direct R&D content of sectoral gross output r is defined as R&D expenditure, R_i, per unit of sectoral gross output, $r_i = R_i / X_i$. The input-output (direct plus indirect) R&D intensity per unit of final consumption is then:

$$\rho' = r'(\mathbf{I} - \mathbf{A}^*)^{-1} \tag{17}$$

This is the direct analogue of the input-output labour intensity λ above. We equate the rate of product quality improvement, Δq, with this R&D intensity of final consumption. This implies the assumption that sectoral R&D, and therefore product improvement, is embodied to an equal degree in the sector's output irrespective of purchaser. This is the standard 'product homogeneity' assumption of input-output models and parallels the method used by Scherer (1982, 1984) for patented inventions deemed to have a wide variety of general applications.

This measure of the change in embodied product quality can be decomposed as above into the amount attributable to the sector's own R&D (Δq_{own}) and the amount embodied in purchases from supplying sectors $(\Delta q_{\text{input}})$:

$$\begin{aligned} \Delta q' = \rho' &= r'(\mathbf{I} + \hat{\mathbf{A}}^*) + r'(\mathbf{A}^* - \hat{\mathbf{A}}^* + \tilde{\mathbf{A}}^*) \\ &= \Delta q'_{\text{own}} + \Delta q'_{\text{input}} \end{aligned} \tag{18}$$

where:

$$\Delta q'_{\text{own}} = r'(\mathbf{I} + \hat{\mathbf{A}}^*)$$

$$\Delta q'_{\text{input}} = r'(\mathbf{A}^* - \hat{\mathbf{A}}^* + \tilde{\mathbf{A}}^*)$$

Because the change in input product quality is observed within years there is no corresponding change in the **A** or **J** matrices; thus (18) is the within-year equivalent of (8) above.

Total R&D use embodied in each sector's final output can be derived by evaluating (18) at actual levels of final consumption:

$$\Delta q'\hat{\mathbf{C}} = \Delta q'_{\text{own}}\hat{\mathbf{C}} + \Delta q'_{\text{input}}\hat{\mathbf{C}} \tag{19}$$

where $$\Delta \text{q}'_{\text{own}}\hat{\mathbf{C}} = \text{r}'(\mathbf{I} + \hat{\mathbf{A}}^{*})\hat{\mathbf{C}}$$

and $$\Delta q'_{\text{input}}\hat{\mathbf{C}} = r'(\mathbf{A}^{*} - \hat{\mathbf{A}}^{*} + \tilde{\mathbf{A}}^{*})\hat{\mathbf{C}}$$

The 'forward linkages' transmission of R&D, which traces product quality improvements forward from the industry of origin, as in (16) above, is given by:

$$\Delta \hat{q}_{\text{fwd}}\mathbf{C} = \hat{\rho}_{\text{fwd}}\mathbf{C} = \hat{r}(\mathbf{A}^{*} - \hat{\mathbf{A}}^{*} + \tilde{\mathbf{A}}^{*})\mathbf{C} \tag{20}$$

Input-Output Data 1979-90

Input-output tables for the UK are available for 1979, 1985 and 1990 (BSO 1983, CSO 1989, CSO 1994). All are based on the 1980 Standard Industrial Classification, and are in current prices only. The tables are constructed on a commodity x commodity basis. This is preferable to an industry x industry basis, as commodity-specific technologies are a more persuasive assumption than industry technologies. The level of commodity disaggregation has varied over time but is around 100 sectors, with a more detailed disaggregation for manufacturing than for services. A common 87 sector classification has been adopted, with outputs deflated to 1985 values by sectoral producers' output price indices. (Further details of these data issues and those discussed below are given in the Data Appendix).

Sales of output supplied as capital goods are available for all commodity sectors, but to purchasers classified by around 40 industries. Conversion from the commodity x industry to a commodity x commodity basis has been carried out using the 'make' matrix for the appropriate year. Under the assumption that homogeneous sectoral outputs are sold to all purchasers, sales of capital goods have been deflated by the producers' price index as applied to sectoral gross output.

For constructing our measure of sectoral labour demand we use employment income generated in the production of gross output, taken directly from the value added entries in the input-output tables. This was converted to real terms by revaluation at constant 1985 hourly earnings (see Appendix for details). This measures real outlay on labour from the employer's perspective, in effect combining a head-count of workers and hours, weighted by earnings levels, so avoiding the need to control for changes in proportions of full- and part-time workers. Furthermore any substitution of a skilled worker for one or more less skilled workers which causes a rise in employment income is reflected as a rise in labour demand, following the concept of efficiency units of labour used in the growth literature. A further advantage of this measure is that the input-output framework imposes consistency between the measure of labour cost on the input side and sectoral outputs, including an exact match in sectoral classification. However there is an unavoidable problem arising from rising self-employment during the period of this study as the incomes of the self-employed are classified to profits. A switch in employment status from employed to self-employed creates an inflation of profit compared to employment income and may cause a small upward bias in the assessment of increased labour efficiency.

Our measure of R&D is UK business expenditure on R&D (BERD) (CSO 1996). Unfortunately, while these data are supplied for 33 sectors they are on the 1992 Standard Industrial Classification. Aligning with the 1980 SIC reduces the available disaggregation to 19 sectors. In recognition of the fact that R&D expenditure has a very different composition from sectoral outputs or inputs, deflation to constant 1985 prices has been carried out using the deflators developed by Cameron (1996).

An immediate issue in the empirical implementation of the model is the form in which R&D expenditure best represents our variable of interest, the rate of product innovation or product quality improvement (Griliches, 1995). We use current-dated R&D expenditure. Several points can be made in support of this. Business R&D is often concerned with near-market research to refine prototypes and commercialise developments from more fundamental research; this indicates relatively short lags. It also suggests that the rate of depreciation - a problematic issue in the construction of a 'stock' measure of business R&D - may be quite high. Moreover, although levels of R&D differ widely and persistently across sectors, sectoral R&D intensity changes only slowly; any potential distributed-lag or cumulated stock series would show only limited variability over time. Arguments similar to some of these underpin the extensive use of the Terleckyj transformation (Terleckyj, 1974, 1980). As a further practical consideration, R&D data are not available prior to our data period at the level of disaggregation which we use; the construction of a distributed-lag variable would therefore involve the sacrifice of current sample information. We are supported by other studies which have found that R&D stock and flow measures are equally useful in panel data analysis (Hall, 1993 and references there). In practice we faced the further limitation that industry-level R&D data is available only at a more aggregated level before 1981. However, we found that the 1981 totals were closely similar to those for 1979, having peaked in 1980, and thus adopted the 1981 figures to gain the necessary industry breakdown.

The analysis is carried out for three dates 1979, 1985 and 1990, determined by the availability of input-output data. The first and last dates were around cyclical peaks, indicating that capacity utilisation should be reasonably comparable between them. With the 1980s in effect spanning one long cycle, 1985 was a year of recovery but neither a peak nor trough. In spite of this asymmetry, the two sub-periods can offer a useful contrast of periods of recession and recovery.

A 15 sector level of aggregation has been applied in all the computations. This is close to the maximum level of disaggregation consistently attainable, as limited by the R&D data. The only further aggregation, of several smaller manufacturing sectors, reducing the number of sectors from 19 to 15, aims to keep sectors at roughly equal size and maintain balance between the number of manufacturing sectors and those in service activities. Conditions for consistent aggregation have been extensively discussed in the input-output context, as aggregation across unlike activities introduces bias into estimates of coefficients. The extent of the bias is an empirical issue, depending on the characteristics of the data in each case. For the period we analyse it appears to be minimal.

The most extreme test for aggregation bias which we can apply is based on labour cost-saving without endogenous capital, for which data is available at 87 sectors. Since the focus of our analysis is the decomposition of changes over time we applied this approach to the first part of equation (1), decomposing the change in employment between 1979 and 1990 between the change in output and the change in direct labour-intensity:

$$\Delta \mathrm{L} = \ell' \Delta \mathbf{X} + \Delta \ell' \mathbf{X} \tag{21}$$

This was computed at 87 sectors and the estimates aggregated to 15 sectors. For comparison the 87-sector levels of output and employment were pre-aggregated to 15 sectors, the new Leontief inverse computed, and the decomposition repeated. As Table 1 shows, the results were virtually identical.

Results I: Labour productivity growth and transmission

The main vehicle for our analysis of labour productivity change is the sectoral input-output labour intensity λ, the labour required through all lines of business, including supplies of capital goods, to generate a unit of the sector's output, a commodity for final consumption. As defined in equation (2) this depends on the structure of the sector's inter-industry demands, encapsulated in the extended Leontief inverse $(\mathbf{I}-\mathbf{A}^*)^{-1}$, in conjunction with direct labour intensity ℓ in each sector. It can usefully be thought of as a weighted sum of direct labour intensities in all sectors, with the weights determined by this structure of sectoral input purchases.

Direct labour-intensity is shown in Table 2 columns 1-3; the range across sectors is wide, in 1979 from 75p of labour cost per £1 of gross output in Personal and Public Services to just 13p in Energy and Utilities, and from 56p to 8p in 1990. The conventional view that Services are more labour intensive than Manufacturing is clearly confirmed. (Manufacturing is defined as sectors 3-10, Services as 12-15). When labour intensity is measured on the I-O basis λ, shown in Table 2 columns 4-6, the levels are uniformly higher, partly because these are being expressed per unit of the sector's final consumption rather than its gross output. The range narrows substantially, in 1990 from 7:1 to under 3:1, reflecting the 'weighted sum' structure. (The value of λ of £1.30/£ in Business Services in 1979 is the only instance where capital goods purchases in an investment boom are sufficiently large relative to trading profits for input purchases to exceed gross output; see the discussion on page 7 above.) Individual sector rankings remain broadly similar, with the correlation coefficient between 0.8 and 0.9 in each year. Services are again more labour-using than Manufacturing, but by a reduced margin, as Manufacturing tended in the past to use more intermediate inputs, so drawing on more employment through the supply chain; however as can be seen the two broad aggregates have drawn closer together through time (columns 7-9).

On both measures the labour-intensity of production has been falling in all sectors of the economy over the 1980s; the aggregate effect of technical and structural change has been labour-saving almost universally. Perhaps contrary to the received view, direct labour-saving has proceeded more rapidly, both absolutely and proportionally, in Services than in Manufacturing. These aggregates, however, span considerable diversity of performance. The three top performers comprise one sector in Services and two in Manufacturing (Business Services, Transport Equipment and Electrical Equipment) as do the three poorest performers (Trade & Catering, Food & Drink, and Manufacturing nes). On the I-O measure the pattern is much more clear-cut. Manufacturing moves clearly ahead of Services, with annual productivity gains of 3.8 percent, double the rate for Services. This superiority of Manufacturing is broadly based, with all sectors out-performing each of the Services sectors apart from Business Services. The comparative record of these two measures of labour productivity growth for Britain in the 1980s indicates that the traditional view of manufacturing as the superior source of productivity gains (Rowthorn and Wells, 1987 Chapter 1) has to be formulated with care. *It is in the production of Manufactures, rather than in Manufacturing establishments, that the labour productivity performance has been notable; but the production of Business Services ranks higher than any Manufacturing supply chain in its overall productivity performance* .

Alongside direct productivity change the important further element incorporated into the change in I-O productivity $\Delta\lambda$ is structural change in the use of inputs, measured through changes in the Leontief inverse. This is shown in Table 3. Two features are of key importance. The first is the greatly increased use of Business Services for every type of output. This was evident for Services at least as strongly as for Manufactures, with the share of Business Services in production costs typically rising by between 10 and 20 percentage points. Part of this is likely to reflect the increased service content of commodity supply, for example through marketing, software development and information technology support. A further part will represent the contracting-out of conventional service functions, such as recruitment, tax and accountancy, to consultancies and specialist agencies. This parallels the shift towards transactional services and out-sourcing in the US economy described by Blair and Wyckoff (1989). The second major development has been the trend towards increased use of inputs in Services production, notably in Personal and Public Services (some elements of which were affected by privatisation), against a trend towards input-saving for Manufactures. Services have increased their input purchases, for example from Transport &

Communications, as well as on the investment side from Construction and Electrical Equipment. For Manufactures, although the changes in the use of intermediates are individually quite small, their cumulative effect has been to generate significant input-saving in certain sectors. To sum up, *the phenomenon of 'contracting-out' of Services supply was quite general, not confined to Manufacturing or to Services affected by privatisation; inter-industry purchases mostly fell between Manufacturers and rose between Service providers.*

Following this direct look at the changing Leontief inverse, for each commodity the total labour-saving on the I-O measure can be attributed, using equation (5) above, between direct labour saving in all supplying sectors $\Delta\ell$, and changes in the structure of inter-industry purchases, $\Delta(\mathbf{I}-\mathbf{A}^{*})^{-1}$. Table 4 presents these results for 1979-90. The message can be summarised simply: *direct labour use declined in the production of all commodities, but the changes in inter-industry purchases for the production of Services were job-creating, while those for the production of Manufactures were generally job-destroying*. The same broad picture emerges when this breakdown is evaluated at average final consumption over the period, reflecting the impact of the differing sizes of sectors (Table 4, lower panel, and Chart 1). However size matters for total impact: although labour-saving was greater for Manufactures, at 24p/£ against 16p for Services, the larger size of the Services final demands meant that labour-saving in their supply chains at £30 billion reduced total employment by more than for Manufactures (£25 billion). In the production of Services and Construction the increased use of intermediates generated employment growth in supplying sectors which partially offset direct job-shedding. In the production of Manufactures, on the other hand, the trend to labour-saving tended to be reinforced by input-saving more widely.

How far might these results have been affected by changing patterns of intermediate imports? In Gregory and Greenhalgh (1997, Table 10) we showed that the employment effects of import penetration during this period largely arose from the loss of final goods markets; the effects of rising purchases of intermediates were very muted. Added to this, the differentials between Manufactures and Services in their use of intermediate inputs would act against the finding of higher productivity in the supply chain for Business Services, so this result is robust. In Table 4 we see that production of high technology Manufactures (Chemicals, Transport Equipment and Electrical Equipment) achieved among the highest efficiency gains, as measured by I-O labour intensity. These productivity gains in high tech products would support the strong export performance of high technology manufactures noted in our earlier work (Gregory and Greenhalgh, 1997, Tables 3, 6). However, because of the smaller size of these sectors, the overall efficiency gains measured by total labour saving attributable to each of them are substantially less than for Personal & Public Services in spite of its low productivity growth.

Looking briefly at these developments over the sub-periods 1979-85 and 1985-90, Table 5 shows a clear sequencing. In the early 1980s recessionary period 1979-85 direct labour saving dominates, with labour cost being reduced by an average of 14p/£, while changes in inter-industry purchases were neutral overall in their impact. In 1985-90, on the other hand, labour saving continued, but at a reduced rate. However, the increased purchases by Services and of Services began to have a positive impact. In this respect the second half of the 1980s marks a significant phase in the development of the UK as a Services-based economy.

In the above discussion note that in terms of I-O productivity change the output of each sector benefits from productivity growth in all sectors. Following equation (9) we now divide the changes into 'own' effects, attributable to decisions made by the sector itself, and 'input' effects embodying direct labour saving by the sectors from which inputs have been purchased, and further back in the supply chain. Table 6 shows the input changes sub-divided in this way. This four-way decomposition demonstrates conclusively that the biggest productivity gains were made as a result of 'own' within sector effects (col. 1). The direct rationalisation of labour purchases, totalling £44 billion, comprised 74 percent of total labour saving. These reductions occurred across all sectors, with the biggest savings being made in Services, in particular Personal & Public Services and Business Services. Substantial economies were also made as input purchases further back in the supply chain embodied fewer labour resources (col. 3); once again direct labour saving, now embodied in input purchases, had a larger impact on labour use than business re-organisation (col. 4). Services in particular benefited from buying-in efficiency gains made in other sectors, with Trade & Catering the largest beneficiary, acquiring an estimated £9 billion of labour saving embodied in inputs such as Food & Drink, and Transport & Communications. For Food & Drink production these bought-in effects dominate all others, contributing 75 percent of the overall £5 billion fall in labour use.

Forward linkages give an alternative perspective on the role of individual sectors in economy-wide productivity change, through the sales of intermediate goods and services to the rest of the economy. These forward linkages by sector, reflecting equation (11) above, are also presented in Table 6, (columns 5 and 6). The dramatic implication to emerge, which is also pictured in Chart 2, is the dominant role of the Business Services sector in the forward supply chain. It dominates in two quite separate respects. The first is labour saving/productivity gains; of the total £40 billion in labour saving transferred across sectors through input purchases/sales, Business Services supplies £16 billion (Table 6 col. 5). However, these huge labour-saving effects which it has generated internally and transferred across other sectors have been counterbalanced by the expanded demand for Business Services from other sectors of £18 billion (Table 6 col. 6). Personal & Public Services, by contrast, which recorded major within-sector productivity gains of £16bn, do not figure as strongly in forward productivity transmission, being mostly used in final demand.

Results II: Product quality growth and transmission

Turning to the sources and transmission of R&D, Table 7 shows the direct R&D intensities of gross output by sector, *r* above. This displays the well known concentration of British R&D in a narrow band of the manufacturing sector, namely Chemicals, Electrical Equipment and Transport Equipment. All of these sectors undertook between 4p and 7p of R&D per £ of gross output in 1990. Outside these sectors and apart from Mechanical Equipment and Business Services, very little R&D is reported as being done, the intensity of R&D spending being under 1p/£. Moreover, the R&D intensity of output fell during the 1980s in all these major contributors to product quality improvement, with the exception of Chemicals. In the Electrical Equipment sector R&D intensity fell from 7.2p/£ to 5.7p/£, while in Transport Equipment it fell from 6.3p/£ to 4.7p/£. Meanwhile, in Chemicals it increased from 3.7p/£ to 6.6p/£.

However, when R&D intensities are measured on the I-O basis ρ, including the indirect content of R&D bought in from other sectors (equation 17) this picture is significantly modified (Table 7, lower panel). *The spreading effects of inter-industry purchases of intermediates and capital goods ensure that at least some domestic R&D content is effectively present in either the new process technology or the improved final products across the whole range of goods and services delivered to consumers*.

Table 8 partitions the I-O R&D intensity into the part generated within the sector and the part acquired through purchases of intermediate or capital goods from the R&D spenders (equation (18)). For the big R&D spenders 'own' R&D dominates, providing at least 80 percent, sometimes 90 percent of the total used. Among Low Technology Manufacturers (sectors 3-7) the proportion of 'own' R&D falls to just 30 percent. In this respect they are more similar to Services than to the High Technology sectors. Trade & Catering presents a limiting case, with almost 100 percent of the R&D embodied in production being bought in from outside.

Turning to the levels of R&D use, Table 9 presents evidence of both backward and forward linkages after scaling for the size of sectoral final consumption, including the split between R&D undertaken within sector and that purchased or supplied (equation 19). As we found for productivity growth, the large and increasing size of the Service sectors converts the low levels of R&D intensity (from Table 8) into substantial, and increasing, inter-industry flows of prospects for enhanced product quality. Trade & Catering again provides the most striking example. Its direct R&D expenditure has been negligible; on the I-O measure its R&D intensity remains one of the lowest; but when scaled by the size of final consumption, its R&D use places it behind only the 'major three' in 1985 and 1990. R&D use in the Trade & Catering sector increased by 44 percent over the 1980s, to £615 million, against £953 billion in Transport Equipment, the smallest of the major three. Personal & Public Services provide a similar example of all these phenomena. *The I-O perspective on the transmission of R&D embodied in inter-industry product sales thus shows the Service sectors as major users of R&D, even where their direct R&D spending is negligible.*

Returning to the theme of key sectors, we see that the principal generators of R&D are the same at the start and the end of the period. The major three - Chemicals, Electrical Equipment and Transport Equipment - dominate. The remaining figures in Table 9 give the forward impact of R&D from each sector through its inter-industry sales (equation (20)). *Whilst the High Technology Manufacturing doers of R&D are also the major feeders for other sectors, the interesting feature is the rise of the Business Services sector, which by 1990 had become a major 'supplier' of R&D although still only a small R&D spender*. The rapid growth in demand for Business Services has meant that, in terms of the total amount of R&D embodied in its output it had jumped to second place. By 1990 this sector was transmitting £597 million worth of R&D spending, compared to £657 million for Electrical Equipment, £428 million by Transport Equipment and £408 for Chemicals. As with the analysis of labour productivity this points to the need to differentiate high vs. low technology sectors within both manufacturing and services rather than equating stationary technology with services and dynamic technology with manufacturing.

Similar results on the role of Services sectors in transmitting R&D through their purchases of intermediate and capital goods have recently been reported by the OECD for ten leading industrialised countries in the early 1990s (OECD, 1996; also Sakurai, Papaconstantinou and Ioannidis, 1997). Our estimates reinforce the results on the role of capital goods purchases in the transmission of R&D outputs between manufacturing and services found by Wolff and Nadiri (1993) for the US up to the 1970s; our period has the advantage of including the era of what has been termed the paradigm shift from electro-mechanical to micro-chip based office technology. Our findings extend earlier work by Geroski (1991) which established the importance of the inter-industry spread of innovation within UK Manufacturing and our results for user industries broadly match the findings by Scherer for the US, again in the 1970s (Scherer, 1984). However we find lower rates of spreading from the producer industries as a proportion of their R&D than in Scherer's work, possibly due the larger 'leakage' of R&D through exports from the UK. This greater openness to trade, while reducing the feed-through of the UK's domestic R&D, also enhances the product quality of inputs by improvements made elsewhere which are not captured by our analysis (on this see OECD 1996).

Conclusions

By using the complete accounting framework provided by the input-output statistics together with R&D data matched by sector, we have been able to trace the sources and impacts of various aspects of the process of technological change in the Thatcher era. The search for key sectors, generating cost savings and product improvements which spread throughout the economy, has led to a re-evaluation of the relative contributions of manufacturing and services to productivity growth. A general feature of this analysis is the demonstration of the symbiosis between manufacturers and service providers in the advanced industrial economy; developments in value added in any one sector are clearly not independent of the evolution of the quantity and quality of supply in others.

In the analysis of labour productivity growth we found the dynamic areas of the Services sector, notably Business Services, to be key elements in the productivity record of the 1980s. This was due to their own high rate of productivity growth, combined with the very rapid expansion in their role as suppliers to the rest of the economy. More widely, we found dynamic and sluggish elements on both sides of the 'goods vs. services' divide, confirming that key sectors have to be identified at a more disaggregated level than these conventional distinctions.

From the R&D analysis, tracking contributions to rising product quality, we revealed that high technology manufacturing and services bear more similarities to each other than high and low technology manufacturing. While the presence of the big R&D spenders in Manufacturing ensure that product quality improvements are mostly generated there, the inter-sectoral transfer of these across sectors through sales of improved inputs facilitated efficiency gains and improvements in product and service quality much more widely. In particular the Business Services sector has become an important player in the forward transmission of rising product quality. If more accurate indicators of innovation in services were available, for example measuring copyright in information technology and software, these would enhance the estimated contribution of high-technology services, whose contribution to improved product quality is likely to be underestimated by the patterns of declared R&D.

Data Appendix: sources and adjustments

Input-output tables

Input-output tables for the UK are available for 1979, 1984, 1985 and 1990 (BSO 1983; CSO 1988; CSO 1989; CSO 1994). All are at current prices only, and are based on the 1980 Standard Industrial Classification. We have used the tables for 1979, 1985 and 1990. Although the 1985 tables are essentially an update of the benchmark tables for 1984, the miners' strike of 1984-85 introduced distortions into purchases of materials and fuels over that period. New estimates adjusting for this were made for 1985. 1985 has the further advantage of being a base year for constant-price output series, and cyclically more comparable with 1979 and 1990.

For 1979 both industry by industry and commodity by commodity domestic use tables are available, but for the later years only the commodity by commodity basis is available, and this has been used throughout. It is also the preferable basis, corresponding more closely to the homogeneous product and common technology assumptions of input-output analysis. Although the tables for all three years are based on the same Standard Industrial Classification they contain minor differences in commodity aggregation: 100 sectors in 1979, 102 in 1985 and 123 in 1990. A maximum of 97 sectors could be achieved through direct aggregation. This was further reduced to 87 by the limited availability of sectoral deflators, particularly within the engineering sectors.

The GDFCF published matrices contain purchases of domestically produced and imported capital goods combined, with the domestic/import split available only for each sector's total purchases. The proportions from the row sum was applied to each element in the sector (row) to obtain an estimate of the domestically produced capital matrix. Since the GDFCF matrix is supplied only on an industry x commodity basis, these also had to be converted to a commodity x commodity basis by application of the 'make' matrix.

Conversion to constant prices

The 87-sector current price data from CSO were deflated to a common 1985 price basis by sector-specific deflators. For the 76 primary and manufacturing sectors, including construction, we were able to use producer price indices and import average value indices which had been compiled by Oxford Economic Forecasting with assistance from CSO. To derive deflators for the 11 categories of domestically produced and imported services a more piece-meal approach had to be adopted. For domestic output of the three categories of financial services, other (mainly private sector) services and public services we derived implicit deflators from the CSO current and constant price net output data given in the Blue Book. (For the public sector this required the weighted aggregation of deflators from subheadings within this sector). Although formally these implicit deflators relate to net output, the CSO indicate that many of the indicators used in the construction of the constant price series for net output are in practice gross output measures (CSO 1985).

Similar implicit deflators are available for distribution, hotels and catering, which we distinguish as two sectors, and for transport and communications, where we distinguish six separate sectors. Our overall approach was to refine these to the more disaggregated level which we required. We first adopted the two more aggregated deflators as interim estimates for each of the two and six constituent sectors respectively. For the eight disaggregated sectors this completed the 87-sector vector of their inter-industry purchases at constant prices. The addition of sectoral employment income and gross profits, deflated as described below, gave an interim estimate of constant-price gross output for each of these sectors, derived through the constant-price gross output for each sector, derived as the column-total of its purchases. Juxtaposed with the current-price valuation of gross output this measure provided our final estimate of the implicit deflator for domestic output in each of the eight sectors.

Deflation of employment income

Employment income generated in each sector was converted to a "constant 1985 price" basis by revaluing at 1985 sectoral hourly earnings. The method developed is analogous to the deflation of gross output. The quantity units of employment, or weights, in each sector were the total person-hours worked there in 1985 by up to six groups: full-time manual and non-manual workers, male and female, and part-time female manual and non-manual workers. Sector-specific data on hourly earnings for each of the six groups from the New Earnings Survey provided the "price relative". Combining these gave the index of earnings change for each sector, which was then used to deflate employment income. Our measure of real employment income thus represents the employment income generated in each sector, revalued at 1985 earnings per person-hour in that sector.

The fifteen sector aggregation

After all matrices had been constructed and deflated at the highest level of disaggregation possible we proceeded with aggregation to 15 sectors for computation of results; the aim of this aggregation was to rebalance the data between the high degree of detail available for manufacturing, which is about one quarter of the economy, and to achieve a level suitable for matching with R&D data. Short descriptions of the 15 sectors used are given below, along with their composition in terms of both the SIC80 and SIC92 classifications.

The R&D data

The data used was UK business expenditure on R&D (BERD), obtained from the CSO Business Monitor series MO14 entitled “Research and Development in UK Business”. R&D data is provided on a nominal basis by 33 sectors organised according to the SIC92. It was deflated according to the above method, that is, each sector was deflated using an individual sectoral R&D deflator calculated by Cameron (1996). The concordance used to map the data on SIC92 into the 15 sectors on SIC80 follows.

SIC80-SIC92 Mapping

Sector	Full Description
1	Agriculture, Hunting, Forestry & Fishing
2	Extractive industries, utilities, oil & nuclear processing
3	Manufacture of Food Products, Beverages & Tobacco
4	Manufacture of Pulp, Paper & - products, Publishing & Printing
5	Manufacture of Basic Metals & Fabricated Metal Products
6	Manufacture not elsewhere classified
7	Manufacture of Machinery & Equipment not elsewhere classified
8	Manufacture of Chemicals, Chemical products & Man-made fibres
9	Manufacture of Electrical & Optical Equipment
10	Manufacture of Transport Equipment
11	Construction
12	Wholesale and Retail Trade, Repair, Hotel & Restaurants
13	Transport, Storage & Communication
14	Financial Intermediation, Real Estate, Planning & Business Activities
15	Public Administration & Defence, Social Services, Education, Other Services

Sector	Description used in charts	SIC80	SIC92
1	Agriculture	01,02,03	01,02,05
2	Energy & Utilities	11,12,13,14,15,16,17, 21,23	10,11,12,13,14,23,40,41
3	Food & Drink	41,42	15,16
4	Paper & Printing	47	21,22
5	Metals	22,31	27,28
6	Manufacturing n.e.s.	24,43,44,45,46,48,49	17,18,19,20 (+36.1)25,26,36,37
7	Mechanical Engineering	32	29
8	Chemicals	25,26	24 (inc 23.3 = 0)
9	Electrical Equipment	33,34,37	30,31,32,33
10	Transport Equipment	35,36	34,35
11	Construction	50	45
12	Trade & Catering	61,62,63,64,65,66,67	50,51,52,55
13	Transport &Communications	71,72,74,75,76,77,79	60,61,62,63,64
14	Business Services	81,82,83,84,85,94	65,66,67,70,71,72,73,74
15	Personal & Public Services	91,93,95,92,96,97,98, 99,00	75,80,85,90

Table 1: Comparison of Results Calculated at 87 and 15 Sector Level
Percent Change

	1979-90		1979-85		1985-90	
	output	labour intensity	output	labour intensity	output	labour intensity
	$\ell'\Delta\mathbf{X}$	$\Delta\ell'\mathbf{X}$	$\ell'\Delta\mathbf{X}$	$\Delta\ell'\mathbf{X}$	$\ell'\Delta\mathbf{X}$	$\Delta\ell'\mathbf{X}$
87 sectors	34.2	-39.6	9.2	-20.3	23.6	-17.2
15 sectors	33.7	-39.1	9.0	-20.1	23.5	-17.2

Table 2: Levels of Direct and I-O Labour Intensities

	Direct Labour Intensity ℓ £ employment income per £ gross output			Indirect Labour Intensity λ £ employment income per £ final consumption			Sectoral Leontief Multiplier Column sum of $(\mathbf{I}-\mathbf{A}^{*})^{-1}$		
	1979	**1985**	**1990**	**1979**	**1985**	**1990**	**1979**	**1985**	**1990**
1 Agriculture	0.18	0.11	0.12	0.72	0.48	0.37	2.78	2.55	2.20
2 Energy and Utilities	0.13	0.11	0.08	0.37	0.34	0.26	1.83	1.95	2.07
3 Food & Drink	0.16	0.15	0.14	0.62	0.52	0.42	2.50	2.55	2.36
4 Paper & Printing	0.35	0.33	0.25	0.71	0.61	0.49	1.91	1.90	1.93
5 Metals	0.32	0.24	0.22	0.77	0.53	0.46	2.31	2.04	1.99
6 Manufacturing nes	0.31	0.29	0.26	0.65	0.54	0.48	2.00	1.87	1.91
7 Mechanical Engineering	0.37	0.35	0.29	0.76	0.67	0.56	2.03	2.08	2.07
8 Chemicals	0.21	0.17	0.15	0.64	0.43	0.38	2.35	2.05	1.97
9 Electrical Equipment	0.43	0.31	0.26	0.79	0.58	0.51	1.96	1.93	1.96
10 Transport Equipment	0.41	0.32	0.23	0.81	0.62	0.46	2.13	2.01	1.91
11 Construction	0.32	0.22	0.18	0.72	0.55	0.51	2.20	2.17	2.43
12 Trade & Catering	0.41	0.36	0.34	0.72	0.64	0.61	1.82	1.95	2.11
13 Transport & Comms	0.43	0.40	0.32	0.68	0.64	0.58	1.69	1.84	2.04
14 Business Services	0.63	0.35	0.28	1.30	0.72	0.73	2.80	2.24	2.85
15 Personal and Public Servs	0.75	0.64	0.56	0.86	0.74	0.75	1.28	1.34	1.75
Manufacturing	0.30	0.26	0.22	0.70	0.55	0.46	2.20	2.12	2.06
Services	0.56	0.45	0.38	0.84	0.69	0.68	1.68	1.71	2.02
Total	0.39	0.33	0.28	0.75	0.61	0.57	1.87	1.87	2.05

Table 3: The Change in the Leontief Inverse 1979-90

$$\Delta\{(\mathbf{I}-\mathbf{A}^{*})^{-1}\}$$

Sectors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Agriculture	-0.076	0.001	-0.031	0.001	-0.001	0.004	0.000	-0.005	0.001	0.000	0.001	0.005	0.003	0.002	0.003
2 Energy and Utilities	-0.077	0.236	-0.038	-0.028	-0.113	-0.062	-0.029	-0.120	-0.045	-0.078	-0.027	-0.003	-0.005	-0.017	0.016
3 Food & Drink	-0.126	0.002	-0.046	0.000	-0.002	0.003	0.000	-0.016	0.002	-0.001	0.004	0.011	0.010	0.007	0.008
4 Paper & Printing	-0.020	0.001	-0.021	-0.078	-0.017	-0.012	-0.003	-0.018	0.000	-0.007	-0.001	-0.005	-0.014	-0.017	0.005
5 Metals	-0.027	-0.018	-0.009	-0.006	-0.050	-0.017	-0.022	-0.037	-0.059	-0.087	-0.017	-0.001	-0.006	-0.040	0.009
6 Manufacturing nes	-0.032	-0.018	0.001	-0.002	-0.026	-0.057	-0.017	-0.016	-0.004	-0.012	-0.046	-0.003	0.004	-0.050	0.018
7 Mechanical Engineering	-0.052	0.005	-0.025	0.002	-0.036	-0.018	0.036	-0.038	-0.017	-0.047	-0.001	-0.002	0.001	-0.025	0.008
8 Chemicals	-0.032	-0.008	-0.019	-0.017	-0.020	-0.041	-0.012	-0.154	-0.015	-0.024	-0.022	-0.006	-0.004	-0.024	0.003
9 Electrical Equipment	-0.003	0.011	0.001	0.002	-0.003	0.003	-0.004	-0.003	-0.001	-0.009	0.003	0.006	0.022	-0.013	0.010
10 Transport Equipment	-0.013	0.005	-0.007	-0.001	-0.012	-0.005	0.002	-0.005	0.001	0.012	-0.002	-0.006	-0.006	-0.046	0.009
11 Construction	-0.023	-0.040	0.026	0.053	0.004	0.025	0.032	0.014	0.039	0.020	0.118	0.064	0.067	-0.092	0.119
12 Trade & Catering	-0.097	-0.012	-0.051	-0.046	-0.100	-0.018	-0.046	-0.028	-0.012	-0.062	-0.028	-0.010	0.011	-0.054	0.007
13 Transport & Com	-0.031	0.000	-0.027	-0.013	-0.039	-0.004	-0.020	-0.032	-0.015	-0.033	-0.011	0.036	0.070	-0.048	0.019
14 Business Services	0.124	0.089	0.175	0.215	0.135	0.154	0.161	0.160	0.184	0.144	0.269	0.227	0.196	0.507	0.194
15 Personal and Public Servs	-0.091	-0.013	-0.063	-0.063	-0.043	-0.041	-0.046	-0.079	-0.048	-0.037	-0.014	-0.026	-0.004	-0.038	0.041
Total	-0.575	0.240	-0.134	0.021	-0.322	-0.086	0.032	-0.375	0.010	-0.221	0.227	0.286	0.345	0.051	0.470

Note: The *ij* th element gives the change in sector *j* 's purchases, direct and indirect, of intermediate and capital goods from sector *i* , for one unit of final consumption in sector *j* . The column sum therefore expresses total input change to meet one unit of final consumption in sector *j* .

Chart 1: Change in I-O Labour Use; labour saving vs I-O change 1979-90;

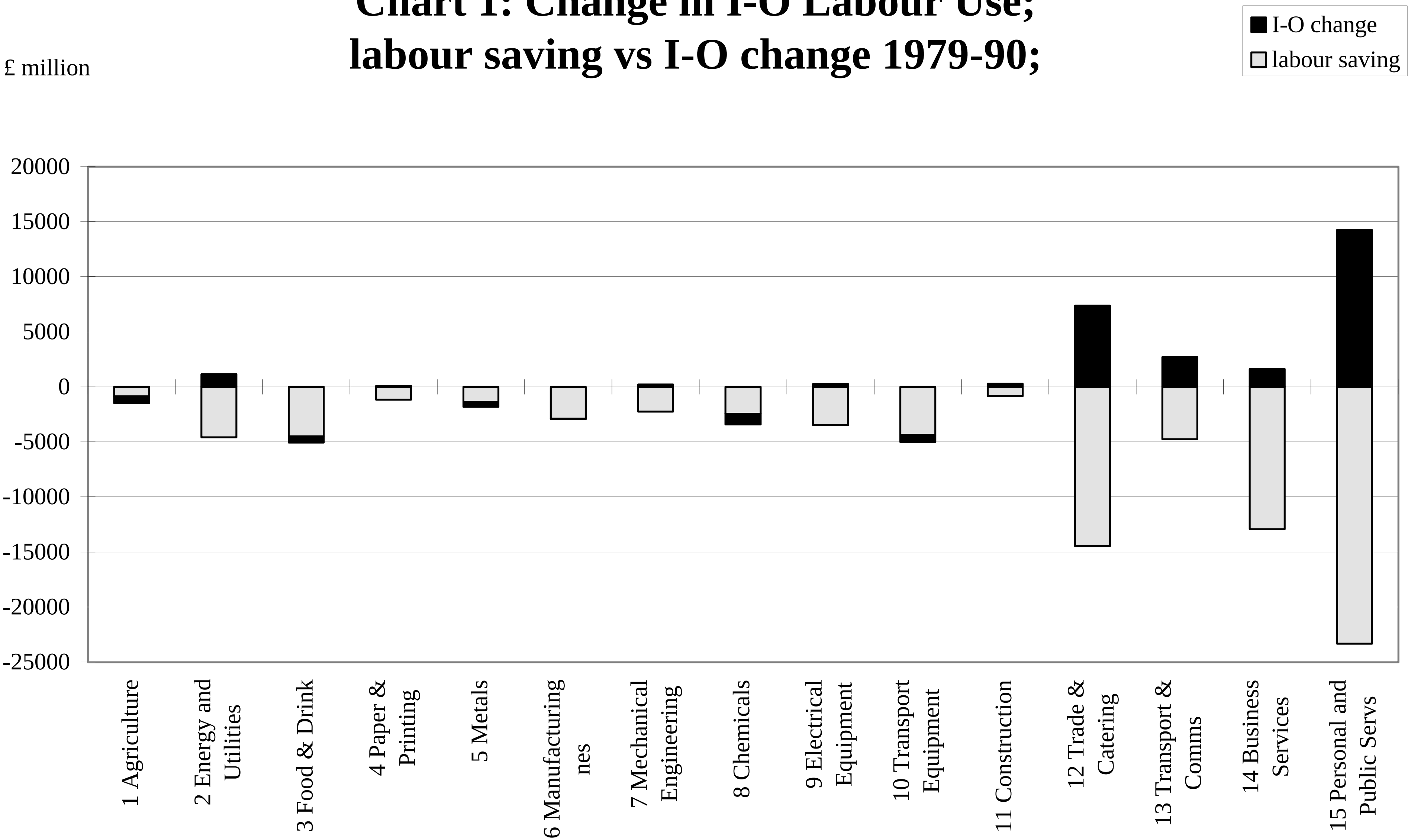

Table 4: Change in Labour Intensity and Labour Use 1979-90

	labour intensity		
£ employment income per £ final consumption	**total** $\Delta\lambda$	**labour saving** $\Delta\ell'(\mathbf{I}-\mathbf{A}^*)^{-1}$	**I-O change** $\ell'\Delta((\mathbf{I}-\mathbf{A}^*)^{-1})$
1 Agriculture	-0.35	-0.21	-0.15
2 Energy and Utilities	-0.12	-0.15	0.04
3 Food & Drink	-0.20	-0.17	-0.02
4 Paper & Printing	-0.22	-0.24	0.02
5 Metals	-0.31	-0.24	-0.08
6 Manufacturing nes	-0.17	-0.17	0.00
7 Mechanical Engineering	-0.20	-0.22	0.02
8 Chemicals	-0.27	-0.19	-0.08
9 Electrical Equipment	-0.28	-0.30	0.02
10 Transport Equipment	-0.35	-0.31	-0.05
11 Construction	-0.21	-0.32	0.10
12 Trade & Catering	-0.10	-0.21	0.11
13 Transport & Comms	-0.10	-0.24	0.13
14 Business Services	-0.57	-0.65	0.08
15 Personal and Public Servs	-0.11	-0.29	0.18
Manufacturing	-0.24	-0.22	-0.02
Services	-0.16	-0.29	0.14
Total	-0.18	-0.26	0.07
	labour use		
£ million	**total** $\Delta\lambda'\hat{\mathbf{F}}$	**labour saving** $\Delta\ell'(\mathbf{I}-\mathbf{A}^*)^{-1}\hat{\mathbf{F}}$	**I-O change** $\ell'\Delta((\mathbf{I}-\mathbf{A}^*)^{-1})\hat{\mathbf{F}}$
1 Agriculture	-1481	-873	-608
2 Energy and Utilities	-3437	-4579	1142
3 Food & Drink	-5073	-4499	-574
4 Paper & Printing	-1088	-1172	84
5 Metals	-1823	-1380	-443
6 Manufacturing nes	-2950	-2894	-56
7 Mechanical Engineering	-2051	-2259	208
8 Chemicals	-3420	-2436	-984
9 Electrical Equipment	-3234	-3484	250
10 Transport Equipment	-5022	-4369	-652
11 Construction	-563	-837	273
12 Trade & Catering	-7104	-14468	7365
13 Transport & Comms	-2063	-4757	2694
14 Business Services	-11309	-12930	1622
15 Personal and Public Servs	-9069	-23327	14258
Manufacturing	-24662	-22494	-2168
Services	-30108	-56320	26212
Total	-59688	-84266	24578

Table 5: Change in I-O Labour Intensities 1979-85 and 1985-90

	1979-85		
£ employment income per £ final consumption	**total** $\Delta\lambda$	**labour saving** $\Delta\ell'(\mathbf{I}-\mathbf{A}^*)^{-1}$	**I-O change** $\ell'\Delta((\mathbf{I}-\mathbf{A}^*)^{-1})$
1 Agriculture	-0.25	-0.18	-0.07
2 Energy and Utilities	-0.03	-0.08	0.04
3 Food & Drink	-0.10	-0.11	0.01
4 Paper & Printing	-0.11	-0.09	-0.01
5 Metals	-0.24	-0.16	-0.08
6 Manufacturing nes	-0.11	-0.08	-0.04
7 Mechanical Engineering	-0.09	-0.11	0.02
8 Chemicals	-0.21	-0.12	-0.09
9 Electrical Equipment	-0.21	-0.21	0.00
10 Transport Equipment	-0.19	-0.17	-0.03
11 Construction	-0.18	-0.19	0.02
12 Trade & Catering	-0.08	-0.13	0.05
13 Transport & Comms	-0.04	-0.09	0.04
14 Business Services	-0.59	-0.42	-0.16
15 Personal and Public Servs	-0.12	-0.15	0.02
Manufacturing	-0.15	-0.13	-0.02
Services	-0.15	-0.16	0.01
Total	-0.14	-0.14	0.00
	1985-90		
£ employment income per £ final consumption	**total**	**labour saving**	**I-O change**
1 Agriculture	-0.11	-0.04	-0.07
2 Energy and Utilities	-0.08	-0.08	0.00
3 Food & Drink	-0.10	-0.07	-0.03
4 Paper & Printing	-0.11	-0.13	0.02
5 Metals	-0.08	-0.07	-0.01
6 Manufacturing nes	-0.05	-0.08	0.02
7 Mechanical Engineering	-0.11	-0.11	0.00
8 Chemicals	-0.06	-0.06	0.01
9 Electrical Equipment	-0.07	-0.09	0.02
10 Transport Equipment	-0.16	-0.14	-0.02
11 Construction	-0.04	-0.11	0.07
12 Trade & Catering	-0.03	-0.08	0.05
13 Transport & Comms	-0.06	-0.13	0.07
14 Business Services	0.02	-0.16	0.17
15 Personal and Public Servs	0.01	-0.11	0.12
Manufacturing	-0.09	-0.09	0.00
Services	-0.01	-0.11	0.10
Total	-0.04	-0.10	0.05

Chart 2: Change in I-O Labour Use; Forward Linkages labour saving vs I-O change 1979-90

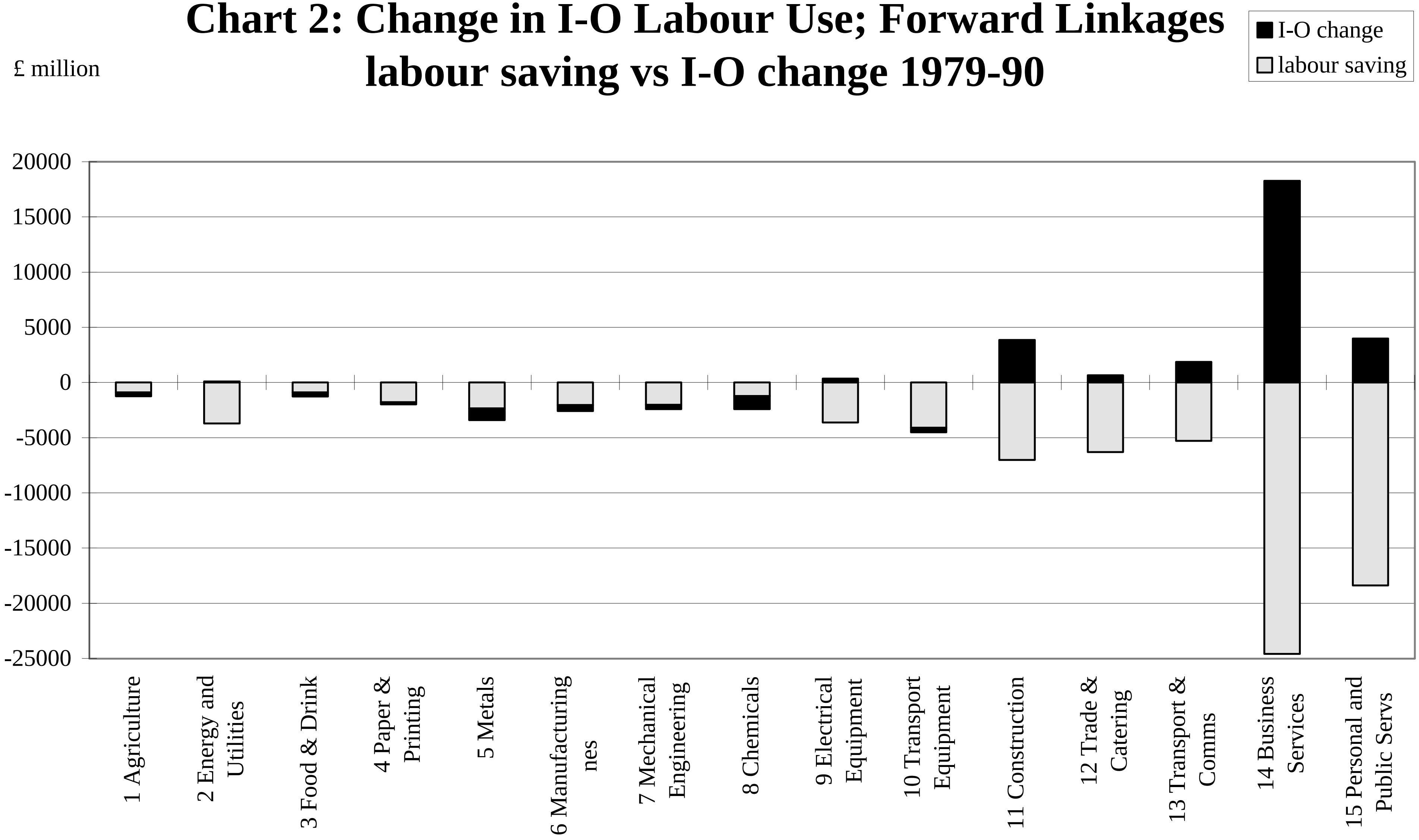

Table 6: Change in I-O Labour Use 1979-90; Backward and Forward Linkages

£ million	**own labour saving** $\Delta\ell'(\mathbf{I}+\hat{\mathbf{A}}^*)\hat{\mathbf{C}}$	**own I-O change** $\ell'(\Delta\mathbf{A}^*)\hat{\mathbf{C}}$	**input labour saving** $\Delta\ell'(\mathbf{A}^*-\hat{\mathbf{A}}^*+\tilde{\mathbf{A}}^*)\hat{\mathbf{C}}$	**input I-O change** $\ell'\Delta\tilde{\mathbf{A}}^*\hat{\mathbf{C}}$	**lab. saving supplied** $\Delta\hat{\ell}(\mathbf{A}^*-\hat{\mathbf{A}}^*+\tilde{\mathbf{A}}^*)\mathbf{C}$	**supplier (I-O) change** $\hat{\ell}\Delta\tilde{\mathbf{A}}^*\mathbf{C}$	**total input**	**total supplied**
1 Agriculture	-288	-287	-585	-321	-617	-56	-1481	-1249
2 Energy and Utilities	-2167	50	-2412	1092	-1550	49	-3437	-3618
3 Food & Drink	-691	-302	-3808	-273	-203	-78	-5073	-1274
4 Paper & Printing	-575	-117	-597	201	-1215	-75	-1088	-1982
5 Metals	-683	-285	-697	-158	-1674	-772	-1823	-3415
6 Manufacturing nes	-1010	-279	-1884	223	-1031	-264	-2950	-2584
7 Mechanical Engineering	-969	-74	-1290	283	-1050	-312	-2051	-2406
8 Chemicals	-816	-613	-1620	-370	-410	-564	-3420	-2404
9 Electrical Equipment	-2104	-97	-1380	347	-1517	449	-3234	-3269
10 Transport Equipment	-2651	-436	-1718	-216	-1440	11	-5022	-4516
11 Construction	-462	64	-375	209	-6552	3792	-563	-3158
12 Trade & Catering	-4971	1930	-9497	5435	-1334	-1265	-7104	-5641
13 Transport & Comms	-2364	1023	-2393	1672	-2929	851	-2063	-3420
14 Business Services	-8366	-109	-4564	1730	-16229	18369	-11309	-6335
15 Personal and Public Servs	-16226	6273	-7101	7985	-2171	-2295	-9069	-14419
Manufacturing	-9500	-2205	-12995	37	-8539	-1605	-24662	-21849
Services	-31928	9116	-23555	16822	-22662	15659	-29545	-29815
Total	-44344	6739	-39921	17840	-39921	17840	-59688	-59688

Table 7: Direct and Indirect R&D Intensities

£ R&D per £ gross output	Direct R&D Intensity *r* 1979	1985	1990
1 Agriculture	0.001	0.001	0.003
2 Energy & Utilities	0.004	0.004	0.004
3 Food & Drink	0.003	0.003	0.004
4 Paper & Printing	0.001	0.001	0.002
5 Metals	0.005	0.005	0.004
6 Manufacturing n.e.s.	0.003	0.003	0.003
7 Mechanical Engineering	0.012	0.012	0.010
8 Chemicals	0.037	0.045	0.066
9 Electrical Equipment	0.072	0.061	0.057
10 Transport Equipment	0.063	0.058	0.047
11 Construction	0.000	0.000	0.000
12 Trade & Catering	0.000	0.000	0.000
13 Transport & Comm.	0.003	0.004	0.003
14 Business Services	0.015	0.007	0.007
15 Personal & Public Servs	0.000	0.000	0.000
Manufacturing	0.011	0.023	0.024
Services	0.002	0.001	0.001
Total	0.009	0.008	0.009
£ R&D per £ final consumption	I-O R&D Intensity ρ **1979**	**1985**	**1990**
1 Agriculture	0.013	0.013	0.014
2 Energy & Utilities	0.010	0.012	0.012
3 Food & Drink	0.012	0.013	0.012
4 Paper & Printing	0.008	0.008	0.009
5 Metals	0.015	0.012	0.012
6 Manufacturing n.e.s.	0.012	0.012	0.011
7 Mechanical Engineering	0.022	0.023	0.020
8 Chemicals	0.054	0.058	0.080
9 Electrical Equipment	0.085	0.075	0.069
10 Transport Equipment	0.078	0.071	0.059
11 Construction	0.009	0.008	0.009
12 Trade & Catering	0.007	0.008	0.008
13 Transport & Comm.	0.013	0.014	0.014
14 Business Services	0.031	0.016	0.019
15 Personal & Public Servs	0.002	0.003	0.005
Manufacturing	0.017	0.034	0.034
Services	0.008	0.007	0.008
Total	0.017	0.016	0.017

Table 8: I-O R&D Intensities: Backward Linkages

£ R&D per £ final consumption	1979 own	1979 input	1985 own	1985 input	1990 own	1990 input
1 Agriculture	0.001	0.012	0.001	0.012	0.003	0.010
2 Energy & Utilities	0.005	0.005	0.005	0.007	0.006	0.006
3 Food & Drink	0.004	0.008	0.004	0.009	0.004	0.008
4 Paper & Printing	0.002	0.006	0.002	0.006	0.002	0.007
5 Metals	0.006	0.009	0.006	0.006	0.005	0.007
6 Manufacturing n.e.s.	0.003	0.009	0.004	0.008	0.003	0.008
7 Mechanical Engineering	0.013	0.009	0.014	0.009	0.012	0.008
8 Chemicals	0.045	0.009	0.051	0.008	0.073	0.007
9 Electrical Equipment	0.079	0.007	0.069	0.007	0.062	0.007
10 Transport Equipment	0.067	0.011	0.061	0.010	0.051	0.008
11 Construction	0.001	0.008	0.001	0.007	0.000	0.008
12 Trade & Catering	0.000	0.008	0.000	0.008	0.000	0.008
13 Transport & Comm.	0.003	0.010	0.004	0.010	0.004	0.010
14 Business Services	0.016	0.015	0.008	0.008	0.009	0.010
15 Personal & Public Serv	0.000	0.002	0.000	0.003	0.000	0.005
Manufacturing	0.027	0.009	0.026	0.008	0.026	0.008
Services	0.002	0.006	0.001	0.006	0.001	0.007
Total	0.010	0.007	0.009	0.007	0.010	0.007
	Proportion own	Proportion input	Proportion own	Proportion input	Proportion own	Proportion input
1 Agriculture	0.08	0.92	0.08	0.92	0.25	0.75
2 Energy & Utilities	0.48	0.52	0.41	0.59	0.48	0.52
3 Food & Drink	0.31	0.69	0.31	0.69	0.32	0.68
4 Paper & Printing	0.21	0.79	0.20	0.80	0.22	0.78
5 Metals	0.39	0.61	0.47	0.53	0.43	0.57
6 Manufacturing n.e.s.	0.29	0.71	0.33	0.67	0.26	0.74
7 Mechanical Engineering	0.60	0.40	0.61	0.39	0.59	0.41
8 Chemicals	0.83	0.17	0.87	0.13	0.92	0.08
9 Electrical Equipment	0.92	0.08	0.91	0.09	0.90	0.10
10 Transport Equipment	0.86	0.14	0.86	0.14	0.86	0.14
11 Construction	0.07	0.93	0.08	0.92	0.03	0.97
12 Trade & Catering	0.00	1.00	0.00	1.00	0.00	1.00
13 Transport & Comm.	0.25	0.75	0.28	0.72	0.27	0.73
14 Business Services	0.51	0.49	0.49	0.51	0.48	0.52
15 Personal & Public Serv	0.05	0.95	0.04	0.96	0.02	0.98
Manufacturing	0.76	0.24	0.76	0.24	0.77	0.23
Services	0.25	0.75	0.18	0.82	0.16	0.84
Total	0.59	0.41	0.58	0.42	0.57	0.43

Table 9: I-O R&D Use: Backward and Forward Linkages									
	1979			1985			1990		
£ million	**own**	**input**	**supplied**	**own**	**input**	**supplied**	**own**	**input**	**supplied**
1 Agriculture	3	30	9	4	48	10	20	60	30
2 Energy & Utilities	131	142	97	165	237	98	182	200	124
3 Food & Drink	96	221	23	96	218	27	101	209	35
4 Paper & Printing	7	27	16	7	27	14	11	38	21
5 Metals	34	53	84	29	34	66	30	40	72
6 Manufacturing n.e.s.	60	152	55	57	114	62	47	134	57
7 Mechanical Engineering	151	101	149	121	77	138	112	76	138
8 Chemicals	468	98	318	667	100	274	1121	102	408
9 Electrical Equipment	735	64	538	879	84	576	929	100	657
10 Transport Equipment	758	126	505	780	127	443	824	129	428
Construction	4	52	16	3	35	18	2	63	15
Trade & Catering	0	426	0	1	504	0	2	613	1
Transport & Comm.	63	190	68	63	159	75	75	202	106
Business Services	244	236	162	149	157	327	227	251	597
Personal & Public Servs	4	123	1	6	207	0	10	473	1
Manufacturing	2310	842	1689	2637	781	1601	3173	828	1816
Services	312	976	231	219	1028	402	315	1539	704
Total	2759	2042	2042	3027	2128	2128	3693	2690	2690

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