# Fields of influence of technological change in EC intercountry input-output tables, 1970-80

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# Fields of Influence of Technological Change in

# EC Intercountry Input-Output Tables, 1970-80


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## Abstract


The development of the impact of technological change on the interdependence of sectors and countries in the EC is investigated by means of weighted Fields of Influence of column-wise changes in technical coefficients on the Leontief-inverse. In this manner, the propulsiveness of the member countries' sectors is analysed and spatially decomposed into a 'domestic', an 'intercountry spillover', an 'intercountry return' and a 'rest of the EC' effect. Analogously, the reactiveness to technological change of each sector's multiplier, and the dependence on technological change of each sector's production level are analysed.



JEL C67, F15, O33, O52.

# 1. Introduction

Innovations and technological change are known to spread over time and over space. In the literature, Carter's (1970) pioneering study provided a useful methodological approach to the issue of system-wide aggregate change. In addition, extensive models of innovation diffusion have been developed to this date [see *e.g.* Davies (1979), Nijkamp (1986)]. Most of these theories, however, concentrate upon the diffusion process of one type of innovation at a time. Some studies deal with the simultaneous diffusion process of independent but mutually competing innovations, each maybe having its own specific niche and maximal penetration [see *e.g.* Sonis (1992)]. As far as interdependent innovations are concerned one finds some attention to the spillover of key-innovations in one area (e.g. microprocessors) unto the technologies used in other areas (e.g. consumer electronics). These latter theories, e.g., concentrate on the phenomenon of technological trajectories [Dosi (1984)]. However, we have not found studies of the system-wide implications of changes in technology, nor comparative studies into the system-wide implications of series of different new technologies, although Grossman and Helpman (1991) have attempted to explore the basis for an approach to this problem.

In this paper we will set a prudent first step to fill this gap. Of all system-wide implications of new technologies we will deal only with one major, but specific, effect of new technologies, namely their impact on the interdependence of an economic system. In this context, interdependence has two important aspects which we would like to investigate simultaneously. First, technological change influences of course the way in which sectors interact with one another through the exchange of products. Second, we would like to investigate the extent to which this influence spills over into other countries. In this last context we are interested in the question whether this intercountry spillover of technological change increases over time or not, especially, when countries integrate their economies such as is done in the European Community.

The ideal data base to investigate the above questions consists of a time series of intercountry input-output tables which allows us to study the intersectoral interaction both within and between countries over time. Recently such tables have been constructed for the EC for 1970 and 1980. The next section gives an outline of the construction method [see Van der Linden and Oosterhaven (1995) for details].

The effect of technological change on the interdependence of sectors, within and between countries, is best measured by the effects of changes in a column of technical coefficients on the values of the intercountry Leontief-inverse $(\mathbf{I}\text{-}\mathbf{A})^{-1}$. Section 3 explains the method used to calculate these effects, namely a weighted variant of the Fields of Influence of Column Change [see Sonis & Hewings (1992) for details on other types of Fields of Influence].

Sections 4-6 then give a three-way summary description of the empirical results that consist of 5x6 (countries x industries) Fields of Influence with each 30 rows and columns for 1970, and 7x6 Fields with 42 rows and columns for 1980. In Section 4 we analyse the impact of a comparable change in factor productivity in every sector in each EC-country on the aggregate value of the intercountry Leontief-inverse as well as on its aggregate spatial structure. Thus we identify so-called *propulsive* sectors studied earlier for Brazil by Cuello *et al.* (1992). Next, in Section 5, we analyse which production multipliers are most sensitive to EC-wide factor productivity increases in order to identify *reactive* sectors [see also Cuello *et al.* (1992)]. Finally, in Section 6, we extend the analyses of Cuello *et al.*, and we analyse how the rows of the intercountry Leontief-inverse change as a consequence of EC-wide changes in factor productivity. In this manner, *dependent* sectors and countries are identified as those whose production levels are most sensitive to overall changes in factor productivity within the EC.

At each level of analysis, attention will of course be given to the temporal changes in propulsiveness, reactiveness and dependence of sectors and countries within the EC over the period 1970-80.

# 2. EC Intercountry Input-Output Tables

The data used in examining the fields of influence of technological change in the European Community are intercountry input-output tables for 1970 and 1980. These tables are constructed from a set of mutually harmonized national input-output tables [see Eurostat (1979) for the methodology]. In these harmonized tables, domestic transactions are valued in producers' prices, and imports in ex-customs prices. Furthermore, the imports are distinguished according to two origins, namely imports from within the EC and imports from outside the EC. Such tables are issued every five years, but they are not available for all member states. For both years there are no tables for Luxembourg, and for 1980 the table for Ireland is lacking too. So, the data suitable for analysis relate to five and seven countries for 1970 and 1980, respectively [see Eurostat (1978,1986)].

To obtain the intercountry tables, the intra-EC imports of the respective member states were first disaggregated into bilateral, intersectoral transactions. International trade data, as harmonized by Eurostat (1990), were used to do this. Second, to reassess the ex-customs values of the intra-EC imports into producers' prices, the RAS method was applied to these bilateral transactions. Details of the construction method are given in Van der Linden and Oosterhaven (1995). For earlier constructions and applications of EC intercountry input-output tables, see Schilderinck (1984), Langer (1987), Lanza and Rampa (1988), Oosterhaven (1989a) and Fehr *et al.* (1991). In all these tables, however, ex-customs prices were not reassessed.

The original intercountry tables of Van der Linden and Oosterhaven (1995) have 44 sectors. For our present analysis, we aggregated them into 6 sectors, namely Agriculture, Energy, Manufacturing, Building, Market Services and Public Services.

# 3. Fields of Influence of technological change

The notion of Fields of Influence was originally developed to guide the construction and estimation of regional input-output tables. As such, it focused on error and sensitivity analysis and the identification of inverse-important coefficients [Sonis and Hewings (1989)]. Later on, the approach also proved to be useful for the analysis of the structure of input-output tables and the identification of key sectors [Cuello *et al.* (1992), Sonis and Hewings (1992)].

## *3.1. The Notion of Fields of Influence*

The basic formula of the impact of a change in one input coefficient on the whole Leontief-inverse is:

$$\boldsymbol{B}(\boldsymbol{E}) = \boldsymbol{B} + \frac{1}{1 - b_{ch}e_{hc}} \boldsymbol{F}\begin{pmatrix} c \\ h \end{pmatrix} e_{hc} \quad , \tag{1}$$

where $e_{hc}$ is the change in use of, say, input $h$ in sector $c$. **B** and **B**(E) are the Leontief-inverses before and after the change, built up of output multipliers $b_{ij}$ and $b(E)_{ij}$ respectively, which gives the output of sector $i$ per unit of final demand for commodity $j$. **F** is the Field of Influence:

$$\boldsymbol{F}\begin{pmatrix} c \\ h \end{pmatrix} = \begin{pmatrix} b_{1h} \\ b_{2h} \\ . \\ . \\ b_{nh} \end{pmatrix} (b_{c1}, b_{c2}, ..., b_{cn}) \quad , \tag{2}$$

where $n$ is the number of sectors and commodity types. The typical element of **B**(E) is thus calculated as:

$$b_{ij}(E) = b_{ij} + \frac{b_{cj}b_{ih}e_{hc}}{1 - b_{ch}e_{hc}} \quad , \qquad i,j = 1,.....,n, \tag{3}$$

which is the well-known Sherman and Morrison (1950) formula of inverse change.

In order to analyse the sensitivity of the Leontief-inverse to the technological change in a whole sector instead of only one coefficient, we need to consider possible sets of changes in one column ***c***:

$$\boldsymbol{e}^{\,c} = (e_{1c}, e_{2c}, ..., e_{nc}) \quad . \tag{4}$$

In this case, the extension of (3) is [Sherman and Morrison (1949)]:

$$b_{ij}(E) = b_{ij} + \frac{b_{cj}\sum_h b_{ih}e_{hc}}{1 - \sum_h b_{ch}e_{hc}} \quad , \qquad i,j = 1,.....,n. \tag{5}$$

One can make many alternative assumptions about the structure of the changes in (4). The most obvious one is an equal relative increase in all coefficients. Such a change is the typical result of an increase in primary input (e.g. capital or labour) productivity, under the assumption of an unchanged mix of intermediate inputs. This case is specified as:

$$e_{ic} = \alpha a_{ic} \quad , \qquad i = 1,.....,n, \quad (6)$$

where $a_{ic}$ is the use of input $i$ in sector $c$.

Other obvious assumptions are, for example, a substitution between two specific intermediate inputs $h_0$ and $h_0'$:

$$e_{h_0 c} = -e_{h_0' c} \quad , \qquad (6')$$

or a more efficient use of one specific intermediate input:

$$e_{h_0 c} = \alpha a_{h_0 c} \quad , \qquad (6'')$$

with

$$e_{h_i c} = -\frac{e_{h_0 c} a_{h_i c}}{\sum_{h_i \neq h_0} a_{h_i c}} \quad , \qquad \text{for } \forall\, h_i \neq h_0$$

In these cases too, the mix of other intermediate and primary input coefficients of sector $c$ remains unchanged. Hence, these three alternatives represent some basic cases of column change.

In this paper, we will only analyse the implications of the first alternative. This alternative is analytically most tractable and thus convenient as a first step in the analysis. Furthermore, it seems to be the most general and empirically reasonable assumption. It should, however, not be regarded as the one giving the most convenient outcomes. The other two would give equally convenient outcomes. They merely study other questions in the same framework. Thus starting from (6), substitution into (5) results in:

$$b_{ij}(E) = b_{ij} + \frac{\alpha b_{cj} \sum_h b_{ih} a_{hc}}{1 - \alpha \sum_h b_{ch} a_{hc}} \quad . \qquad (7)$$

To obtain the structure of the impact of $\alpha$ on the Leontief-inverse, we only need to investigate the linear part of the change:

$$f_{ij}^{c} = b_{cj} \sum_h b_{ih} a_{hc} \quad , \qquad (8)$$

where the matrix $\mathbf{F}^c = ||f_{ij}^c||$ is called the *Weighted* Field of Influence of

Column Change or the *Column Field of Influence*. It is defined as the weighted sum of the Fields of Influence of the elements of column $c$ [see Sonis and Hewings (1992) for the unweighed version].

The interpretation of our weighted column Field of Influence, $\mathbf{F}^c$, can easily be simplified, using the property that

$$||\Sigma_h b_{ih} a_{hj}|| = \mathbf{BA} = (\mathbf{B} - \mathbf{I}) = ||b_{ij} - \delta_{ij}||,$$

in which

$$\delta_{ij} = 1, \text{ if } i=j;$$

$$\delta_{ij} = 0, \text{ if } i \neq j.$$

The elements of $\mathbf{F}^c$ can now be presented in a form where the direct backward linkages, $a_{ij}$, are excluded:

$$f_{ij}^c = b_{cj}(b_{ic} - \delta_{ic}) \ . \qquad (8')$$

In this expression, the components $b_{cj}b_{ic}$ are the elements of the Field of Influence, $\boldsymbol{F}\begin{pmatrix} c \\ c \end{pmatrix}$, of the change occurring in the place $(c,c)$. Therefore, the weighted Column Field of Influence has the form:

$$\boldsymbol{F} = \boldsymbol{F}\begin{pmatrix} \boldsymbol{c} \\ \boldsymbol{c} \end{pmatrix} - \boldsymbol{B}\langle \boldsymbol{Row\ c} \rangle \ ,$$

where the matrix **B**(**Row c**) is filled with zero's, except for row $c$, which is row $c$ of the Leontief-inverse.

From (8'), it is clear that a Column Field of Influence depends on backward linkages. The impact on the individual multiplier $b_{ij}$ will be stronger:

(1) the stronger $j$'s cumulative backward linkages with respect to $c$; and

(2) the stronger $c$'s cumulative indirect backward linkages with respect to $i$.

Hence, strong backward linkages, both of and with respect to a sector, cause that sectors' technological changes to have a strong impact on the Leontief-inverse. This means that a productivity increase in a key sector, as defined in the traditional sense [see *e.g.* Dietzenbacher (1992)], will have a particular strong impact on the Leontief-inverse.

Could we use these Column Fields of Influence for the analysis of the impact of a change in one sector, for comparative purposes we basically cannot. The ranking of sectors according to their impact on the Leontief-inverse is also dependent on a scaling factor, the denominator of (7). However, when $\alpha$ is sufficiently small, the ranking will not be influenced by that scaling factor, and (8) can be used for comparative purposes too. This can be proven by taking the derivative of (7) with respect to $\alpha$ [Sonis and Hewings (1992)].

The Column Fields of Influence can be represented by a three-dimensional table, with $i$ and $j$ as the horizontal and vertical dimensions and $c$ as the 'depth' dimension. In the next three sections, we will analyse the above defined interindustry and intercountry Column Fields of Influence of the EC. These analyses will be made by means of summary measures of these 'block'-tables for 1970 and 1980, with 30 and 42 sectors respectively. Each time, elements of the basic interpretation of the Fields of Influence given above will return. The remainder of this section explains the methodology of the analyses.

## *3.2. Methodology of the empirical analyses*

Most straightforward is the analysis of the impact of comparable sectoral productivity increases on the aggregate value of the Leontief-inverse. In this way *propulsive* sectors are identified as those sectors that produce a relatively large increase in the overall interdependence between all sectors of the EC-countries [Cuello *et al.* (1992)].

As we are dealing with an intercountry system, we need to introduce additional indices to indicate the countries of origin and destination. For convenience, however, we introduce the indices $p$ and $q$ as the combined index for country and sector. Thus, propulsiveness is defined as the total of the effects on the Leontief-inverse, *i.e.* as the Volume of Column Field of Influence:

$$V^{c} = \sum_{pq} b_{cq}(b_{pc} - \delta_{pc}) = \sum_{q} b_{cq}\left[\sum_{p}(b_{pc} - \delta_{pc})\right] = b_{c}(b^{c} - 1) \ , \qquad (9)$$

with

$$b_{c} = \sum_{q} b_{cq} \ , \quad \text{and} \quad b^{c} = \sum_{p} b_{pc} \ .$$

This Volume is equal to the sum of row $c$ times the sum of column $c$ of the Leontief-inverse, the latter without the direct effect. Hence, the total impact of a productivity increase in sector $c$ depends on its own backward linkages, via changes in the rest of the system, interpreted through the Field of Influence. Section 4.1 analyses the empirical results.

There are many ways to analyse the structure of an individual Field of Influence further. They range from a detailed element by element approach to a global approach, building on broad aggregations of the matrix. For our present purposes we will confine ourselves to the latter, and make three aggregations. The first concerns an intercountry decomposition of the Volume of Fields of Influence. The second and third concern straightforward column and row aggregations of the individual Fields of Influence respectively.

To see whether the individual Fields have a largely domestic character or also have significant intercountry elements, let $p_{pq}^{c}$ be defined as the percentage of the Volume of Column Field of Influence that is found in cell ($p$,$q$). The aggregate spatial structure is then obtained by summing $p_{pq}^{c}$ into four components:

$$P_{CC}^{c} = \sum_{\substack{p\in C \\ q\in C}} p_{pq}^{c} \qquad P_{Cs}^{c} = \sum_{\substack{p\in C \\ q\in s\neq C}} p_{pq}^{c}$$

$$P_{rC}^{c} = \sum_{\substack{p\in r\neq C \\ q\in C}} p_{pq}^{c} \qquad P_{rs}^{c} = \sum_{\substack{p\in r\neq C \\ q\in s\neq C}} p_{pq}^{c} , \tag{10}$$

where $r$ and $s$ denote the countries of origin and destination, and $C$ is the country in which industry $c$ is located. In this decomposition of $\mathbf{V}^{c}$:

$P_{CC}^{c}$ represents the percentage of the total effect on the Leontief-inverse that is located in its block diagonal *domestic* part. It consists of pure domestic and intercountry feedback effects. The latter, however, are more or less negligible [see *e.g.* Oosterhaven (1981), Miller (1986)]. Hence, the domestic part gives an indication of the closed nature of an economy to the effects of its productivity changes.

$P_{rC}^{c}$ is the *intercountry-spillover* effect induced by imports from the rest of the EC. It will be large if country $C$ has a large share of intra-EC imports, *i.e.* strong intercountry backward linkages. Foreign industries will thus be influenced by technological developments in country $C$.

$P_{Cs}^{c}$ is called the *intercountry-return* effect induced by exports to the rest of the EC. Its value will be large when country *C*'s products are important for other EC-countries. In that case, the other member states have strong backward linkages with respect to *C*.

$P_{rs}^{c}$, finally, is the sum of all the multiplier effects that are not related to country *C*. Hence, it is labelled as the *rest of the EC* effect. Its value will vary with country *C*'s openness as regards its intra-EC imports and exports.

Of these four components, the first is expected to be the largest. Despite the growing economic integration of the EC, the strongest linkages are still domestic. Both intercountry components are expected to be smaller, although they may grow in importance [see Oosterhaven (1989a)]. In the fourth component, the effects of the second and third are combined in a multiplicative sense. Therefore, it is expected to be very small. The empirical analysis confirmed these expectations (see Section 4.2).

The two other types of aggregations of the block with Column Fields of Influence go into more detail. They involve aggregations over the individual Column Fields of Influence. They are set up to compare, respectively, the sensitivity per column and per row of the Leontief-inverse.

The analysis of column sensitivity identifies *reactive* sectors as those sectors (and countries) whose multipliers are most sensitive to comparable factor productivity increases in all sectors and countries of the EC. For each individual *c*, we can identify reactive sectors, *q*, by ranking $\sum_p f_{pq}^{c}$, $q = 1, 2, ..., n$. Each *c*, however, will give a different ranking, with *c* itself as the most reactive sector[1]. Hence, the general set of reactive sectors cannot be derived unambiguously. For the moment we will assign all sectors an equal weight, *i.e.*, we assume that all sectors have an equal chance to meet a productivity change. So we identify *'average' reactive* sectors by summing $\sum_p f_{pq}^{c}$ over *c*:

$$S_q = \sum_{pc} b_{cq}(b_{pc} - \delta_{pc}) = \sum_{c} b_{cq}(b^{c} - 1) \qquad q = 1, 2, ..., n. \quad (11)$$

This is the column multiplier of sector *q* itself, but weighted with the indirect

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[1]This is obvious from $\sum_p f_{pq}^{c} = b_{cq}(b^{c}-1)$, which is high when $q = c$.

backward linkages of *c* from (9). The average reactiveness of a sector is thus strongly dependent on its backward linkages. When *q* is a key sector, its position is reinforced by productivity increases anywhere in the economy, in particular when there are strong relations with other key sectors.

Although this analysis looks along the columns of the intercountry Fields of Influence, the results should not be confused with measures of backward linkages. The relation actually runs the other way round. It is the impact of changes in technologies transmitted through backward linkages that is measured, and not the backward linkages themselves. In Section 5 we analyse the average reactiveness of the EC sectors.

With the third type of aggregation it is analysed how the rows of the intercountry Leontief-inverse would change as a consequence of comparable changes in factor productivity in all sectors in all countries. Here it would be wrong to associate the results with measures of forward linkages just because of the row-wise instead of column-wise approach[2]. Actually, this way of analysis identifies what may be called *dependent* sectors. These are sectors and countries whose production levels, through backward linkages of other sectors, are most sensitive to overall changes in factor productivity within the EC.

Like the previous case, we again have the problem of ambiguity, which is now even stronger. Not only for each *c*, but also for each *q* we can derive an alternative ranking of sectors. Again we assume that all sectors have an equal factor productivity increase. We now also assume that (implicit) changes in demand for commodities from sector *q* are equally important[3]. Hence, we now sum $f_{pq}^{c}$ over *c* and *q*:

$$S_p = \sum_{cq} b_{cq}(b_{pc} - \delta_{pc}) = \sum_{c \neq p} b_c b_{pc} + b_p(b_{pp} - 1) \quad , \qquad p = 1, 2, ..., n. \quad (12)$$

In (12), strong backward linkages with respect to *p* make its production highly

[2]See Oosterhaven (1988, 1989b) for a critical discussion of applications of forward linkages; and Dietzenbacher *et al*. (1993) for a clear distinction between both types of linkages.

[3]This assumption was already made (implicitly) in the calculation of the Volume of the Column Fields of Influence.

sensitive to technological changes elsewhere in the economy. In Section 6 we analyse the average dependence of the EC sectors.

# 4. Analysis of Propulsive Sectors

In this section we will concentrate on a comparison of the separate Column Fields of Influence by looking at the aggregate size and spatial structure of changes in the Leontief-inverse that are due to a small factor productivity increase in each sector *c*. First, we will analyse the Volumes of the Fields as calculated from (9). Secondly, we will look at the spatial structure of the Fields by means of the intercountry decomposition of the Volumes given in (10).

## *4.1. The Volume of Column Fields of Influence*

The EC-wide Volumes of Fields of Influence in 1970 and 1980 are given in Table 1 and illustrated in Figures 1 and 2. The Volumes are arranged in a two-dimensional (country by sector) way. This shows not only which sectors' productivity changes would have the strongest impact upon the Leontief-inverse, but also which member states would exert the greatest influence. The criterion for the arrangement of countries is the average Volume of Column Field of Influence per country. For the arrangement of sectors, an analogous criterion is applied. In both parts of Table 1 the propulsiveness declines from the upper left to the lower corner. In Figures 1 and 2 this is shown graphically.

Both from Table 1 and Figure 1 we observe that for 1970, productivity changes in the German Manufacturing sector would have the strongest impact on the Community Leontief-inverse, followed by Manufacturing in France, The Netherlands, Italy and Belgium, respectively. Then, we find Agriculture, Market Services and Building, with only small mutual differences between their impacts. Here we find some exceptions to the general order of the member states. French and Italian Agriculture, Belgian Market Services, and French and German Building would have relatively weak impacts. The weakest influences would be exerted by Energy and Public Services in all member states. Here, only German Energy, which is strongly based on (domestic) coal, is an exception.

To understand the pattern of Figure 1, one has to remember that the impact of productivity changes in sector *c* primarily depends on its own indirect backward linkages and on the total backward linkages of the other sectors with respect to *c*. In 1970, Manufacturing had the strongest linkages of both types in all five countries. This would explain its dominance upon the Leontief-inverse. This linkage strength itself, however, is largely dependent on the relative size of the sector. A lower level of aggregation would reveal a more varied pattern of potential impacts.

In Agriculture and Building, both the column and the row elements of the Leontief inverse are close to the average, which explains their middle position in the ranking of propulsive sectors. Market Services and Energy have relatively weak backward linkages since they use little material inputs (roughly about 30%). However, this is compensated by the strong use of their products by other sectors. Of these two sectors, Market Services strongly depends on labour, whereas Energy uses significant oil imports from outside the EC. Finally, Public Services have very weak linkages, which explains the small potential impact of productivity changes in this sector.

Just as with the sectoral order, economic size explains part of the country order in Figure 1. For the other part, the country order is explained by the openness with respect to the other EC-countries. The latter explains why the propulsiveness of the Benelux sectors ranked between those of two larger countries, France and Italy.

In 1980 (see Table 1 and Figure 2) the pattern essentially remained unaltered. The order of sectors was still the same. Even the exceptions were the same. This suggests the presence of a strong structural component in the relationships between most sectors. Only the Dutch Building sector, having a much stronger potential impact in 1980, may be added to the exceptions. Contrary to the order of sectors, however, the order of countries did change, but not in a dramatic way. Italy 'climbed' to a mid-position (due to increases in the linkages of its Manufacturing and Market Services), but the differences with France, The Netherlands and Belgium were still small.

Of the two *new* member states, Denmark fitted well between the other two small economies. Only its Energy productivity changes would have a relatively strong impact on EC interdependence. The strong position of the United Kingdom, however, was surprising. The productivity changes of four sectors, Agriculture, Building, Energy and Public Services, would have the largest impact on the intercountry Leontief-inverse. For the other two sectors, the impacts would only be slightly weaker than the German ones. The British impacts, however, would be largely domestic, as will be shown below.

## *4.2. The Spatial Structure of Column Fields of Influence*

Next, we turn to the spatial structure of the individual Column Fields of Influence. The hypothesis about the relative size of the components of (10), as formulated in Section 3.2, is confirmed by the empirical outcomes shown in Table 2. In 1980, the domestic component generally ranged between 70 and 90% of the Volume of the individual Fields, the intercountry-spillover effect was mostly between 10 and 30%, and the other two components hardly exceeded 10% and 2%, respectively[4].

Although this spatial structure of the individual Fields appears to be quite general, Table 2 also shows some interesting differences among sectors and member states. In 1980, Agriculture, Building and both Services sectors would have much stronger domestic effects than Energy and Manufacturing. This is caused by the traditionally high openness for fuel and manufacturing products. The openness to agricultural products and services is generally lower. In 1970, the pattern was the same except for Energy which showed much larger domestic impacts than in 1980.

As could be expected, the small countries' openness is reflected in their relatively small domestic and large intercountry effects, while the closed nature of the large member states is reflected in large domestic and small intercountry effects. Here we indeed find that the strong overall multiplier effects of the United Kingdom are largely domestic. This implies that the rest of the EC would feel little influence of UK productivity changes. Italy too seems to be quite closed but more so in 1970 than in 1980. Of the three small economies, the Danish is most closed. Remember, however, that we are only evaluating openness with respect to the EC, not with respect to third countries. Hence, the Danish economy may well be quite open with respect to, *e.g.*, the other Scandinavian countries.

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[4]A zero in the table has to be interpreted as an 'almost zero'. It denotes a percentage smaller than 0.5.

The distinction between the large and the small member states is also reflected in the differences between the intercountry-spillover and -return effects. Although the small economies are the most open ones, their return effects are weaker than those of the large countries. This represents the strong backward linkages of the small countries with respect to the EC, but the weak backward linkages of the EC with respect to them. In other words, the small countries are more dependent on the EC than the EC is on the small countries [see also Dietzenbacher *et al.* (1993)]. For the large member states, the opposite holds. In British Energy, German Manufacturing and Market Services, and French Manufacturing, the intercountry-return effects of productivity changes would even be stronger than the intercountry-spillover effects. This illustrates the relatively strong backward dependence of the EC on their products.

# 5. Column-wise Search for Reactive Sectors

Section 4 provided an impression about the total influence that EC-sectors may exert on the Leontief-inverse. Now, we can go a step further, and ask which sectors' production multipliers will be most affected by a productivity change in some sector.

Under the assumption that every industry has an equal chance to meet a productivity change, a general ranking of reactive sectors is derived from (11). Manufacturing, Agriculture and Building turned out to be the most reactive sectors, with small mutual differences (see Figures 3 and 4). The other three sectors are less reactive. As argued before, this pattern is explained by the backward linkages of the sectors, and can be derived from the column multipliers and specific linkages with the propulsive sectors.

As mentioned in Section 3.2, each of the $n$ Fields of Influence will have a different set of reactive sectors, the most reactive of course being sector $c$ itself. This is clearly illustrated in the upper, sector by sector, part of Table 3 where the potential effects of productivity changes on the Leontief-inverse are summed over the member states. This summation may be accomplished without much loss of information, as the sector-by-sector pattern is essentially the same for each domestic and bilateral submatrix. Since there were no essential differences between 1970 and 1980, Table 3 only presents the 1980-results.

The extent to which the most reactive sector is sector *c* itself, is not the same for each sector. It ranged from over 90% (Building and Public Services), via about 80% (Agriculture and Energy) to less than 60% (Manufacturing and Market Services). Its counterpart is the intersector-spillover effect, which ranged from less than 10% to over 40%. This also explains the small mutual differences between the reactive sectors in Figure 3 and 4. In 1980, 47% of the sensitivity to productivity change in Manufacturing would be off-diagonal while for productivity changes in Building this would only be 9%. In the measurement of reactiveness, this compensates for the large differences between the respective production multipliers. Likewise, the low column sensitivity of the Market Services is partly caused by the strong spillover effects of its productivity changes.

These results indeed illustrate that strong linkages with propulsive sectors will make a sector strongly reactive. Moreover, the position of a key sector will be reinforced after a productivity change, especially when it occurs in the sector itself.

The lower part of Table 3 gives the sensitivity of the production multipliers per member state. Here the potential effects of productivity changes are summed over sectors. Hence, we obtain the sensitivity pattern of the member states' production multipliers. It is obvious that there are no big differences between the countries. The United Kingdom and Germany, which were the most propulsive countries, were the most reactive countries too.

The 'landscapes' of column sensitivity are summarized in Figures 3 and 4 for 1970 and 1980, respectively. They give the pattern of the $S_q$'s of (11). The order of sectors and countries is the same as in Figures 1 and 2. This enables a good comparison between propulsive and reactive sectors. The flatness of the figures is due to the compensating effects of the intersector-spillovers discussed above. The figures also illustrate the slightly higher sensitivity of Manufacturing, Agriculture and Building, and of the United Kingdom and Germany. Finally, note the small differences between the 1970 and the 1980 patterns.

Next, we turn to the final step of the analysis, the row-wise evaluation of the Leontief-inverse change.

# 6. Row-wise Search for Dependent Sectors

Under the assumption of an equal importance of demand changes in any sector, Figures 5 and 6 give the patterns of the product or row sensitivity of equation (12), for 1970 and 1980, respectively. They show, on average, the size of the production effects of an equal productivity change over sectors and countries.

The 'landscape' of dependent sectors is not nearly as flat as that of the reactive sectors. The production of Manufacturing goods, especially in the large countries, is most strongly influenced by system-wide productivity developments, followed by the provision of Market services. Energy and Agricultural products take an intermediate position. Building and the provision of Public services are hardly influenced by EC productivity changes.

Just as in the case of column sensitivity, there is a characteristic pattern of the effect of productivity changes on the rows of the Leontief-inverse. For each of the *n* Fields of Influence there is a different set of dependent sectors. This pattern is given in Table 4, which is constructed analogous to Table 3. In the upper part, we indeed see patterns of product sensitivity that are different for each productivity change. For example, for productivity developments in Agriculture, Manufacturing is the most dependent sector, followed by Market Services and Agriculture itself, while for Energy the most dependent sector is Energy itself. On the other hand, a strong general dependency of Manufacturing and Market Services is also evident.

The ranking of dependent countries is not much different to that of the propulsive countries. Only Germany and the United Kingdom have switched their positions. The lower part of Table 4 illustrates the lower variability of sensitivities between the member states, which is also obvious from Figures 5 and 6.

The interpretation of these results is straightforward. As the elements of each column in the upper part of Table 4 are calculated by summing the intercountry equivalent of (8') over $q$[5], they are strongly determined by $(b_{pc} - \delta_{pc})$. This latter expression indicates the indirect backward linkage between industry $c$ and $p$. By

[5]and then, analogous to Table 3, over $c^r$ and $s$, where $c^r$ is the country-part of the combined index $c$.

summing over the columns, *c*, so that (12) is obtained, all indirect linkages with respect to *p* are taken into account. As argued before, however, these latter linkages are strongly related to the size of the sector. A lower level of aggregation may show more varied results.

# 7. Summary and conclusions

In this paper an explorative analysis of the impacts of technological change on the multipliers of an intercountry input-output system is made. Using the notion of the weighted Column Fields of Influence, four types of issues were examined: (1) the identification of propulsive sectors by the total impact their productivity change would have on the systems' interdependence; (2) an analysis of the spatial structure of the effects of productivity change; (3) the identification of reactiveness of sectors by the sensitivity of individual columns of the Leontief-inverse to EC-wide productivity changes; and (4) the identification of dependence of sectors by the sensitivity of individual rows of the Leontief-inverse to EC-wide productivity changes.

From the theoretical and empirical analysis it is derived that these reactions are positively related to the size of the backward linkages, the specific linkages between pairs of industries, the size of the sectors, and the size and openness of the countries at hand. The application was based on six-sector intercountry input-output tables of the European Community for 1970 (5 countries) and 1980 (7 countries).

In both years there were only small differences between the member states, with Great Britain and Germany exerting the strongest impact. The impact of these and the other large countries (France and Italy), however, would be largely domestic. The rest of the EC would only feel little influence from their productivity changes. Because of their strong intercountry linkages, technological developments in the smaller countries (Belgium, the Netherlands and Denmark) would have large intercountry-spillovers. This makes their total impact comparable to that of France and Italy. Of the smaller countries, the Danish openness as regards the EC was, like the British, quite small.

In each country Manufacturing is both the most propulsive, most reactive and most dependent sector. Although the linkages of this sector are indeed strong, the impact is also strongly determined by its relative size. Agriculture, Market Services and Building are moderately propulsive. Of these, Market Services is also quite dependent, while the other two sectors are rather reactive. Finally, Energy and Public Services are hardly propulsive nor reactive, while Energy is quite dependent instead.

The analysis also illustrates the importance of economic openness as regards the sensitivity of some products to productivity changes. Traditionally, an economy is open to manufactured goods, but not to services and agricultural products. This closed nature has further implications than just numerical ones. It also relates to the size of market areas and the economic base [Dicken and Lloyd (1990), Richardson (1978)]. It may even provide a method to the identification of a Fundamental Economic Structure [Jensen *et al.* (1987,1988)].

A global and qualitative comparison between 1970 and 1980 did not reveal strong developments during the seventies. This might indicate a lack of convergence between the member states. Each country seems to keep some specific technology. True analysis of temporal developments, however, would only be possible when the analysis is conducted on five-countries-only tables, and extended over a longer period. In this case we will have a more sophisticated incremental, temporal analysis, but lose information about the new member states instead.

Some directions of further research can be identified. First, the present analysis is a tentative one. On the one hand, it can be deepened by adopting a lower level of aggregation. This will qualify the results, especially those of the Manufacturing sector. On the other hand, an extended period can be taken into consideration. Second, the present analysis has a strong hypothetical character. This can be overcome by a temporal analysis of the *actual* differences between pairs of input coefficient matrices[6]. Finally, a decomposition of the actual multiplier changes into the impacts of changes in individual columns may be made.

[6]This may, for example, be done by using the RAS method, or using decomposition techniques. See Van der Linden and Dietzenbacher (1995) for the former, and Van der Linden and Oosterhaven (1993) and Oosterhaven *et al* (1995) for the latter.

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Table 1: Impact of productivity changes on EC output multipliers.

| Sectors where a change would occur | Countries | | | | | | |
|---|---|---|---|---|---|---|---|
| (1970) | D | F | NL | B | I | | |
| Manufacturing | 5.05 | 2.83 | 2.47 | 2.27 | 2.34 | | |
| Agriculture | 1.73 | 1.05 | 1.31 | 1.35 | 0.79 | | |
| Market services | 1.96 | 1.28 | 1.20 | 0.69 | 0.94 | | |
| Building | 1.02 | 0.90 | 1.02 | 0.88 | 0.83 | | |
| Energy | 0.98 | 0.54 | 0.56 | 0.49 | 0.33 | | |
| Public services | 0.60 | 0.57 | 0.41 | 0.38 | 0.36 | | |
| (1980) | UK | D | F | I | NL | DK | B |
| Manufacturing | 3.60 | 4.39 | 2.69 | 3.03 | 2.53 | 1.89 | 2.14 |
| Agriculture | 1.83 | 1.33 | 1.34 | 1.00 | 1.33 | 1.23 | 1.26 |
| Market services | 1.62 | 1.68 | 1.38 | 1.37 | 1.06 | 1.15 | 0.76 |
| Building | 1.58 | 0.96 | 0.84 | 0.98 | 1.38 | 1.02 | 0.87 |
| Energy | 1.31 | 1.09 | 0.52 | 0.38 | 0.42 | 0.72 | 0.39 |
| Public services | 0.75 | 0.60 | 0.44 | 0.40 | 0.38 | 0.42 | 0.31 |

Units: Volume of Column Fields of Influence.

Table 2: Spatial structure of the impact of productivity changes on EC output multipliers.

| Sectors where a change would occur | | 1970 I | 1970 II | 1970 III | 1970 IV | 1980 I | 1980 II | 1980 III | 1980 IV |
|---|---|---|---|---|---|---|---|---|---|
| UK | Manufacturing | | | | | 73 | 13 | 12 | 2 |
| | Agriculture | | | | | 89 | 8 | 3 | 0 |
| | Market services | | | | | 85 | 8 | 6 | 1 |
| | Building | | | | | 90 | 9 | 1 | 0 |
| | Energy | | | | | 75 | 6 | 17 | 1 |
| | Public services | | | | | 89 | 9 | 2 | 0 |
| D | Manufacturing | 64 | 9 | 23 | 3 | 59 | 10 | 26 | 5 |
| | Agriculture | 87 | 8 | 5 | 0 | 82 | 12 | 5 | 1 |
| | Market services | 80 | 7 | 12 | 1 | 76 | 8 | 15 | 2 |
| | Building | 90 | 9 | 1 | 0 | 87 | 12 | 1 | 0 |
| | Energy | 81 | 11 | 7 | 1 | 72 | 18 | 8 | 2 |
| | Public services | 89 | 10 | 1 | 0 | 86 | 12 | 1 | 0 |
| F | Manufacturing | 70 | 12 | 15 | 3 | 63 | 16 | 17 | 4 |
| | Agriculture | 83 | 9 | 8 | 1 | 79 | 12 | 8 | 1 |
| | Market services | 85 | 7 | 7 | 1 | 79 | 10 | 10 | 1 |
| | Building | 86 | 13 | 0 | 0 | 80 | 19 | 1 | 0 |
| | Energy | 87 | 10 | 3 | 0 | 78 | 16 | 5 | 1 |
| | Public services | 92 | 8 | 0 | 0 | 89 | 11 | 1 | 0 |
| I | Manufacturing | 77 | 15 | 7 | 1 | 72 | 18 | 8 | 2 |
| | Agriculture | 88 | 10 | 2 | 0 | 85 | 13 | 2 | 0 |
| | Market services | 90 | 7 | 4 | 0 | 87 | 8 | 5 | 0 |
| | Building | 89 | 11 | 0 | 0 | 86 | 13 | 0 | 0 |
| | Energy | 85 | 12 | 2 | 0 | 82 | 15 | 2 | 0 |
| | Public services | 92 | 7 | 0 | 0 | 90 | 10 | 0 | 0 |
| NL | Manufacturing | 51 | 38 | 6 | 5 | 50 | 35 | 9 | 6 |
| | Agriculture | 75 | 21 | 3 | 1 | 73 | 22 | 4 | 1 |
| | Market services | 62 | 31 | 5 | 2 | 68 | 20 | 9 | 3 |
| | Building | 57 | 42 | 0 | 0 | 67 | 32 | 1 | 0 |
| | Energy | 70 | 25 | 4 | 1 | 43 | 39 | 9 | 8 |
| | Public services | 72 | 28 | 0 | 0 | 78 | 21 | 1 | 0 |
| DK | Manufacturing | | | | | 69 | 29 | 2 | 1 |
| | Agriculture | | | | | 76 | 24 | 1 | 0 |
| | Market services | | | | | 84 | 15 | 1 | 0 |
| | Building | | | | | 77 | 23 | 0 | 0 |
| | Energy | | | | | 49 | 51 | 0 | 0 |
| | Public services | | | | | 83 | 17 | 0 | 0 |
| B | Manufacturing | 44 | 42 | 7 | 7 | 37 | 49 | 6 | 8 |
| | Agriculture | 73 | 24 | 2 | 1 | 66 | 32 | 1 | 1 |
| | Market services | 67 | 27 | 4 | 2 | 66 | 28 | 4 | 2 |
| | Building | 61 | 38 | 0 | 0 | 56 | 44 | 0 | 0 |
| | Energy | 68 | 29 | 2 | 1 | 59 | 34 | 5 | 3 |
| | Public services | 65 | 35 | 0 | 0 | 65 | 35 | 0 | 0 |

Units: Percentages of Volume of Column Fields of Influence (A 0 denotes a percentage < 0.5).
Columns: I, Pure domestic effect; II, Effect on foreign multipliers of demestic demand ('intercountry spillover'); III, Effect on domestic multipliers of foreign demand ('intercountry return'); IV, Rest of the EC effect; I + II + III + IV = 100.

Table 3: Sensitivity of output multipliers to productivity change, 1980.

| Multiplier sensitivity: | Sectors where a change would occur | | | | | |
|---|---|---|---|---|---|---|
| | Manu-factu-ring | Agri-culture | Market ser-vices | Buildin g | Energy | Public ser-vices |
| Manufacturing | 10.85 | 0.84 | 0.97 | 0.09 | 0.29 | 0.07 |
| Agriculture | 3.14 | 7.94 | 0.80 | 0.12 | 0.30 | 0.09 |
| Market services | 1.22 | 0.12 | 5.41 | 0.18 | 0.19 | 0.05 |
| Building | 3.40 | 0.26 | 0.95 | 6.92 | 0.17 | 0.04 |
| Energy | 0.53 | 0.04 | 0.32 | 0.13 | 3.72 | 0.02 |
| Public services | 1.15 | 0.11 | 0.59 | 0.18 | 0.15 | 3.02 |
| United Kingdom | 3.42 | 1.81 | 1.56 | 1.57 | 1.08 | 0.74 |
| Germany | 3.31 | 1.30 | 1.48 | 0.96 | 1.05 | 0.60 |
| France | 2.50 | 1.24 | 1.30 | 0.83 | 0.53 | 0.44 |
| Italy | 3.04 | 1.02 | 1.37 | 0.98 | 0.40 | 0.40 |
| The Netherlands | 2.94 | 1.34 | 1.10 | 1.37 | 0.44 | 0.39 |
| Denmark | 2.40 | 1.27 | 1.23 | 1.03 | 0.89 | 0.42 |
| Belgium | 2.66 | 1.33 | 0.99 | 0.88 | 0.44 | 0.32 |

Units: Column-sums of Column Fields of Influence, aggegated over the EC member states.

Table 4: Sensitivity of output to productivity change, 1980.

| Output sensitivity: | Sectors where a change would occur | | | | | |
|---|---|---|---|---|---|---|
| | Manu-factu-ring | Agri-culture | Market ser-vices | Buildin g | Energy | Public ser-vices |
| Manufacturing | 10.63 | 4.25 | 2.58 | 3.98 | 0.86 | 1.27 |
| Agriculture | 2.41 | 1.84 | 0.29 | 0.34 | 0.07 | 0.13 |
| Market services | 4.59 | 1.87 | 4.56 | 1.88 | 0.85 | 1.07 |
| Building | 0.26 | 0.18 | 0.43 | 0.85 | 0.24 | 0.22 |
| Energy | 1.92 | 0.91 | 0.95 | 0.48 | 2.73 | 0.38 |
| Public services | 0.45 | 0.26 | 0.22 | 0.10 | 0.08 | 0.22 |
| United Kingdom | 3.79 | 1.93 | 1.69 | 1.66 | 1.63 | 0.76 |
| Germany | 5.42 | 1.67 | 1.87 | 1.44 | 1.07 | 0.68 |
| France | 3.18 | 1.48 | 1.45 | 0.96 | 0.55 | 0.48 |
| Italy | 2.87 | 0.99 | 1.35 | 0.99 | 0.37 | 0.40 |
| The Netherlands | 2.19 | 1.29 | 1.01 | 1.13 | 0.49 | 0.38 |
| Denmark | 1.41 | 0.96 | 1.00 | 0.81 | 0.36 | 0.35 |
| Belgium | 1.41 | 0.99 | 0.66 | 0.64 | 0.36 | 0.25 |

Units: Row-sums of Column Fields of Influence, aggegated over the EC member states.

Figure 1: Impact of productivity changes on EC output multipliers, 1970.

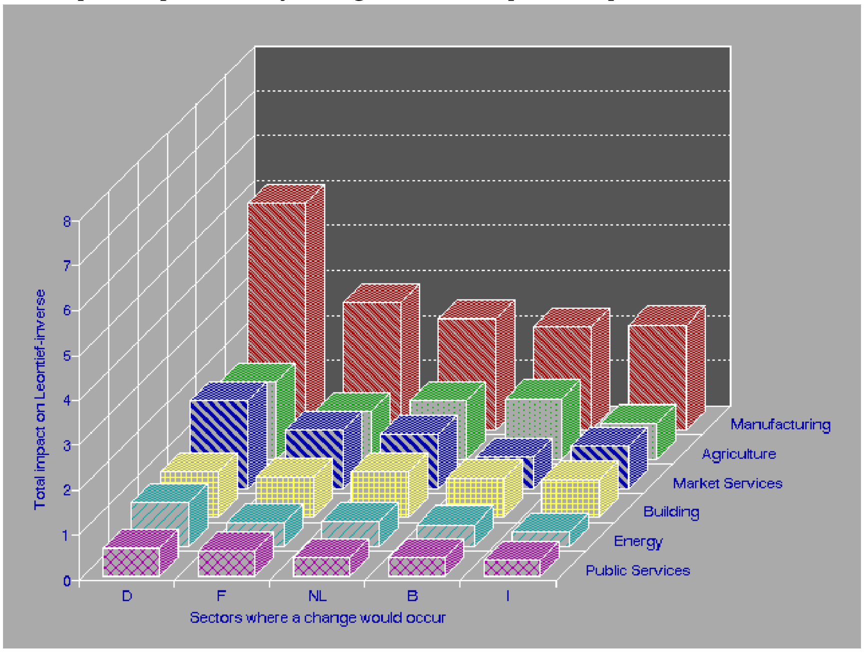


Figure 2: Impact of productivity changes on EC output multipliers, 1980.

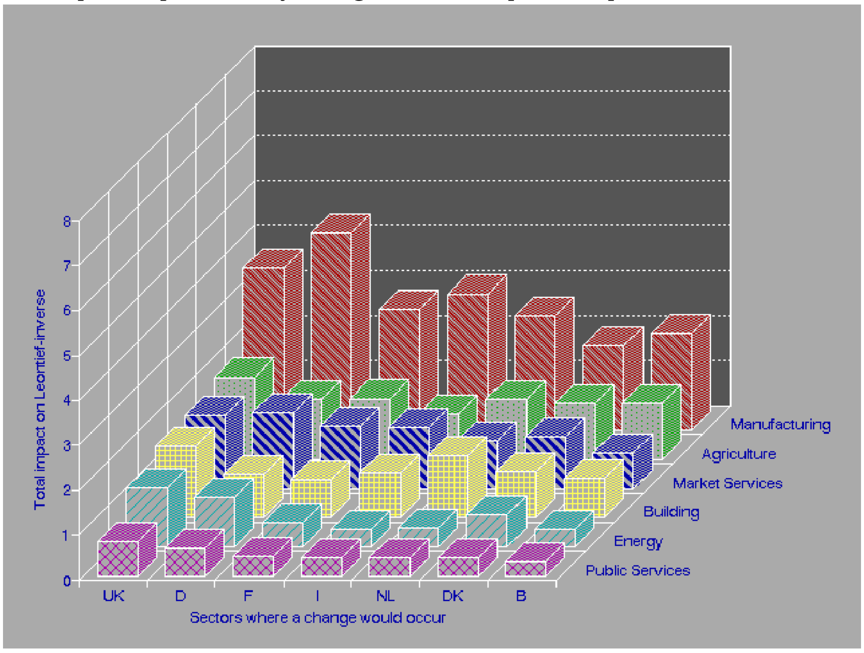

Figure 3: Sensitivity of output multipliers to productivity changes, 1970.

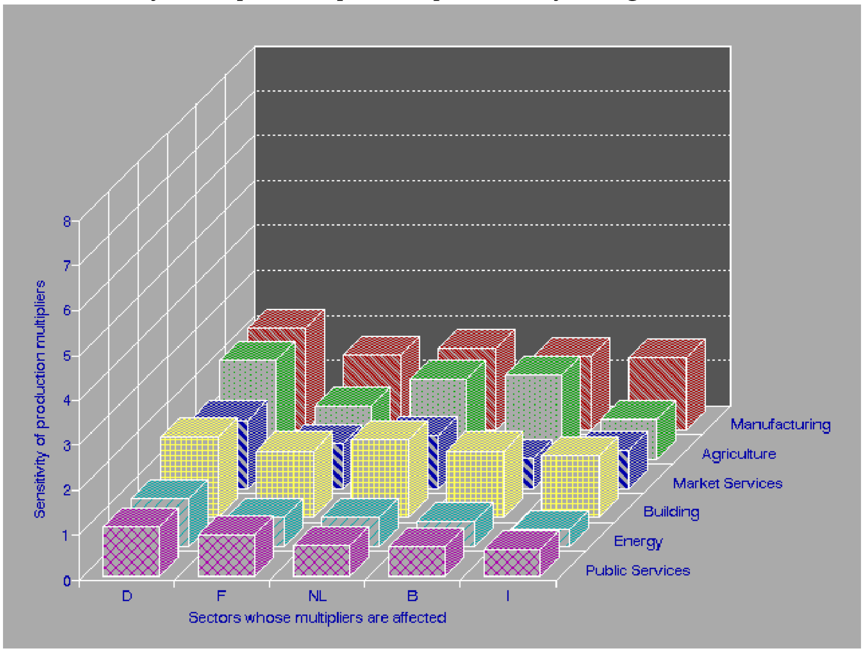


Figure 4: Sensitivity of output multipliers to productivity changes, 1980.

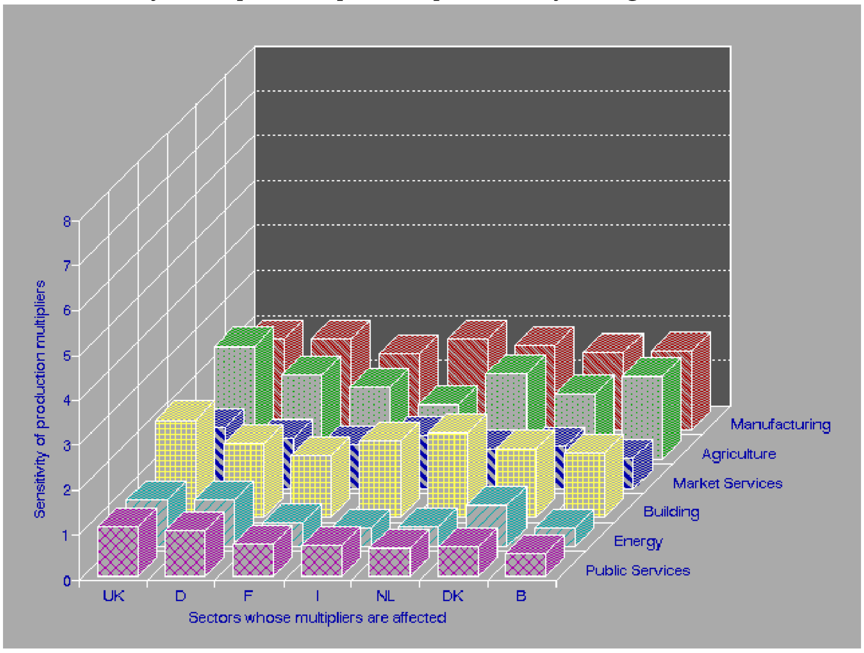

Figure 5: Sensitivity of sector output to productivity changes, 1970.

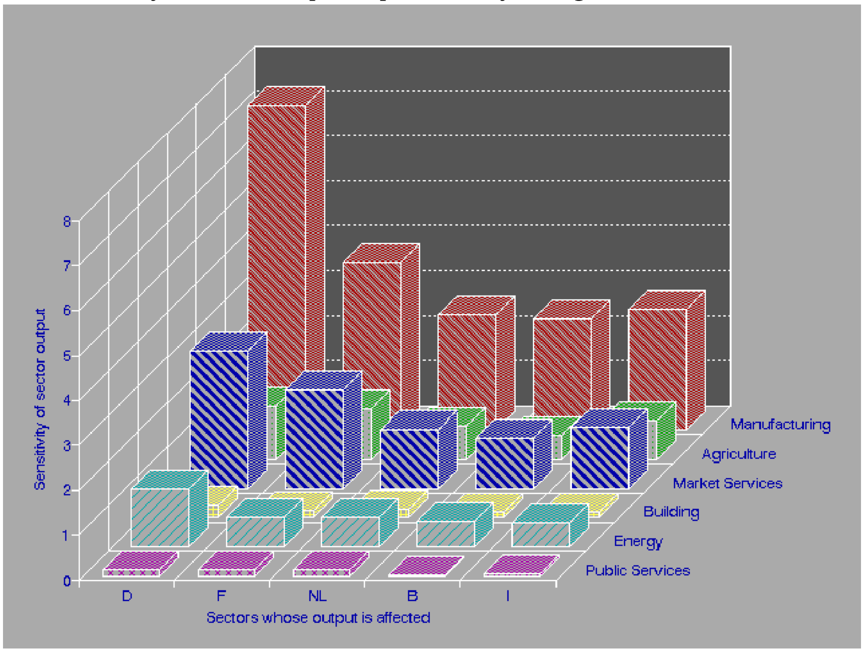


Figure 6: Sensitivity of sector output to productivity changes, 1980.