The determinants of structural change in the European Union

Linden, Jan A. van der; Dietzenbacher, Erik

The Determinants of Structural Change in the European Union: A New Application of RAS

by
Jan A. van der Linden and Erik Dietzenbacher[1]

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Abstract

In economic theory and practice, technological developments and changes in relative prices lead to changes in the input mix of one or more industries. Via intersectoral and interregional relations, this affects the entire production structure. In analyzing the structural changes in an economy, changes in the input coefficients are a major determinant. Typically, however, this determinant is not unravelled further into its underlying sources. The present paper applies the RAS method to decompose the input coefficient changes into column-specific, row-specific and cell-specific changes. They respectively indicate the change in the productivity of primary factors in a sector, the average substitution of the intermediate goods and services provided by a sector, and the sector-specific substitutions. The method is applied to input-output tables of European Union (EU) member states, as issued every five years between 1965 and 1985. The usefulness of the RAS method as a descriptive tool is established.

Keywords: Input-output tables, technological change, RAS, European Union.

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[1]Department of Economics, University of Groningen, P.O.Box 800, NL-9700 AV Groningen, The Netherlands (tel: +31-50-3637074/3740, fax: +31-50-3637337). We thank professor Jan Oosterhaven for his helpful comments and suggestions.

1. Introduction

Explaining economic growth has been a topic for long[2]. Technological development is widely considered to be one of its driving forces. In a single production process, technological development expresses itself in the productivity growth of the primary production factors, and in the substitution between the intermediate goods and services. As a consequence, the input coefficients corresponding to this production process are changed. In a multisectoral input-output framework, these two components interact for all sectors simultaneously affecting the entire matrix of input coefficients.

A common approach for analyzing the contribution of changes in the technical coefficients to economic growth is the structural decomposition approach (Carter, 1970)[3]. This method decomposes *e.g.* output or value added changes into a number of key determinants, one of which is technological change, as reflected by changes in the input-output structure of the economy. Typically, however, this determinant is not decomposed further. The present paper aims at quantifying the underlying sources of technological change. To this end, the changes in the input-output structure are decomposed into (i) the productivity change in each sector, (ii) the average substitution of each of the products, and (iii) sector-specific substitutions. It is shown that the RAS method may be used for this purpose.

The RAS method is well-known and widely used as a technique for

[2]Seminal publications in this field include Solow (1956), Romer (1986), Grossman and Helpman (1990) and Maddison (1991).

[3]For recent contributions, see e.g. Round (1985), Wolff (1985; 1994), Feldman *et al.* (1987), Blair and Wyckoff (1989), Kanemitsu and Ohnishi (1989), Skolka (1989), Barker (1990), Afrasiabi and Casler (1991), Fujita and James (1991), Van der Linden and Oosterhaven (1993), Miller and Shao (1994), Lin and Polenske (1995), Oosterhaven *et al.* (1995). For critical evaluations of structural decomposition techniques, see Schumann (1994) or Dietzenbacher and Los (1995).

updating input-output matrices or tables. Its economic background, however, has been criticized (see *e.g.* Lecomber, 1975; Miernyk, 1977; Lynch, 1986; or Rose and Miernyk, 1989). In Section 2 we develop the decomposition and show that RAS may be used for this purpose as a descriptive tool. This new application of RAS overcomes the criticisms and allows for an economically meaningful interpretation.

It should be emphasized that our decomposition aims at describing and measuring what actually has happened. Earlier attempts[4] to quantify the effects of technological change have approached the issue from the opposite direction. That is, imposing specific changes in the matrix of input coefficients, the effects (upon *e.g.* output or value added) are examined under the assumption that all other things remain the same. In this way it is possible to single out (sets of) coefficients that are important, in the sense that a change induces large effects. Although such analyses provide important insight into the current production structure and the potential effects of technological change, they cannot be used to describe the sources of the changes as they have taken place. Analyses of this form answer hypothetical questions of the "what-if" type. Neither the hypothesis nor the ceteris paribus assumption is adequate when confronted with actually observed changes.

The decomposition is applied to the input-output tables of the European Union (EU), both for the EU as a whole and for its member states individually. The tables are issued every five years, covering the period 1965-1985. They are valued in current prices and use a 44-sector classification. For our purpose they are aggregated into 31 sectors. A disadvantage is that, since the tables are not recorded in constant prices, our results refer to cost structures rather than to strictly technical structures. Another disadvantage is that, since economic activities are aggregated into sectors, technological developments also cover changes in the composition of the sectors. In contrast, a major advantage of the

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[4]See, for example, Bullard and Sebald (1977; 1988), Jensen and West (1980), West (1981; 1982), Defourny and Thorbecke (1984), Hewings (1984), Schintke and Stäglin (1988), Hewings *et al.* (1989), Sonis and Hewings (1989; 1992), Cuello *et al.* (1992), and Van der Linden *et al.* (1995).

database is that the tables have a very high degree of comparability between the countries.

The data are further discussed in Section 3, the empirical results are presented in Section 4, and Section 5 contains the conlusions.

2. The Decomposition of Structural Change

At time t, each sector in an economy uses a mix of intermediate and primary inputs to produce its output. The precise composition of this mix is dependent on the state of technology. In an input-output context, the state of technology is represented by the matrix $\mathbf{A}_t$ of input coefficients,

$$\boldsymbol{A}_t = [\boldsymbol{Z}_t + \boldsymbol{M}_t]\hat{\boldsymbol{x}}_t^{-1}, \tag{1}$$

where $\mathbf{Z}_t$ and $\mathbf{M}_t$ denote the intermediate deliveries and imports, respectively, and $\hat{\boldsymbol{x}}_t^{-1}$ is the inverse of the diagonal matrix of outputs. Each element of $\mathbf{A}_t$,

$$a_{ij}^t = (z_{ij}^t + m_{ij}^t)/x_j^t, \qquad i,j = 1,.....,n, \tag{2}$$

gives the use of goods or services of type i per unit of output of sector j. The use of primary inputs other than imports can implicitly be defined as

$$c_j^t = 1 - \Sigma_i a_{ij}^t, \qquad j = 1,.....,n. \tag{3}$$

Thus, each *column* of $\mathbf{A}_t$ represents the state of technology of one sector.

Technological developments, such as *e.g.* innovations into products and production processes, and price changes induce the inputs to be substituted. The difference between two subsequent coefficients matrices reflects that. In each column of the resulting $\Delta\mathbf{A}$, inputs with a negative sign have been substituted for inputs with a positive sign. Moreover, the column sums of $\Delta\mathbf{A}$ show substitution between intermediate and primary inputs, which is related to productivity change. A positive column sum might indicate a productivity increase, a negative sum might indicate a decrease. Additional information on the primary inputs will reveal the category where the productivity change must have occurred - labour, capital, or other. So, an analysis of the columns of $\Delta\mathbf{A}$ could provide us with a rough picture of technological development per sector.

This picture, however, is likely to be rather differentiated. In some cases, substitution between two intermediate inputs holds for only one particular sector. In other cases, it may hold for the entire economy. Moreover, productivity changes may be so strong that most of the elements of a column of $\mathbf{A_t}$ either increase or decrease. This clearly obscures the picture of substitution between intermediate inputs in that sector. Hence, there is a need to look for a general pattern of change along the rows and columns of $\mathbf{A_t}$.

In this paper we consider the ratio of change in the input coefficients, a_{ij}^{t+1}/a_{ij}^{t} (i,j = 1,.....,n), from which the percentage changes can be derived. For each ratio we determine (i) the part that is caused by a productivity change in sector j, affecting column j uniformly, (ii) the part that is caused by an economy-wide change in the use of input i, affecting row i uniformly, and (iii) the part that is caused by other circumstances.

Define s_j as the productivity effect upon the coefficient changes of sector j, applying uniformly along column j of $\mathbf{A_t}$. This productivity effect reflects that more output is produced per unit of primary inputs. It can therefore be interpreted as the productivity change of the joint primary inputs. Note that, by applying s_j to each element in column j of $\mathbf{A_t}$, it is implicitly assumed that the mix of intermediate inputs in sector j remains constant. Hence, s_j actually measures the 'average' effect.

Next, define r_i as commodity i's average substitution effect, applying uniformly along row i of $\mathbf{A_t}$. This effect is the average of the substitutions between intermediate inputs that have occurred in all sectors. It may either be a mere average of all substitutions regarding commodity i, or reflect economy-wide changes in prices or the use of certain inputs, or both.

When both r_i and s_j are applied simultaneously to $\mathbf{A_0}$, we obtain

$$\tilde{a}_{ij}^{1} = r_i a_{ij}^{0} s_j, \qquad \text{or} \qquad \tilde{A}_1 = \hat{r} A_0 \hat{s}, \tag{4}$$

in which $\hat{r}$ and $\hat{s}$ are the diagonal matrices of r_i and s_j (i,j = 1,.....,n) respectively. Since both effects are *average* effects, they should correctly reflect the average changes as they have occurred in each row and column. In other words, they should satisfy the condition that the row and column sums of the actual transactions matrix, $[\mathbf{Z_1} + \mathbf{M_1}]$, are equal to the ones obtained from $\tilde{A}_1$.

Denote the row sums of $[\mathbf{Z_1} + \mathbf{M_1}]$ by $\mathbf{u_1}$, then

$$[Z_1 + M_1]e = A_1 x_1 = u_1, \tag{5}$$

in which $\mathbf{e}$ is the n-element summation vector. Denote the column sums of $[\mathbf{Z_1} + \mathbf{M_1}]$ by $\mathbf{v}_1'$, then

$$e'[Z_1 + M_1] = e' A_1 \hat{x}_1 = v_1'. \tag{6}$$

The conditions now read as follows,

$$\begin{aligned} A_1 x_1 &= \tilde{A}_1 x_1 = u_1 \qquad \text{or} \qquad \hat{r} A_0 \hat{s} x_1 = u_1 \\ e' A_1 \hat{x}_1 &= e' \tilde{A}_1 \hat{x}_1 = v_1' \qquad \text{or} \qquad e' \hat{r} A_0 \hat{s} \hat{x}_1 = v_1'. \end{aligned} \tag{7}$$

This set of $2n$ equations is solved for the $2n$ elements of $\hat{r}$ and $\hat{s}$. Because the equations are not independent, however, the solution will be a parametric one. We discuss this later. The model in (7) may be solved iteratively by the RAS method. RAS was developed for updating input-output tables under the precondition of known row and column sums $\mathbf{u_1}$ and $\mathbf{v}_1'$ (Stone, 1963). For an elaborate introduction to the RAS method we refer to Miller and Blair (1985). Technical details with respect to the existence and uniqueness of the solution can be found in Bacharach (1970) or MacGill (1977)[5].

The interpretation of $\hat{r}$ and $\hat{s}$ being the average substitution and productivity effects, respectively, is well-known. It was introduced by Stone (1963), who *assumed* these effects to *determine* the changes in an input coefficients matrix[6]. In the 1970s, many empirical studies have been carried out in order to examine the performance of the method as an updating technique (see, for example, Allen and Gossling, 1975; Lynch, 1986). Unfortunately, the results were rather disappointing in the sense that $\tilde{\boldsymbol{A}}_1$ did not resemble $\boldsymbol{A}_1$. Curiously, this poor empirical performance has induced a critical attitude towards the economic interpretation and relevance of RAS. Not only were Stone's assumptions considered to be invalid, RAS was also considered to be just a mechanical tool, absent of any economic underpinning (Lecomber, 1975; Miernyk, 1977).

In our view, this conclusion is not justified. The poor empirical results rather show that the productivity and substitution effects *alone* are insufficient to explain the changes in the coefficients. Indeed, productivity and substitution effects as the sole determinants of changes may have a poor explanatory power. But this is no reason to abandon the economic interpretation behind RAS. It just expresses that other determinants should be taken into account as well. In this study, these other determinants are embodied in a third component, taken as a rest factor,

$$d_{ij} = a_{ij}^1 / \tilde{a}_{ij}^1, \qquad i,j = 1,\ldots\ldots,n, \quad (8)$$

so that

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[5]An interesting alternative for updating matrices has recently been suggested by Golan *et al.* (1994).

[6]Stone used the term 'fabrication effect' instead of 'productivity effect'.

$$a_{ij}^{1} = r_i \, a_{ij}^{0} \, s_j \, d_{ij}, \qquad i,j = 1,.....,n. \quad (9)$$

This formulation shows how RAS is used as a descriptive tool to decompose input-output coefficient changes into the productivity effect, the average substitution effect, and the sector-specific substitution effect.

In general, the elements of $\hat{r}$ and $\hat{s}$ will not be equal to the mere ratios of change of the row averages ρ_i and column sums σ_j of $\mathbf{A_0}$, with

$$\rho_i = \frac{\sum_j a_{ij}^{1} x_j^{1}}{\sum_j a_{ij}^{0} x_j^{1}} \quad \text{and} \quad \sigma_j = \frac{\sum_i a_{ij}^{1}}{\sum_i a_{ij}^{0}} \qquad i,j = 1,.....,n, \quad (10)$$

respectively. Each of the expressions in (10) focuses on only one side of the picture, either rows or columns, neglecting the interaction between them. For instance, it may happen (examples are easily constructed) that $s_j > 1$, while $\sigma_j = 1$. The simultaneity of productivity effects and average substitution effects induces that for this particular sector the productivity effect is offset by the average substitution effect. Note that either ρ_i or σ_j are used to as the first iterative step of the RAS method. As such σ_j can for example be interpreted as a first approximation of s_j (Van der Linden, 1993).

A problem with the RAS method is the non-uniqueness of the outcomes $\hat{r}$ and $\hat{s}$. As already mentioned above, the solution of (7) is parametric, the outcomes being only unique up to a scalar. It matters for example whether the solution algorithm begins with a row or a column operation. It is easily seen that when $\hat{r}$ and $\hat{s}$ satisfy (7), any $\lambda\hat{r}$ and $\lambda^{-1}\hat{s}$ will also satisfy (7). In other words, a sector for which we find a productivity increase might have shown a productivity decrease when the iterative procedure was begun in another way. This suggests that the method generates outcomes with some degree of arbitrariness.

Economically speaking, however, it seems plausible to require that the sum of all substitution effects equals zero. The reason for this is that substitution essentially involves the interchange of two or more inputs without any net 'gain' or 'loss' in total inputs. Hence, the total intermediate use should be the same as in the case in which no substitution would have occurred,

$$\frac{\boldsymbol{r}'\boldsymbol{A}_0\hat{\boldsymbol{s}}\boldsymbol{x}_1}{\boldsymbol{e}'\boldsymbol{A}_0\hat{\boldsymbol{s}}\boldsymbol{x}_1} = 1, \qquad \text{or} \qquad \frac{\boldsymbol{e}'\boldsymbol{u}_1}{\boldsymbol{e}'\hat{\boldsymbol{r}}^{-1}\boldsymbol{u}_1} = 1, \tag{11}$$

which is a weighted average of the substitution effects, r_i, (i = 1,.....,n). The numerator of (11) expresses the total intermediate deliveries of period 1, the denominator the total intermediate deliveries as corrected for substitution. This condition 'closes' the model of (5) to solve for unique values of r_i and s_j (i,j = 1,.....,n).

3. Empirical Analysis of Technological Change

In the previous section, a theoretical account was given of the interpretation of the RAS method for the analysis of technological development in an input-output context. Before we present the details of the European input-output tables, to which we have applied the decomposition, we discuss some of the limitations of the data.

For several reasons, a theoretically 'ideal' decomposition of technological change as given in the previous section cannot be given for most input-output tables. The most important of these are the level of aggregation and the valuation of the transactions. Both limitations also hold for the European input-output tables that we have used.

In actual input-output tables, all economic activities are usually aggregated into only some tens of sectors. Though account is of course taken of the congeniality of products or production processes, the nature of the sectors is usually not very homogeneous (United Nations, 1973; Carter, 1970). The output of a sector consists of several types of commodities, produced by different technologies. Moreover, different technologies may be used for the production of one type of commodity. This implies that what we refer to as ’technological development’ may also involve a change in the composition of the output of a sector. Using detailed make-and-use tables (Oosterhaven, 1984) or the *ex ante* method of interviewing technicians (Fisher, 1975) or managers (Miernyk, 1977) would provide a more elaborate picture of technological development.

Many input-output tables are valued in current prices. If technological development is analyzed from a series of such tables, the effects of relative price changes can thus not be singled out. Applying our decomposition then implies that we are rather analyzing cost structures instead of technology. The ’productivity’ changes therefore reflect profitability changes in the sense of gross margins between sales and purchases. In the following, we will therefore use the more general notion of ’intensity in the use of primary inputs’. The ’substitution’ also involves changes in the prices of intermediate inputs. Like the analysis of make-and-use tables, analysis of input-output tables in constant prices would provide a more elaborate picture of technological development. We will nevertheless use the notion of ’substitution’.

The EU input structure is analyzed empirically for the period 1965-1985, using the harmonized input-output tables of the European Union (see Eurostat, 1970; 1978; 1983; 1986; 1992a-e). They are issued every five years, and are available for Germany, France, Italy, The Netherlands, Belgium, The United Kingdom and Denmark[7]. In these tables, all transactions are divided into three types of geographical origin: domestic, imported from EU countries, and imported from outside the EU. The domestic transactions are valued in current producers’ prices (= production cost + indirect taxes). The imports are valued in current ex-customs prices (= c.i.f. price + indirect taxes). For this study, the tables have been aggregated into 31 sectors (see Appendix A for the classification of sectors).

[7]For The Netherlands and Belgium there are no 1985 tables available. This study uses tables estimated by ourselves. Details are given in Van der Linden (1995) and Hoen (1994), respectively.

Because of the harmonization and the subdivision of imports (see Eurostat, 1976), the domestic and EU-imports tables of all member states can easily be aggregated into one consolidated input-output table for the Union as a whole. This allows for an analysis at the Union level. The only problems posed by this consolidation are the non-availability of tables for some member states, and the ex-customs valuation of the imports. This type of valuation is of course appropriate for national input-output modelling, but should be reassessed into producers' prices when the bilateral transactions are included in the 'domestic' Union transactions. Otherwise, the services contained in the c.i.f. price are incorporated into the goods transactions. For the same reason, the analysis of technological development demands for valuation in producers' prices. Only then, technical coefficients without some 'c.i.f.-bias' can be derived.

To this end, the RAS method is again an adequate tool, now for carrying out the reassessment. With the properly valued column of *exports* to other member states as a yardstick, the ex-customs values of the EU-*imports* are then approximately reassessed into producers' prices. Consequently, the imports from outside the EU are not reassessed. A part of the c.i.f.-bias thus remains, which is generally negligible. Van der Linden and Oosterhaven (1995) give the details of the construction method.

In the reassessed EU input-output tables, each column represents the cost structure of one sector. Table 1 gives a brief overview by summarizing the main coefficients in the period 1965-1985. Note that most sectors are dominated by only one or a few types of input, mostly their own outputs. In part this is caused by the relatively high level of aggregation of the tables.

4. The Empirical Results for the EU

The sector-specific intensity change Roughly speaking, the intensity of the use of primary inputs in the EU has on average risen moderately between 1965 and 1985. The use of agricultural products, minerals and metals in the production process has been substituted for the use of energy, office machines and services. These general observations hide a wealth of different productivity developments and substitutions per sector and per member state, which will be discussed in this section. Before going further into the empirical matter, however, it should be stressed once again that the results are only indicative. Because the input-output tables are valued in current prices, the effects of relative price changes could not be singled out.

4.1. The Primary Input Intensity Changes

The results for the primary input intensity changes are given in Table 2. The numbers in the middle part of this table are the elements of $\hat{s}$ as percentage changes, *i.e.* $100(s_j\text{-}1)$. The left (right) column in Table 2 presents each sector's column sum of intermediate input coefficients for the year 1965 (1985). The sectors are ranked according to the size of this column sum of coefficients in 1985. The bottom row gives the weighted averages of $100(s_j\text{-}1)$ and the 1965 (1985) coefficient sums respectively, with (end-year) output shares used as weights[8].

In interpreting the results, it should be noted that, if sector j's column sum for 1965 is multiplied with the corresponding s_j for each of the four periods, the result will in general be different from sector j's column sum for 1985. Equality would be obtained if the four values of σ_j as defined in (10) were used instead. As already stated, σ_j of (10) has a different meaning and cannot be interpreted as changes in the primary input intensity.

The intensity of the use of primary inputs in the EU has on average risen

[8]For example, for the period 1965-1970, this average is calculated as

$$100\left(\frac{\sum_j s_j x_j^{1970}}{\sum_j x_j^{1970}} - 1\right).$$

moderately between 1965 and 1985, indicating a growth of productivity. Note that about three quarters of the sectors showed a strong growth (i.e. $s_j > 1.1$) in at least one period. Of the 31 sectors, 14 had a persistent growth (i.e. $s_j \geq 1$ in each period). Five of these sectors (milk, meat, coal, agriculture, public utilities) had an average growth of more than 10%. Seven sectors (other food, textile, wood, machines, minerals, metal products, beverages) had an average growth between 5 and 10%, while two (chemicals and rubber) had a weak average growth (≤ 5%).

The remaining seventeen sectors faced a decline in one or more periods. In almost all cases, however, did the growth outweigh the declines. Average growth rates larger than 5% are reported for basic metals, tobacco, communication, paper, and building, despite a decline in at least one period. The average productivity growth was small (< 2%) for leather, electrical goods and transport, and negative for petroleum and lodging. The negative average growth of petroleum was solely caused by the severe decrease in the period 1975-80. For this sector as well as for public utilities, however, price changes have obscured the true productivity changes. A persistent decline, finally, was observed for other market services, which may be explained from a growing labour intensity.

Another aspect is the variation of the growth rates of a sector between the periods. Large fluctuations were found for basic metals, coal, petroleum, trade, tobacco, and communication. The smallest fluctuations were observed for textile, wood, rubber, minerals, agriculture, electrical goods, transport and public services.

When considered *period-by-period*, a major determinant of the economy-wide productivity growth of 1965-1970 seems to be the growth for trade, a sector which produces about ten percent of the Union's total output. Though this indeed suggests a significant productivity growth, one should keep in mind that the extensive use of intermediate inputs in this sector (see also Table 1) will give a relatively high value of s_j for a relatively small productivity increase. The same holds for tobacco, a very small sector producing only half a percent of the Union's output. In this period, there was a strong decline for basic metals and other market services.

The economy-wide intensity growth of 1970-1975 is more of a ’profitability’ than a ’productivity’ kind. It was mainly caused by the rising energy prices and subsequent recession, forcing down the profits. This was especially felt in the public utilities sector, but also in some ’traditional’ sectors like coal mining and basic metals. Some other sectors had a peak increase in this period too.

In 1975-1980 there was a moderate growth or a minor decline in almost all sectors, with agriculture, milk and other manufacturing at the upper, and most of the services sectors at the lower end. This may be reflective of the growing importance of the labour intensive business services. The decline for some services sectors in the other periods is in line with this observation. The only exception for this period was petroleum, which had a strongly falling primary input intensity as caused by an increasing profitability from the earlier price increases.

The 1980-1985 changes, finally, did not show a clear pattern. The economy-wide productivity growth was relatively strong, but some sectors showed remarkable fluctuations with respect to the previous period. This was especially the case for petroleum, leather, other manufacturing, building and lodging. Extension of the analysis to more recent periods might give more clarity on these developments[9].

When considered *country-by-country*, all member states must have had a more or less persistent productivity growth, but not synchronous. Table 3 gives the member states’ weighted average changes[10]. Most countries had a peak

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[9]The harmonized input-output tables of 1990 are not yet available.

[10]Analogously to the bottom row of Table 2, output shares are used as weights, but now for the individual member states,

$$100\left(\frac{\sum_j s_{kj} x_{kj}^{1970}}{\sum_j x_{kj}^{1970}} - 1\right) \qquad k = 1,.....,m,$$

growth in 1980-1985. Only the Italian productivity growth must have slowed down since 1975.

Behind the summary figures of Tables 2 and 3, there is a widely diversified pattern of sectoral productivity changes. Note that the results in Table 2 are obtained using tables that were aggregated over the countries. Table 3 gives summarized results in the sense that averages over the sectors are used. So, the patterns described above are merely an average, which may hide notable differences between the member states. Especially for tobacco, communication, public utilities and coal, the changes varied widely among the member states. In 1970-1975, for example, the change for public utilities varied between -6% in Belgium and +69% in Italy, with a standard deviation of 28%-points. 1980-1985, the change for coal varied between -8% in Italy and +87% in France, with a standard deviation of 36%-points. In other sectors, however, changes per member state deviated only little from the EU average, with standard deviations down to 3%-points. Among these sectors are chemicals, paper, leather, rubber and wood.

In the light of the European integration, one might wonder whether the productivity has converged or not. Assume that, before the integration begun, there were large differences between the productivity levels of the member states, but that they converged afterwards. If this assumption holds, it seems likely that the productivity *changes* would initially be different as well, indicating a catch-up. The changes would be strong in low-productivity member states, and less strong in high-productivity member states. When the convergence has completed, both the productivity levels and the productivity changes would be about the same in all member states.

Between 1965 and 1985, such a pattern was found only for about one third of the sectors, whereas the change in productivity for most of the remaining sectors was still diverging. For some sectors, this divergence restarted after an initial period of convergence. On the one hand, 1985 might be too early to serve as a yardstick for concluding on convergence, so the analysis needs to

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Where m is the number of member states.

be extended with more recent input-output tables. On the other hand, also the productivity levels themselves seem to diverge. The standard deviation of the average intermediate use did not fall, but rose instead, from 0.048 in 1965 to 0.061 in 1985[11]. This may, however, also indicate some intercountry specialization within sectors. In any case, the results clearly do not suggest a strong form of convergence[12].

4.2. The Economy-wide Pattern of Substitution

The patterns of substitution are analyzed by means of the changes in the average intensity of the use of intermediate inputs. These changes are given by the elements r_i of the matrix $\hat{\mathbf{r}}$. Table 4 presents these intermediate input changes as a percentage, that is as $100(r_i\text{-}1)$, in the middle part. The left (right) column reports each sector's average row coefficient in 1965 (1985). The sectors are ranked according to the average row coefficients of 1985. Similar to our observation for Table 2, it should be emphasized that in general the 1985 average row coefficient cannot be obtained by multiplying the 1965 average row coefficient with the corresponding values of r_i.

The results in Table 4 show that only the use of other market services has increased in each period. Persistent decreases were observed for eight sectors (agriculture, paper, other food, textile, communication, wood, coal, and beverages). The average row coefficient of other market services has quadrupled, while it has halved for petroleum and textile. For most goods and services, there were remarkable fluctuations in their use over time. Roughly speaking, there has been a substitution from the use of goods to the use of services and energy, at least in terms of costs. This does of course not mean in itself that less goods are

[11]This refers to the EU-5 only. If the United Kingdom and Denmark were taken into account too, the standard deviation would have been 0.066 in 1985.

[12]Using a 25-sector classification, Van der Linden and Dietzenbacher (1995) provide a detailed analysis of the changes in the standard deviations.

used in the respective production processes. It rather shows the increasing growth towards an economy dominated by services and information, thereby reducing the relative importance of goods. On the other hand, these tendencies also reflect the fluctuating relative prices of energy and other goods and services. Table 4 gives the results. Analogous to Table 2, it shows the elements of $\hat{\mathbf{r}}$ as percentage changes. The four middle columns do therefore not sum to zero, because they are not weighed with the average input coefficients. Again, the inputs are ranked according to the size of the average 1985 coefficients.

When considered *period-by-period*, Table 4 shows that the changes did not occur synchronously. In 1965-1970 a clear substitution towards commercially exploited services occurred, indicating a major step towards a post-industrial economy. The impressive increase of the use of other market services suggests the rise of a ’new’ sector, rendering services that were formerly incorporated in the activities of the manufacturing sectors[13]. One might, for example, think of contracting out activities as goods transport, debt-cashing, cleaning and the like. There also was an increase in the use of motor vehicles, trade, transport, milk and rubber, the former three of course being related to the increase of the services. Significant ’losers’ were public services (see also footnote 13), agricultural products, textiles, coal, public utilities and machines.

In 1970-1975 a substitution towards energy (petroleum and public utilities) occurred, while the increasing use of transport equipment and transport services stagnated. This is probably related to the rising energy prices. The use of other market services continued to increase strongly, now supplemented by an increased use of office machines. This latter increase, however, though indicating the growing importance of office machines and computers in the economy, only concerns a relatively small coefficient. The use of public services, agricultural products, textiles, coal and machines kept on declining, and the use of basic

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[13]This increase, combined with the equally remarkable decrease of the public services, may in part also be due to a reallocation of transactions in the input-output tables, or even to a statistical redefinition (see Eurostat, 1970; 1976). Nevertheless, the results for 1970-1985 support the suggestion of a spectacular rise of this sector.

metals, trade, building and meat contracted now too.

In 1975-1980 the pattern of substitution was less pronounced than before. The strong tendency towards petroleum and office machines continued, while the growth of the other market services slowed down. Against the background of the recession, the ’revival’ of the building activities is remarkable. As for these activities, however, it should be noted that most of their output is used as investment goods. This is a part of final demand to which our analysis does not extend. Most other goods, finally, were used less intensively.

In 1980-1985 there have been some remarkable changes in the pattern of substitution. The use of other market services kept on increasing, while the use of petroleum now strongly decreased. This may be caused by both falling energy prices and a more economic use of energy. The latter possibility does not seem to be the case since the use of public utilities has increased. There was also a remarkable increase in the use of public services and meat. The use of rubber decreased for the first time. The use of most other goods also kept on decreasing, as did the use of lodging and transport services.

When considered *country-by-country*, the changes for some sectors strongly differed between the member states. The variation in the elements r_i across countries is reflected by its standard deviation in each period. Averaging over time yields the average standard deviation. For public services it is as high as 105%-points which is caused by some exceptionally strong intensity changes. Also the average standard deviations for tobacco and office machines are large, 71 and 43%-points respectively. For 25 out of the 31 sectors, however, the average standard deviation is less than 30%-points. These results are comparable with the average standard deviations of the elements s_j in Section 4.1. For many basic goods (like agricultural products, basic metals, minerals, chemicals and wood) the member states’ intensity changes did not deviate much from the EU average.

Recall that Table 4 is based on calculations with the aggregated input-output table of the EU. Computations for the separate countries yield tables similar to Table 4. The observations from these country-specific tables can be summarized as follows. The remarkable 1965-1970 substitution between the other market services and public services occurred in all member states, the strongest in Belgium, and the weakest in Italy. In The Netherlands the use of transport services seemed to be favoured as well. In 1970-1975, The Netherlands had the strongest deviations of the EU substitution pattern, dominated by a strong increase in the use of public utilities and public services. In 1975-1980, Germany had the strongest deviations, but this was caused solely by an exceptionally strong increase in the use of public services. For most of the other sectors, the Dutch and Belgian deviations were the strongest. In particular the increases in the use of transport and transport equipment were dominant. In 1980-1985 finally, The Netherlands again had the strongest deviations from the EU pattern, now dominated by increases in the use of meat, milk and some services, and a notable decrease in the use of office machines.

4.3. The Sector-specific Intensity Changes

The sector-specific component of intensity change involves a wealth of data for sector-specific and/or country-specific studies. This section only indicates the most salient changes at the EU level. As such, it could serve as an incentive for more detailed studies.

The analysis of the sector-specific changes is closely related to the issue of accurateness of the RAS method (see Allen and Gossling, 1975). The accurateness of the method is reflected by the extent to which the new technical coefficients matrix ($\boldsymbol{A_1}$) is determined by the first two components ($\boldsymbol{\tilde{A}_1}$) only. For this purpose, the sample determination coefficient (R^2) could be used as an indicator of accurateness

$$\boldsymbol{R}^2 = \frac{\left[\Sigma_{ij}(a_{ij}^1 - a^1)(\tilde{a}_{ij}^1 - \tilde{a}^1)\right]^2}{\left[\Sigma_{ij}(a_{ij}^1 - a^1)^2\right]\left[\Sigma_{ij}(\tilde{a}_{ij}^1 - \tilde{a}^1)^2\right]}, \tag{12}$$

in which

$$\boldsymbol{a}^1 = \Sigma_{ij} \boldsymbol{a}^1_{ij} \ / \ n^2 \qquad \text{and} \ \tilde{\boldsymbol{a}}^1 = \Sigma_{ij} \tilde{\boldsymbol{a}}^1_{ij} \ / \ n^2 .$$

In ordinary correlation analysis 100*R^2 is interpreted as the percentage of the total variation in the $\boldsymbol{a}^1_{ij}$'s which is accounted for by the (linear) relationship with $\tilde{\boldsymbol{a}}^1_{ij}$.

In the present case we have used an adapted R^2. Since we are estimating average input coefficients, it is more important that coefficients of large sectors are weighted heavier than coefficients of small sectors. Therefore, each coefficient is weighted with its sectors' output share $x^1_j/\Sigma_j x^1_j$. This actually comes down to analyzing the accuracy of the new intermediate deliveries plus imports table. The results are given in Table 5 and show that for no country and period the RAS estimation explained the true table for less than 90%[14]. So, for purposes of updating input-output tables, RAS can be considered to give quite reliable estimations given the limited information available. For our purpose, there nevertheless remains scope for analyzing the sector-specific intensity changes, *i.e.* the part of the input substitution that is not explained by economy-wide changes.

It should be noted that it is not adequate to take into account only the multiplicative component as in (8). A relatively small sector-specific change of a small coefficient may, for example, give a relatively large d_{ij}. A relatively large sector-specific change of a large coefficient may give a relatively small d_{ij}. Hence, also the additive counterpart of (8),

$$\boldsymbol{d}^*_{ij} = \boldsymbol{a}^1_{ij} - \tilde{\boldsymbol{a}}^1_{ij}, \qquad i,j = 1,.....,n. \qquad (13)$$

must be taken into account. This alternative expression also applies in cases of

[14]In the unweighted version, the lowest result was very high as well, 83%.

zero division. If some coefficient a_{ij}^0 is zero, $\tilde{a}_{ij}^1 = r_i a_{ij}^0 s_j$ will also be zero, and d_{ij} can not be calculated. If the corresponding a_{ij}^1 is non-zero, then d_{ij}^* in (13) indicates the emergence of input i in sector j[15].

The sector-specific intensity change *enhances* the economy-wide change when the actual change in coefficient a_{ij}^1 is stronger than the economy-wide change. The sector-specific intensity change is *absent* when the actual change is equal to the economy-wide change. The sector-specific intensity change *neutralizes* the economy-wide change when the actual coefficient a_{ij}^1 resembles a_{ij}^0 more than the estimation $\tilde{a}_{ij}^1$ does. It is partly neutralizing when a_{ij}^1 is between a_{ij}^0 and $\tilde{a}_{ij}^1$. It is fully neutralizing when the actual coefficient had not changed between period 0 and 1. It may even be more than neutralizing when the actual coefficient change points in the other direction than the estimated change. Hence, five cases can principally be distinguished:

1. Enhancing:

$$a_{ij}^1 > \tilde{a}_{ij}^1 > a_{ij}^0 \quad (d_{ij}^* > 0) \qquad \text{or } a_{ij}^1 < \tilde{a}_{ij}^1 < a_{ij}^0 \quad (d_{ij}^* < 0)$$

2. Absent:

$$a_{ij}^1 \approx \tilde{a}_{ij}^1 > a_{ij}^0 \quad (d_{ij}^* \approx 0) \qquad \text{or } a_{ij}^1 \approx \tilde{a}_{ij}^1 < a_{ij}^0 \quad (d_{ij}^* \approx 0)$$

3. Partly neutralizing:

$$\tilde{a}_{ij}^1 > a_{ij}^1 > a_{ij}^0 \quad (d_{ij}^* < 0) \qquad \text{or } \tilde{a}_{ij}^1 < a_{ij}^1 < a_{ij}^0 \quad (d_{ij}^* > 0)$$

[15] Statistically, such an ’emergence’ should be interpreted as the rise of that intermediate delivery above some threshold, for example above 500.000 ECUs.

4. Fully neutralizing:

$$\tilde{a}_{ij}^{1} > a_{ij}^{1} \approx a_{ij}^{0} \quad (d_{ij}^{*} < 0) \qquad \text{or } \tilde{a}_{ij}^{1} < a_{ij}^{1} \approx a_{ij}^{0} \quad (d_{ij}^{*} > 0)$$

5. More than neutralizing:

$$\tilde{a}_{ij}^{1} > a_{ij}^{0} > a_{ij}^{1} \quad (d_{ij}^{*} < 0) \qquad \text{or } \tilde{a}_{ij}^{1} < a_{ij}^{0} < a_{ij}^{1} \quad (d_{ij}^{*} > 0)$$

A sixth case would be case that $\tilde{a}_{ij}^{1} \approx a_{ij}^{0}$. It needs, however, not be considered separately, because its interpretation resembles that of case 1 (or 2, should the case arise). In the remainder of this section we briefly discuss the most interesting results. For most of the 31 sectors j, some remarkable values of d_{ij} or d_{ij}^{*} are reported on.

For *agriculture*, the use of agricultural products decreased stronger than in the economy as a whole, in favour of especially food, petroleum and chemicals. This reflects the more intensive use of industrially processed cattle-feeds and chemical herbicides. The sector-specific intensity change of agricultural goods can therefore be classified as ’enhancing’. In the 1980s, however, the substitution between agricultural products and food completely ceased.

For *coal*, there were neutralizing sector-specific components for coal and public utilities, except for 1975-1980, when the use of coal fell much more than the economy-wide decrease. Besides, there were positive components for machines, which might indicate some mechanisation in mining techniques.

The *petroleum* sector involves not only the extraction of oil and gas, but also the further processing into secondary energy products such as gasoline. Therefore, it has felt a very strong influence of the relative price changes. In the period 1970-1975 the sector-specific component d_{ij} was 1.09 (2.6%-points in terms of d_{ij}^{*}), in 1980-1985 it was 0.96 (-1.7%-points). This sector thus caused a bias to the economy-wide intensity change of petroleum, implying a neutralizing, but virtually zero, specific intensity change in other sectors. The share of most other inputs in the cost structure of the Fuels sector of course decreased in 1970-1975 and increased in 1980-1985.

Like petroleum, *public utilities* felt a strong influence of the price changes of oil, but it was less than in the petroleum sector itself. After 1975, however, the cost share of petroleum stabilized, giving a negative sector-specific component up to 1980, and a positive thereafter. The use of coal strongly fell, except for 1975-1980 when oil prices were high. In that period, there seemed to be a reversed substitution towards coal.

Basic metals had a persistent decrease in the use of basic metals, but by far not as strong as in the other sectors. So, the accompanying sector-specific components were neutralizing. As some other important inputs - coal and public utilities - had neutralizing components too, this sector may thus be an example of a matured sector with hardly any room left for major innovations. There were only some sector-specific fluctuations in the use of transport and trade services

During 1965-1970, *minerals* had a very strong increase in the relative use of its own output (1.45, 4.6%-points!), compensated by a relative decrease in the use of especially chemicals, trade and metal products. After 1970 there were no large sector-specific input substitutions, and they were mostly fluctuating.

The use of basic metals for *metal products* initially increased, but decreased strongly afterwards, in both cases stronger than the average. The same held for the use of metal products, especially before 1975.

For *machines* the use of its own output and of other market services strongly increased, the use of basic metals and metal products decreased. In most of the cases, the changes were enhancing the economy-wide changes. This suggests the growing complexity of the machines and installations built in this innovative sector. It does not suggest the use of other materials as inputs to the products of this sector.

Virtually the same held for *office machines*, though the increasing use of its own output strongly fell behind the economy-wide increases of 1970-1980. The increase of the use of other market services was well above the economy-wide increase, up to 2.4%-points (2.87) of the coefficient in 1975-1980. In 1980-1985, there was a notable increase in the use of paper.

For *electrical goods* too, the use of its own output and of other market services strongly increased, and the use of basic metals decreased. In most of the cases, the changes were again enhancing the economy-wide changes. In this sector, however, the changes did not occur synchronous. Before 1975, the use of electrical goods increased strongly. After 1975, it stagnated and even declined, whereas the use of the other market services begun to increase then.

For *motor vehicles*, the use of its own output had neutralizing components. This may indicate a stable need for parts, whereas in the other sectors the need for the final products of this sector is fluctuating. The use of basic metals fell more than average.

In 1965-1970, *other transport equipment* had a very strong sector specific substitution from basic metals, metal products and rubber to other transport equipment. This might indicate some vertical integration within this sector[16]. In 1980-1985 there was a sector-specific substitution from machines towards electrical goods. This might indicate a growing complexity of the equipment.

In 1970-1975, *meat* had a sector specific substitution from meat towards agricultural products. In 1980-1985 it faced a very strong substitution in the

[16]Again, a statistical redefinition may be the cause too, especially because this sector hardly showed any further deviations from the economy-wide pattern of substitution.

other direction.

For *milk* there was an enhancing substitution from agricultural products towards milk and other food in all four periods. The economy-wide decrease of the use of other food was even more than neutralizing. This might indicate the growing importance of milk products instead of milk proper.

For *other food* the opposite has happened. The use of other food fell more than the economy-wide average, while the use of agricultural products fell less.

Beverages took hardly part in the decreasing use of agricultural products too. The use of chemicals decreased instead.

Before 1975, *tobacco* hardly deviated from the economy-wide pattern of substitution. Afterwards, there was a sector-specific increase of other market services, and a decrease of agricultural products.

During the 1970s, the sector-specific components of *textile* had somewhat neutralizing tendencies from the economy-wide intensity change towards the 1970 input structure. Like basic metals, this may also be an example of a matured sector with only little room for innovations. Only the substitution from agricultural products to various services is somewhat notable, and may reflect the migration of the early production stages of this sector to developing countries.

Likewise, the sector specific components of *leather* were mostly neutralizing too. Only for 1965-1970 and 1975-1980 the decrease of agricultural products was more than the economy-wide average.

The use of wood in the *wood* sector had strong positive sector-specific components. It thus remained about constant. The use of agricultural products strongly declined. The use of rubber strongly increased. This suggests a growing complexity of the sectors' products, and the use of recycled materials.

For *rubber*, there was a strong sector-specific substitution from chemical products to rubber in 1965-1970 (both about 4.5%-points). After 1970, there has been little deviation from the economy-wide pattern, only the use of chemicals stayed behind the average.

Other manufacturing had a very unstable pattern of intensity change. It had strong fluctuations, especially for metal products and machines, Nevertheless, there was a tendency to the use of less rubber and textiles, and more basic metals, electrical goods and other market services.

For *building*, the use of metal products, rubber and trade decreased relative to the economy-wide pattern, whereas the use of building and other market services increased. This latter increase may be caused by a growth of subcontracting. The relative use of minerals, its most important input, fluctuated somewhat.

Lodging had neutralizing sector-specific components of agricultural products and trade. The use of beverages surprisingly decreased stronger than in the other sectors. Besides some recent deviations for other market services and public services, the intensity changes were close to the economy-wide changes.

Transport had neutralizing sector-specific components of petroleum, which thus had quite constant cost shares in this sector. This might indicate a rapid reaction to the price changes. In 1965-1970 the use of its own outputs increased strongly, that of building and other market services decreased. The use of motor vehicles fluctuated, with a peak notably in 1970-1975.

In three of the four periods, the use of communication services for *communication* increased, while the increase of other market services fell behind the economy-wide increase. In one period, 1970-1975, the opposite happened.

Public services has only small intermediate input coefficients (together about 0.3), and has had very small deviations from the economy-wide pattern. The only significant difference was found in 1980-1985, where the use of other market services fell behind, and the use of public services firmly stayed ahead of that pattern.

For the remaining four sectors, *chemicals*, *paper*, *trade* and *other market services*, there were hardly any changes from the economy-wide pattern.

Looking back to this long list of brief results, it can be said that, at the EU level, no sector had a clear substitution pattern between 1965 and 1985. Instead, there seemed to be a high level of volatility in the respective cost structures. This was especially true for the use of services inputs, that mostly had very strong fluctuations. The volatility may reflect ever changing relative prices or, indeed, the innovative character of many sectors.

Nevertheless, some tendencies could be found. First, the use of energy did not increase too much, except in the energy sectors themselves. This possibly indicates an early reaction to the price increases of oil during the 1970s. Second, matured sectors may stop being innovative, while young sectors may have very unstable patterns of substitution. Finally, the method we used is vulnerable to the effects of exceptionally large sector-specific coefficient changes in only one or a few sectors.

5. Summary and Conclusion

The method applied in this paper to quantify technological development in input-output tables is built on the RAS method, borrowed from the literature on updating input-output tables. In the past there have been serious doubts about the adequacy of RAS for such a purpose. In this paper it is argued that for the purposes of measuring (in contrast to forecasting) the RAS method may be a useful tool. The well-known problem of the non-uniqueness of the solution is solved by adopting an economically plausible scaling technique. The method proposed in this paper decomposes the technological development into a productivity effect, an economy-wide substitution effect and a sector-specific substitution effect.

The empirical analysis is applied to the harmonized input-output tables of the EU, for five-year periods from 1965 to 1985. The nature of these data does not allow the analysis of technological change properly, but rather that of changes in cost structure. Nevertheless, the results indicate productivity increases in almost all sectors throughout the EU. Especially in the agriculture, minerals, metal products, food and building sectors, the increases were relatively strong, up to about 2% per year. In contrast to traditional methods, that analyze the sensitivity of the input-output model to hypothesized coefficient changes, the present approach sketches a rough picture of the underlying sources of the actual coefficient changes.

The results also show an economy-wide substitution from the use of goods to the use of services and energy. For some sectors the intermediate input substitution was more or less the same as the economy-wide substitution, so there was hardly any sector-specific substitution. Among them are chemicals, paper, trade and other market services. In other sectors, the substitution was clearly different than the economy-wide substitution. Among these are petroleum, public utilities, minerals, office machines and rubber. For basic metals and textile, finally, there was hardly any substitution. In the analysis this is shown by sector-specific substitution components that neutralize the economy-wide components. These results also augment the Structural Decomposition method by analyzing the nature of the structural changes.

Furthermore, the results show that there are large variations between the member states of the EU as regards technological (or cost) changes. Finally, for these data RAS appears to be making accurate estimations of five year ahead input-output tables.

References

Afrasiabi, A., and S.D. Casler, 1991, Product-Mix and Technological Change within the Leontief Inverse. *Journal of Regional Science*, Vol.31, pp.147-160.

Allen, R.I.G, and W.F. Gossling (Eds.), 1975, *Estimating and Projecting Input-Output Coefficients*. Input-Output Publishing Company, London.

Bacharach, M., 1970, *Biproportional Matrices and Input-Output Change*. Cambridge University Press, London.

Barker, T., 1990, Sources of Structural Change for the UK Service Industries 1979-84. *Economic Systems Research*, Vol.2, pp.173-183.

Blair, P.D., and A.W. Wyckoff, 1989, The Changing Structure of the U.S. Economy: An Input-Output Analysis. In R.E. Miller, K.R. Polenske and A.Z. Rose (Eds.), *Frontiers of Input-Output Analysis*, pp.293-307. Oxford University Press, New York.

Bullard, C.W., and A.V. Sebald, 1977, Effects of Parametric Uncertainty and Technological Change on Input-Output Models. *Review of Economics and Statistics*, Vol.59, pp.75-81.

Bullard, C.W., and A.V. Sebald, 1988, Monte Carlo Sensitivity Analysis of Input-Output Models. *Review of Economics and Statistics*, Vol.70, pp.708-712.

Carter, A.P., 1970, *Structural Change in the American Economy*. Harvard University Press, Cambridge.

Cuello, F.A., F. Mansouri and G.J.D. Hewings, 1992, The Identification of Structure at the Sectoral Level: A Reformulation of the Hirschman-Rasmussen Key-Sector Indices. *Economic Systems Research*, Vol.4, pp.285-296.

Defourny, J., and E. Thorbecke, 1984, Structural Path Analysis and Multiplier Decomposition within a Social Accounting Matrix Framework. *Economic Journal*, Vol.94, pp.111-136.

Dietzenbacher, E., and B. Los, 1995, Analyzing Decomposition Analyses. In A.

Simonovits and A.E. Steenge (Eds.), *Prices, Growth and Cycles - Essays in Honour of Andràs Bródy*, forthcoming. Macmillan, London.

Eurostat, 1970, *Tableaux Entrées-Sorties 1965, Communauté Economique Européenne*. Série spéciale 7-1970, Luxembourg.

Eurostat, 1976, *Methodologie voor de Communautaire Input-Output Tabellen 1970-1975*. Speciale serie 1-1976, Luxemburg.

Eurostat, 1978, *Input-Output Tables, the Nine and the Community, 1970*. Special series 8-1978, Luxembourg.

Eurostat, 1983, *National Accounts ESA, Input-Output Tables 1975*. Luxembourg.

Eurostat, 1986, *National Accounts ESA, Input-Output Tables 1980*. Luxembourg.

Eurostat, 1992a, *National Accounts ESA, Input-Output Tables for Denmark 1985*. Luxemburg.

Eurostat, 1992b, *National Accounts ESA, Input-Output Tables for France 1985*. Luxemburg.

Eurostat, 1992c, *National Accounts ESA, Input-Output Tables for Germany 1985*. Luxemburg.

Eurostat, 1992d, *National Accounts ESA, Input-Output Tables for Ireland 1985*. Luxemburg.

Eurostat, 1992e, *National Accounts ESA, Input-Output Tables for Italy 1985*. Luxemburg.

Feldman, S.J., D. McClain and K. Palmer, 1987, Sources of Structural Change in the United States, 1963-1978: An Input-Output Perspective. *Review of Economics and Statistics*, Vol.69, pp.503-510.

Fisher, W.H., 1975, Ex Ante as a Supplement or Alternative to RAS in Updating Input-Output Coefficients. In R.I.G. Allen and W.F. Gossling (Eds.), *Estimating and Projecting Input-Output Coefficients*, pp.94-97. Input-Output Publishing Company, London.

Fujita, N., and W.E. James, 1991, Growth Patterns of the Japanese Economy in the 1980s: Before and After the Depreciation of the Yen. *Economic Systems Research*, Vol.3, pp.399-412.

Golan, A., G. Judge and S. Robinson, 1994, Recovering Information from Incomplete or Partial Multisectoral Economic Data. *Review of Economics* *and Statistics*, Vol.76, pp.541-549.

Grossman, G.M., and E. Helpman, 1990, Comparative Advantage and Long-Run Growth. *American Economic Review*, Vol.80, pp.796-815.

Hewings, G.J.D., 1984, The Role of Prior Information in Updating Regional Input-Output Models. *Socio-Economic Planning Sciences*, Vol.18, pp.319-336.

Hewings, G.J.D., M. Fonseca, J. Guilhoto and M. Sonis, 1989, Key Sectors and Structural Change in the Brazilian Economy: A Comparison of Alternative Approaches and their Policy Implications. *Journal of Policy Modeling*, Vol.11, pp.67-90.

Hoen, A.R., 1994, *Constructie van de Input-Output Tabel van 1985 voor België*. Mimeo, Rijksuniversiteit Groningen.

Jensen, R.C., and G.R. West, 1980, The Effects of Relative Coefficient Size on Input-Output Multipliers. *Environment and Planning A*, Vol.12, pp.659-670.

Kanemitsu, H., and H. Ohnishi, 1989, An Input-Output Analysis of Technological Changes in the Japanese Economy: 1970-1980. In R.E. Miller, K.R. Polenske and A.Z. Rose (Eds.), *Frontiers of Input-Output Analysis*, pp.308-323. Oxford University Press, New York.

Lecomber, J.R.C., 1975, A Critique of Methods of Adjusting, Updating and Projecting Matrices. In R.I.G. Allen and W.F. Gossling (Eds.), *Estimating and Projecting Input-Output Coefficients*, pp.43-56. Input-Output Publishing Company, London.

Lin, X., and K.R. Polenske, 1995, Input-Output Anatomy of China's Energy-Demand Change. *Economic Systems Research*, Vol.7, forthcoming.

Linden, J.A. van der, 1993, *The Nature of Changes in the EC Production Structure 1965-1980: A RAS Approach*. Paper presented at the 34th European RSA Congress, Groningen, University of Groningen.

Linden, J.A. van der, 1995, *Note on the Construction of a 1985 Input-Output Table for The Netherlands, by "Downdating" the 1987 Eurostat Table*. Mimeo, University of Groningen.

Linden, J.A. van der, and E. Dietzenbacher, 1995, The Nature of Changes in the

EU Cost Structure of Production 1965-85: An RAS Approach. Forthcoming in H. Armstrong and R. Vickerman (Eds.), *Convergence and Divergence among European Regional Economies*. Pion, London.

Linden, J.A. van der, and J. Oosterhaven, 1993, *Intercountry EC Input-Output Relations: An Income Growth Decomposition for 1970-1980*. Paper presented at the 10th International Input-Output Conference Seville, March 1993.

Linden, J.A. van der, and J. Oosterhaven, 1995, Intercountry EC Input-Output Relations: Construction Method and Main Results for 1965-1985. *Economic Systems Research*, Vol.7. pp.249-169.

Linden, J.A. van der, J. Oosterhaven, F.A. Cuello, G.J.D. Hewings and M. Sonis, 1995, Fields of Influence of Technological Change in EC Intercountry Input-Output Tables, 1970-80. *SOM Research Reports*, No.95D17.

Lynch, R.G., 1986, An Assessment of the RAS Method for Updating Input-Output Tables. In I. Sohn (Ed.), *Readings in Input-Output Analysis: Theory and Applications*, pp.271-284. Oxford University Press, New York.

MacGill, S.M., 1977, Theoretical Properties of Biproportional Matrix Adjustments. *Environment and Planning A*, Vol.9, pp.687-701.

Maddison, A., 1991, *Dynamic Forces in Capitalist Development*. Oxford University Press, Oxford.

Miernyk, W.H., 1977, The Projection of Technical Coefficients for Medium-Term Forecasting. In W.F. Gossling (Ed.), *Medium-Term Dynamic Forecasting, The 1975 London Input-Output Conference*, pp.29-42. Input-Output Publishing Company, London.

Miller, R.E., and P.D. Blair, 1985, *Input-Output Analysis, Foundations and Extensions*. Prentice-Hall, Englewood Cliffs.

Miller, R.E., and G. Shao, 1994, Structural Change in the US Multiregional Economy. *Structural Change and Economic Dynamics*, Vol.5, pp.41-72.

Oosterhaven, J., 1984, A Family of Square and Rectangular Interregional Input-Output Tables and Models, *Regional Science and Urban Economics*, Vol.14, p.565-582.

Oosterhaven, J., J.A. van der Linden and A.R. Hoen, 1995, *European Technology, Trade and Income Changes for 1975-1985: An EC Intercountry Input-Output Decomposition* Paper to be presented at the 11th International Input-Output Conference Delhi, November 1995. University of Groningen.

Romer, P.M., 1986, Increasing Returns and Long-Run Growth. *Journal of Political Economy*, Vol.94, pp.1002-1037.

Rose, A., and Miernyk, W., 1989, Input-Output Analysis: The First Fifty Years. *Economic Systems Research*, Vol.1, pp.229-271.

Round, J.I., 1985, Decomposing Multipliers for Economic Systems involving Regional and World Trade. *Economic Journal*, Vol.95, pp.383-399.

Schnitke, J., and R. Stäglin, 1988, Important Input Coefficients in Market Transactions Tables and Production Flow Tables. In M. Ciaschini (Ed.), *Input-Output Analysis - Current Developments*, pp.43-60. Chapman & Hall, London.

Schumann, J., 1994, Does it Make Sense to Apply the Static Open Input-Output Model for Imputation and Structural Decomposition?, *Economic Systems Research*, Vol.6, pp.171-178.

Sherman, J., and W.J. Morrison, 1950, Adjustment of an Inverse Matrix Corresponding to a Change in one Element of a Given Matrix. *Annals of Mathematical Statistics*, Vol.21, pp.124-127.

Skolka, J., 1989, Input-Output Structural Decomposition Analysis for Austria. *Journal of Policy Modelling*, Vol.11, pp.45-66.

Solow, R.M., 1956, A Contribution to the Theory of Economic Growth. *Quarterly Journal of Economics*, Vol.3, pp.65-94.

Sonis, M., and G.J.D. Hewings, 1989, Error and Sensitivity in Input-Output Analysis: A New Approach. In R.E. Miller, K.R. Polenske and A.Z. Rose (Eds.), *Frontiers of Input-Output Analysis*, pp.232-244. Oxford Press, New York.

Sonis, M., and G.J.D. Hewings, 1992, Coefficient Change in Input-Output Models: Theory and Applications. *Economic Systems Research*, Vol.4, pp.143-157.

Stone, R. (Ed.), 1963, *Input-Output Relationships, 1954-1966, A Programme for Growth*, Vol.3. Chapman and Hall, London.

United Nations, 1973, Input-Output Tables and Analysis. *Studies in Methods*, Series F, No.14a. New York.

West, G.R., 1981, An Efficient Approach to the Estimation of Regional Input-Output Multipliers. *Environment and Planning A*, Vol.13, pp.857-867.

West, G.R., 1982, Sensitivity and Key Sector Analysis in Input-Output Models. *Australian Economic Papers*, Vol.21, pp.365-378.

Wolff, E.N., 1985, Industrial Composition, Interindustry Effects, and the U.S. Productivity Slowdown. *Review of Economics and Statistics*, Vol.67, pp.268-277.

Wolff, E.N., 1994, Productivity Measurement within an Input-Output Framework. *Regional Science and Urban Economics*, Vol.24, pp.75-92.

Appendix: Specification of Sector Labels

1.	Agriculture	Agricultural, forestry and fishing products
2.	Coal	Coal, lignite and cokes
3.	Petroleum	Crude and refined petroleum, and natural gas
4.	Public utilities	Electricity, distributed gas, steam, water and compressed air
5.	Basic metals	Metallic and nuclear ores, and basic metal products
6.	Minerals	Basic and processed salt, stone, clay and glass
7.	Chemicals	Basic and processed chemical products
8.	Metal products	Processed metals, tanks and tools
9.	Machines	Agricultural and industrial machines, and parts thereof
10.	Office machines	Office machines, computers and instruments
11.	Electrical goods	Electrical installations and apparatuses, and parts thereof
12.	Motor vehicles	Motor vehicles and parts thereof
13.	Other transport equipment	Other transport equipment and parts thereof
14.	Meat	Meat and products thereof
15.	Milk	Milk and products thereof
16.	Other food	Other food products
17.	Beverages	Alcohol products and beverages
18.	Tobacco	Tobacco products
19.	Textile	Textiles and products thereof
20.	Leather	Leather and products thereof
21.	Wood	Wood, wooden products and furniture
22.	Paper	Paper and printing products
23.	Rubber	Rubber and plastic products
24.	Other manufacturing	Jewelry, musical instruments, photos and toys
25.	Building	Building and construction works, and demolition
26.	Trade	Trade, recycling and repair services
27.	Lodging	Lodging and catering services
28.	Transport	Transport and transport related services
29.	Communication	Communication services
30.	Other market services	Financial, rental and other commercial services
31.	Public services	Education, health, government and other non-commercial services

Table 1: Main features of EU technical structure, 1965-1985.

Average technical coefficients 1965-1985	1 Agriculture (Agri)	2 Coal (Coal)	3 Petroleum (Petr)	4 Public utilities (Util)	5 Basic metals (BMet)	6 Minerals (Mine)	7 Chemicals (Chem)	8 Metal products (MetP)
Most important inputs	Agri 0.18 OFoo 0.11 Chem 0.05 Trad 0.04	Coal 0.27 Util 0.06 Mach 0.03 Buil 0.03	Petr 0.45	Petr 0.12 Coal 0.10 Util 0.08	BMet 0.47 Trad 0.08 Coal 0.04 Util 0.04 Trsp 0.03	Mine 0.14 Petr 0.05 Trsp 0.05 Trad 0.04 Util 0.04 MSer 0.03 Chem 0.03	Chem 0.28 Petr 0.06 MSer 0.04 Util 0.04 Trad 0.03 Trsp 0.03 Pape 0.03	BMet 0.22 MetP 0.09 Trad 0.04 MSer 0.03
Other	0.12	0.18	0.10	0.15	0.10	0.12	0.15	0.16
Value added	0.50	0.44	0.46	0.55	0.23	0.50	0.35	0.46

	17 Beverages (Beve)	18 Tobacco (Toba)	19 Textile (Text)	20 Leather (Leat)	21 Wood (Wood)	22 Paper (Pape)	23 Rubber (Rubb)	24 Other manufact. (OMan)
Most important inputs	Agri 0.08 Beve 0.06 OFoo 0.05 Trad 0.04 MSer 0.04 Trsp 0.03 Mine 0.03	Agri 0.10 Pape 0.03	Text 0.34 Chem 0.07 Trad 0.04 Agri 0.04 MSer 0.03	Leat 0.20 Meat 0.08 Trad 0.05 Rubb 0.04 Text 0.04 Chem 0.04 MSer 0.03	Wood 0.22 Agri 0.08 Trad 0.05 MetP 0.03 MSer 0.03 Chem 0.03 Text 0.03 Rubb 0.03	Pape 0.31 Trad 0.04 MSer 0.04 Chem 0.04 Trsp 0.03	Chem 0.26 Rubb 0.06 Trad 0.03 MSer 0.03 Text 0.03	BMet 0.14 OMan 0.07 Rubb 0.04 Trad 0.04 Chem 0.03 MetP 0.03 MSer 0.03 Pape 0.03
Other	0.13	0.08	0.10	0.11	0.11	0.12	0.15	0.14
Value added	0.55	0.79	0.39	0.41	0.41	0.43	0.44	0.45

Table 1(*contd.*): Main features of EU technical structure, 1965-1985.

Average technical coefficients 1965-1985	9 Machines (Mach)	10 Office machines (OfMa)	11 Electrical goods (ElGo)	12 Motor vehicles (Moto)	13 Other transport equipment (OTra)	14 Meat (Meat)	15 Milk (Milk)	16 Other food (OFoo)
Most important inputs	Mach 0.12	OfMa 0.08	ElGo 0.15	Moto 0.17	OTra 0.12	Agri 0.63	Agri 0.66	Agri 0.29
	MetP 0.11	ElGo 0.07	BMet 0.09	MetP 0.09	BMet 0.08	Meat 0.06	Milk 0.03	OFoo 0.20
	BMet 0.09	MSer 0.05	MetP 0.05	BMet 0.08	MetP 0.08	Trad 0.05	Trad 0.03	Trad 0.04
	Trad 0.04	MetP 0.04	Trad 0.04	Rubb 0.05	Mach 0.06			Pape 0.03
	ElGo 0.04	BMet 0.04	MSer 0.04	Trad 0.04	ElGo 0.05			
	MSer 0.03	Trad 0.04	Rubb 0.03	ElGo 0.04	MSer 0.04			
			Chem 0.03	MSer 0.03	Trad 0.03			
Other	0.12	0.15	0.12	0.14	0.13	0.09	0.13	0.17
Value added	0.45	0.53	0.47	0.36	0.41	0.18	0.16	0.27

	25 Building (Buil)	26 Trade (Trad)	27 Lodging (Lodg)	28 Transport (Trsp)	29 Communi-cation (Comm)	30 Other market services (MSer)	31 Public services (PSer)	
Most important inputs	Mine 0.12	MSer 0.06	Beve 0.13	Trsp 0.12	MSer 0.03	MSer 0.27	PSer 0.04	
	Metp 0.05	Trsp 0.04	OFoo 0.09	Petr 0.09	ElGo 0.03	Buil 0.03	MSer 0.04	
	MSer 0.05	Trad 0.03	Trad 0.07	Trad 0.04		PSer 0.03		
	Wood 0.04		Meat 0.05	MSer 0.04				
	Buil 0.04		Agri 0.05					
	Trad 0.04		MSer 0.03					
	BMet 0.03							
Other	0.13	0.18	0.15	0.13	0.12	0.09	0.22	
Value added	0.50	0.69	0.43	0.57	0.82	0.59	0.71	

Table 2: Primary input changes in the EU (percentage changes).

Sectors	1965 column coeffi-cient	1965 | 1970	1970 | 1975	1975 | 1980	1980 | 1985	1985 column coeffi-cient
Milk	0.88	+12	+5	+15	+20	0.87
Meat	0.83	+20	+7	+12	+15	0.81
Basic metals	0.78	-9	+27	+10	+12	0.80
Other food	0.71	+14	+4	+9	+11	0.75
Chemicals	0.61	+0	+4	+11	+0	0.70
Motor vehicles	0.63	-6	+3	-0	+17	0.66
Textile	0.61	+11	+3	+9	+6	0.62
Paper	0.53	+5	+15	+7	-2	0.61
Coal	0.55	+2	+36	+2	+17	0.61
Wood	0.55	+11	+6	+11	+10	0.61
Rubber	0.53	+4	+0	+8	+5	0.61
Leather	0.59	-1	+7	+9	-8	0.60
Other transport equipment	0.55	+8	+10	-4	+1	0.59
Machines	0.53	+0	+12	+5	+9	0.58
Minerals	0.41	+13	+9	+6	+12	0.58
Metal products	0.51	+1	+12	+9	+13	0.57
Office machines	0.44	-8	+4	+7	+15	0.56
Petroleum	0.45	+2	+7	-25	+7	0.55
Agriculture	0.45	+15	+12	+14	+8	0.54
Other manufacturing	0.53	-5	+17	+15	-8	0.54
Building	0.48	-0	+10	-4	+16	0.54
Public utilities	0.35	+7	+18	+8	+11	0.53
Electrical goods	0.53	+4	-2	+2	+2	0.52
Transport	0.38	-6	+6	-1	+8	0.47
Beverages	0.41	+13	+9	+9	+3	0.47
Lodging	0.61	+3	-5	+10	-16	0.46
Other market services	0.41	-29	-16	-5	-2	0.44
Trade	0.26	+27	-9	+0	+2	0.32
Public services	0.29	+3	+4	-3	+5	0.31
Tobacco	0.19	+38	-5	+10	-4	0.18
Communication	0.13	+42	+0	-0	-10	0.18
All sectors	0.47	+4	+4	+1	+5	0.49

Table 3: Average primary input changes in the EU.

Member states	1965 | 1970	1970 | 1975	1975 | 1980	1980 | 1985
West-Germany	+7	+3	0	+12
France	+3	-1	+3	+5
Italy	+1	+12	+4	+1
The Netherlands	+7	+1	+7	+9
Belgium	-3	+6	+3	+4
United Kingdom			-2	+1
Denmark			+4	+6
EU-5	+4	+4		
EU-7			+1	+5

Table 4: Intermediate input changes in the EU (percentage changes).

Goods & services	1965 average row coeff.	1965 | 1970	1970 | 1975	1975 | 1980	1980 | 1985	1985 average row coeff.
Other market services	0.022	+99	+32	+6	+18	0.085
Petroleum	0.022	-0	+34	+25	-15	0.044
Trade	0.031	+19	-11	-6	+4	0.032
Chemicals	0.028	+2	+2	-6	+2	0.031
Agriculture	0.061	-21	-7	-15	-18	0.030
Basic metals	0.047	+6	-23	-11	-12	0.029
Transport	0.020	+15	-4	+6	-15	0.024
Paper	0.020	-2	-7	-7	-2	0.021
Public services	0.024	-76	-18	-13	+52	0.020
Public utilities	0.015	-10	+13	-9	+12	0.017
Metal products	0.023	+3	-2	-17	-15	0.017
Electrical goods	0.013	-7	+4	+7	-3	0.015
Other food	0.019	-3	-3	-15	-4	0.014
Building	0.011	-7	-21	+29	-16	0.013
Minerals	0.018	+2	-7	-4	-14	0.013
Machines	0.012	-10	-10	+5	-6	0.012
Textile	0.020	-13	-10	-9	-10	0.011
Rubber	0.008	+18	+4	+4	-9	0.010
Communication	0.007	-4	-3	-2	-0	0.009
Motor vehicles	0.007	+23	+0	-12	-18	0.008
Wood	0.011	-2	-18	-8	-21	0.007
Other transport equipment	0.003	+10	-4	+4	+7	0.006
Coal	0.009	-13	-15	-9	-21	0.006
Lodging	0.006	-18	-3	+9	-17	0.004
Meat	0.004	+11	-25	-4	+50	0.004
Milk	0.002	+28	+5	-4	+15	0.003
Office machines	0.002	-16	+26	+27	-10	0.003
Leather	0.002	+0	-18	-11	+13	0.002
Beverages	0.005	-10	-4	-8	-37	0.002
Other manufacturing	0.001	+11	-40	+33	-23	0.001
Tobacco	0.001	-15	-44	+46	-69	0.000

Table 5: Accuracy of RAS estimations (R^2).

Member states	1965 | 1970	1970 | 1975	1975 | 1980	1980 | 1985
West-Germany	.95	.96	.98	.93
France	.90	.99	.99	.98
Italy	.98	.99	.99	.99
The Netherlands	.91	.98	.97	.94
Belgium	.97	.99	.99	.99
United Kingdom			.91	.94
Denmark			.98	.95
EU-5	.97	.99		
EU-7			.99	.98