Linkages, key sectors and structural change: some new perspectives

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Linkages, Key Sectors and Structural Change: Some New Perspectives[1]

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Abstract

Recent exchanges in the literature on the identification and role of key sectors in national and regional economies have highlighted the difficulties of consensus regarding terminology, appropriate measurement as well as economic interpretation. In this paper, some new perspectives are advanced which provide a more comprehensive view of an economy and offer the potential for uncovering alternative perspectives about the role of linkages and multipliers in input-output and expanded social accounting systems. The analysis draws on some pioneering work by Miyazawa in the identification of *internal* and *external* multiplier effects. The theoretical techniques are illustrated by reference to a set of input-output tables for the Brazilian economy. The paper thus provides a more comprehensive view than the ones proposed by Baer, Fonseca, and Guilhoto (1987), Hewings, Fonseca, Guilhoto, and Sonis (1989) and the recent contributions of Clements and Rossi (1991, 1992) that draw on some earlier work of Cella (1984).

1. Introduction

While there is general agreement about the importance of linkages among the sectors of an economy in the promulgation of economic growth stimuli, there seems to be little consensus about the ways in which *key sectors* (to use the Rasmussen-Hirschman term) or *pôles de croissance* (Perroux) can be identified. Part of the confusion stems from difficulties in interpretation of such sectors as above average contributors to the economy from either an *ex post* or an *ex ante* perspective. However, there seems to be general agreement that the processes of economic change are often stimulated by a relatively small number of sectors initially even if the whole economy ends up experiencing change. In this paper, some alternative perspectives to this debate are offered; these perspectives provide some potential for resolution of the debates that have continued between Cella (1984), Guccione (1986), Clements and Rossi (1991, 1992) on Cella's decomposition technique and Clements and Rossi's (1992) criticism of the application of

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traditional key sector techniques by Baer, Fonseca, and Guilhoto (1987) to the Brazilian economy.

However, the major contribution of this paper is to place these debates into a broader context by revealing perspectives that enhance the rather narrow view of linkages that has become associated with key sector analysis. This paper only draws on a small set of these perspectives (see Sonis, Hewings, and Lee, 1994 for a more comprehensive evaluation) that adopt an hierarchy of micro-, meso- and macro-levels of economic analysis. Essentially, the focus will be on ways in which a *meso-level* perspective that describes the distribution of changes in direct coefficients on the whole economic system can be used to enhance the understanding and interpretation of key sectors. This interpretation is made by reference to a field of influence of change which may be considered for all combinations of direct and synergetic changes through the specification of additive components of the Leontief inverse. It is felt that this perspective will help inform on the nature of economic structure and, most critically, on the ways in which the transmission of structural change penetrates the complex web of interactions that characterize an economy.

The paper is organized as follows; in the next section, a brief review of some of the more recent debates on key sector identification will be provided. Thereafter, the meso level perspective will be presented and interpreted through the use of the field of influence. The major empirical evaluation will occur in the next section; here the link between the more traditional and the newer approaches will be made clear by reference to a set of tables for the Brazilian economy for selected years between 1959 and 1980. The paper will conclude with an evaluation and interpretation of the techniques.

2. Key Sectors, Linkages and Decomposition

There is a lengthy set of literature on the concept of key sector analysis; Rasmussen and Hirschman's notions have received widespread application and significant critical commentary (see, for example, McGilvray, 1977, Hewings, 1982). These debates will not be revisited in this paper; rather the focus will begin with a more recent exchange centering on a proposition by Cella (1984) for a measurement of total, backward and forward linkages that employed a matrix decomposition technique. Cella's technique, and a subsequent modification, were used by Clements and Rossi (1991, 1992) in an application to Brazil. In this application, Clements and Rossi criticized an earlier application of the Rasmussen-Hirschman techniques by Baer, Fonseca, and Guilhoto (1987) but were unaware of a subsequent paper (see Hewings, Fonseca, Guilhoto, and Sonis 1989) that extended the techniques in the directions that will be highlighted in the present paper.

Essentially, the concern of the present paper is to direct attention to alternative perspectives on the measurement and identification of key sectors (and associated concepts such as analytically important or inverse important parameters) and to suggests that the presentation of alternative visions about the structure and structural change in economies will facilitate a more balanced view of economic transformation processes. To date, the literature on key sector analysis has tended to focus attention on the promotion of one technique as superior to others, rather than considering several procedures as complements.

3. The Rasmussen/Hirschman Approach

The work of Rasmussen (1956) and Hirschman (1958) led to the development of indices of linkage that have now become part of the generally accepted procedures for identifying key sectors in the economy.

Define b_{ij} as a typical element of the Leontief inverse matrix, B; B^* as the average value of all elements of B, and if B_{*j} and B_{i*} are the associated typical column and row sums, then the indices may be developed as follows:

Backward linkage index (power of dispersion):

$$U_j = B_{*j} / n \ / B^* \tag{1}$$

Forward linkage index (sensitivity of dispersion):

$$U_i = B_{i*} / n \ / B^* \tag{2}$$

One of the criticisms of the above indices is that they do not take into consideration the different *levels* of production in each sector of the economy. Based on that criticism, Cella (1984) developed the approach that is shown below; Cella's indices are the basis for the improvements that are described in Section 5 where the notion of a *Pure Linkage* index is introduced.

4. The Cella/Clements Approach

Using the Leontief matrix of direct inputs coefficients (A), Cella (1984) defined the following block matrices

$$A = \begin{bmatrix} A_{jj} & A_{jr} \\ A_{rj} & A_{rr} \end{bmatrix} \tag{3}$$

and

$$\overline{A} = \begin{bmatrix} A_{jj} & 0 \\ 0 & A_{rr} \end{bmatrix} \tag{4}$$

Where A_{jj} and A_{rr} are square matrices of directs inputs, respectively, within sector j and within the rest of the economy (economy less sector j); A_{jr} and A_{rj} are rectangular matrices showing, respectively, the direct inputs purchased by sector j from the rest of the economy and the direct input purchased by the rest of the economy from sector j. $\overline{A}$ is a matrix of direct inputs coefficients, defined to confine interaction to those between establishments within sector j and, similarly, to interaction among the rest of the sectors but excluding sector j. In essence, one can imagine these divisions to represent two separate economies with no trading relationships.

Following Sonis and Hewings (1993), equation (3) can be solved for the Leontief inverse resulting in:

$$L = (I - A)^{-1} = \begin{bmatrix} \tilde{\Delta}_j & \tilde{\Delta}_j A_{jr} \Delta_r \\ \Delta_r A_{rj} \tilde{\Delta}_j & \Delta_r (I + A_{rj} \tilde{\Delta}_j A_{jr} \Delta_r) \end{bmatrix} \tag{5}$$

Where:

$$\tilde{\Delta}_j = (I - A_{jj} - A_{jr} \Delta_r A_{rj})^{-1} \tag{6}$$

$$\Delta_r = (I - A_{rr})^{-1} \tag{7}$$

In the same way, equation (4) can be solved for the Leontief inverse yielding:

$$\overline{L} = (I - \overline{A})^{-1} = \begin{bmatrix} \Delta_j & 0 \\ 0 & \Delta_r \end{bmatrix} \tag{8}$$

where:

$$\Delta_j = (I - A_{jj})^{-1} \tag{9}$$

Cella (1984) used this approach to define the total linkage effect of sector *j*, (*TL*), in the economy, i.e., the difference between the total production in the economy and the production in the economy if sector *j* neither bought inputs from the rest of the economy nor sold its output to the rest of the economy. In development terms, this might be regarded as the opposite of import substitution, namely, the disappearance of a whole industrial sector from an economy. Given this assumption, the following definition of TL may be derived:

$$TL = i' \left(L - \bar{L} \right) f = i' \begin{bmatrix} \tilde{\Delta}_j - \Delta_j & \tilde{\Delta}_j A_{jr} \Delta_r \\ \Delta_r A_{rj} \tilde{\Delta}_j & \Delta_r A_{rj} \tilde{\Delta}_j A_{jr} \Delta_r \end{bmatrix} \begin{bmatrix} f_{jj} \\ f_{rr} \end{bmatrix} \qquad (10)$$

Where i' is a unit row vector of the appropriate dimension, and f, f_{jj}, f_{rr} are column vectors of final demand for, respectively, the total economy, sector *j* alone, and the rest of economy, excluding sector *j*.

Cella (1984) then defined the backward (*BL*) and forward (*FL*) linkage:

$$BL = \left[(\tilde{\Delta}_j - \Delta_j) + i'_{rr} (\Delta_r A_{rj} \tilde{\Delta}_j) \right] f_{jj} \qquad (11)$$

$$FL = \left[(\tilde{\Delta}_j A_{jr} \Delta_r) + i'_{rr} (\Delta_r A_{rj} \tilde{\Delta}_j A_{jr} \Delta_r) \right] f_{rr} \qquad (12)$$

where i'_{rr} is a unit row vector of the appropriate dimension.

Clements (1990) argues that the second component of the forward linkage belongs to the backward linkage, as in his words, "it quantifies the stimulus given to supplying sectors caused by intermediate demand for a given sector" (Clements 1990, p. 339). In this way, he proposed a definition of backward and forward linkage as:

$$BL = \left[(\tilde{\Delta}_j - \Delta_j) + i'_{rr} (\Delta_r A_{rj} \tilde{\Delta}_j) \right] f_{jj} + \left[i'_{rr} (\Delta_r A_{rj} \tilde{\Delta}_j A_{jr} \Delta_r) \right] f_{rr} \qquad (13)$$

$$FL = \left[(\tilde{\Delta}_j A_{jr} \Delta_r) \right] f_{rr} \qquad (14)$$

The original definition of Cella (1984) for backward and forward linkage indices was applied by Clements and Rossi (1991) for the Brazilian Economy using the 1975 input-output table. The definition by Clements (1990) was used in Clements and Rossi (1992) in an examination of the Brazilian economy using the 1980 input-output table. We make use of the latter definition for the estimations made in this paper. In the next section, some comments about the Cella/Clements technique are provided, and a new approach is presented.

5. The Pure Linkage Approach

While, in essence, the idea behind the derivation of the Cella/Clements approach is correct, we think that the application can be improved and the following suggestions are provided. First of all, if one wants to isolate sector *j* from the rest of the economy, one should start with the following decomposition as an alternative to that provided in (4):

$$A = \begin{pmatrix} A_{jj} & A_{jr} \\ A_{rj} & A_{rr} \end{pmatrix} = \begin{pmatrix} A_{jj} & A_{jr} \\ A_{rj} & 0 \end{pmatrix} + \begin{pmatrix} 0 & 0 \\ 0 & A_{rr} \end{pmatrix} = A_j + A_r \tag{15}$$

where matrix A_j represents sector *j* isolated from the rest of the economy, and matrix A_r represents the rest of the economy. As before, define the Leontief inverse:

$$L = (I - A)^{-1} \tag{16}$$

then we can show that each additive decomposition of the matrix of direct inputs (equation 15) can be converted into the two alternative multiplicative decompositions of the Leontief inverse as follows (see Sonis and Hewings, 1993):

$$L = P_2 P_1 \tag{17}$$

or

$$L = P_1 P_3 \tag{18}$$

where:

$$P_1 = (I - A_r)^{-1} \tag{19}$$

$$P_2 = (I - P_1 A_j)^{-1} \tag{20}$$

$$P_3 = (I - A_j P_1)^{-1} \tag{21}$$

Equation (17) isolates the interaction within the rest of the economy, (P_1), from the interaction of sector *j* with the rest of the economy, (P_2). As can be seen in equation (20), P_2 shows the direct and indirect impacts that the demand for inputs from sector *j* will have over the economy ($P_1 A_j$).

Equation (18) on the other hand, isolates the interaction within the rest of the economy, (P_1), from the interaction of the rest of the economy with sector *j* through (P_3). P_3 reveals what the level of the impacts on sector *j* will be generated by the direct and indirect needs of the rest of the economy ($A_j P_1$).

Working with equations (17), (19), and (20), equation (17) can be expressed in the following form:

$$L = \underbrace{\begin{bmatrix} \tilde{\Delta}_j & \tilde{\Delta}_j A_{jr} \\ \Delta_r A_{rj} \tilde{\Delta}_j & I + \Delta_r A_{rj} \tilde{\Delta}_j A_{jr} \end{bmatrix}}_{P_2} \underbrace{\begin{bmatrix} I & 0 \\ 0 & \Delta_r \end{bmatrix}}_{P_1} \tag{22}$$

where all the variables are as defined before, and the first term in the RHS is P_2 while the second term is P_1.

From the first term in the RHS of equation (22), we can present the following decomposition:

$$P_2 = \begin{bmatrix} I & 0 \\ \Delta_r A_{rj} & I \end{bmatrix} \begin{bmatrix} \tilde{\Delta}_j & 0 \\ 0 & I \end{bmatrix} \begin{bmatrix} I & A_{jr} \\ 0 & I \end{bmatrix} \tag{23}$$

where:

$$P_2 = (I - B_j)^{-1} \tag{24}$$

and

$$B_j = P_1 A_j = \begin{bmatrix} A_{jj} & A_{jr} \\ \Delta_r A_{rj} & 0 \end{bmatrix} \tag{25}$$

From equation (25) we can define a *Pure Backward Linkage* (*PBL*) as:

$$PBL = i'_{rr} \Delta_r A_{rj} q_{jj} \tag{26}$$

where q_{jj} is the value of total production in sector *j*, and the other variables are defined as before. If one wants to treat sector *j* as a sector isolated from the rest of the economy, we propose that it will be more appropriate to use the value of total production, instead of the value of final demand as used by Cella (1984), given that the vector of total production will work like a vector of final demand in terms of the impact of sector *j* on the rest of the economy.

The *PBL* will give the pure impact on the economy of the value of the total production in sector *j*, i.e., the impact that is free from: a) the demand of inputs that sector *j* makes from sector *j*; and b) the feedbacks from the economy to sector *j* and vice-versa.

Using (18), (19), and (21), equation (18) can be expressed as:

$$L = \underbrace{\begin{bmatrix} I & 0 \\ 0 & \Delta_r \end{bmatrix}}_{P_1} \underbrace{\begin{bmatrix} \tilde{\Delta}_j & \tilde{\Delta}_j A_{jr} \Delta_r \\ \Delta_r A_{rj} \tilde{\Delta}_j & I + A_{rj} \tilde{\Delta}_j A_{jr} \Delta_r \end{bmatrix}}_{P_3} \tag{27}$$

where all the variables are as defined before, and the first term in the RHS is P_1 while the second term is P_3.

From the second term in the RHS of equation (27), we can have the following decomposition:

$$P_3 = \begin{bmatrix} I & 0 \\ A_{rj} & I \end{bmatrix} \begin{bmatrix} \tilde{\Delta}_j & 0 \\ 0 & I \end{bmatrix} \begin{bmatrix} I & A_{jr} \Delta_r \\ 0 & I \end{bmatrix} \tag{28}$$

where:

$$P_3 = (I - F_j)^{-1} \tag{29}$$

and

$$F_j = A_j P_1 = \begin{bmatrix} A_{jj} & A_{jr} \Delta_r \\ A_{rj} & 0 \end{bmatrix} \tag{30}$$

From equation (30) we can derive a *Pure Forward Linkage* (*PFL*) that is given by:

$$PFL = A_{jr} \Delta_r q_{rr} \tag{31}$$

where q_{rr} is a column vector of total production in each sector in the rest of the economy. Again, the reason for using the value of total production instead of the value of final demand is the isolation of sector *j* from the rest of the economy, as stated above.

The *PFL* will give the pure impact on sector *j* of the total production in the rest of the economy. Again, this impact is freed from some of the confusion of definition in the earlier Cella and Clements/Rossi approaches noted in the definition of *PBL*.

If one wants to know what the *Pure Total Linkage* (*PTL*) of each sector is in the economy, for example, to rank them, it is possible to add the *PBL* with the *PFL*, given that these indices, as defined above, are expressed in currency values. Hence:

$$PTL = PBL + PFL \tag{32}$$

The above derivation is an improvement over the method developed by Cella (1984) and applied by Clements and Rossi (1991, 1992) to Brazil. However, there is another perspective, introduced by Hewings, Fonseca, Guilhoto, and Sonis (1989) in an application to Brazil that will complement the definitions used in (32). The notion of a *field of influence* provides a more analytical procedure for evaluating a sector's (or some components of it) influence on the rest of the economy; the methodology is described in the next section and used to help interpret the several sets of key sector identification procedures described in this paper in section 7.

6. The Field of Influence Approach[6]

In the development of the analytical form of the fields of influence, the ideas of Sherman and Morrison (1949, 1950), Evans (1954), Park (1974), Simonovits (1975) and Bullard and Sebald (1977, 1988) should be acknowledged. The presentation of the material is inductive; first, the general formulation of concepts is given followed by an exposition of the final results of the mathematical analysis. All of the proofs are provided in Sonis and Hewings (1994).

6.1 Theoretical Basis for Coefficient Change: A Synopsis

The condensed form of the solution of the coefficient change problem can be presented in the following manner: let $A = (a_{ij})$ be an *nxn* matrix of direct input coefficients; let $E(e_{ij})$ be a matrix of incremental changes in the direct input coefficients; let $B = (I - A)^{-1} = \|b_{ij}\|$, $B(E) = (I - A - E)^{-1} = \|b(e)_{ij}\|$ be the Leontief inverses before and after changes and let *detB*, *detB(E)* be the determinants of the corresponding inverses. Then the following propositions hold:

Proposition 1.

The ratio of determinants of the Leontief inverses before and after changes is the polynomial of the incremental changes e_{ij} expressed in the following form:

$$Q(E) = \frac{\det B}{\det B(E)} = 1 - \sum_{j_1 i_1} b_{j_1 i_1} e_{i_1 j_1} + \sum_{k=2}^{n} (-1)^k \sum_{\substack{i_r \neq i_s \\ j_r \neq j_s}} B_{or} \begin{pmatrix} j_1 & j_2, & \ldots, & j_k \\ i_1 & i_2, & \ldots, & i_k \end{pmatrix} e_{i_1 j_1} e_{i_2 j_2} \ldots e_{i_k j_k} \tag{33}$$

[6] This section draws on Sonis and Hewings (1989, 1994)

where:

$B_{or}\begin{pmatrix} j_1 & j_2, & \ldots, & j_k \\ i_1 & i_2, & \ldots, & i_k \end{pmatrix}$ is a determinant of order k that includes the components of the Leontief inverse B from the ordered[7] set of columns $i_1, i_2, \ldots, i_k$, and rows $j_1, j_2, \ldots, j_k$. Further, in the sum $\sum$, the products of the changes $e_{i_1 j_1} e_{i_2 j_2} \cdots e_{i_k j_k}$ that differ only by the order of multiplication, are counted only once.

Proposition 2.

This provides a fundamental formula between the Leontief matrices in matrix form:

$$B(E) = B + \frac{1}{Q(E)} \left[\sum_{k \geq 1} \sum_{\substack{i_r \neq i_s \\ j_r \neq j_s}} F\begin{pmatrix} i_1 & \cdots & i_k \\ j_1 & \cdots & j_k \end{pmatrix} e_{j_1 i_1} \cdots e_{j_k i_k} \right] \tag{34}$$

where the matrix field of influence, $F\begin{pmatrix} i_1 & \cdots & i_k \\ j_1 & \cdots & j_k \end{pmatrix}$ of the incremental changes $e_{j_1 i_1} \cdots e_{j_k i_k}$ includes the components:

$$f_{ij}\begin{pmatrix} i_1 & \cdots & i_k \\ j_1 & \cdots & j_k \end{pmatrix} = (-1)^k \left[B_{or}\begin{pmatrix} i_1 & \cdots & i_k & i \\ j_1 & \cdots & j_k & j \end{pmatrix} - b_{ij} B_{or}\begin{pmatrix} i_1 & \cdots & i_k \\ j_1 & \cdots & j_k \end{pmatrix} \right] \quad i,j = 1,\ldots,n \tag{35}$$

Proposition 3.

This proposition provides the fine structure of the fields of influence. Initially, two types may be identified, the first order being confined to changes in only one element in the matrix while the second order examines the field of influence associated with changes in two elements. While higher order fields can be defined, they are not presented here.

(1)The first order field of influence $F\begin{pmatrix} i_1 \\ j_1 \end{pmatrix}$ of the increment e_{ji} is the matrix generated by a multiplication of the j^{th} column of the Leontief inverse B with its r^{th} row:

$$F\begin{pmatrix} i \\ j \end{pmatrix} = \begin{bmatrix} b_{1j} \\ b_{2j} \\ \vdots \\ b_{nj} \end{bmatrix} . \left(b_{i1} b_{i2}, \ldots b_{in} \right) \tag{36}$$

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[7] It should be emphasized that the order of columns and rows in B_{or} is essential.

Moreover, the first order field of influence includes the components of the gradient of the function, $b_{i_1 j_1}$, considered as a scalar function of all components of the matrix, A:

$$F\begin{pmatrix} i_1 \\ j_1 \end{pmatrix} = \text{grad } b_{i_1 j_1}(A) \tag{37}$$

(here, the pq^{th} component of the gradient is placed in the intersection of the q^{th} row and p^{th} column).

(2) The second order synergetic interaction between two incremental changes $e_{j_1 i_1}$ and $e_{j_2 i_2}$ is reduced to the following linear combination of four first order fields of influence:

$$\begin{aligned} F\begin{pmatrix} i_1 & i_2 \\ j_1 & j_2 \end{pmatrix} &= b_{i_1 j_1} F\begin{pmatrix} i_2 \\ j_2 \end{pmatrix} - b_{i_1 j_2} F\begin{pmatrix} i_2 \\ j_1 \end{pmatrix} \\ &\quad - b_{i_2 j_1} F\begin{pmatrix} i_1 \\ j_2 \end{pmatrix} + b_{i_2 j_2} F\begin{pmatrix} i_1 \\ j_1 \end{pmatrix} \end{aligned} \tag{38}$$

Obviously, if $i_1 = i_2$ or $j_1 = j_2$, then $F\begin{pmatrix} i_1 & i_2 \\ j_1 & j_2 \end{pmatrix}$ is a null matrix.

(3) For each $k = 2,3,...,n-1$, then the following recurrent formula is true:

$$F\begin{pmatrix} i_1 & \cdots & j_k \\ j_1 & \cdots & i_k \end{pmatrix} = \frac{1}{k-1} \sum_{s=1}^{k} \sum_{r=1}^{k} (-1)^{s+r} b_{j_s i_r} F\begin{pmatrix} i_1 & \cdots & i_{s-1} & i_{s+1} & \cdots & i_k \\ j_1 & \cdots & j_{r-1} & j_{r+1} & \cdots & j_k \end{pmatrix} \tag{39}$$

This formula also provides for the possibility of presenting the field of influence of order k through the use of fields of influence of lesser order, *1,2,...,k-1*. Further, the implication of the above theory provides the basis for the consideration of different, economic-based combinations of changes.

Sonis and Hewings (1994) provide more detailed presentations of the ways this concept can be applied to consider cases of changes in just one coefficient, a complete row or column or the whole matrix. The main problem with the linkage methods to date is that even though they evaluate the importance of a sector in terms of its system-wide impacts, it is difficult to visualize the degree to which these impacts reflect the importance of one or two coefficients (or major flows) within the sector and the nature of the impact outside the sector. For example, is the impact concentrated on one or two other sectors or more broadly diffused throughout the economy (see Van der Linden et al. 1993, for a discussion of how this issue may be addressed in the field of influence approach)? From a policy analysis perspective, this is very important. In the next section, an attempt will be made to evaluate the different contributions that can be made by the alternative linkage approaches in combination with interpretation through the fields of influence.

7. Application to the Brazilian Economy

In this section, comparative analysis of the approaches presented above will focus on: a) Rasmussen/Hirschman backward and forward linkage indices; b) Cella and Clements backward, forward, and total linkage indices; c) pure backward, forward, and total linkage indices; and d) fields of influence;

To undertake the comparative analysis, use was made of the Brazilian input-output tables constructed for the years of 1959 (Rijckeghem, 1969), 1970 (IBGE, 1979), 1975 (IBGE, 1987), and 1980 (IBGE, 1989). All of those tables were aggregated to the level of 27 sectors, following the tradition of the previous analysis for the Brazilian economy by Baer, Fonseca and Guilhoto (1987), Hewings, Fonseca, Guilhoto, and Sonis (1989), and Guilhoto (1992).

Tables 1 through 8 present the results of the various indices for the each year, as well as the rank of the each sector for a given index in a given year. Figures 1 through 40 present in a most clear way the data presented in Tables 1 through 8 and the results of the field of influence approach as presented in Hewings, Fonseca, Guilhoto, and Sonis (1989), and in Guilhoto (1992). The analysis which will follow will be divided in the following way: first, an examination of the data and the figures; then, a comparison of the indices. Finally, an attempt will be made to use the alternative approaches to provide an interpretation of the evolution of the structure of the Brazilian economy.

A comparison of the backward linkage indices shows that the Rasmussen/Hirschman index have a small variance in their values for any given year, with the values concentrated around the mean (1.0); the Cella/Clements and the Pure linkage indices reveal, in a better way, the difference among sectors, taking into consideration the level of production, and the internal structure of the indices as displayed by the Rasmussen/Hirschman indices. The value of the Cella/Clements indices are close to the Pure linkage indices and, with two exceptions - sectors 6 and 4, in 1959 and sectors 25 and 19 in 1970 - both indices provide the same ranking for each year. This confirms that the definition of backward linkage made by Cella/Clements are close to the definition presented in the Pure backward linkage.

For the forward linkage indices, the Rasmussen/Hirschman index shows a much larger spectrum of variance than their backward linkage index; the Cella/Clements and the Pure linkage indices, in the same way as their backward indices, show greater differences among sectors, taking into consideration the level of production and the internal structure of the economy. The index by Cella/Clements has a lower value than the Pure linkage index, and also the ranks of the sectors are different from the Pure linkage. This difference may be ascribed to the fact that Cella/Clements underestimate the forward linkage.

Aggregation of the backward and forward linkage indices provides an alternative basis for comparison. The following procedure is used: for the Rasmussen/Hirschman indices, the backward linkage index is plotted in the *X* axis while the forward linkage index is plotted in the *Y* axis. Thus, sectors that have both forward and backward linkage indices greater than one are considered key sectors in the economy. For the Cella/Clements and for the Pure indices, the backward and forward linkage indices are summed to yield the total linkage indices, and sectors which have the greatest value of total linkage are considered key economic sectors. However, it should be noted that there is really no generally accepted criteria for the definition of key sectors using these approaches.

The field of influence approach is closely related to the aggregated results of the Rasmussen/Hirschman linkage indices; it turns out that the sectors that have backward and forward linkages great than one are the ones that dominate the sectors with coefficients that have the greatest value in the field of influence.

A comparison of the results shows that in the Rasmussen/Hirschman linkage indices and in the field of influence approach, what is more important in defining which are the key sectors is the internal structure of the economy regardless of the value of the total production in the economy. For the Cella/Clements and for the Pure linkage indices not only is the internal structure important, but the level of production of each sector in the economy needs to be considered. As a result, the definition and the determination of key sectors is quite different from the Rasmussen/Hirschman and field of influence approach; rather than engaging in debate about the efficacy of one method over the other, it is proposed that these alternative views should be seen as complementary ways of identifying economic structure. In addition, the Cella/Clements linkage indices underestimate the forward linkage, and hence, the total linkage index is also underestimated, revealing a quite different ranking of key sectors than that given by the Pure linkage indices. In summarizing the analysis, one might wish to make the following distinction;

the Rasmussen/Hirschman and field of influence approaches identify what may be referred to as *potential* impacts from changes in any sector while the other indices examine *realized* effects through their consideration of the volume of activity. However, none of the approaches fully addresses the issue raised by McGilvray (1977) over *ex ante* and *ex post* distinctions; the application of the fields on influence in terms of volumetric changes over two time periods by Van der Linden *et al.* (1993) represents an attempt to combine a number of desired attributes of all the techniques.

Finally, some comments will be made concerning the evolution of the economic structure of the Brazilian economy from 1960 to 1980, focusing on issues and interpretations not highlighted in earlier work (Baer, Fonseca, and Guilhoto, 1987, Hewings, Fonseca, Guilhoto and Sonis, 1989, and Guilhoto, 1992). For the Brazilian economy from the Rasmussen/Hirschman and from the field of influence approach, the key sectors from 1959 to 1980 are sectors: 4 (Metal Products), 10 (Paper), 13 (Chemicals), 17 (Textiles), and 19 (Food). From the Pure linkage approach, the key sectors are: 1 (Agriculture), 4 (Metal Products), 13 (Chemicals), 19 (Food), 25 (Construction), 26 (Trade/Transport), and 27 (Services). The common sectors in both approaches are 4 (Metal Products), 13 (Chemicals), and 19 (Food). It is important to note that the Pure linkage approach shows the importance of sectors like Agriculture and Services for the economy, importance derived from the *volume* of production in those sectors. This effect is not totally captured by the Rasmussen/Hirschman and field of influence approaches. On the other hand, the importance of sectors like Paper and Textiles that are crucial for the growth of the economy are not captured by the Pure linkage, given the low value of production in those sectors, compare to the other sectors in the economy. Through the years 1959 to 1980 one can see an increase in the complexity of the Brazilian economy where the primary and secondary sectors are loosing in importance to the tertiary sector, showing a trend that is common in more developed nations.

8. Conclusion

The concept and the determination of key sectors in a economy can be presented in different ways, and the basic need is to explore the insights provided by each kind of analysis, rather than focusing on the real or apparent advantages any one technique might offer. It would be surprising if there was complete consistency; as Diamond (1976) noted, the multiplicity of objectives that characterize the growth and development strategies of most countries make it unlikely that a small sector of sectors would yield all the requisite requirements for satisfying employment, income, output, foreign exchange and other objectives.

The Rasmussen/Hirschman indices and the field of influence approach were used to see how the internal structure of the economy behaved, without taking into consideration the level of production in each sector, while the pure linkage indices were used to look at the productive structure when the different levels of production in each sector were taken in consideration. The first kind of analysis is important, for if the internal structure of the economy is overlooked in defining key economic sectors, one can arrive at bottlenecks that will limit the growth of the economy. On the other hand, the level of production in each sector is also important as it helps to determine which sectors will be the mainly responsible for changes in the levels of GNP and other macro-level measures of the economy. Hence, both kind of analyses need to be combined, as has been the case in this presentation.

An improvement over the work completed would be to make a complementary analysis, in the tradition of the Leontief-Miyazawa approach, in which the structure of the household final demand is incorporated into the analysis. Preliminary work done by Hewings, Fonseca, Guilhoto, and Sonis (1989) using the concept of field of influence shows that this kind of analysis will add another important dimension to the determination of economic key sectors. The analysis can also be enhanced by addressing the temporal changes explicitly, for example, using the allocation of changes in outputs between two time periods that can be ascribed to changes in coefficients, changes in final demand and changes in their interactive effects and the distinction between changes originating within the sector and those originating elsewhere in the economy (see Sonis, Hewings, and Guo, 1993).

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