AN ANALYSIS OF THE RELATIONSHIP BETWEEN SECTORAL ACTIVITY, DIVERSIFICATION, AND STRUCTURAL CHANGE IN THE ECONOMY.

by

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(ABSTRACT)

The purpose of this study is to analyse the changes, if any, that take place in regional economic structures in the process of diversification, and the roles of sectors in such changes. Input-Output and Structural Path Analysis are used to develop indices that may be used for carrying out the analysis of these issues. A method is also developed for examining the role of linkages with respect to the fundamental structure of production outlined by Simpson and Tsukui. Using these indices and methods, the economic relationships between sectors and the economic structures of six planning districts in Virginia, in addition to the economies of the state of Virginia and the U.S. are analysed and compared. On the basis of these analyses, it is concluded that: (a) The feature of bloc independence found at the level of first order transactions in an economy is diluted at the level of higher order transactions in the metals bloc. However it persists strongly at higher levels of transactions in the nonmetals bloc. (b) The sectors of the metals, nonmetals and services blocs show a proportionate development of linkages irrespective of the degree of diversification of the economy. (c) Contrary to Hirschman's suggestion that complexity of linkages increases with diversification, the results suggest that diversification leads to less complexity in the linkage relationships. (d) The linkages of the agricultural sectors in Virginia are biased towards the services sectors. In the case of the agricultural sectors at the national level, the linkages are biased primarily towards the manufacturing sectors. The implications of these findings for development policy are discussed.

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Chapter 1

STATEMENT OF OBJECTIVES

1.1. Introduction

The assessment of the contribution of an industry to the economy in which it functions is often required, especially in connection with the targeting of key industries for inducing or aiding development of an economy, or the attainment of policy objectives such as employment creation and income generation. However, measures of the details of regional economic structure, and of the contribution of an industry to the regional economic structure, are lacking. Intuitively, it is apparent that the contribution of an industry is predicated by the structure of the economy within which it functions. The structure referred to in this context consists of the interindustry transactions in the economy. Knowledge of the development of structures of regional economies is meagre. As stated by Hewings, *et al.*, "We have little understanding, except in very general terms, about the differences in the structure of a rural regional economy, a more industrialized regional economy and the national economy in which the two regions are located. Similarly, we know little about the characteristic developments in structure which may occur as a region grows over time (p.1)." An understanding of the structure of regional and national economies would allow more informed and perceptive decisions to be made regarding such concerns as the choice of key sectors for development or revitalization of a particular economy, or to gauge the implications of changes in sectoral contributions as the industry mix changes in an economy, or the impacts of policy decisions that affect economic structure.

In addition to these practical concerns, there are theoretical issues that justify greater understanding of regional and national economic structures. Theories of development postulate various sequential changes in an economy. For example, the sequence starting with an agriculture based primary economy, evolving into a manufacturing based and subsequently to a service dominated economy has been suggested by some development economists. However, the way in which these changes occur, and the manner in which they are reflected in the economy's structure and the activities of individual sectors are not known. An understanding of these processes may lend more insight into policies aimed at bringing about development.

Various questions regarding economic structure have been raised frequently in the literature. These questions have been stated explicitly by Hewings *et al.*. They may be summarized as follows: Are there any distinguishing features, in terms of linkages and multipliers, that is, in sectoral contribution, between the structures of rural and urban economies? How does structure, as evidenced by the network and magnitude of linkages, change from one economy to another? Is there a sequence of changes, or in other words, a life cycle process in the development of the structure of an economy and the attendant contributions by sectors as the economy develops over time and space?

Answers to these questions would, in turn, suggest possible answers to the more basic questions raised by regional scientists: Is there a "fundamental structure of production" where "fundamental structure" refers to "that part of the system whose retention is absolutely essential to ensure maximal interaction, given a set of interindustry flows (Hewings *et al.*, p.46)." In addition, if there is an evolutionary sequence in the development of economies as well as sectors over time and space, would it be possible to develop a classification, or, stated in taxonomic terms, an identifiable ontogeny[1] and a phylogeny[2] of economic development over time and space? While it would be presumptuous to expect that definitive answers to all these questions would be available from the results of a study of a single regional economy, some evidence of the direction in which the answers lie may be expected. It may be seen from the foregoing discussion that an understanding of the behavior of regional structures over space and time could have wide ramifications on perceptions of structural change and sectoral roles in the economy.

[1] Ontogeny refers to the stages of evolution of individual organisms, the economic equivalent of which would be the individual sectors.

[2] Phylogeny refers to the stages of evolution of a class of organisms, represented, in economic terms, by the interindustry table of the economy.

1.2. Objectives of this Study

The broad aim of this study is to gain a greater understanding of the changes experienced by regional economies as a result of changes in their industrial mix. This will entail a study of the differences in economic structure between varied regional economies. At the same time it will require analyses of the activity of individual industries and sectors in the economy (the term sector refers to an aggregation of industries for purposes of analysis), and the manner in which these activities change as the economic structure changes. Thus, one aspect of the objectives of this study concerns the method to be used for the analysis of structure. These aims may be stated explicitly as follows:

- (i) To develop measures of the activity of individual sectors and industries in the economy that will be sensitive to structural change.

- (ii) To develop measures describing the overall structure of an economy which will capture the effects of structural changes.

- (iii) To develop a means of modeling, in a detailed manner, the various interactions that take place in an economy so that they can be subject to analysis.

The second aspect of the objectives of this study concerns the examination of several issues regarding the structure of economies. These issues, which will be examined using data obtained by the application of methods developed during the course of the study, may be stated as follows:

- (i) There exists a "fundamental structure of production" common to all modern economies. This fundamental structure, which has been identified at the level of first order transactions (that is, the direct transactions between industries represented in the transactions matrix of an input-output model and also known as the first round transactions) does not extend to the deeper levels of transactions in the economy (that is, the second and subsequent orders/rounds of transactions). One manifestation of this fundamental structure was the feature of "bloc independence" observed in the economies examined by Simpson and Tsukui. This research will, therefore, seek to answer the question: Does the feature of bloc independence extend beyond the first level of transactions in the economy?

- (ii) As the structure of the economy changes with industrial diversification, there is a corresponding change reflected in the concentration of interindustry linkages in the economy. Thus, as the structure increases in complexity, the relative role of the agricultural sector has been postulated to decrease. This study will, therefore, examine whether this relative decrease is reflected in the proportional contribution of the agricultural sector to the linkages in the economy, relative to other sectors.

- (iii) Do the structures of economies become increasingly complex with industrial diversification? (Hirschman)

- (iv) The indices and methods developed for the analysis will be used to examine the pattern of linkages of the agricultural sectors in Virginia, and to compare this with the pattern of linkages in the agricultural sectors at the national level.

1.2.1. The Need for a Method

The role of sectors in an economy has been the subject of various studies. The conventional ways in which the role of a sector has been analysed can be classified into one of two approaches. In the first approach, the primary aim has been to assess the sectoral role in contributing to the economy in terms of its multiplier. This is the approach favored in studies relating to key sector analysis and in the majority of studies aimed specifically at assessing sectoral contribution in terms of magnitude rather than density of linkages. The second method analyses sectoral contribution in terms of its role in facilitating, and in participating in, the linkages between sectors. This latter approach is connected with studies attempting to trace the linkages between sectors, *per se*, rather than the magnitude of contributions by a sector to the economy. In this sense these studies have been directed at assessing the physical interconnections in the economy with the magnitude of the economic effects transmitted through these interconnections being more or less ignored.

However, this dichotomy in approaches is artificial since the magnitude of a multiplier is associated with the magnitude of the transactions taking place between a sector and the other sectors, as well as the density of its linkages with other sectors. Thus both aspects of the contribution by a sector, that is, its contribution to the economy in terms of the magnitude of its transfers, and also the density and direction of the network of linkages that it supports within the economy in the process of making these transfers, need to be taken into account in any attempt seeking to assess the holistic contribution of a sector to the economy and the changes in sectoral contribution that occur as the economy's structure changes.

The method most frequently used to obtain a quantitative value for sectoral contribution is input-output analysis. Input-output analysis, which is carried out in a general equilibrium framework, lends itself to such studies because it takes into account macroeconomic impacts by potentially including all the actors in the economy. At the same time, it accounts for the microeconomic interactions through a system of production function relationships for each sector. In addition, input-output analysis is amenable to procedures that reveal significant details regarding the network of linkages and the structure of the economy. Any method developed to analyze structure is, therefore, likely to be based on the input-output analytical framework.

1.2.2. The Issues to be Examined

The first issue to be examined owes its origin to a study by Simpson and Tsukui, based on the triangularization of the transactions matrices of several modern national economies. They interpreted their findings as indicating the presence of a fundamental structure of production which manifested itself in the form of certain characteristics regarding the behavior of sectors in the economy. These views are detailed in Chapter 2.

The second issue is an extension of the three stages of sequential change postulated by development economists - a primary industry dominated economy with few linkages evolving into a manufacturing and subsequently a services dominated economy. These stages were defined on the basis of changes in final demand, that is, in terms of sectoral output to meet final demand. Presumably, increases in the final demand for the output of a particular group, services, for example, will lead to increased diversification of sectors in this group and, consequently, increased linkage. Similarly, the setting up of a manufacturing activity usually stimulates the development of ancillary manufacturing industries. Of course this increase in the sectoral representation, in terms of sectoral linkages in one bloc, may give rise to the development of sectors in the other blocs, such as the services bloc, as a consequence. But is the net effect likely to be an increase in the linkages in a particular bloc? Simpson and Tsukui's conclusion regarding "bloc independence" which states that sectors in a particular bloc are isolated from other blocs, in terms of (first order) linkages, suggests that the increase in linkages due to the appearance of a new sector is largely confined to the bloc to which the new sector belongs. Based on this hypothesis it may be expected that, as an economy diversifies, and its emphasis shifts through the postulated sequence, the linkage will also show a corresponding shift in concentration from primary industries to manufacturing and subsequently, to service industries. If this is indeed the case, it may be possible to use the information from linkage analysis to recognize a sequence of changes in the economy as diversification proceeds, that may be used to draw up a scheme for classifying economies.

The third aspect to be examined was developed by Hirschman. The literature, in general, contributes to the view stated by Hirschman, that the relative contributions of the primary sectors (agriculture and mining primarily) to the economy decrease as diversification (which is synonymous with development in Hirschman's view) occurred. In order to induce development, therefore, sectors which have a greater impact on the economy would be the obvious choice, from a policy viewpoint, for inducing change (this is the major premise of key sector analysis).

Hirschman hypothesized that with industrialization, the complexity of the network of linkages increases due to the increasing economic interdependence between sectors. On the other hand, the less industrialized a region, or the more primary the nature of its economic activity, (primitive agriculture and mining are the examples cited by Hirschman in this regard) the less the interdependence among sectors in the economy.

This view of industrialization and complexity of linkages contrasts with those of more recent investigators who appear to perceive diversification as leading to less connectedness. Thus, Ulanowicsz (1981), writing mainly in regard to interconnectedness in ecological systems, interprets the results as indicating that a well developed system (which, presumably, is a well diversified system), is not a well interconnected one (he looked only at the direct interconnections, that is, those of the transactions matrix). His argument was that intersectoral specialization increases as a function of development so that, with a high level of development, each sector has transactions with only a small number of suppliers and receivers. Thus, "each industry obtains its inputs from very few (at best from only one) highly specialized suppliers and is also a highly specialized producer which sends its output to very few receipients (Szyrmer, 1985. p.1581)".

This view of diversification and linkages is also embodied in the Yan and Ames idea of technological progress and the Zuchetto view of efficiency, which maintain that efficiency is a function of specialization and diversity. They argue that greater specialization would lead to less diversity (in linkages), so that greater efficiency could be attained. Presumably, technological progress implies a greater specialization in the mix of industries. These contradictory views form the basis for the formulation of the third issue to be examined in this study.

1.3. Summary

In this chapter the objectives of this study, and some of the reasons why such a study is required were explained. The details of existing research in areas related to this topic and a review of the relevant literature are given in the chapter which follows. The various indices developed for the measurement of structure and the roles of sectors, and their shortcomings, will be examined in some detail since they may offer guidelines for formulating more appropriate indices. Since input-output analysis forms the best approach to a holistic view of inter-industry relationships, this method and its development is examined in Chapter 3. The extension of the input-output model to the Social Accounting Matrix (SAM) framework has formed the basis for the decomposition of multipliers in several ways. Since such decompositions offer insights into the roles of sectors in the economy, and are comparable with Structural Path Analysis (SPA), which is the method used for analysis in this study, the literature relating to the SAM framework and the possible decompositions of multipliers is also examined in Chapter 3. Following the review of the literature, SPA is described in detail and potential indices for measuring and comparing sectoral roles based on the results of SPA are developed in the same chapter. Chapter 4 outlines the sources of the data used in this study, the choice of the regions used in the analysis and the basis for their selection, and a brief overview of the IMPLAN program which was used for setting up the input-output tables that were used in SPA. The results of the application of SPA and the indices developed for analysis of structure and sectoral roles are set out in Chapter 5. The findings are summarized and their policy implications, together with potential areas of further study are laid out in Chapter 6.

Chapter 2

REVIEW OF THE LITERATURE

2.1. Introduction

In view of the aims of this study, as stated in the preceding chapter, the relevant literature falls into two categories:

- (i) Studies pertaining to the development and analysis of multipliers. While multipliers have, in some of the literature, been regarded as proxies for linkages (Chenery and Watanabe; Rasmussen; Yotopoulos and Nugent; etc.) no details regarding the participants, or the density of the linkages that gave rise to the multiplier, are available from such studies.

- (ii) Studies which look at the input-output matrix and attempt to develop measures of the interconnectedness between sectors in the input-output table. This group of studies tends to ignore, or to hold subordinate, the magnitude of the economic effect that is transmitted via a linkage, and focus mainly on the presence or absence of linkages, and the diversity and density of linkages in the economy.

This review of the literature examines studies concerned with both these aspects of sectoral contribution. In the process, the aspects of interconnectedness and sectoral roles that have been considered important by various authors will become evident. At the same time, the strengths and weaknesses of existing indices should help to draw up a blueprint of the features that the ideal indices of connectedness and sectoral roles may be expected to have. The techniques of Input-Output analysis and Structural Path Analysis, which are the primary methods of analysis used for drawing up such indices, are described in Chapter 3, where the basis for the methods of analysis and the indices developed for this study are also discussed.

2.2. Measures of Sectoral Contribution through Multipliers

As a region develops, it acquires greater economic activity in the form of increased production of goods, greater employment and income, a greater variety in the goods manufactured, and a greater interaction between individual sectors in the economy. Hirschman first extended this intuitively obvious observation to formulate a hypothesis of the growth of interdependency in the process of development (diversification). He hypothesized that, as development occurred, the extent of interdependency or linkage between sectors increased. Building on this, he further hypothesized that, by encouraging the development of industries that had greater intersectoral linkages than others, the process of development could be speeded up. Thus was born the concept of key sectors - that is, sectors which induce development through the nature of their interdependencies with other sectors in the economy. Thus, key sectors were those that had more than average linkages in the economy, so that their presence gave rise to greater interactions among sectors. Hirschman recognized two types of linkages or interdependencies (Hirschman, p.100):

> 1. The input-provision, derived demand, or BACKWARD LINKAGE EFFECTS, i.e., every nonprimary economic activity, will induce attempts to supply through domestic production the inputs needed in that activity.
>
> 2. The output-utilization or FORWARD LINKAGE EFFECTS, i.e., every activity that does not by its nature cater exclusively to final demands, will induce attempts to utilize its outputs as inputs in some new activities.

The formulation of the linkage and key sector hypotheses by Hirschman initiated a period of intense attention to the subject of key sectors. Numerous studies attempted to identify, empirically, key sectors for particular regions which could be used to trigger development (Hazari; Boucher; Riedel; to name a few.)

Since then, the study of the nature of intersectoral dependencies has been utilised to assess changes in the structure of an economy and to test the hypothesis that systematic structural changes occur in the process of economic development. The pioneers in the development of linkage analysis measures were Chenery and Watanabe, and Rasmussen. The techniques initiated by these researchers form the basis for current measures of sectoral contributions. Their measures of backward linkages are, therefore, described below in some detail together with some of the refinements suggested (Hazari; Diamond; etc.), in the case of backward linkages, for enhancing their applicability to policy analysis.

2.2.1. The Chenery and Watanabe Indices

The earliest method developed for measuring linkages was suggested in a study by Chenery and Watanabe. Their study related to an international comparison of the structure of production. In the course of this study, they developed several measures of the use of factors by the different sectors under different structural regimes. According to them, the extent of indirect use of factors could be measured by the ratio of purchased input (U_j) to the value of total production (X_j) so that:

$$\frac{U_j}{X_j} = u_j. \tag{2.1}$$

A second measure to denote the ratio of intermediate (W_i) to final demand for a given product was given by:

$$\frac{W_i}{D_i} = w_i. \tag{2.2}$$

In terms of matrix notation:

$$U_j = \sum_{i=1}^{n} x_{ij} \quad (j = 1,2, \ldots ,n), \tag{2.3}$$

and,

$$X_j = U_j + V_j, \tag{2.4}$$

where,

U_j = total purchases of input by sector j[3],

x_{ij} = the amount of transactions between sector i and j,

V_j = total value added by sector j,

W_i = intermediate use by sector i,

X_j = total output of sector j,

Y_i = the final demand of sector i, and

D_i = total demand of sector i.

A sector with strong backward linkages would have a high U_j, that is, it purchases large amounts of inputs from other sectors in relation to its total output.

Although the Chenery and Watanabe indices of linkages were used in a number of studies, and found approval with Hirschman, it was pointed out by Yotopoulos and Nugent that these indices took only direct effects of intersectoral transactions into account. Recognition of this drawback led to the development of the multiplier based on the inverted (I - A) matrix where I is the identity matrix and A is the matrix of input-output coefficients as derived from the input-output table. The inverted or Leontief matrix includes the indirect as well as direct effects of a dollar of sales on final demand. Thus the measure of backward linkages was: backward linkage = $\sum_{i=1}^{n} Z_{ij}$ in the $(I - A)^{-1}$ matrix, where Z_{ij} refers to an individual element of the Leontief inverse. It is

[3] All data are usually expressed in monetary terms.

also to be noted, as stated earlier, that the Chenery and Watanabe indices are based on the implicit assumption that the magnitude of the index is also a proxy for the density of its linkages.

2.2.2. The Rasmussen Indices

Rasmussen developed a measure for linkages that was based on averages and, therefore, reduced the effects of extreme values. His index used the inverted (I - A) matrix to initially calculate the backward linkages for a sector y by computing its column total ($Z_{.j}$), in the same manner as was done by Yotopoulos and Nugent.

(2.5) $$Z_j = \sum_{i=1}^{n} Z_{ij} \qquad (j = 1,2, \dots, n).$$

Rasmussen introduced refinements into the measure of linkages by taking the ratio of $Z_{.j}$ to the number of sectors (n) recognized in the input-output analysis. Thus,

(2.6) $$\bar{Z}_j = \frac{1}{n} \sum_{i=1}^{n} Z_{ij} \quad (j = 1,2, \dots ,n).$$

$\bar{Z}_{.j}$ was interpreted as an estimate of "the (direct and indirect) increase in output to be supplied by an industry chosen at random if final demand for the product of industry j (j = 1,2,..., n) increases by one unit (Rasmussen, p.134)".

These averages were then converted to common units in order to facilitate intersectoral comparisons. This was achieved by taking the overall average defined as:

(2.7) $$\bar{\bar{Z}} = \frac{1}{n^2} \sum_{i=1}^{n} \sum_{j=1}^{n} Z_{ij} \quad (i = 1,2,\dots,n; \; j = 1,2,\dots,n)$$

The above measures were used to obtain the index:

(2.8) $$U_{.j} = \frac{\bar{Z}_{.j}}{\bar{\bar{Z}}}.$$

It is evident that if $\bar{Z}_{.j}$ is greater than $\bar{\bar{Z}}$, $U_{.j}$ will be greater than one. This implies that sector j requires larger outputs from other sectors, in response to a one dollar increase in final demand of the j^{th} sector in comparison with all sectors in general and vice versa for $U_{.j} < 1$.

Rasmussen recognized that the index $U_{.j}$ being an average, could be influenced by extreme values and is, thus, unsuitable by itself for identifying key sectors. He, therefore, introduced a measure of the variability of each column using the standard deviation of each sector:

(2.9) $$S_{.j} = \sqrt{\frac{1}{m-1} \sum_{i=1}^{m} (Z_{ij} - \bar{Z}_{.j})^2} \quad (j = 1,2,\dots,m)$$

In order to carry out intersectoral comparisons, $S_{.j}$ is divided by $\bar{Z}_{.j}$:

(2.10) $$V_{.j} = \frac{S_{.j}}{\bar{Z}_{.j}}.$$

The index $V_{.j}$ is the *coefficient of variation* and is interpreted as the extent to which industry j draws evenly on the system of industries or, in the case of a relatively great value of the index, whether industry j draws one sidedly on the system of industries.

Under this scheme, when the policy objective is to bring about homogenous development of the sectors in an economy, key sectors will be chosen which have high $U_{.j}$ and relatively low $V_{.j}$. On the other hand, where growth in the economy is the priority in the policy framework, it may be necessary to identify a sector as the key sector because it gives rise to the greatest increase in the multipliers in the economy, although index $V_{.j}$ may indicate that the sector is skewed in terms of its interactions with other sectors in the economy.

In the above methods for identifying key sectors through multipliers, equal importance is assigned to every sector. In reality, however, some sectors may be more important than others. This has been accounted for by various authors by means of different weighting schemes. Weighting as a means of assigning relative importance to the above indices was first suggested by Rasmussen.

2.2.3. The Hazari Weighted Indices

One of the first attempts at weighting was carried out by Hazari. Basing his argument on the premise that the planner has an objective function, he suggested that the weighting scheme should be in accordance with this objective function. One such weight suggested was the proportion of the final demand of sector i to the total final demand:

(2.11) $$P_i = \frac{F_i}{\sum_{i=1}^{m} F_i} \quad (i = 1,2,\ldots,m),$$

where,

P_i = weight of sector i,

F_i = the final demand for sector i.

To find the weighted indices, the column total ($Z_{,j}$) is multiplied by the weight of the corresponding sector:

(2.12) $$\lambda_j = Z_{,j} P_i.$$

The index λ_j provides weighted measures for identifying key sectors. Sectors in which λ_j were high were regarded as key sectors with reference to: (a) the planners policy objective implicit in the final demand sector, and (b) the importance of each sector in the economy as a contributor to final demand.

2.2.4. The Diamond Weighted Indices

Diamond also drew attention to the fact that the Rasmussen indices are derived in terms of unweighted increases in intermediate inputs making them less suitable for policy formulation. Diamond suggested that, in order to take into account variables other than intermediate output, such as employment, income and import use, which may be more important for policy purposes, these variables may be used for weighting the interindustry indices. In order, therefore, to obtain a more appropriate policy oriented index, Diamond started with a modified version of the standard Leontief model given by:

$$(I - A + M^{*})X_i = d + f, \tag{2.13}$$

where,

I = unit matrix of order n,

A = square matrix of input-output coefficients,

M^{*} = diagonal matrix of import coefficients m_i^{*},

X_i = column vector of output totals,

d = column vector of consumption demand (including imports),

f = column vector of final demands other than consumption, taken to be exogenous.

This represents the unweighted total output multiplier matrix for the closed model (with respect to households) and Diamond suggested weighting the multiplier matrix with the policy measure of concern. For instance, in the case where employment is the focus of policy concerns, the matrix is weighted by simple linear employment coefficients to give rise to the relevant policy matrix. Thus,

$$N = L[(I - D)(I - A) + M^{*}]^{-1}, \tag{2.14}$$

where:

D = a matrix such that $D_{ii} = (C_{ii} - m_i)$, that is sector consumption coefficients (C) minus import propensities (m), and $D_{ij} = C_{ij}$, $i \neq j$ with C_{ij} representing consumption deliveries from sector i to sector j, per unit increase in income of j.

L = diagonal matrix of normalized industry labor-output ratios,

N = employment multiplier matrix, each element N_{ij} indicating the increase in industry i's employment given an increase of one unit in j's final demand.

Similar weighting of the matrix may be carried out with other relevant policy parameters such as the income multiplier matrix (Y), the multiplier matrix of net foreign exchange use (F), the normalized diagonal matrix of industry value-added ratios (V) and the diagonal matrix of industry net import coefficients. By taking the column sum of these weighted inverse matrices Diamond developed backward linkages similar to those developed by Rasmussen:

(2.15) $$\sum_{i=1}^{n} N_{ij} = N_{.j},$$

indicating the total labor input ($N_{.j}$) required per unit final demand for the product of any sector.

The drawbacks in the case of both the Hazari and Diamond weighted indices are similar. Both place importance on the magnitude of the muliplier generated by the Leontief inverse. However, two multipliers having the same magnitude may have been generated by very different transactions in the economy. Thus, while the magnitude of one multiplier may have been achieved by a single transaction, the magnitude of the second may have required a number of transactions between it and other sectors in the economy. If the intent of the policy maker was to bring about as extensive (as opposed to intensive) development as possible in the economy, in terms of income distribution or employment, it might be preferable to choose the second sector rather than the first. In addition, neither weighted index takes the actual linkages between sectors into consideration.

The lack of sensitivity of the weighted indices to variations in the activity of a sector in the economy, in terms of its linkages, reduces their applicability for policy purposes. This leads to the next group of indices developed, which are based primarily on the nature of the linkages of a sector rather than the magnitude of its multipliers.

2.3. Measures of Sectoral Contribution through Linkages

Every sector in an economy interacts with one or more of the other sectors in the economy. Each transaction represents a linkage between sectors. The first interaction between two sectors may be characterized as the primary or first order linkage and may be the only link between two sectors. An example of such a backward linkage would be the purchase of fertilizers directly from the chemicals sector by the agricultural sector (*ag* → *chem*). On the other hand, the agricultural sector may purchase its fertilizer inputs from the agribusiness sector which, in turn, purchases the fertilizer from the chemicals sector. In this case there is an indirect linkage between the agricultural and chemicals sectors via the agribusiness sector (*ag* → *ag.bus* → *chem*). This represents the indirect or second order linkage. These secondary linkages may be of any length greater than one, depending on the number of intermediary sectors linking the agricultural and chemicals sectors. It may also be possible that the agribusiness sector, which acts as a link between the chemicals and agricultural sectors, itself requires inputs in the form of services from the transport industry for bringing the fertilizer to its warehouses. In such a case the secondary transaction or linkage between the agricultural and chemicals industries is seen to induce a third level of transaction by the agribusiness sector. This linkage between the agribusiness and transportation sectors represents the induced component of the multiplier and the third order linkages in the economy.

The primary linkages (or first order linkages) among sectors in an economy are represented by the inter-industry (that is, the input-output, or X matrix) table. These linkages thus give rise to the direct component of the multiplier. However, the linkages giving rise to the indirect and induced components of the multiplier cannot be separately deduced from conventional methods of multiplier analysis. The various measures described below seek to develop indices which would measure these higher order linkages, in order to assess the role of a sector in the economy.

As will be seen from the following literature review covering the interconnectedness aspect of linkages (rather than the magnitude), the methods suggested involve the analysis and manipulation of the input-output table and/or its modifications in terms of the A matrix or the $(I - A)^{-1}$ matrix. Besides these, the table has also been subjected to Boolian analysis and several other methods in an attempt to obtain measures of interconnectedness. The various methods for developing indices used by those who have carried out research in this area are categorized as follows:

(i) Indices based on the interindustry/transactions matrices.

(ii) Indices based on Boolian matrices.

(iii) Indices based on the Leontief inverse.

(iv) Indices based on miscellaneous approaches.

Although there is some overlap among the above categories, it provides a useful framework in which to examine the different methods. The literature pertaining to studies of interconnectedness has been surveyed in articles by Hamilton and Jensen, Hewings *et al.*, and Szyrmer (1985, 1986). The following descriptions of the various measures are based primarily on these surveys.

2.3.1. The X and A Matrix Approaches

In the X and A matrix approaches to the assessment of structure, the elements of the interindustry table (the X matrix) or the normalized [4] interindustry table (the A matrix) are used as indicators of the degree of interconnectedness of the economy.

2.3.2. The Percentage of Intermediate Transactions

The Percentage of Intermediate Transactions (PIT), developed by Chenery and Watanabe, involves calculation of the proportion of an industry's output that is utilised in interindustry transactions. The PIT measure is:

[4] Normalization is carried out by taking the ratio of each element of the X matrix over the sum of the respective column of elements.

$$PIT = \sum_{i=1}^{n} \sum_{j=1}^{n} \left(\frac{x_{ij}}{\sum_{j=1}^{n} \sum_{i=1}^{n} x_{ji}} \right) \tag{2.16}$$

where x_{ij} is an element of the transactions matrix. PIT implies that the degree of interconnection is directly related to the percentage of intermediate flows. However, this measure may respond in the same way for a system with a large number of interconnections involving small flows as it would to a sparsely interconnected system with one, or a few, large flows. This insensitiveness to the magnitude and density of flows decreases its interpretative value.

2.3.3. Coefficient Sums and Means

Jensen and West developed this variant of a measure for interconnectedness, which uses the sums of the column elements of the A matrix for each sector ($\sum_{i=1}^{n} a_{ij}$) and the mean of these sums as summary measures of interconnectedness, such that:

$$\bar{A} = \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{a_{ij}}{n}, \tag{2.17}$$

with $\bar{A}$ representing mean row or mean column sums of the A matrix.

This method takes into account the magnitudes of the a_{ij}. However, the inherent assumption that small a_{ij}'s indicate little interconnectedness and vice versa may not be true as had been suggested earlier, since the magnitude of a mutliplier is not an index of its linkages, and multipliers of small magnitudes may involve many linkages and vice versa.

2.3.4. The Zuchetto Diversity Index

An index developed for ecological applications by Zuchetto has general use as a measure of diversity in the economic activity of a region. This index is based on measures of system entropy enunciated by Theil using information formulae developed by Shannon. The expression is developed by normalizing the intermediate flows[5]:

(2.18)
$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij}},$$

and this is then used in calculating the overall entropy of the system using the Shannon formula:

(2.19)
$$I^{info} = -\sum_{i=1}^{n}\sum_{j=1}^{n} p_{ij} \ln p_{ij}.$$

The resulting index ranges between 0 and ln (n), where n is the number of sectors. The sensitivity of the index to relative inequalities in the magnitude of coefficients of the A matrix is enhanced by this procedure, with a direct relationship between the level of the index and the evenness of distribution of the coefficients (Szyrmer, 1985). Thus, the index is able to distinguish between a matrix containing a few large primary transactions,

[5] It will be evident that expression (2.18) is a subset of the PIT index (expression 2.16) developed by Chenery and Watanabe.

and another which has more homogenous primary transactions than in the first case. Indexes such as PIT would fail to make this distinction and would, therefore, suggest that the sectors in the two matrices are equally interconnected. However, this index suffers from the drawback of taking into account only direct flows between i and j. In addition, although the magnitude of the index is assumed to indicate the level of density in interconnectedness (an assumption with weaknesses indicated earlier), there is no indication as to the sectors involved in the linkages that give rise to this level of linkage. As a result, different combinations of flows in the interindustry matrix could give rise to the same level of diversity, thus reducing the insights that the index can offer. Hewings (1983) and Jackson and Hewings encountered this problem while using the index in connection with a study of the Washington state input-output tables. They found that a matrix of flows, when transposed, yielded similar levels of entropy, according to this index, indicating that the dispersion or diversity levels of interconnectedness had not changed although the structural implications of the interconnections had, in reality, been altered radically.

2.3.5. The Ulanowicsz Structural Indices

Ulanowicsz (1980, 1981), applying input-output techniques to ecological situations, developed several measures based on Shannon's formula for assessing structure and interrelatedness in a system. These measures, which have been reviewed by Szyrmer (1985), are also applicable to the economic milieu and are described below.

2.3.6. The Development Capacity Index

The development capacity index expresses the degree of evenness of the flow structure in the input-output table (or X matrix) and is given by:

(2.20) $$I^{dc} = -\sum_{i=1}^{n} x_i \sum_{i=1}^{n} \left(x_i / \sum_{i=1}^{n} x_i \ln x_i \right),$$

with $\left(x_i / \sum_{i=1}^{n} x_i \right)$ representing the probability of sector i being a part of any flow in the system.

The development capacity index is based on four other indices of system structure developed by Ulanowicsz: the ascendency index (I^a), the tribute index (I^{tr}), the dissipation index (I^{di}), and the redundancy index (I^r), where,

(2.21) $$I^{dc} = I^a + I^{tr} + I^{di} + I^r$$

The ***ascendency index*** is regarded by Ulanowicsz as a measure of the degree of coherence (as opposed to the degree of diversity) of the flows in an input-output model. Thus the ascendency index is inversely related to diversity of flows and is represented by:

(2.22) $$I^a = t \sum_{k=1}^{n} \sum_{j=1}^{n} s_{kj} g_k \ln \left[s_{kj} / \sum_{i=1}^{n} s_{ij} g_i \right],$$

where, $t = \sum x_i$ so that $g = x_i / t$ and $s_{ij} = x_{ij} / x_i$ (the output coefficient).

Transactions between sectors involve some costs, and these are represented by the tribute and dissipation indices. Thus, the ***tribute index*** captures flows outside the system (i.e. exports) and is expressed as:

(2.23) $$I^{tr} = -t\sum_{i=1}^{n} s_{ie} g_i \ln g_i,$$

where s_{ie} represents exports from sector i.

The ***dissipation index*** was developed by Ulanowicsz to capture the direct cost of the functioning of the system and is represented by:

(2.24) $$I^{di} = (-t)\sum_{i=1}^{n} s_{id} g_i \ln g_i.$$

Some economic equivalents of these dissipation costs cited by Szyrmer (1985, p. 1580) are human consumption (labor costs), transportation (transfer costs), and rent or amortization (capital costs).

The fourth index developed by Ulanowicsz is the ***redundancy index*** which attempts to measure the "multiplicity of pathways between any two arbitrary input-output sectors" (Szyrmer, 1985, p.1581). The index is expressed as:

(2.25) $$I^{r} = -t\sum_{i=1}^{n}\sum_{j=1}^{n} s_{ij} g_i \ln\left[s_{ij} g_i / \sum_{k=1}^{n} b_{kj} g_k \right].$$

Redundancy is directly related to the diversity of flow networks and higher levels of redundancy have been interpreted as a reduction in the level of specialization and a consequent slowing down in the development of the system.

The measures described so far have all been concerned with elements of the X and A matrices. The indices are, therefore, restricted in their interpretative ability since they are confined to the direct relationships between sectors only. Indirect or second and higher order transactions are ignored. The usefulness of these indices is consequently limited, since a substantial portion of the nexus of interrelationships could take place in the second and subsequent rounds. The Boolian approach to interconnectedness, which is described in the following section, attempts to assess these higher order linkages.

2.4. The Boolian Approach to Interconnectedness

The application of Boolian techniques to the input-output table leads to consideration of the elements of the A matrix, and the power series approximation of the Leontief inverse[6] , as consisting of either 1 (when the matrix element is a positive number) or 0 (when the matrix element is 0). This method is used in various procedures developed to assess the structural interconnectedness of the system. The obvious weakness of this approach is the fact that any measure developed on such a basis will (a) fail to indicate the magnitude of the linkages, and (b) fail to indicate the participants in a particular linkage, so that different combinations of intersectoral transactions would show the same index level. The indices based on the Boolian method are described below.

[6] This approximation is based on the relationship $(I - A)^{-1} = (I + A + A^2 + A^3 + \cdots)$

2.4.1. The Yan and Ames Interrelatedness Index

The procedure involved in determining the Yan and Ames interrelatedness index, while not strictly associated with Boolian matrices, does look at the input-output matrix and its power series expansion to find out the round in which individual elements of the matrix first show a positive number. This is then recorded in a second matrix known as the **order matrix.** Thus, positive elements in the A matrix are assigned the number 1 in the corresponding order matrix. Where elements that were zero in the A matrix are positive in the A^2 matrix, the corresponding element in the order matrix is 2, and so on. Thus, the elements of the order matrix indicate the particular round of the power series expansion of the A matrix in which the element was first non-zero. From the resulting order matrix (O), the interrelatedness function (R) was represented by Yan and Ames in terms of its elements. Thus, R for a single element (o_{ij}) was represented by:

(2.26) $$R_{ij} = \frac{1}{o_{ij}},$$

so that the overall index of interrelatedness is given by:

(2.27) $$R = \frac{1}{n^2} \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{1}{o_{ij}}.$$

Yan and Ames also expressed the interrelatedness function (R) as:

(2.28) $$R = \frac{m_1}{n^2} + \frac{m_2}{n^2} + \cdots + \frac{m_k}{n^2},$$

where $m_1, m_2 \ldots m_k$ represent the number of elements in the order matrix whose values are equal to $1, 2 \ldots k$.

The first term in this expression represents the ***index of diversification*** according to Yan and Ames, and the remaining terms together constitute the ***index of indirect interrelatedness***.

These measures have been criticized on several counts. Szyrmer (1985) argues that by focussing on the first transaction between two sectors, and ignoring subsequent interactions, this index ceases to represent overall interrelatedness. The suggestion by Hamilton and Jensen that by taking the reciprocals the importance of a particular linkage is emphasized is hard to accept since there is no reason why an earlier transaction should be of greater importance (in terms of magnitude) than a subsequent one. Blin and Murphy have also criticized the Yan and Ames index on the grounds that it takes only the most direct or shortest path joining two sectors into account and ignores the remaining paths [7].

2.4.2. The Transactions Rounds Matrix of Robinson and Markandaya

Using Boolian means of analysis, Robinson and Markandaya developed a Transactions Rounds Matrix (T) similar to the Yan and Ames order matrix. The elements T_{ij} of the matrix T are such that:

[7] Path in this context refers to a flow of transactions from one sector a to another sector b, either directly, or via one or more sectors c, d, e. The complete linkage from a to b is the path. The terminology is described in greater detail in section 3.15.

(2.29) $$T_{ij} = \begin{cases} t_j & if \quad a_{ij} \neq 0 \\ 0 & if \quad a_{ij} = 0 \end{cases},$$

with t_j being an integer representing the number of rounds in which the sector j produces a positive output. As in the case of the order matrix, the values are obtained from the power series expansion of the Leontief inverse matrix. The row sums of the T matrix indicate the total deliveries by a sector to all other sectors. By weighting these measures appropriately, three summary measures of the magnitude and density of connectedness were developed. Thus, by weighting each sector's number of rounds by its share of total orders placed (that is, the column totals of T), an index R_1 was obtained. Two other indices R_2 and R_3 were similarly developed using shares of total deliveries and share of the value of total domestic product, respectively, as weights. Robinson and Markandaya were of the view that R_1 and R_2 focus on the number, rather than the value, of transactions, and R_3 "reflects the value of transactions (p.126)".

Using these indices, Robinson and Markandaya studied the linkage patterns and transmission of economic effects (referred to, by them, as "churning") through the linkages. Hewings, *et al.* criticize this procedure on the grounds that it does not distinguish between the more important transactions and those of lesser significance "in an analytical sense (p. 10)". Another disadvantage is that the procedure, while it may reveal the number of times a sector is involved in a transaction, does not indicate the particular path of the transaction (or chain of linkages) in which it forms a link. Moreover, only the shortest path connecting two sectors is taken into account by this procedure. There may be more paths between two sectors other than the shortest, but these would not be considered.

2.4.3. The Bosserman Complexity Index

The Bosserman (1981a, 1981b, 1982) indices were developed in connection with ecosystem modeling, and are based on the analysis of Boolian matrix equivalents of the input-output table, with properties similar to those set down by Robinson and Markandaya, that is,

$$k_{ij} \in K = \begin{cases} 1 & if \quad a_{ij} > 0 \\ 0 & if \quad a_{ij} = 0 \end{cases} \tag{2.30}$$

The Bosserman index is then contained in the expression:

$$I^B = \frac{1}{n^3} \sum_{p=1}^{n} (M^P), \tag{2.31}$$

where M^p represents the partial matrix sums and is calculated as follows:

$$\begin{aligned} M^1 &= K \\ M^2 &= K + K^2 \\ &\dots \\ M^p &= K^{(p-1)} + K^p \end{aligned} \tag{2.32}$$

The elements of the partial sums matrix M^p are obtained as follows:

$$M_{ij} \in M^2 = \begin{cases} 1 & if \quad k_{ij} = 1 \\ 1 & if \quad k_{ij}^2 = 1 \\ 0 & if \quad k_{ij} = k_{ij}^2 = 0 \end{cases} \tag{2.33}$$

The matrix is, therefore, similar to a shortest path matrix but differs from it in that the elements only indicate the presence of a linkage, if any, but do not provide any idea of the length of the path or the participants in the linkage. Connectivity is expressed in binary terms in that it is perfect when $I^B = 1$ and absent when $I^B = 0$

Szyrmer (1985) and Hewings, *et al.* suggest that application of the Bosserman index leads to overestimation of connectivity because of double counting of transfers in this method. Hewings, *et al.* suggest that the Robinson and Markandaya indices may, therefore, be more appropriate measures of connectedness. The index has also been criticized because of its failure to distinguish between specific arrangements of flows in the matrix. A third criticism is directed at the choice of n rounds as being appropriate for calculating the values of the indices. Szyrmer argues that use of this limit would eliminate important connections in the case of a small matrix, and include very insignificant connections (in terms of magnitude) in the case of a large matrix.

2.5. Measures of Connectivity Based on the Leontief Inverse Matrix

2.5.1. The Average Output Multiplier

One of the standard measures of interconnectedness is represented by the arithmetical average of the column sums of the Leontief inverse, and is known as the average output multiplier.

(2.34) $$AOM = \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{z_{ij}}{n}.$$

This measure includes second and subsequent round effects. However, it does not indicate the number of paths or the lengths of the paths (number of links) involved in contributing to the index. The "churning" effect espoused by Robinson and Markandaya cannot, therefore, be gauged from this index. Moreover, the magnitudes of the elements of the matrix are assumed to be proxies for the number (densities) of interconnections while indicating levels of transfers at the same time. However, this is an unsuitable proxy since a single transaction involving a large transfer could yield results identical to that of a number of transactions involving less significant levels of transfer.

2.5.2. The Finn Cycling Index

Finn (1976, 1980) developed several indices applicable to ecosystems, which also have applicability in economic systems. Based on the ecological view that increasing cycling (which could be considered to have similar connotations to the "churning" of Robinson and Markandaya) is associated with greater complexity in ecosystems, Finn used the elements of the Leontief inverse to develop an index of "cycling" given by:

(2.35) $$I^c = \frac{b}{\sum_{i=1}^{n} x_i},$$

where $b = \sum_{j=1}^{n} (1 - \frac{1}{z_{jj}}) x_j$ and $z_{jj} \in Z = [I - A]^{-1}$.

This measure is taken in conjunction with a second index (I^s) known as the ***straight through flow index*** and is expressed as:

(2.36)
$$I^S = \frac{(\sum_{i=1}^{n} x_i - b)}{\sum_{i=1}^{n} x_i},$$

so that $I^s + I^c = 1$.

As a result, according to these indices, more complex systems (i.e. those with more off diagonal elements) would give rise to a higher value of I^s and a lower value of I^c and vice versa. This, as indicated earlier, contrasts with the Hirschmanian view of complexity vis-a-vis development, and concurs with Ulanowicz' view.

Finn also developed two other measures, the ***total system output*** and the ***mean path length index*** which are analogous to the total output of the input-output table, and the percentage of intermediate transactions index proposed by Chenery and Watanabe.

2.5.3. The Szyrmer Indices

Szyrmer (1985, 1986) argues that the Leontief inverse, with its preoccupation with ascertaining the intermediate requirements necessary for meeting the exogenously determined final demand, fails to account for all the transactions that take place in the interindustry matrix. He, therefore, develops a ***total flow approach*** to account for all the interactions that take place in the transactions table. To develop the measure used in this approach, Szyrmer applies techniques similar to those used in the "hypothetical extraction method" developed by Schultz. By application of this method, which involves extraction of the column entries of sector j which represent internal purchases of inputs by the sector, and assuming external supply of the extracted inputs to sector j, Szyrmer develops a measure which, he suggests, takes into account interindustry flows not accounted for in the $(I - A)^{-1}$ matrix. The total flow matrix thus developed is expressed as:

$$Z^{total} = A\hat{B}B^{-1}\hat{X} = [B - I]\hat{B}^{-1}BY, \tag{2.37}$$

where $\hat{B}$ is the diagonal matrix composed of diagonal elements from the Leontief inverse.

Based on this matrix, Szyrmer develops partial flow matrices represented by Z (the conventional Leontief inverse), Z^{ind} representing the matrix of indirect intermediate flows, Z^{trans} representing the matrix of transit flows, and a destination flow matrix Z^{dest} . He then establishes that $Z^{total} = Z + Z^{ind} = Z^{dest} + Z^{trans}$ and develops three ratios from these matrices as follows:

$$\gamma = \frac{1}{n^2} i^T Z^{total} i;$$

(2.38)
$$\alpha = \frac{Z_{ij}}{n^2} = \frac{Z_{ij}^{dest}}{n^2};$$

$$\beta = \frac{Z^{ind}}{n^2} = \frac{Z^{trans}}{n^2},$$

so that:

(2.39)
$$\gamma = \alpha + \beta,$$

Asserting that this expression represents the "quintessence of input-output connectedness" Szyrmer (1986, p.115) considers α to be a measure of ***simplicity*** of the matrix whereas β represents the complexity in the internal configuration of flows. This leads to the derivation of measures analogous to the cycling and straight through flows of Finn and are expressed by σ and κ , respectively, as:

(2.40)
$$\sigma = \frac{\alpha}{\gamma}, \quad \kappa = \frac{\beta}{\gamma}, \quad \sigma + \kappa = 1.$$

Szyrmer also develops indices for ***specific*** and ***technical*** measures of connectedness. In order to derive specific measures, $s_{ij} \in S$ is defined as the sales or output coefficients matrix (the flow from i to j induced by a unit sale of i). The resulting measures are given by :

(2.41)
$$\alpha^{*} + \beta^{*} = \gamma^{*},$$

where,

$$\alpha^{\bullet} = \left(\frac{1}{n^2}\right) i^T B i$$
$$\beta^{\bullet} = \left(\frac{1}{n^2}\right) i^T G i$$
$$\gamma^{\bullet} = \left(\frac{1}{n^2}\right) i^T H i$$

and • indicates relevance to specific output and final demands ($\underline{X}, \underline{Y}$). H represents the total flow matrix normalized by the total output vector x. G is a matrix representing the proportion of output that is transferred indirectly to j, and B represents the direct output coefficient matrix which shows the proportion of output i that is transferred directly to j.

All the above measures of connectedness are based on arithmetical averages and are, therefore, subject to the distortions that averaging gives rise to, such as those resulting from extreme values. To counter this, Szyrmer develops variants of the above indices based on the Shannon formula. Thus,

$$\begin{aligned} \alpha^{sh} &= -\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{z_{ij}}{t}\ln\frac{z_{ij}}{t} \\ \beta^{sh} &= \gamma^{sh} - \alpha^{sh} \\ \gamma^{sh} &= -\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{z_{ij}^{total}}{t}\ln\frac{z_{ij}^{total}}{t} \end{aligned} , \tag{2.43}$$

which are similar to the Zuchetto index but use total instead of direct flows and normalize the flows by using system output (t) instead of total intermediate flows (z).

The Szyrmer indices attempt to give an idea of the strength and the density of linkages, but suffer from the shortcomings common to indices based on the (I - A) matrix. They do not indicate the specific paths, the lengths of the paths, or the linkages involved in contributing to a specific multiplier. While magnitudes may be captured by these indices, the information about the network of linkages is assumed to be indicated by the level of the linkages. However, as stated earlier, there is no valid reason why a high multiplier magnitude cannot exist without a high level of interconnectedness and vice versa.

2.6. Triangulation Approaches

The triangulation technique of analysing the structure of an economy assumes that the flow of most transactions in an input-output table is unidirectional and, therefore, linear. Based on this assumption, triangulation attempts to rearrange the elements of the input-output matrix so as to emphasize the linear structure. This is achieved by developing a hierarchy in the ordering of the sectors of the input-output matrix so that the sum of the transactions on one side of the diagonal is maximized, while that on the other side is minimized. This approach was initially applied by Chenery and Watanabe, and was subsequently used in studies by Simpson and Tsukui, Helmstadter, and Lamel *et al.*.

Following triangulation of the matrix, several ratios and indices were developed in order to ascertain the degree of linearity [8] of the matrix. A high degree of linearity was

[8] Linearity, in this context, refers to the degree of one-way interconnection between sectors. Thus, the sequence $a \rightarrow b \rightarrow c \rightarrow d$ would represent a high degree of linearity whereas a sequence $a \rightarrow b \rightarrow c \rightarrow a \rightarrow b$ would indicate less well developed linearity. Poorly developed linearity would result in ill-defined triangularity.

considered to be associated with a low degree of interdependence. Ratios were also developed in an attempt to measure the number of flows rather than the volume.

Lamel *et al.*, based on their triangulation studies, suggested that linearity is inversely related to the degree of development. Some of the studies (Simpson and Tsukui, Lamel *et al.*) yielded results suggesting very stable positions for certain sectors in the hierarchy, across economies of several countries. This led to speculation by Simpson and Tsukui that there exists a "fundamental structure of production" recognizable across space and time. This conclusion was based on their study of triangularization of technical coefficient matrices of several national economies. Triangularization was displayed by the matrices after the sectors in the economy had been ordered in a sequence that grouped them into "blocs" on the basis of their physical qualities. The four resulting blocs were (i) metals (ii) nonmetals (iii) energy, and (iv) services. A triangular disposition of the elements of the technical coefficients matrix was observed by them when the major elements of the matrix were considered. This feature, described as bloc triangularity, was accompanied by a second feature known as bloc independence. This was evidenced by the fact that transactions between sectors were almost completely restricted to those in the same bloc. An example of these features is seen in Table 2.1 on page 44, taken from the Simpson and Tsukui study.

Bloc triangularity and independence reflect the underlying inter-industry relationships in an economy, and indicate that groups of particular sectors have linkages which are largely confined among themselves. The occurrence of bloc triangularity, with each "triangle" encompassing the same sectors across economies, and the independence of these blocs of sectors implies that the economies being compared have similar production relationships, that is, that the linkages among sectors in the economies being compared are similar. Since these two features of bloc triangularity and independence were found to be a feature common to a number of developed economies, and involved more or less the same groups of sectors, Simpson and Tsukui postulated the existence of a "fundamental structure of production". Thus, the concept of a fundamental structure is based on the nature of the linkages occurring in an economy.

The triangulation approach suffers from the shortcoming that it takes only the first round (that is, the Z and A matrices) into account in developing indices. Subsequent round effects, which can be substantial, are ignored. Moreover, the nature of the linkages, the paths and their number and lengths, are not revealed by the analysis.

2.7. Miscellaneous Approaches

Several approaches which have a greater or lesser bearing on structure and interconnectedness are briefly described in this section.

2.7.1. Campbells Graph Theoretic Approach

Campbell (1972, 1974, 1975) used graph theoretic methods to obtain an idea of the connectedness in a system. This approach was based on development of Boolian matrices from input-output tables, to which graph theoretic methods were then applied to obtain diagramatic representations of the interconnections in order to identify and analyze them. Campbell was, on this basis, able to classify industries into those with strong input ties (transmitter industries), those with strong forward linkages (receiving

Table 2.1. A Triangularized Transactions Table (Source: Simpson and Tsukui).

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	GDO BILLIONS OF YEN
1	RAIL AND AIR TRANSPORT EQUIPMENT	104																																					2.8
2	MOTOR VEHICLES	30	263																																				13.1
3	SHIPS																																						.9
4	MACHINERY	39	47	57	163				28		28																							30					12.1
5	ELECTRICAL EQUIPMENT	48	62	31	40	175																																	12.8
6	FABRICATED METAL PRODUCTS	45	87	85	58	65	110											33																					10.0
7	IRON AND STEEL	110	86	53	108	51	207	321																															12.1
8	IRON ORE MINING							30																															.3
9	BASIC METALS					73	54			432								47																					5.5
10	NON FERROUS METAL MINING									117																													.5
11	LEATHER											307																											3.7
12	TOBACCO AND ALCOHOL												243																										53
13	FOOD PRODUCTS													134																									16.7
14	FISHING AND HUNTING																																						.4
15	APPAREL															156																							11.3
16	DAIRY PRODUCTS																282																						87
17	MISCELLANEOUS MANUFACTURING																	101		30																			59
18	RUBBER		45																231																				33
19	PLASTICS																			97																			1.1
20	ORGANIC CHEMICALS										34								63	230	183	87																	8.1
21	INORGANIC CHEMICALS																				35	147																	1.6
22	NON METALLIC MINERALS																						91																4.2
23	NON METALLIC MINERAL MINING																					65	44																.9
24	PULP PAPER PRINTING																	108		52	31		69		329													35	13.7
25	LOGGING ETC.										33															228													8.8
26	FIBRES AND TEXTILES														50	289			136	42						32	238		34										11.8
27	LIVESTOCK													32							59						53	400											25.5
28	GRAIN MILL PRODUCTS													50			62											63	69										5,3
29	GRAIN CROPS												206	108			214				66						129	203	479	172									20.2
30	ELECTRICITY										41																				88								4.4
31	GAS																															200							1.8
32	COKE AND PRODUCTS							55																									28						1.2
33	COAL																														86		410						3.0
34	PETROLEUM																															152			419	37			12.1
35	TRANSPORT							46														71	54		34	41			58		34		280			96			21.5
36	TRADE															27	30	28												30								28	41.8
37	SERVICES			29									50	43				33			62			55		33				117						51	158	90	93.7
	VALUE ADDED	481	268	582	504	440	474	411	818	327	788	519	344	470	800	314	438	468	428	631	388	423	560	774	516	523	446	231	239	587	722	572	276	825	604	748	788	688	

industries), and a residual group consisting of those industries with no dominating characteristics. The limitations mentioned earlier, with respect to measures based on Boolian matrices are applicable to the Campbell study also.

2.7.2. Cluster Analytic Techniques

Czamanski and Czamanski, Blin and Cohen, and O'hUllachain attempted to identify clusters of industries, that is, those with strong links to each other in terms of sales and purchases of output. Czamanski and Czamanski, and Blin and Cohen applied network and multivariate analysis in an attempt to identify clusters and produced some consistent results. Roepke *et al.* and O'hUllachain used factor analysis as a means of identifying industrial clusters.

2.7.3. Determinants

The value of the determinant of the Leontief matrix was interpreted by Wong as a measure of complexity and was expressed as

$$(I-A)^{-1} = \frac{adj(I-A)}{|I-A|}, \tag{2.44}$$

where adj (I - A) is the adjoint matrix. The resulting value of the determinant was considered to be inversely related to connectedness (Hamilton and Jensen). This index does not take into account the linkages in the economy that are responsible for the complexity. Thus, in common with other indices based on magnitudes, this index is unable to distinguish between an economy in which a few transactions of large magnitude take place, and another in which many transactions of lesser magnitudes occur. This index would indicate that the first economy was more complex, whereas, in terms of actual interconnectedness, which is the feature being measured, the second economy is more complex.

2.8. Summary

The existing literature regarding analysis of economic structure and sectoral activity has been briefly described in this chapter. Four basic approaches to the development of measures for analysis of structure and/or sectoral activity were identified. It was noted that the existing measures suffered from one or more of several shortcomings which may be listed as follows:

- (1) The magnitudes of interaction were taken into account by some indices (those based on multiplier analysis), but the nature and identity of linkages responsible for the interactions were ignored.

- (ii) The indices analysed linkages but took only the shortest paths linking two sectors into account. The possible existence of paths other than the most direct, between any two sectors, was ignored. The magnitude of influence conveyed by the linkages was also ignored. The Boolian approach exemplifies this method.

- (iii) A detailed look at the influence generated by interactions at various levels (primary, secondary, and tertiary), and the magnitudes of the influences involved in interactions at different levels, was not attempted.

These shortcomings, and the approaches to the development of indices of measurement of economic structure and sectoral activity that were surveyed, can be used to draw up the features that may be considered desirable in the ideal indices of interconnectedness and sectoral roles in an economy. The features that emerge as being important to such indices are: (a) the ability to take into account the linkages between sectors as well as the magnitude of the economic influence transmitted along the linkage, (b) the ability to account for all the linkages, or at least the more important linkages between two sectors, (c) the ability to distinguish between the direct, indirect, and induced components of the transactions between two sectors[9], (d) the ability to provide summary, as well as detailed, information about the interconnections and sectoral roles in an economy, and (e) the ability to permit comparison of interconnectedness and sectoral roles in input-output tables of different economies. Ideally, the indices should be independent of the degree of aggregation of the matrix.

Based on this review and analysis, and the template drawn up of features considered desirable in indices, Chapter 3 looks at possible ways of developing indices that approach the ideal. That chapter is, therefore, concerned with the development of the concepts, the indices, and the methods pertinent to a detailed analysis of economic structure and sectoral roles in terms of the aims of this research.

[9] The connotations of the terms direct, indirect, and induced are described in greater detail in Section 3.15.

Chapter 3

DEVELOPMENT OF THE METHODS OF ANALYSIS

3.1. Introduction

The scope of the present research, as outlined in Chapter 1, and the survey of the literature on the measurement of sectoral roles suggest that the current technique of using multiplier analysis offers the most favourable basis from which to embark on a search for a more comprehensive measure of linkages. However, a means for analysing linkages in a manner that also considers the magnitude of the economic influence transmitted by them is necessary. Thus, multipliers and linkages will play important roles in any method used to achieve the desired objective.

It is evident that any comprehensive measure of sectoral contribution should take into account the following factors:

(1) The role of a sector in contributing to the magnitude of the intersectoral transactions as indicated by its multipliers.

(2) The role of a sector in contributing to the network of linkages within the economy, which allows economic influence to be transmitted.

(3) The supportive role of a sector with respect to other sectors in the economy through its backward linkages.

This chapter looks briefly at the development of the input-output model and the means of its regionalization. This is relevant because the scope of the present study requires the development of several regional models for analysis. Methods of decomposition of multipliers are also relevant to the aims of this study. However, most of the methods developed for decomposing multipliers have been in connection with Social Accounting Matrices (SAM). SAM's are based on a more detailed accounting system than the open input-output model, taking into account households, household consumption, employment, etc. in addition to the inter-industry table. Multipliers developed in this framework, therefore, take into account the interactions between these components of the SAM. The methods of multiplier decomposition developed with the SAM framework are reviewed following a description of the SAM table.

3.2. The Input-Output Model

The input-output model has proven to be the best approach to the development of disaggregated multipliers and the analysis of the structure of the economy. The standard version of the input-output model represents the accounting balance equations as:

$$\text{(3.1)} \qquad \begin{aligned} \sum_j x_{ij} + Y_i = X_i \\ \sum_i x_{ij} + P_j = X_j \end{aligned}$$

where x_{ij} represents interindustry transactions or the flows between industries and Y_i, P_j and X_i represent the vectors of final demand, primary inputs, and total output respectively, and X_j represents total inputs. The final demand vector Y, in this system, is a composite of purchases by consumers and government, investment by industries, and exports. The vector P, similarly, comprises the various components of value-added (wages and salaries, profits, undistributed dividends) and imports. The standard assumptions of input-output models include Leontief type isoquants, that is, that the underlying production functions for each sector are linear and homogenous of degree one. Additional assumptions are that supply of inputs is unlimited and the economy is demand driven.

Under these circumstances, the input coefficients, also known as the technical coefficients, have been defined as:

$$\text{(3.2)} \qquad a_{ij} = \frac{x_{ij}}{X_j}.$$

Substituting in 3.1, we have,

(3.3) $$\sum_j a_{ij}X_j + Y_i = X_i$$

This may be stated in matrix terms as:

$$AX + Y = X \tag{3.4}$$

where,

A = (nxn) matrix of technical coefficients or input coefficients (a_{ij}'s),

Y = (nx1) vector of final demands, and

X = (nx1) vector of total output.

From 3.4 we have,

(3.5) $$X = [I - A]^{-1} Y$$

with $[I - A]^{-1}$ being the standard Leontief inverse from which the matrix of interindustry multipliers is derived in terms of employment, income and output.

This standard formulation of the input-output model is applicable at the national or the regional level. However, the technical coefficients are usually calculated for input-output models at the national level and require some modification in order to be applicable to regional models. Two reasons are cited by Hewings (1983) for such a requirement. One reason is that national input-output coefficients represent an average derived from data from individual producers in specific regions. However, the structure of production in a sector may vary widely between different regions. The second reason is that, generally, a regional economy is far more "open" than a national economy, with greater dependency on goods imported into the region and exports from the region. These two features that distinguish regional from national economies need to be taken into account when constructing regional models.

3.3. Construction of Regional Input-Output Tables

The need to regionalize input-output tables has spawned a number of approaches to the development of regional coefficients. These may be broadly classified, on the basis of the manner in which the data used in constructing the input-output tables are obtained, into (i) survey based, and (ii) non-survey methods.

3.4. Survey Based Methods

Survey based tables are developed mainly by obtaining primary data through surveys. Survey based tables are demanding, in terms of time and expense, and are not discussed in any detail here. It need only be mentioned that the primary data are used to form rows-only and columns-only matrices of the industry sales and purchase patterns. Since there are likely to be differences between the quantities indicated in the two matrices, one of the major problems associated with survey based tables is that of reconciliation between the two. This problem has sparked a number proposals for its resolution

(Borque; Miernyk; Jensen and McGaurr, 1976; Gerking, 1976, 1979) none of which has proved to be entirely satisfactory.

3.5. Non-Survey Methods

The cost of constructing survey based tables, and the problems associated with obtaining regional data, led to attempts to develop short-cuts or simpler and more cost effective ways of constructing regional input-output matrices using non-survey techniques. Such techniques depend, more than survey based models do, on the use of indicators, ad hoc judgment or some data reconciliation technique.

Regional coefficients are considered to be a product of the region's technical and trade coefficients. The amounts of commodities required by an industry, irrespective of source of supply, comprise its technical coefficients. On the other hand, the supply of the requirements by the various regions constitute the trade coefficients. Thus, the trade coefficient has a spatial connotation. As a result of this dichotomy between trade and technical coefficients, the regional input-output coefficient for a region p may be denoted by:

$$a_{ij}^{R} = r_{ij} a_{ij}^{T}, \qquad (3.6)$$

where a_{ij}^{R} is the regional input-output coefficient; a_{ij}^{T} is the technical requirement of commodity i per unit output of j, and r_{ij} is the requirement of commodity i by sector j which is supplied from within the region. The principal nonsurvey techniques of regionalization of the national coefficients have focused on deriving regional trade coefficients.

A detailed review of the various non-survey techniques has been carried out by Round. Only a brief summary of the main approaches to non-survey methods, based primarily on Round's review, is presented below. These approaches are classified into the following categories:

(i) Commodity Balance Methods
(ii) Location Quotient Methods
(iii) Iterative Methods
(iv) Regional Purchase Coefficients

3.6. Commodity-Balance Methods.

The commodity-balance approach, also known as the Supply-Demand Pool Technique (Schaffer and Chu) was introduced by Isard. The method involves the calculation of the balance, B_i, between the local output x_i^R and local demand D_i for good i. Following the estimation of D_i using the national technical coefficients, such that $D_i = \sum_j x_j^R a_{ij}$, it is used to calculate B_i so that, $B_i = x_i^R - D_i$. A positive magnitude of B_i is considered to indicate that local supply suffices in meeting local demand and, therefore, the national technical coefficients may be used in row i of the regional trade coefficients matrix, that is, a commodity surplus is treated as a net export, so that the trade coefficient in such a case is unitary. On the other hand, when B_i is negative, implying that local demand exceeds local supply, and that imports are required, the national technical coefficients of row i are reduced by the factor $\frac{x_i^R}{D_i}$, which is a trade coefficient ratio of regional output to regional requirements. There have been several applications of this procedure, including one by Nevin, Roe and Round, to generate a regional table for Wales.

3.7. Location Quotient Methods

The location quotient method attempts to estimate the regional trade coefficients by assuming that $a_{ij}^R = r_{ij}.a_{ij}^N$ (the superscript N denotes elements of the national matrix), so that $r_{ij} \leq 1$. This technique of attempting to regionalize national coefficients has led to the development of several variants as described below:

3.7.1. Simple Location Quotients

The simple location quotient may be expressed as:

(3.7) $$LQ_i^R = \left[\frac{X_i^R / X^R}{X_i^N / X^N} \right],$$

where,

X_i = gross output of sector i,

X = total output,

and superscripts R and N connote region and nation, respectively.

In the above measure, the numerator represents the proportion of total output in the region that is comprised of output from sector i, and the same measure at the national level is specified in the denominator. Thus, where $LQ_i^R > 1$, the implication is that the concentration of industries in sector i is greater in region R than in the nation, and vice versa, in the case where $LQ_i^R < 1$. This interpretation has been extended to indicate a measure of the ability of industry i to fulfill the regional needs of other regional industries for its output. Thus, where $LQ_i^R < 1$, the inference drawn is that sector i is unable to meet fully the need for input i by other regional industries. In such a case, the regional technical coefficients are estimated by multiplying the national coefficients by the simple location quotient. In the case where $LQ_i^r > 1$, it is assumed that national coefficients a_{ij}^N are applicable to the region. Thus,

$$a_{ij}^r = \begin{cases} a_{ij}^N (LQ_i^R) & \text{if} \quad LQ_i^R < 1 \\ a_{ij}^N & \text{if} \quad LQ_i^R \geq 1 \end{cases} \tag{3.8}$$

The simple location quotient suffers from the drawback of taking only the output of the selling industry into consideration. But, the extent of large industrial imports will also depend on the relative output of purchasing industries and this must be taken into account. This shortcoming led to the development of the purchase-only location quotient which is described below.

3.7.2. Purchase-Only Location Quotients

The purchase-only location quotient differs from the simple location quotient in that it relates the regional supply of inputs for sector i to the national supply. The representation of the purchase-only location quotient is, therefore, given by:

$$PLQ_i^R = \left[\frac{X_i^R / X^{\star R}}{X_i^N / X^{\star N}} \right] \tag{3.9}$$

where, X_i^R, and X_i^N represent the regional and national outputs of good i respectively, and $X^{\star R}$ and $X^{\star N}$ represent regional and national output levels, respectively, of only those sectors that purchase the output of i. By using this procedure, the intention is to take into account only those sectors that are of relevance to sectors in terms of output, thus giving rise to a more appropriate means of adjusting regional coefficients. The utilization of the purchase-only location quotient for adjusting the national technical coefficients to regional levels is similar to the procedure followed in the case of the simple location quotients (as seen in equation (3.8)).

3.7.3. Cross-Industry Location Quotients

This location quotient variant attempts to take into account the importance of both the selling and the buying sectors at the regional level, relative to the national level. The cross-industry location quotient is represented by:

$$CIQ_{ij}^R = \left[\frac{X_i^R / X_i^N}{X_j^R / X_j^N} \right] \tag{3.10}$$

where i and j represent selling and buying sectors respectively. This method results in each element of the row of an input-output matrix being adjusted by a unique modifier (instead of one modifier for the entire row as in the case of the simple and purchase-only location quotients). The application of the cross-industry quotient is similar to that of the simple location quotient and may be represented as follows:

$$a_{ij}^{R}=\begin{cases}a_{ij}^{N}(CIQ_{ij}^{R}) & if \quad CIQ_{ij}^{R}<1\\ a_{ij}^{N} & if \quad CIQ_{ij}^{R}\geq 1\end{cases} \tag{3.11}$$

The implications of this method are straightforward and indicate that, when the output of the regional selling sector i is greater, relative to the output of i at the national level, and the same holds true for the sector j, then all of sector j's requirement of input i can be met from regional production. Where that does not hold, some imports of sector i's outputs will take place.

It is evident that the cross industry quotient can be represented, alternatively, by $CIQ_{ij}=\frac{LQ_i}{LQ_j}$. The implication from this, that CIQ_{ii} is unity for all i, indicating that each sector's requirement of inputs from its own sector is met indigenously, has met with some criticism (Morrison and Smith).

There are many variations on the basic location quotient framework outlined. In addition, where output data are not available, other measures such as income, employment, value-added, etc., have been used in lieu of output.

3.8. Iterative Methods

Iterative methods were introduced by Czamanski and Malizia, and by Schaffer and Chu. These methods are similar to the commodity-balance approach, but have an added iterative element which is intended to bring about a convergence towards a final balance.

The procedure consists of adjusting individual preassigned elements (usually national technical coefficients), to conform with known regional constraints. These consist of the vectors of total intraregional intermediate sales and purchases. Thus, the A matrix chosen is critical to the results generated. The biproportional transformation of a national input-ouput coefficient using iterative techniques (such as the RAS [10] technique) may be represented by:

(3.12) $$a_{ij}^R = r_i^R a_{ij}^N s_j^R$$

where r_i^R and s_j^R represent multipliers determined from constraints on total intraregional sales of sector i, and total intraregional purchases of sector j.

McMenamin and Haring attempted to expand the focus of the iterative procedures, from their concentration exclusively on intraindustry coefficients, by extending the biproportional adjustments to the vectors of final demand and value-added but the efficacy of the procedure has been questioned by Giarratani.

3.9. Regional Purchase Coefficients

The Regional Purchase Coefficients (RPC) technique for regionalizing national input-output technical coefficients was developed by Stevens *et al.*. An RPC has been defined as " the proportion of a good or service used to fulfill demands in a region which is supplied by the region to itself rather than being imported. " (Stevens *et al.* p.272). Thus, for a good i in region L, the RPC may be denoted by:

---

[10] named after the variables on the right hand side of equation (3.12).

(3.13) $$R_i^L = \frac{S_i^{LL}}{(S_i^{LL} + S_i^{UL})}$$

where,

S_i^{LL} = intraregional shipment of good i within region L.

S_i^{UL} = amount of good i imported into L from the rest of the nation.

Thus, 3.13 can be rewritten as:

(3.14) $$R_i^L = \left[\frac{1}{[1 + 1/(S_i^{LL}/S_i^{UL})]} \right]$$

so that the values of R_i^L lie between zero (when $S_i^{LL} = 0$), and one (when $S_i^{UL} = 0$). Data limitations preclude direct estimation of the ratio S_i^{LL}/S_i^{UL} and Stevens et al. have resorted to neoclassical location and trade theory to lay the groundwork for developing an estimation equation for this ratio. Thus, from the theories of Isard, relative shipments are a function of relative delivered costs, so that[11]:

(3.15) $$\frac{S^{LL}}{S^{UL}} = f_1\left(\frac{c^{LL}}{c^{UL}} \right)$$

where,

c^{LL} = average intraregional costs of delivery of good i produced in L.

c^{UL} = average intraregional costs of delivery from the rest of the nation to L.

[11] Subscripts indicating good i have been eliminated but apply to all the elements. In subsequent discussions, the superscripts convey the same regional and national connotations.

The assumption is made that the function is continuously differentiable, and that $\infty > f'_1 > 0$, that is, a finite elasticity of substitution exists between supplies of good i from intraregional and extraregional sources over the range of relative prices.

Relative delivered costs are defined as:

(3.16)
$$\frac{c^{LL}}{c^{UL}} = \frac{(c^L + t^{LL})}{(c^U + t^{UL})}$$

where c^L and c^U refer to regional and average national unit production costs respectively, and t^{LL} and t^{UL} refer to the relative shipment costs.

A further assumption is represented by:

(3.17)
$$\frac{c^L}{c^U} = f_2\left(\frac{w^L}{w^U}, \frac{o^L}{o^U}, \frac{Q^L}{Q^U} \right)$$

where $\frac{w^L}{w^U}$ and o^L and o^U represent cost factors divided into wages and "other" costs, respectively, and $\frac{Q^L}{Q^U}$ represents a scale factor, denoting outputs of the good i in the region and in the rest of the nation.

Equation 3.16, and the production function implied in f_2 (equation 3.17) are assumed to be continuously differentiable. In the case of equation 3.16, the first partials in terms of c^L and t^{LL} , relative to the nation, are both positive.

Assuming that transportation rates are the same for the region and the nation, and are a decreasing function of distance, it follows that:

(3.18)
$$\frac{t^{LL}}{t^{UL}} = f_3\left(\frac{d^{LL}}{d^{UL}} \right)$$

where d represents average shipment distance.

Data limitations prevent a ready solution for RPC's by fitting functions f_1, f_2, and f_3. To circumvent this, a predicting equation is fitted using a sample of available RPC's and other data and this is then used to estimate the missing RPC's. The aim, therefore, is to develop an estimable form of the equation such as:

$$R^L = \pi_j \left(\frac{X_j^L}{X_j^U} \right)^{b_j} \tag{3.19}$$

where X_j represents variable j, and b_j is the elasticity of response of the RPC to a change in the ratio of the variable j.

The elasticity of response of R^L to a change in ratios $\frac{c^L}{c^U}$ and $\frac{t^{LL}}{t^{UL}}$ is dependent on the size of ratios $\frac{t^{UL}}{c^U}$ and $\frac{t^U}{c^L}$. In order to capture this effect, an approximation is modeled by:

$$\frac{t^{KL}}{c^K} = f_4\left(d^{KL}, \frac{W}{V}\right) \tag{3.20}$$

where,

$\frac{W}{V}$ = weight over value ratio of good i,

K = region of shipment origin.

From the above and function f_3, equation 3.13 can be restated as:

$$\frac{c^{LL}}{c^{UL}} = f_5\left(\frac{c^L}{c^U}, \frac{d^{LL}}{d^{UL}}, \frac{W}{V} \right). \tag{3.21}$$

Since identification of the physical location of producers or users in or outside a region cannot be carried out with available data, this is approximated using the function:

$$(3.22)\qquad \frac{d^{LL}}{d^{UL}} = f_6\left[\frac{(n^L/N^L)}{(n^U/N^U)}\,\frac{A^L}{A^U}\right],$$

where n and N are the number of producers and users of the good, respectively, and A is the land area.

The above discussion leads to a representation of RPC's denoted by:

$$(3.23)\qquad R^L = K\left(\frac{w^L}{w^U}\right)^{b_1}\left(\frac{o^L}{o^U}\right)^{b_2}\left(\frac{Q^L}{Q^U}\right)^{b_3}\left(\frac{W}{V}\right)^{b_4}\left[\frac{(n^L/N^L)}{(n^U/N^U)}\right]^{b_5}\left(\frac{A^L}{A^U}\right)^{b_6}$$

where K is a constant.

In order to make this estimable in the context of data limitations, the final version of the above equation is:

$$(3.24)\qquad R_i^L = K\left(\frac{w_i^L}{w_i^U}\right)^{b_i}\left(\frac{e_i^L}{e_i^U}\right)^{b_2}\left[\frac{W_i^U}{(e_i^U/w_i^U)}\right]^{b_3}\left[\frac{(e_i^L/E^L)}{(e_i^U/E^U)}\right]^{b_4}\left(\frac{A^L}{A^U}\right)^{b_5}$$

where,

w = average annual wage per worker

e = employment

E = total manufacturing employment

W = total tonnage

A = land area

$$\left[\frac{(e_i^L / E^L)}{(e_i^U / E^U)} \right]$$ = the employment location quotient for industry i in region L.

3.10. Non-Survey Methods - Some Criticisms

Nonsurvey methods concentrate on deriving regional trade coefficients and no attention is paid to regional technical coefficients. However, it is possible that regional technical coefficients for particular sectors may vary considerably from those derived at the national level. Experiments by Harrigan *et al.*, (1981) suggest that errors are minimized by using information on a combination of trade and technical coefficients, rather than any one in isolation.

The commodity-balance and location quotient techniques have concentrated exclusively on deriving regional trade coefficients. In addition, these approaches ignore cross-hauling affects and are biased towards local supply in meeting local demands. The RAS and similar iterative procedures attempt to jointly determine trade and technical coefficients, but, as pointed out by Round "the efficacy of the resulting regional coefficients, a_{ij}^R, depends on the appropriateness of the national coefficients, a_{ij}, as a first estimate of the regional technical coefficients. (p.199)". Thus, the national matrix may not be the most appropriate choice in the context of a particular region. This conclusion is further supported by the finding, by Harrigan *et al.*, (1981), that large import coefficients (i.e. small trade coefficients) tend to be associated with large technical coefficients. Hewings (1977) has suggested the use of a regional input-output matrix of another region , of similar size and structure, as the initial matrix for applying the RAS procedure, in order to get better results.

3.11. Extensions of the Basic Regional Static Input-Output Framework

While the basic static input-output table has been used as the framework for a number of studies regarding the structure of the economy and its multipliers, several extensions of this basic framework have been developed within the last two decades. These have been concerned primarily with inclusion of demographic and household aspects of the economy within the accounting framework. This has resulted in more comprehensive coverage of the economy and, consequently, of its analysis. The three major extensions of the input-output table are (i) the Miyazawa framework, (ii) the Batey-Madden Extension of the Miyazawa framework, and (iii) the social accounting matrix (SAM) framework.

Of these three extensions of the input-output framework, the SAM framework is pertinent to this study since it has formed the basis for several attempts to disaggregate the multiplier. This framework and the attempts at disaggregation are, therefore, described briefly below.

3.12. The Social Accounting Framework

The input-output framework was an important step towards disaggregation of production activities, and led to the development of an array of models that provided insights into the functioning of the economy and its structure. However, it was gradually realized that, "the framework for data and models must recognize the central importance of people, not commodities, if it is to serve best the interests of policy design (Pyatt and Round, 1985, p.1)". This realization led to concern about the manner in which changes in the living standards of different groups take place as economic development occurs.

These factors led to the development of the social accounting approach, which provides a data base that may be viewed as a statement of initial conditions in an economy from which analysis may proceed. The fundamental strength of the Social Accounting Matrix (or SAM) approach is that it emphasizes "the fact that the distribution of employment opportunities and living standards in a society is inextricably interwoven with the structure of production and the distribution of resources (Pyatt and Round, 1985, p.2)". The SAM is a general equilibrium data system which, by linking together production activities, factors of production, and institutions, is able to represent the interdependence that exists between production, the distribution of income (that is, value added) among factors as a result of their activity in production, and the income distribution among institutions, particularly among different socio-economic household groups (Defourny and Thorbecke).

The SAM has, under assumptions of fixed prices and excess capacity, been used for modeling the effects of exogenous injections on the whole economy (and not just the production activities as in input-output analysis). The procedure involves partitioning of the matrix into the endogenous accounts, such as factors, institutions (companies and households) and production activities, and the exogenous accounts, which usually consist of government, capital and the rest of the world.

The SAM system may typically be represented as in Figure 3.1 on page 68 which shows the partitioned SAM and the three endogenous accounts (T_{13},T_{33} and T_{21}). T_{13} assigns the value-added from the production activities to the various factors as income. T_{33} is the input-output matrix representing intermediate requirements for production and T_{21} allocates the factorial income to the various households which are distinguished by socio-economic characteristics. The inter-household income transfers are mapped by matrix T_{22} and the consumption expenditures of the households are represented by T_{32}.

The development of multipliers in such a system has been described by Stone. The generalized inverse $[I-A]^{-1}$ in the case of the SAM, however, includes not only the Leontief inverse of interindustry transactions, but is, in this context,

> a multiplier matrix which links all endogenous income levels in a SAM to exogenous injections. Hence, if the endogenous incomes include those of factors, institutions and activities, then $[I-A]^{-1}$ embraces not only what happens within these broad groups of accounts (e.g. the interindustry transactions among production activities), but also what goes on between them. (Pyatt and Round, 1985, p.9).

Thus, the macroeconomic conception of the circular flow of income from the demands on activities resulting in the demand for factors, which, in turn, effects the income of institutions, thus completing the cycle back to demands on activities, is fully captured in the SAM.

3.13. Development of Multipliers in the SAM

The input-output model, which is usually an open model with respect to households, can be used for predicting the vector of gross outputs that result from a given vector of final demand. There are no welfare implications contained in such a model. However, by closing the model with respect to the disaggregated factors of production, welfare

				Expenditures				
				Endogenous accounts			Exog.	
				Factors	Households	Production activities	Sum of other accounts	Totals
				1	2	3	4	5
Receipts	Endogenous accounts	Factors	1	0	0	$\mathbf{T}_{13}$	$\mathbf{x}_1$	$\mathbf{y}_1$
		Households	2	$\mathbf{T}_{21}$	$\mathbf{T}_{22}$	0	$\mathbf{x}_2$	$\mathbf{y}_2$
		Production activities	3	0	$\mathbf{T}_{32}$	$\mathbf{T}_{33}$	$\mathbf{x}_3$	$\mathbf{y}_3$
	Exog.	Sum of other accounts	4	$\mathbf{l}_1'$	$\mathbf{l}_2'$	$\mathbf{l}_3'$	$\mathbf{t}$	$\mathbf{y}_x$
		Totals	5	$\mathbf{y}_1'$	$\mathbf{y}_2'$	$\mathbf{y}_3'$	$\mathbf{y}_x$	

Figure 3.1. A Schematic Social Accounting Matrix (Source: Defourny and Thorbecke).

		Expenditures				
		Endogenous	Sum	Exogenous	Sum	Totals
Receipts	Endogenous	$\mathbf{T}_{nn}$	$\mathbf{n}$	Injections $\mathbf{T}_{nx}$	$\mathbf{x}$	$\mathbf{y}_n$
	Exogenous	Leakages $\mathbf{T}_{xn}$	$\mathbf{l}$	Residual balances $\mathbf{T}_{xx}$	$\mathbf{t}$	$\mathbf{y}_x$
Totals		$\mathbf{y}'_n$		$\mathbf{y}'_x$		

Figure 3.2. Exogenous and Endogenous Accounts in a Social Accounting Matrix (Source: Defourny and Thorbecke).

impacts can be modeled as in the case of the Miyazawa, and the Batey and Madden extensions of the static input-output model. By including the distribution of factor incomes to household accounts, and the corresponding disaggregated matrix of household consumption by the various socio-economic groups, a more complete picture of the economy and a more comprehensive representation of its mechanism, is obtained. This may be reflected in a larger multiplier, taking into account the impacts of increases in final demand, not only on interindustry transactions, but through the whole gamut of actors in the economy represented in the accounting matrix - the factors, the households and their income distribution, and consumption and its impact on final demand.

A procedure for developing such composite multipliers and, at the same time, decomposing the multiplier into its various components, such as contribution by intragroup (e.g. interindustry or interhousehold), and intergroup (e.g. industry - household) transactions should be even more revealing about the economy and the contribution by a sector. Such multipliers have been developed using the SAM framework by Pyatt et al. (1977), Stone, and Pyatt and Round (1979), as briefly summarized below, primarily from the description in Defourny and Thorbecke.

The matrix shown in Figure 3.1 can be partitioned into exogenous and endogenous accounts as indicated earlier. The resultant matrix is shown in Figure 3.2, in which the column vector, y_n, indicates the total of incomes received by endogenous accounts consisting of: (1) spending by endogenous accounts, T_{nn}, the summation of which results in a column vector n; and (2) expenditures by exogenous accounts, T_{nx} summing up to x. This expenditure constitutes injections into the economy. Then,

(3.25) $$y_n = n + x.$$

The endogenous transactions, T_{nn}, when normalized, result in a matrix of average expenditure propensities. Thus,

(3.26) $$T_{nn} = A_n\hat{y}_n,$$

$\hat{y}_n$ being a diagonal matrix with elements y_i, and i = 1,...,n.

Similarly,

(3.27) $$T_{xn} = A_1\hat{y}_n,$$

so that,

(3.28) $$n = A_n y_n,$$

and,

(3.29) $$1 = A_1 y_n.$$

from 3.25 and 3.28, there results the matrix of multipliers, M_a , as shown below:

(3.30) $$y_n = A_n y_n + x = [I - A_n]^{-1} x = M_a x.$$

Thus, the multiplier matrix M_a multiplied by injections, x, yields endogenous incomes, y_n. The multiplier M_a has been referred to as the accounting multiplier matrix.

3.14. Decomposition of Multipliers with the SAM

The matrix in the SAM, as was indicated earlier, is partitioned into exogenous and endogenous accounts, and the corresponding matrix of average expenditure propensities obtained on normalizing is as follows:

(3.31)
$$A_n = \begin{bmatrix} 0 & 0 & A_{13} \\ A_{21} & A_{22} & 0 \\ 0 & A_{32} & A_{33} \end{bmatrix}$$

In such a system, solving for the production activities vector using equations 3.30 and 3.31 yields:

(3.32)
$$y_3 = A_{33}y_3 + (A_{32}y_2 + x_3) = [I - A_{33}]^{-1}(A_{32}y_2 + x_3).$$

which is an extended version of the Leontief inverse, which includes the effects of income distribution (y_2) on household consumption (represented by A_{32}). The equivalent formulation of the open Leontief model would be represented by:

(3.33)
$$y_3 = [I - A_{33}]^{-1}f$$

where A_{33} is the input-output coefficient matrix and f is exogenous final demand. M_a, being based on average expenditure propensities, implies unitary income elasticity, which is a rather strong assumption. A modified version using a matrix of marginal expenditure propensities has also been developed, giving rise to what have been designated the fixed-price multipliers.

Pyatt et al. (1977), Stone, and Pyatt and Round (1979), have detailed the manner in which the accounting multipliers, M_a, can, by appropriate partitioning and matrix manipulation, give rise to a multiplicative decomposition of the SAM multipliers into their component parts. Since decomposition of multipliers is expected to play an important role in the present research, a fairly detailed account of the procedure is given below. As already stated, the matrix of normalized endogenous accounts in the SAM may be represented by:

(3.34)
$$A = \begin{bmatrix} 0 & 0 & A_{13} \\ A_{21} & A_{22} & 0 \\ 0 & A_{32} & A_{33} \end{bmatrix}$$

which may be written as,

(3.35)
$$A = \begin{bmatrix} 0 & 0 & 0 \\ 0 & A_{22} & 0 \\ 0 & 0 & A_{33} \end{bmatrix} + \begin{bmatrix} 0 & 0 & A_{13} \\ A_{21} & 0 & 0 \\ 0 & A_{32} & 0 \end{bmatrix}$$

or, A = B + C. Then, 3.30 could be stated as,

(3.36)
$$\begin{aligned} y &= By + Cy + x \\ &= [I - B]^{-1}Cy + [I - B]^{-1}x \\ &= [I - (I - B)^{-1}C]^{-1}(I - B)^{-1}x \\ &= [I + (I - B)^{-1}C + (I - B)^{-1}C(I - B)^{-1}C]x \\ &\quad \{I - [(I - B)^{-1}C(I - B)^{-1}C(I - B)^{-1}C]\}^{-1}x(I - B)^{-1}x \\ &= M_3.M_2.M_1x = M_ax \end{aligned}$$

An additive version of this multiplicative decomposition has been developed by Stone, and results in the following representation (Defourny and Thorbecke, p.115):

$$M_a = I + \underbrace{(M_{a1} - I)}_{T} + \underbrace{(M_{a2} - I)M_{a1}}_{O} + \underbrace{(M_{a3} - I)M_{a2}M_{a1}}_{C} \tag{3.37}$$

which shows that M_a consists of four additive components: (i) the initial injection (I), (ii) the net contribution of transfer (or intra-account) multiplier effects (T), (iii) the net contribution of open-loop or cross multiplier (or inter-account) effects (O), and (iv) the net contribution of the closure of the loop, and the completion of the circuit, followed by the initial impact through the various groups, back to the original group impacted (C).

3.15. Multiplier Decomposition Using Structural Path Analysis (SPA)

Structural Path Analysis (SPA), as already briefly described, was developed in order to provide a detailed picture of the plexus formed by the interdependence among groups and sectors, and to trace the paths along which economic currents are transmitted in the economy. Since the procedure is still relatively new, and is potentially an important tool to be used in the present research, a fairly detailed introduction to the terminology used in describing the procedure is considered relevant and is, accordingly, set out below. A more complete version of the procedure is described by Defourny and Thorbecke, from which the following account is taken.

Consider the relationships that may exist between two sectors such as the agricultural sector (i) and the manufacturing sector (j). Several interactions between them are possible. The most direct transaction is the purchase of machinery directly from the manufacturing sector by the agricultural sector. This constitutes the shortest link ($i \rightarrow j$) between the two sectors (referred to in graph theoretic language as nodes or poles). The purchase of inputs by the agricultural sector from the manufacturing sector results in the flow of economic influence from the agricultural sector to the manufacturing sector. In graph theoretic terminology this constitutes a ***path*** of length one. The agricultural sector could also purchase agricultural machinery from a sales agency (s) which, in turn, purchases the machinery from the manufacturing sector. In this case the path or linkage is from the agricultural to the manufacturing sector, via the services (sales) sector. The path, in this case, is of length two[12], since it consists of two ***arcs*** ($i \rightarrow s$, and $s \rightarrow j$) with the payments for the relevant purchases being transmitted as influence from the purchasing to the selling sector.

A third mode of linkage can be represented by the purchase of high yielding varieties of seeds from a nursery (x) by the agricultural sector. The nursery, in turn, purchases inputs (research and development) from a state university (y) which uses inputs purchased from the manufacturing sector to carry out its research. So far this chain of linkages constitutes a path of length three (the arcs constituting this path are $i \rightarrow x$, $x \rightarrow y$, and $y \rightarrow j$). In addition to these purchases however, the university may require inputs from the nursery for carrying out its research. Thus, there is a flow of economic influence from the university to the nursery ($y \rightarrow x$) in addition to the opposite flow represented by the purchase of inputs from the university by the nursery that was described above. Such a circular flow is described as a ***loop*** in graph theoretic terminology.

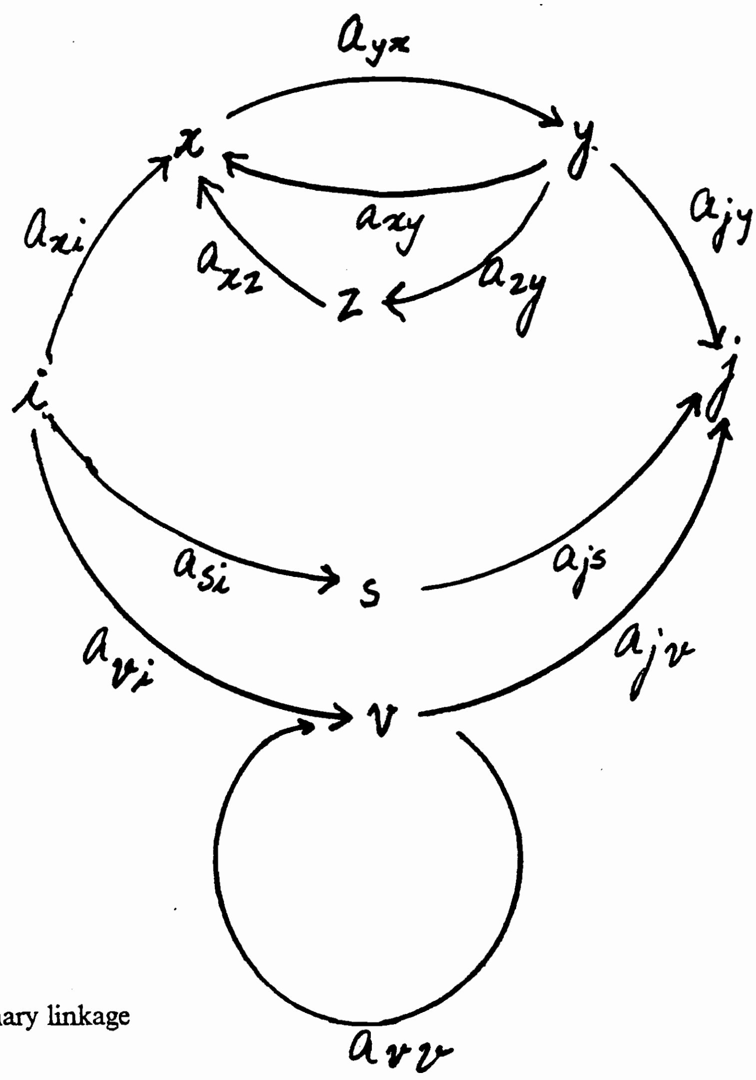
---

[12] A sequence of consecutive arcs forms a path, and its ***length*** consists of the number of arcs (each of which is a path of length one) comprising it.

The linkages described above are a simplified representation of the linkages that are possible between sectors. In addition to the above variations, it is possible that an industry uses its own outputs as input for its product (the use of chemicals to manufacture other chemicals, for example). In such a case the path is a closed loop, with the poles of origin and destination being the same, and it is said to constitute a ***circuit***. A path that does not pass more than once through the same pole constitutes an ***elementary path***. Influence, which was described above as the effect of one sector or pole on another, has been decomposed into three categories - direct influence, total influence, and global influence.

3.15.1. Direct Influence

Direct influence of i on j, along an arc (i,j) (represented by $i \rightarrow j$) is indicated by the change in income (or production) of j, induced by a unitary change in i, under conditions of *ceteris paribus*, with respect to the income (or production) of all other poles along the elementary path. Thus, when the direct influence is measured along a path of unit length, that is, it consists of a single arc between two poles i,j, the level of this influence is identical to the corresponding element of the A matrix, representing average expenditure propensities. Direct influence of i on j, along an arc (i,j) may be represented by $I^D_{(i \rightarrow j)} = a_{ji}$ The A matrix has, therefore, been referred to as the ***matrix of direct influence***. This is analogous to the direct component of conventional multiplier analysis. However, when a path of length greater than unity is being considered (i.e. it consists of more than just two nodes, and may contain one or more intermediate nodes giving rise to several arcs along the path), the level of direct influence cannot be obtained from the A matrix.



i → s = primary linkage

i → s → j = secondary linkage

$\left.\begin{array}{l} y \rightarrow x \\ y \rightarrow z \rightarrow x \end{array}\right\}$ = tertiary linkage (cycling)

Figure 3.3. An Example of the Possible Linkages Between Two Sectors (Source: Defourny and Thorbecke).

Direct influence along an elementary path (i,...,j) has been calculated to be the product of the intensities of the arcs comprising the path. This has been termed the "multiplication rule" Thus, in Figure 3.3 on page 77, the direct influence of elementary path (i,s,j) is given by:

(3.38) $$I^{D}_{(i\to s,\, s\to j)_p} = I^{D}_{(i,s,j)_p} = a_{s,i} \cdot a_{j,s},$$

and the generalization of the measure is given by:

(3.39) $$I^{D}_{(i\to j)_p} = a_{jn}, \dots, a_{mi}.$$

3.15.2. Total Influence

Total influence is the sum of the direct influence of the elementary paths between any two poles i and j, and also the indirect influence contributed by the web of subsidiary circuits related to each pole comprising the elementary path (that is, circuits having one or more poles in common with elementary path (i,...,j)). The elementary path (i,...,j), and its adjacent circuits contributing to the total multiplier, may be seen in Figure 3.3. The total multiplier, for path (i,x,y,j), when broken down into its adjacent parts, can be seen to consist of the following:

- Direct influence between i and y, $I^{D}_{(i\to y)} = a_{x,i} \cdot a_{y,x}$ (multiplication rule)

- This influence is then transmitted from y to x via the two subsidiary circuits along paths $(y \to x)$ and $(y \to z \to x)$. The influence of this indirect transmission is represented by:

(3.40) $$I^I_{(y\rightarrow x)_p} + I^I_{(y\rightarrow z\rightarrow x)} = (a_{x,y}) + (a_{z,y}.a_{y,x}).$$

Thus, the total multiplier for path $(i \rightarrow y)$ consists of the direct and indirect influences, and is represented by:

(3.41) $$I^I_{(i,y)} = (a_{x,i}.a_{y,x})(a_{x,y} + a_{z,y}.a_{y,x}).$$

This influence is then transmitted through path (x,y) again and so on. This leads to a series of dampened impulses between x and y represented by:

(3.42) $$a_{x,i}.a_{y,x}\{1 + a_{y,x}(a_{x,y} + a_{z,y} + a_{x,z}) + [a_{y,x}(a_{x,y} + a_{z,y}.a_{x,z})]^2 + ...\}$$
$$= a_{x,i}a_{y,x}[I - a_{y,x}(a_{x,y} + a_{z,y}a_{x,z})]^{-1}$$

The entire influence represented by the above expression is then transmitted along arc (y,j) thus completing the path. Thus, the total influence along path (i,j) (applying the multiplication rule) becomes:

(3.43) $$I^T_{(i\rightarrow j)_p} = a_{x,i}a_{y,x}a_{j,y}[I - a_{y,x}(a_{x,y} + a_{z,y}a_{x,z})]^{-1}$$

From the earlier definition of direct influence, it can be seen that total influence consists of a multiplicative relationship between direct influence $(a_{x,i}, a_{y,x}, a_{j,y})$ and the indirect influences represented by:

(3.44) $$[I - a_{yx}(a_{zy}a_{xz})]^{-1} = M_p.$$

This expression may be generalized in the relationship,

(3.45) $$I^T_{(i\rightarrow j)_p} = I^D_{(i\rightarrow j)_p}M_p.$$

3.15.3. Global Influence

Total influence measures the direct, indirect, and induced influence along any one path connecting any two poles i and j and its subsidiary network. Global influence, on the other hand, concerns the direct, indirect, and induced effects of all paths connecting any two nodes i and j and their subsidiaries. Thus, global influence is analogous to the multiplier resulting from conventional inversion of the A matrix and is represented in SPA by,

(3.46) $$I^{G}_{(i \to j)} = m_{a_{j,i}},$$

where,

(3.47) $$y = [I - A]^{-1}x = M_a.x.$$

and $m_{a_{j,i}}$ is an element of matrix M_a. Thus, $M_a = [I - A]^{-1}$ is the ***matrix of global influences***, which is the same as the Leontief inverse described in connection with input-output analysis.

In the case of the two poles i, j in Figure 3.3, the global influence would comprise the summation of the total influences of each path connecting poles i and j, that is, path (i,x,y,j), path (i,s,j) and path (i,v,j) (referred to as paths 1, 2 and 3 respectively, in the following discussion). The total influence of each path, in turn, consists of the direct influence and the indirect influences contributed by the subsidiary paths ((y,x), and (y,z,x) in the case of path 1, and loop v in the case of path 3). The global influence between poles (i,j) may then be split into the following components:

$$
(3.48) \qquad \begin{aligned}
I^G_{(i,j)} = m_{a_{ji}} &= I^T_{(i,x,y,j)} + I^T_{(i,s,j)} + I^T_{(i,v,j)} \\
&= I^T_{(i\to j)_1} + I^T_{(i\to j)_2} + I^T_{(i\to j)_3} \\
&= I^D_{(i\to j)_1} M_1 + a_{s,i}a_{js} + (a_{v,i}a_{j,v})(I - a_{v,v})^{-1} \\
&= I^D_{(i\to j)_1} M_1 + I^D_{(i\to j)_2} + I^D_{(i\to j)_3}(M_3)
\end{aligned}
$$

The global influence can, therefore, be generalized in the expression,

$$
(3.49) \qquad I^G_{(i\to j)} = m_{a_{j,i}} = \sum_{p=1}^{n} I^T_{(i\to j)_p} = \sum_{p=1}^{n} I^D_{(i\to j)_p} M_p.
$$

The application of SPA to a SAM (or to an inter-industry table) results in the decomposition of all the networks interlinking any two sectors in the SAM. This gives rise to a far more detailed breakup of the multiplier than is obtained through the Stone technique. Moreover, the contribution to the multiplier, by each path, is also explicitly obtained.

By permitting such a degree of decomposition of the multiplier, SPA provides a means of going beyond the conventional assessment of the gross contribution of a sector in terms of income, output, or employment. It also goes a step further than the Stone technique which decomposes the SAM multiplier only into its components in terms of the interaccount effects, for example, the interindustry component, the industry-factor component, the household-industry component, etc. This third level of decomposition permitted by the SPA technique provides a means for the assessment of the contribution by individual sectors to a multiplier. This has important ramifications for the aims of the present research as will be explained subsequently.

3.16. A Measure of Sectoral Interdependence

The actors in an economy - the factors of production, the consumers, and the producers - are linked together in a network of interrelationships, with each group contributing to, and in turn receiving support from, the growth of the other groups. This contribution by one sector to the viability of another sector may occur in several ways, and may be distinguished as shown below:

- (i) The direct interaction of a sector, i, with another sector, j, either as a purchaser of j's products (the backward linkage effect), or as a supplier of one of j's inputs (the forward linkage effect). Such a relationship may be categorized as *symbiotic* since both partners benefit from this relationship, and contribute to each others viability. In terms of SPA, sector i's role is quantitatively represented by the direct influence of i on j, that is, the elementary path consisting of one or more arcs connecting i and j. The magnitude of this influence is, as previously shown, the same as the direct effect of the conventional multiplier.

- (ii.a.) Sector i, instead of interacting directly with j, may do so indirectly as a result of demand for its output by a third sector k. Thus, an increase in output by k would increase its need for inputs of i, which, in turn, would increase demand for j. Here, i acts as a node transmitting currents to j as an intermediary. This role may be regarded as catalytic, with sector i facilitating the transmission of effects between j and k. The contribution of this catalytic relationship, in quantitative terms, to j's support, may be gauged from the magnitude of the direct path, as obtained by SPA. Thus, the above example may be represented in SPA terms as:

(3.50) $$I_{(k,i,j)} = I_{(k\rightarrow j)_p} = I^D_{(k\rightarrow j)_p}.M_p.$$

In this case, $I_{(k,i,j)}$,which is the total multiplier, would represent the magnitude of the influence that is transmitted along the path in which i acts as a catalyst and would indicate the support, given by i to j, in its catalytic role. Conventional multiplier analysis does not furnish an equivalent means for determining the catalytic role of a sector.

- (ii.b.) In addition to acting as an intermediary in the transmission of effects between two sectors, sector i also transmits the effects of the secondary network of linkages that give rise to the path multiplier, M_p. In this manner, too, i acts as a catalyst transmitting effects between j and k. The magnitude of this secondary catalytic effect is captured in the path multiplier, M_p, in equation (3.50).

- (iii) A third mode of contribution of i to sector j's viability is as a part of the secondary network of linkages constituting the path multiplier, M_p. However, the quantitative contribution of this role is likely to be of a very low magnitude. This is suggested by the finding, by Defourny and Thorbecke, that " it is extremely rare to find a path, of length four or longer, transporting more than one half of a percent of the global influence transmitted from the pole of origin to the pole of destination (footnote 2, p. 123) " This aspect of the supportive role of a sector will not, therefore, be considered further.

SPA thus permits an analysis of the different ways in which a supportive role is played by a sector. An analysis of these different roles would clarify the total contribution of a sector to the structure of the economy.

3.17 Potential Measures of Economic Influence and Their Transmission

From the foregoing description of the SPA method, it is evident that the procedure yields a large amount of detailed data regarding the composition of the multiplier. Stated explicitly, the SPA procedure yields the following information:

- (i) The number, and length, of paths between any two sectors (nodes) that give rise to the multipliers seen as elements of the Leontief inverse.
- (ii) The identity of the arcs, or individual sectoral "links" that give rise to these paths (but not the magnitude of the influence transmitted along individual links).
- (iii) The contribution of each path (represented by the total multiplier) to the global multiplier.
- (iv) The cumulative contribution, to each path, by cycles occurring along the path. This is represented by the path multiplier M_p.

An analysis of the techniques and the aims of previously developed measures of sectoral contribution and structural change may be an appropriate point of departure for attempting to derive more appropriate measures. A synopsis of the various measures, described in detail earlier in the review of the literature, is presented in Table 3.1 on page 85.

As can be seen from the table, despite the variety of the terminology used, the measures can be broadly classified into three categories:

Table 3.1. Various Indices Developed for Measurement of Sectoral Roles in the Economy.

Measures of Direct Paths

- 1. Direct Flow (Szyrmer, 1986)
- 2. Straight through Flow (Finn, 1976)

Measures of Cycling

- 3. Complexity (Robinson & Markandaya, 1973; Bosserman, 1981; Zuchetto, 1981)
- 4. Diversity (Zuchetto, 1981)
- 5. Redundancy (Ulanowicz, 1983)

Measures of Total Contribution

- 6. Connectedness (Jensen, Hewings & West, 1984; Szyrmer, 1985)
- 7. Interrelatedness (Yan & Ames, 1965; Blin & Murphy, 1974)
- 8. Interdependence (Peacock & Dosser, 1957)

- (i) those which aim to measure the number of direct connections or linkages that are caused by a sector interacting with another.

- (ii) those which attempt to measure the indirect contributions to the multiplier in the form of cycles or loops along the paths.

- (iii) those which measure the total contribution to the multiplier by both the above fractions of the linkage between two sectors and the magnitude of the influence transmitted by them.

The present research seeks to obtain measures unifying the linkage aspect of multipliers with the magnitude of the economic influence transmitted by the linkages, and to compare changes in these aspects of the economy between regions. By doing this it might be possible to develop indices of intersectoral relationships and sectoral roles that are closer to the ideal indices described in Chapter 2, than existing indices. The application of such indices to a varied group of economies should lead to some answers to the questions framed in Chapter 1.

3.17.1. Potential Measures

Going by past attempts at measuring linkages and multiplier magnitude, the following aspects of the data yielded by SPA appear to be potentially useful sources of appropriate measures:

- (i) A measure of the number of direct paths between two sectors, *per se*, with the magnitude of the economic influence transmitted by them being taken into consideration.

- (ii) A measure of the magnitude of the economic influence transmitted by the cycles and loops along the individual paths.

- (iii) A measure of the number of arcs comprising the paths indicated in (i), with and without the magnitude of the economic influence transmitted by them being taken into account.

The above parameters must then be manipulated so as to yield information that makes possible comparisons of sectoral roles and sectoral contributions, within the same economy and also across economies. Only then can changes in sectoral roles with changing structures over space and time be analysed. Such manipulations were carried out on the data to give rise to indices that are, in a way, linkage analogues of the indices developed for data based on the multipliers of the Leontief inverse matrix. These indices are described below.

3.17.2. Generalising the Measures

The "raw" data obtained from SPA analysis as indicated above may be generalised using techniques developed by earlier researchers. Several measures are possible, and a list of the possible indices is developed in Table 3.2 on page 88.

Table 3.2. **Potential Indices Developed from Linkage Analysis for Measurement of Sectoral Roles in the Structure of the Economy.**

sectoral ratios 1	Averages 2	Global Ratios 3	Rasmussen indices 4
Summation of Paths			
$P^{ij} = \sum_{m=1}^{k} P^{ij}_{m}$★	$P_j = \sum_{i=1}^{n} P^{ij}$★ $P_{ij} = \sum_{i,j=1}^{n} P_j$★		
Summation of Arcs			
$A^{ij} = \sum_{m=1}^{k} A^{ij}_{m}$★	$A_j = \sum_{i=1}^{k} A^{ij}$★ $A_{ij} = \sum_{i,j=1}^{n} A_j$★		
Linkage Indices			
$L^{PS} = \frac{P^{ij}}{P^{j}}$★	$L^{PG} = \frac{P_j}{P_{ij}}$★	$L^{PR} = \frac{P_j/n}{P_{ij}/n^2}$	$L^{PH} = \frac{\sqrt{\frac{1}{n-1}\sum_{I=1}^{n}(P^{ij} - \frac{1}{n}P_j)^2}}{\frac{1}{n}P_j}$★
Indices Based on Path Multiplier/Direct Effect Ratios			
$MM = \frac{M^{ij}}{D^{ij}}$	$MMS = \frac{M_j}{D_j}$	$MMG = \frac{M_{ij}}{D_{ij}}$★	
Indices Based on Path Multiplier/Path Ratios			
$MP = \frac{M^{ij}_{P}}{P^{ij}}$	$MPS = \frac{M_j}{P_j}$	$MPG = \frac{M_{ij}}{P_{ij}}$★	
Cycling Indices I			
$C^{PS} = \frac{MP}{MPS}$	$C^{PG} = \frac{MPS}{MPG}$	$C^{PR} = \frac{MPS/n}{MPG/n^2}$	$C^{PH} = \frac{\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(MP - \frac{1}{n}MPS)^2}}{\frac{1}{n}MPS}$
Cycling Indices II			
$Y^{PS} = \frac{MM}{MMS}$	$Y^{PG} = \frac{MMS}{MMG}$	$Y^{PR} = \frac{MMS/n}{MMG/n^2}$	$Y^{PH} = \frac{\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(MM - \frac{1}{n}MMS)^2}}{\frac{1}{n}MMS}$

3.18. An Analysis of the Indices

From Table 3.2, it is evident that there are a number of indices that can be developed using the data from the Leontief inverse and from SPA. These indices are described briefly below.

3.18.1. Summations of Paths

The indices in row 1 of the table represent summations of the number of paths at various levels of the economy. Column 1 of this row shows the summation of the number of elementary paths between two sectors ($P^{ij} = \sum_{m=1} P^{ij}_{m}$, where m denotes the path number and the superscript indicates the two sectors which constitute the originating and terminal nodes of the paths). It therefore, represents the number of paths resulting from an interaction between any two sectors and, consequently, is a decomposition of the multiplier, represented by individual elements of the Leontief inverse, into its constituent paths. Thus, in the case of the example shown in Figure 3.3, $P^{ij} = 4$ [13].

The index P_j in column 2 of row 1 represents the summation of the column elements of a sector i and, therefore, is the linkage equivalent of the column sums of the elements of the Leontief inverse. It represents the total number of paths originating in the sector under consideration and terminating at the other sectors in the economy from which sector i purchases inputs.

---

[13] This result follows from the summation of the four individual paths connecting i and j.

The index P_{ij} in column 2 of row 1 represents the number of paths created by intersectoral transactions in the entire economy, and thus represents the gross or global linkage in terms of paths.

3.18.2. Summations of Arcs

The indices in row 2 of the table are calculated in the same way as those in row 1, with the difference that in this case, it is the number of arcs between any two sectors ($\sum_m A^{ij}_m$) that are taken into consideration, instead of the number of paths. As described in Figure 3.3, the paths created between any two sectors i and j by transactions between them ($\sum_m P^{ij}_m$) may be of varying lengths in terms of the number of sectors involved as intermediaries along the path in any transaction. Hence, it may be more pertinent to calculate the indices in terms of the number of arcs between sectors in order to make them more accurate measures of sectoral roles. The indices in columns 2 and 3 of row two are the arc equivalents of the indices in the respective columns in row 1. Thus, referring to Figure 3.3, $A^{ij} = 8$ [14].

3.18.3. Measures of Connectedness

Linkage Indices: The indices in row 3 are intended to measure connectedness, that is, the density of the linkages at several levels of the economy. In column 1 of row 3, by taking the ratio of the number of paths created by a transaction between two sectors ($\sum_m P^{ij}_m = P^{ij}$) to the total number of paths created by interactions between a particular

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[14] This is arrived at by adding the arcs constituting path 1 (3 arcs), path 2 (1 arc), path 3 (2 arcs), and path 4 (2 arcs).

sector and the other sectors in the economy (P^j), a normalized index is obtained. In other words, a measure is obtained, of the number of paths created by an intersectoral transaction as a proportion of the total number of paths created by all the intersectoral transactions of that particular sector with other sectors.

Column 2 of row 3 shows the index developed by taking the ratio of total paths created by intersectoral transactions originating at a sector (P_j) as a proportion of the total (gross or global) number of paths in the economy (P_{ij}).

Column 3 of row 3 shows an index developed on the same lines as the index of dispersion ($U_{j.}$) of Rasmussen described in chapter 2. While Rasmussen used multiplier magnitudes as the basis of his index, the number of paths is used in the present case. This index (L^{PR}) is obtained by taking the ratio of the number of paths created by a sector (P_j) to the total number of sectors in the economy (n) and by normalizing this average by the overall average defined by (P^{ij}/n^2).

As Hazari has noted, indices derived in this fashion are subject to the distortions caused by extreme values. Rasmussen suggested a "coefficient of variation" index (V_j) to circumvent this problem. The equivalent index, using the number of paths instead of the magnitude of the multiplier as the basis of analysis, is shown in column 4 of row 3 of the table. This index, like the Rasmussen index, may be termed a measure of variability. Rasmussen had interpreted a high V_j as showing that "a particular industry draws heavily on one or a few sectors and a low V_j as an industry drawing evenly from other sectors (p. 302)". The same interpretation could be made in the case of the index L^{PH} since it would take the actual number of linkages between sectors into consideration.

3.18.4. The Path Multiplier/Direct Effect Ratio

The indices in row 4 are concerned with the magnitude of the influence transmitted through cycles or loops that are induced by a path. The path multiplier/direct effect results in an index of the tertiary level influence induced (or cycling) per unit of direct effect. The magnitude of the induced influence is represented by the path multiplier (M_p) in structural path analysis. Indices in row 4 are calculated in terms of the economic influence transmitted by cycling along the paths between two sectors (represented by the summation of the path multipliers of the paths between two sectors $\sum_q M_p^{ij}$) as a proportion of the direct influence transmitted by the paths (column 1 row 4). Similar cycling indices as a proportion of the sectoral and global levels of cycling are developed in columns 2 and 3 respectively.

3.18.5. Indices of Connectivity

Connectivity takes into consideration of the number of linkages as well as the magnitude of the influence transmitted along them (Hewings, *et al.*). A measure of this could be achieved by taking the ratio of each element of the matrix of path multipliers to the number of paths involved in giving rise to the multiplier. The result is a measure of the average economic influence at the tertiary level of interaction induced by a path. This measure has been used as the basis for calculation of ratios similar to those described previously at the sectoral and regional levels. Three variations of connectedness indices, which may also be considered to indicate the level of cycling induced by a path, have been developed. These are the indices based on path multiplier/path ratios (row 5), the Cycling Indices I (row 6) and Cycling Indices II (row 7). The equivalents of

Rasmussen's average and dispersion indices have also been calculated so as to obtain connectivity indices C^{PR} and C^{PH} (row 6) and Y^{PR} and Y^{PH} (row 7) in the cases of Cycling Indices I and II respectively. These were developed using the same methods that were used to develop the Linkage Indices described above, and will not be repeated here.

Note that Rasmussen interpreted his index of dispersion (U_j) when the index had a magnitude greater than one, as an indication that the system of industries as a whole would need a comparatively large increase in output to cope with a unit increase in final demand of sector j's product. Such an interpretation cannot be extended to the equivalent path indices L^{PR}. The path indices are not expected to be affected by changes confined to final demand. Changes in structure, reflected in the pattern of linkages, would be expected to occur when endogenous changes in intersectoral transactions take place. Examples of such changes are those resulting from changes in technical coefficients. Thus, while muliplier magnitudes are affected by final demand changes, connectedness is not expected to be affected unless it induces changes in the transactions matrix. Connectivity indices would, however, be affected since multiplier magnitudes are taken into consideration in calculating these indices.

Indices developed in rows 1 to 3 have dealt with connectedness, or the density of linkages between sectors. The connectedness and connectivity indices can be recast equivalently in terms of arcs instead of paths for a more "micro" analysis of linkages and economic influence.

3.18.6 Indices Used in this Study

Not all the indices developed in Table 3.2 could be used in this study. Some of the indices attempt to measure the same feature in the economy at different levels of refinement. For example, there are three levels of indices for measurement of cycling (indices based on the path multiplier/paths ratio, and cycling indices I and II). The first of these indices is the simplest to calculate, while at the same time, providing some idea of the efficacy of such indices in portraying the connectivity of economic structure. Hence, instead of calculating all three indices, the first index was used as the basis of calculation of cycling. At the same time, in order to provide comprehensive information regarding cycling, the indices based on the path multiplier/direct effect ratio (row 4) were also calculated so that information regarding cycling, solely in terms of magnitude of influence (since both the path multiplier and direct effect represent influence rather than physical linkage) was obtained. Since this was a prototype attempt at applying such linkages, the simplest of the possible indices was resorted to, as far as possible, keeping the aims of the research in view. Based on this criterion, the indices marked with an asterisk in Table 3.2 were used in this study.

3.19. Analysis of the Fundamental Structure of Production

As indicated earlier (Section 2.6), Simpson and Tsukui had postulated the existence of a "fundamental structure of production" based on their study of triangularization of technical coefficients matrices of several national economies. The triangularization was carried out after the sectors in the economy had been segregated into groups referred to as "blocs". The blocs were considered to be a natural consequence of grouping the industries according to their physical qualities. The four blocs recognized by them were: (i) metals, (ii) non metals (iii) energy, and (iv) services. When sectors were ordered in this manner, and the major technical coefficients were considered, a distinct triangular disposition of the technical coefficients within each bloc was observed. In addition to this "bloc triangularity" a significant feature observed by the authors was bloc independence, that is, transactions between sectors were almost completely restricted to those within their own blocs. This feature was especially true of the metals and non metals blocs and their linkages with each other. These findings led Simpson and Tsukui to conclude that there existed a fundamental structure of production represented by the blocs, which is a reflection of the technological relationships that exist between sectors in a modern economy.

Simpson and Tsukui's findings of bloc triangularity and bloc independence were based on the technical coefficients matrix, which represents the direct or first order linkages between sectors. The secondary and tertiary linkages were not taken into consideration. The question that arises at this point is : If a fundamental structure of production does exist, does it exist only at the first order level, that is at the level of the transactions matrix only, or could it be traced to deeper levels of the economy? This question was examined in the light of the analysis of the linkages in the various models used in this study.

The bloc triangularity of the transactions matrices of the models used in this study was first examined. There was a distinct triangularity observed in each case although the elements present in the matrix were few and far between in the case of the less diversified economies. Examination of the bloc triangularity of the matrices of paths/arcs/path multipliers/direct effects was prevented by the fact that the diagonal elements of these matrices are all null, since intra-sectoral linkages are not portrayed by structural path analysis. It is the diagonal elements which are primarily responsible for the distinctiveness of the observed triangularity.

In order to examine whether bloc independence extended deeper into the economic structure than the first order linkages, the paths/path multiplier/direct effects matrices were subdivided into submatrices based on the blocs. Each submatrix was square and consisted of the sectors comprising the bloc. Thus, there were three submatrices, along the main diagonal of the linkage matrix for any region, representing the intra-bloc transactions of the metals, nonmetals, and service blocs, together with six off-diagonal submatrices representing inter-bloc transactions. The energy sectors were included in the service bloc. It should be mentioned that the matrices of each region were reduced to conform, as closely as possible, to the pattern of sectors used by Simpson and Tsukui in their analysis (Table 2.1 on page 44). This was carried out by eliminating, from the original matrices, the rows and columns of the sectors that were not to be included. While it would have been preferable to arrive at the reduced matrices by carrying out structural path analysis on the reduced transactions matrix, subsequent results, obtained by the analysis of transactions matrices developed by this method of reduction to conform to the models of Simpson and Tsukui, showed the distinct presence of bloc triangularity and bloc independence in the case of every planning district. That the matrix reduction procedure did not result in any regional model yielding results contradicting the conclusions of Simpson and Tsukui, suggests that the procedure did not detract from the results.

The procedure followed, in attempting to examine the bloc independence and triangularity of economies at levels deeper than the first order, was to compare the

	Metals Bloc	Nonmetals Bloc	Services Bloc
Metals	Intra-bloc Transactions (Metals-Metals)	Inter-bloc Transactions (Nonmetals-Metals)	Inter-bloc Transactions (Services-Metals)
Nonmetals	Inter-bloc Transactions (Metals-Nonmetals)	Intra-bloc Transactions (Nonmetals-Nonmetals)	Inter-bloc Transactions (Services-Nonmetals)
Services	Inter-bloc Transactions (Metals-Services)	Inter-bloc Transactions (Nonmetals-Services)	Intra-bloc Transactions (Services-Services)

Figure 3.4. Schematic Diagram of Submatrices and Intra- and Inter-Bloc Linkages.

linkages (paths/arcs/path multipliers/direct effects) within the on-diagonal submatrices with those lying off the diagonal but in the same bloc. In other words, the backward linkages of the group of sectors of a bloc were calculated in terms of intra-bloc linkages and compared with its inter-bloc linkages. The expectation, using such a procedure is that, if bloc independence extended to levels deeper than the first round of transactions, the intra- and inter-bloc linkage ratios obtained, in the case of the paths matrix (the matrix of secondary influences) and the path multiplier matrix (that is, the matrix of tertiary level influences), would indicate that the major portion of linkages would be intra-bloc especially in comparison to the inter-bloc transactions between the metals and nonmetals blocs. The services bloc had shown a high level of inter-bloc linkages with the other two blocs even at the level of the first order and this feature may be expected to be repeated at deeper levels. A schematic diagram showing the submatrices developed in the process described above is shown in Figure 3.4 on page 97.

3.20. Summary

The regional input-output method and the various means for regionalizing national input-output tables were outlined together with the SAM variant of the input-output table. This matrix has led to the development of several multiplier decomposition techniques but none approaches the level of detail and explicitness of the structural path analytic method, especially in indicating paths of transmission of economic influence and the magnitude of influence transmitted by these paths.

The structural path analysis method has been described in some detail, and the data obtained from such analyses, in conjunction with the data from the Leontief inverse, have been the basis for the development of several sets of indices which allow intersectoral and interregional comparisons of sectoral performance. Such an analysis should result in a quantitative assessment of the total contribution of a sector, in its supportive role.

The manner in which the analysis pertaining to the question of the fundamental structure of production and its extension into the secondary and tertiary levels of transactions could be carried out has also been outlined. With the groundwork for the method of analysis laid out, the sources of data and the regions subjected to analysis are the next items of interest. These are described in the chapter which follows.

Chapter 4

DATA SOURCES AND MODEL CONSTRUCTION

4.1. Introduction

The aims of the research dictate the nature of the models constructed. Since the intention, in this study, was to compare the structure of economies in various stages of diversification, the construction of several models, representing varying degrees of diversification, was called for. As already indicated, one of the most appropriate tools for analysis of linkages and multipliers is the input-output model, and since structural path analysis is based on the input-output model, this was the means used for analysing regional structures.

An input-output model may include the household sector (the closed model), or exclude the household sector and consider only the interactions among the industrial sectors (the open model). The open model was chosen for this study. Two reasons were responsible for this choice. The first was that the aim of this study was to decipher the linkages between the industrial sectors and to map their changing roles with development/diversification. Hence, the household sector was not required for analysing the inter-industrial linkages. The second reason was that the household sector, in a closed model, tends to swamp the interindustry effects. This is seen in the much higher multipliers that are usually obtained in the case of the closed model compared to the open model. It may be expected that there would be a correspondingly large number of industry-household linkages which would tend to overwhelm inter-industry linkages. Since this would hinder, rather than contribute to this study, the closed model was discarded in favor of the open model.

Ideally, comparison of models of a large number of regional economies over time and space would have been the best way to analyze the effects of structural changes with diversification. However, constraints on the availability of regional input-output data over several time periods restricted the analysis to a spatial comparison of regional economies in various stages of diversification. Available resources restricted the number of regions examined to six regional economies in addition to the economy of the state of Virginia as a whole, and the economy at the national level.

The unit chosen for the regional analyses was the planning district. This was because the planning districts, which are groupings of contiguous counties, are treated as single units for purposes of planning and may therefore, be considered to have some homogeneity in terms of the economies of its constituent counties. Thus, some evidence of homogeneity is offered by planning districts 1 and 2, which are primarily counties with economies based on the coal industry. Similarly, planning district 15 consists of 7 counties which are all metropolitan areas. Such similarities lend support to the assumption of homogeneity in the structure and extent of diversification of the economies of the counties in a planning district. The planning district thus appeared to be a viable unit on which to base the regional models. The aim, in choosing six out of the twenty two planning districts in Virginia, was to cover as wide a spectrum of levels of industrial diversification as possible, given the limitations regarding the number of models that were being developed.

The characteristics of the six planning districts chosen for analysis are indicated in Table 4.1 on page 103 and the locations of the planning districts are indicated in Figure 4.1 on page 106. This information regarding the planning districts were obtained from data provided by the Policy Impacts Project of the Economic Research Service. The typology of nonmetro counties developed under this scheme "was designed to capture a large amount of detail in a handful of categories" (preamble to data, ERS/USDA). This classification of nonmetro counties takes into account several economic and social factors. The major factor used in identifying planning districts with economies appropriate for the analysis was the primary source of income in the counties (whether agricultural, mining, manufacturing or government). This was available from the typology indicated above. Besides income, the typology also identified counties with high poverty, high rates of immigration of retirees, and those with a high percentage of government owned land.

Using the major source(s) of income as the basis for the choice of regions for analysis, the planning districts having the largest number of constituent counties in which farming contributed a weighted annual average of 20 percent or more to total labor and proprietor income from 1975 to 1979, were examined in order to choose the planning

Table 4.1. Characteristics of Planning Districts Selected for Analysis.

Planning District 1	No. of Counties 2	Characteristics 3	No. of Sectors 4
1&2	7	High mining income (>20 percent) in 5 counties; high poverty in 1 county	46
3	6	High mfg. income (>30 percent) in 3 counties; 1 metro area; high poverty in two counties; high retiree immigration in 1 county	47
4	4	All 4 counties with high manufacturing income;	47
7	5	4 counties with high mfg. income; 3 counties with high high retiree immigration	45
14	7	3 counties with high agricultural income; 2 counties with high mfg. income; 3 counties with high retiree immigration; 2 counties with high poverty.	45
15	7	all 7 counties are metro areas	50
VA	-	-	51
US	-	-	54

district representing the least diversified, or primary, end of the diversification spectrum (in the Hirschmanian sense). The data indicated that three of the seven counties of planning district 14 received a high proportion (greater than 20 percent) of income from agriculture. It should also be mentioned that two other counties from this planning district had high incomes (greater than 30 percent) from manufacturing. However, since the only three counties in the state with high agricultural income were in this planning district, it was chosen as one of the less diversified of the economies modeled. Although two counties have high manufacturing income, the planning district consists of seven counties and it was thought that the assumption of low diversity in the case of this planning district was reasonable. It may also be noted that three counties of this planning district have high levels of poverty.

At the opposite end of the diversity spectrum, the planning district with counties having high income proportions from manufacturing activity was found to be planning district 4. All four counties comprising this planning district are characterized by high manufacturing income. Using similar reasoning, four other regional areas were identified for the analysis. One of these was a composite of two planning districts (1 and 2) and they were combined into one region for the purposes of this analysis because four of the counties constituting the combined counties of these planning districts are characterized by high income from mining activity (and hence characterized as a less diversified or primary economy in accordance with Hirschman's arguments).

The three other planning districts chosen for the regional analyses were planning districts 15, 7 and 3. All the counties comprising planning district 15 are classified as metro counties under the ERS typology, and it was decided to include this planning district as theoretical argument would suggest that high urbanisation would result in a diversified economy, but the accent was likely to be on service oriented industries with some manufacturing. Planning district 7, which comprises counties in northern Virginia, represents a region with high manufacturing income. In addition, three of its counties have a high proportion (greater than 15 percent) of immigration of retirees. On the basis of Tiebout's hypothesis about people "voting with their feet", it may be assumed that these counties have considerable service oriented economies in addition to manufacturing. Planning district 3 represents a region without any particularly dominant source of income, with a mix of industries. It will be evident from the above discussion that the assumption underlying the choice of regions for analysis was that the major source of income in a region was a good indicator of the industrial activity in the region.

4.2. Data Sources

Data for the modeling of the input-output models of the planning districts was obtained from the IMPLAN modeling program. This software contains data, based primarily on the 1982 industrial census, which enables county and higher levels of input-output models to be constructed. A brief description of the IMPLAN software is given below as an introduction to the procedures used for generating the models used in the analyses.

4.3. The Implan Program

The IMPLAN system was developed by the USDA Forest Service (Alward and Palmer). The model uses "nonsurvey" techniques to construct regional economic accounts and develop input-output models based on such accounts. The strength of the IMPLAN

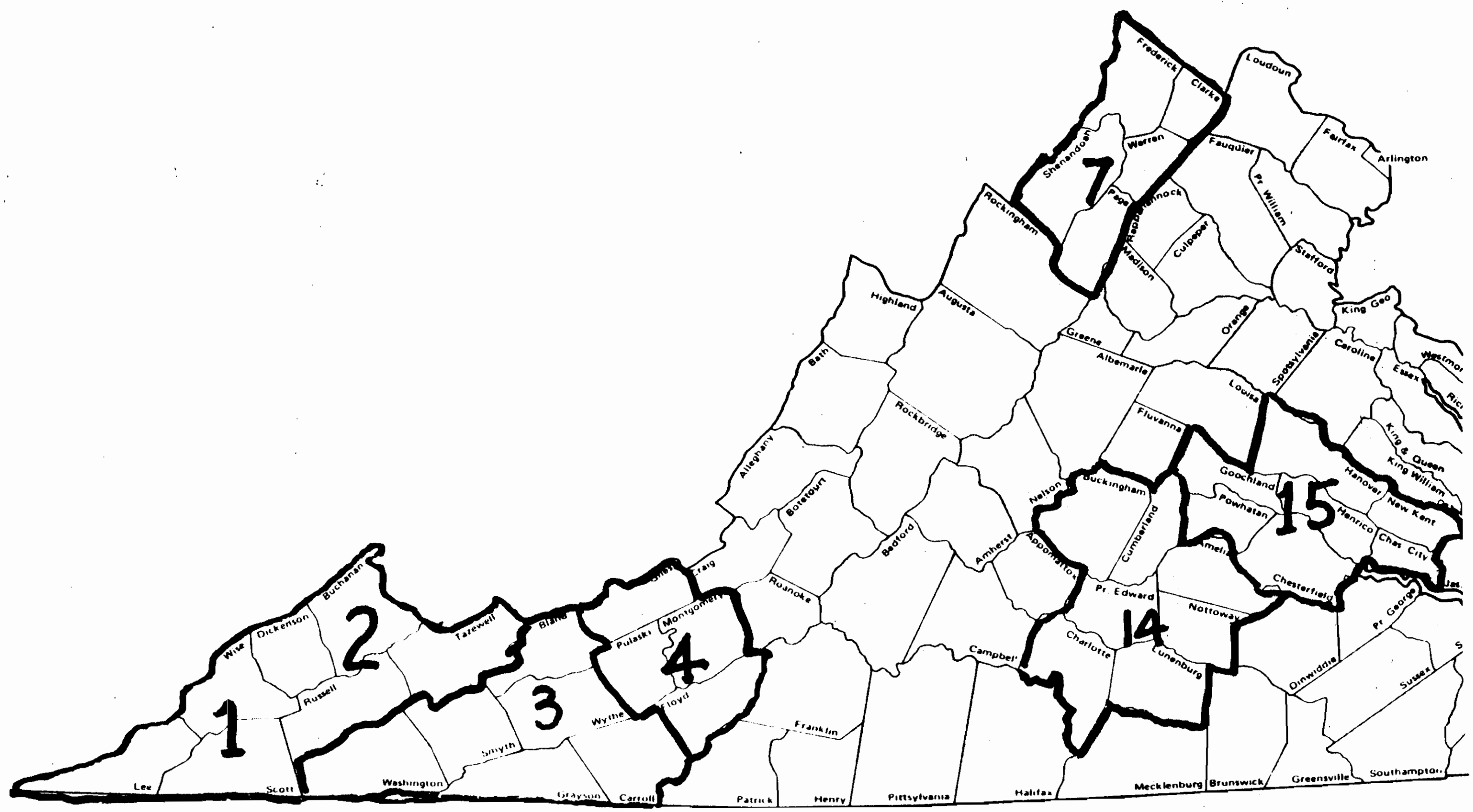

Figure 4.1. Map of Virginia Showing Location of Planning Districts Selected for Analysis.

model lies in its use of the regional purchase coefficient (RPC) method (described in Chapter 3) to estimate the flows of commodity exports and imports across regional boundaries. Estimates of these flows are held to be the primary cause for errors in nonsurvey techniques. The RPC method, by taking into account the effects of cross hauling, reduces such errors. The IMPLAN program can be used to develop input-output models and carry out analysis of the impacts of changes in various components such as final demand and primary input supply. The program was utilised in this study to generate regional accounts for each of the planning districts chosen. These accounts then formed the basis for aggregation of the sectors.

4.3.1. Aggregation of Sectors

It was recognized at the outset that the linkages in an economy (as represented by the number of paths/arcs/path multipliers between any two sectors) is a function of the extent of aggregation of the input-output accounts, the number of sectors actually present in an economy, the presence or absence of interaction between the two sectors, and the source of inputs, whether purchased locally or imported. The more disaggregated the accounts, or the larger the number of sectors represented, the greater would be the number of paths between the two sectors, in absolute terms, indicated by structural path analysis, provided there is interaction between them. It was, therefore, necessary to decide on an appropriate aggregation scheme, given the aims of the research.

IMPLAN is capable of generating a disaggragated matrix representing 528 industries. This is in approximate conformity with the four digit Standard Industrial Classification (SIC) code. Since such a large degree of disaggregation was unlikely to yield any pertinent information which could not be had from a more aggregated input-output table, in terms of the aims of this study, it was decided to aggregate the industries into sectors.

In the aggregation scheme, the agriculture and livestock industries were retained at the disaggregated level in order to allow more detailed analysis of these sectors. The other industries were aggregated into sectors approximating the two digit SIC codes but modified, where necessary, to parallel the aggregation followed by Simpson and Tsukui in their study of the triangularization of matrices, on the basis of which their idea of the existence of a "fundamental structure of production" was postulated. This procedure resulted in a 54 sector square matrix at the national level. The details of the aggregation scheme are given in Appendix B (Tables 7.1 and 7.2).

Using the aggregation scheme developed, input-output models were generated for each of the regions chosen for the analysis. Thus, models were developed for each of the planning districts (or combination of planning districts) identified earlier. In addition, models were developed for the state of Virginia as a whole, and for the U.S. The transactions matrices developed from the input-output matrices formed the basis for structural path analysis.

The theoretical basis for structural path analysis has already been described. In order to carry out the analysis, the MATS (Matrix Accounts Transformation System) software, produced by Berkeley Economic Advising and Research, was used. This program can generate data regarding the linkages between sectors. It is capable of carrying out such analyses at various levels of detail. Thus, it could be used to analyse and identify every path connecting sectors irrespective of the amount of influence transmitted by the path. As may be expected, the number of paths at this level of detail can be substantial, especially in a fairly large matrix[15] Besides the problem that a large number of paths identified are insignificant in terms of the influence transmitted by them, this level of detail also requires substantial computer time. It was, therfore, necessary to decide on a reasonable level of detail to be generated by structural path analysis. Studies by Defourny and Thorbecke had indicated that the major influences transmitted by linkages were captured with paths having a maximum of three arc lengths. Thus, it was decided to restrict the analysis to paths of length three or less, and conveying influence of level .0001 or greater. Subsequent results showed that this level of analysis accounted for more than 80 percent of the influence transmitted along linkages in an economy, as indicated by multipliers. Structural path analysis generated data regarding the number of such paths, the number of arcs comprising such paths, the amount of direct influence transmitted by such path (the direct effect), and the amount of indirect effects transmitted along each path (the path multiplier).

In order to obtain details regarding backward linkages, structural path analysis was carried out on the transactions matrices, for the different regions, generated by the IMPLAN program. Structural path analysis generated a detailed breakdown of the paths, and the influence transmitted, between the sectors in the regions. This detailed information was then aggregated to construct matrices summarizing the linkages between sectors in each region. Four summary matrices were developed for each region, from the analysis of backward linkages. These pertained to paths, the number of arcs making up the paths, the indirect influence generated by each path (the path multiplier), and the direct effect transmitted along each path derived from structural path analysis.

[15] Even a simple 5x5 matrix can give rise to 6000 elementary paths, if all elements in the matrix are greater than zero.The number, N, of all elementary paths connecting all possible pairs of sectors in a matrix of dimension n is given by $N = n!\sum_{k=1}^{n-2}\frac{1}{k!}$ (Sonis and Hewings).

The data resulting from these manipulations were then used to develop indices and examine the changes occurring in the economies with changes in structure.

Chapter 5

ANALYSIS AND RESULTS

5.1. Introduction

Following the development of the models as outlined in the previous chapter, the issues raised in Chapter 1 were examined using the indices and methods outlined in Chapter 3. As explained in Chapter 3, since this was a prototype attempt at unraveling the structure of an economy and its behavior with diversification, where more than one index was available for evaluating a particular aspect of the structure, the simplest alternative was chosen. In order to make the analysis more tractable, the aggregation of the sectors into "blocs" as outlined in Chapter 3, was carried out where necessary[16]. The question regarding the existence of a fundamental structure of production and the

[16] The detailed sectorwise breakdown of the results of the application of the various indices is shown in Tables 8.1 to 8.7 of Appendix C.

extent of its influence was first examined. In addition, the presence and nature of relative changes in complexity of linkages with changes in the level of diversification were subjected to scrutiny. A third aspect examined was the nature of the changes in complexity indicated by the various indices in the cases of the different regions examined. The findings and indices developed from these aspects of the study were then applied to an analysis of agricultural industries in Virginia and in the U.S. economy.

Prior to an examination of the results obtained, two limitations regarding the analysis need to be stated. As stated in Chapter 4, structural path analysis was confined to paths which were of length 3 or less, and conveyed influences of levels .0001 or higher. Thus, the analysis and conclusions reached are based on results obtained within these bounds. At the level of paths of length greater than 3, and/or carrying influences that are less than .0001, it is possible that the patterns of interactions may differ from those observed in this study.

A second limitation to be kept in mind is that all the indices are sensitive to the aggregation scheme that is used, to a greater or lesser extent. The level of aggregation (that is, the number of sectors arrived at in the aggregation scheme), and the industries that are aggregated (or disaggregated), will affect the results that are obtained.

Some of the terms used in the discussion that follows also need to be defined. In the course of the analysis, reference is made to primary, secondary, and tertiary levels of transactions. The primary level transactions, or first order transactions, represent the interactions that are portrayed in the transactions matrix. Secondary level transactions denote those represented by paths, other than paths of unit length (since these are the primary level transactions). The tertiary level transactions are represented by the path multipliers since these indicate influence involving transactions along subsidiary circuits in the economy that are ancillary to the paths.

The term "diversification", as referred to in this study, connotes the number of sectors in the economy. While there may be a large number of sectors in the economy, the majority of the sectors may belong to one particular category or grouping of industries, such as the services group. On the other hand, another economy may have the same number of sectors as the first, but the types of sectors may be more or less equally distributed over a range of groups such as metals, nonmetals, services, etc. In the first case, though there may be a high degree of sectoral diversification present, variety in sectoral representation may not be as high as in the second economy. The behavior of linkages in such differing circumstances is not known. It may be conjectured that the scope for development of linkages in an economy which is lacking in some group of sectors (say those of the metals group) is less than it is in an economy which may not have the same number of sectors as the first, but which has greater variety in its sectors so that the metals, non-metals and service blocs are all represented.

5.2. Analysis of the Fundamental Structure of Production

The Hypothesis: As indicated earlier, Simpson and Tsukui had postulated the existence of a "fundamental structure of production" based on their study of triangularization of technical coefficients matrices of several national economies. Their findings of bloc triangularity and bloc independence were based on the technical coefficients matrix, which represents the direct or first order linkages between sectors. The secondary and tertiary linkages were not taken into consideration. The question to be examined is : If a fundamental structure of production does exist, does it exist only at the first order level, that is at the level of the transactions matrix only, or could it be traced to deeper levels of the economy? It had been hypothesized in Chapter 1 that bloc independence was unlikely to persist at the level of secondary and tertiary level transactions.

The Method of Analysis: In order to examine whether bloc independence extended deeper into the economic structure than the first order linkages, the paths/path multiplier/direct effects matrices were subdivided into submatrices based on the blocs as described in Chapter 3. The next step was to compare the linkages in the on-diagonal submatrices with those lying off the diagonal but in the same bloc. In other words, the backward linkages of the group of sectors of a bloc were calculated in terms of intra-bloc linkages and compared with its inter-bloc linkages. The expectation, using such a procedure would be that, if bloc independence extended to levels deeper than the first round of transactions, the intra- and inter-bloc linkage ratios obtained, in the case of the paths matrix (the matrix of secondary influences) and the path multiplier matrix (that is, the matrix of tertiary level influences), would indicate that the major portion of linkages would be intra-bloc especially in comparison to the inter-bloc transactions between the metals and nonmetals blocs.

The analysis was carried out using the paths and path multiplier matrices. The intra-bloc linkages and the inter-bloc linkages of each bloc with the other two blocs were calculated as a percentage of total linkages in the respective blocs in order to facilitate interregional comparison. The results of the analysis are discussed below.

5.2.1. The Paths Matrix

Table 5.1 on page 117 shows a breakdown of the paths matrix[17] on the basis of the intra-bloc and inter-bloc submatrices, for each of the models. Examining the data for the U.S. model, it may be seen that columns 3, 4, and 5 indicate the number of paths in the metals, non-metals, and services blocs, respectively, in absolute numbers. The diagonal elements (77, 534, and 37) of this 3x3 matrix represent the total intra-bloc paths for the metals, non-metals and services blocs, respectively. The off-diagonal elements represent the total inter-bloc paths. Thus, the total number of paths from the metals bloc to the non-metals bloc is 87. The corresponding number of inter-bloc linkages between the metals and services blocs is 156. The numbers in the other columns may be interpreted in a similar manner. The total number of intra- and inter-bloc paths originating within each bloc are also indicated in the table. The percentage equivalents of the intra- and inter-bloc paths are shown in columns 6,7 and 8 (the percentage is with respect to the total paths in a bloc).

The Metals Bloc: The results of the analysis based on blocs indicates that, in the case of the metals bloc, there is a preponderance of inter-bloc paths over intra-bloc paths in the majority of the models examined (Table 5.1). This tendency is exhibited most distinctly in the cases of planning districts 14 and 7 in which intra-bloc paths constitute 16 and 24 percent (column 6), respectively, and inter-bloc (metal-nonmetal) paths comprise 26 and 36 percent, respectively, of all paths originating in the metals bloc. The tendency towards greater inter- rather than intra-bloc (metals-nonmetal) linkages is much less pronounced in the cases of the national model with the ratio of inter- to intra-bloc paths

[17] The "global" paths and the paths in each submatrix of a bloc were calculated using the indexes $P_{ij} = \sum_{j=1}^{n} P_j$ and $P_j = \sum_{i,j} P^{ij}$ i,j = 1,...n, respectively.

being 24:27. similarly, the ratios for the state model (28:29), and planning district 15 (27:28) show an equal level of inter- and intra-bloc linkages from the metals to the non-metals sector. On the other hand, planning districts 1&2, and 3 indicate that a greater number of paths originating in the metals bloc in these two models are intra-bloc (35 and 28 percent, respectively) compared to the corresponding metal-nonmetal inter-bloc linkages, which constitute 18 and 16 percent, respectively, of the paths originating in the bloc. In every case, the metals-services inter-bloc paths are seen to constitute the largest number of paths.

The Nonmetals Bloc: In the case of paths originating in the nonmetals bloc (column 7), there is clear indication in all the models that the intra-bloc paths exceed, by a large margin, the inter-bloc (nonmetals-metals) paths. The ratio of inter- to intra-bloc paths for this bloc is seen to be 12:41 for the U.S. model and 8:43 for the state. This pattern is repeated for planning districts 15 (7:34), 14 (2:45), 7 (10:40), 4 (24:73), 3 (11:38), and 1&2 (6:27). Thus, bloc independence, which is the tendency for sectors of a particular bloc to transact among themselves rather than with sectors of other blocs, seems to be a strong feature of the second order transactions in the nonmetals bloc. As hypothesized, the nonmetals-services paths constitute a large proportion of the linkages originating in the nonmetals sector.

The results of the analysis suggest that evidence regarding bloc independence, when examined at the level of second order linkages, is mixed. The metals bloc does not furnish unequivocal evidence favoring bloc independence but the evidence from the nonmetals bloc tends to be much more supportive of the idea. It may be recalled that the blocs were drawn up on the basis of the physical characteristics of the sectors, and the transactions are a reflection of the technical relationships between sectors. The

Table 5.1. Intra-Bloc and Inter-Bloc Linkages Measured in Terms of Elementary Paths.

		BLOC TOTALS			PERCENTAGES		
Model	Bloc	Metals(M)	Non-Metals(NM)	Services(S)	(M)	(NM)	(S)
1	2	3	4	5	6	7	8
U.S.							
	Metals	77	162	22	24	12	22
	Nonmetals	87	534	40	27	41	40
	Services	156	611	37	49	47	37
	Totals	320	1307	99			
Virginia							
	Metals	29	28	5	28	8	21
	Nonmetals	30	148	8	29	43	33
	Services	43	166	11	42	49	46
	Totals	102	342	24			
P.D. 15							
	Metals	22	14	0	27	7	0
	Nonmetals	23	65	6	28	34	46
	Services	36	115	7	44	59	54
	Totals	81	194	13			
P.D. 14							
	Metals	6	5	2	16	2	17
	Nonmetals	10	102	5	26	45	42
	Services	22	119	5	58	53	42
	Totals	38	226	12			
P.D. 7							
	Metals	21	25	2	24	10	17
	Nonmetals	31	100	6	36	40	50
	Services	35	122	4	40	49	33
	Totals	87	247	12			
P.D. 4							
	Metals	21	20	7	30	24	44
	Nonmetals	41	62	8	58	73	50
	Services	9	3	1	13	4	6
	Totals	71	85	16			
P.D. 3							
	Metals	19	22	7	35	11	41
	Nonmetals	10	79	3	18	38	18
	Services	26	105	7	47	51	41
	Totals	55	206	17			
P.D. 1&2							
	Metals	16	9	3	28	6	23
	Nonmetals	9	42	2	16	27	15
	Services	33	106	8	57	68	62
	Totals	58	157	13			

above findings would imply that, at the secondary level of transactions, the sectors of the metals bloc are technically related to the sectors of the nonmetals bloc so that their inputs are important at this level of transaction. However, in the case of the sectors of the nonmetals bloc, even at the level of secondary transactions, the great majority of inputs are from the other sectors in the nonmetals bloc. There are few inputs required from the metals bloc.

5.2.2. The Path Multiplier Matrix

The Metals Bloc: While the path matrix represents the first and second order linkages, the path multipliers in the economy consist of influence transmitted along subsidiary networks of transactions induced by the paths and this may be considered to signify the tertiary level of influence among sectors in the economy. The path multiplier matrix, when analysed for bloc independence, indicates whether this feature extends to even deeper levels of the economy's transactions. The analysis carried out was similar to that involving paths. The total magnitude of path multipliers induced by paths between sectors was calculated for each bloc, as was done for paths.

The results of the analysis of the path multiplier matrix are similar to those obtained for intra- and inter-bloc linkages in the case of path matrices (Table 5.2 on page 120). The national matrix quite distinctly shows that the metals bloc has a greater level of tertiary level influence (represented by the path multiplier) induced by paths which are inter-bloc with respect to the nonmetals and services blocs (31 percent and 47 percent respectively, as indicated in column 7) than by those which are intra-bloc (22 percent), suggesting that bloc independence is weak or lacking at this level of interdependence in the case of the metals bloc. The equivalent figures for planning district 14 are 29 percent (metals-nonmetals), 55 percent (metals-services), and 16 percent (metals-metals). In the case of planning district 7, these figures are 35, 41 and 24 percent, respectively. Similarly, in planning district 4, intra-bloc linkages induce 29 percent of the tertiary level influence in the metals bloc whereas inter-bloc transactions induce 58 percent (metals-nonmetals), and 13 percent (metals-services) of the influence. The same relationship is shown by the metals bloc of the state model and those of planning districts 15 and 4 but the levels of difference between intra- and inter-bloc linkages are not as distinct as in the cases mentioned previously. Thus, in the Virginia model, the intra-bloc linkages of the metals bloc induce 27 percent of the total magnitude of tertiary level influence generated by paths originating in the metals sector. The corresponding figures for the paths from the sectors of the metals bloc to those of the nonmetals bloc, and from the metals to the services bloc are 31 and 42, respectively. In the case of planning district 15 the equivalent figures are 27 (intra-bloc), 29 (metals-nonmetals) and 44 (metals-services).

The two exceptions to the linkage patterns noted above are the metals blocs of planning districts 3 and 1&2. In the case of these regions, the metals bloc shows a tendency towards bloc independence, with a larger proportion of the influence being transmitted along paths that are intra-bloc (35 and 26 percent, respectively) rather than along paths linked with the nonmetals bloc (19 and 17 percent, respectively). Significantly perhaps, both these planning districts have a nonmetals bloc in which the agricultural industries are lacking or are not very developed.

The Nonmetals Bloc: While the existence of bloc independence appears to be weak or non existent in the case of influence transmitted along subsidiary paths induced by paths originating in sectors of the metals bloc, it is strongly supported by the evidence from the nonmetals blocs in all the economies examined (column 7). In the case of this bloc,

Table 5.2. Intra-Bloc and Inter-Bloc Linkages Measured in Terms of the Magnitude of Path Multipliers.

		BLOC TOTALS			PERCENTAGES		
Model	**Bloc**	**Metals(M)**	**Non-Metals(NM)**	**Services(S)**	**(M)**	**(NM)**	**(S)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
U.S.							
	Metals	119.532	229.473	28.829	22	13	22
	Nonmetals	168.76	739.431	56.513	31	41	43
	Services	250.679	833.737	46.677	47	46	35
	Totals	538.971	1802.641	132.019			
Virginia							
	Metals	30.835	33.389	5.683	27	8	20
	Nonmetals	35.182	194.642	9.763	31	46	35
	Services	48.562	197.144	12.772	42	46	45
	Totals	114.579	425.175	28.218			
P.D. 15							
	Metals	24.021	15.253	0	27	7	0
	Nonmetals	25.593	72.334	6.919	29	34	48
	Services	39.698	127.028	7.453	44	59	52
	Totals	89.312	214.615	14.372			
P.D. 14							
	Metals	6.87	6.176	2.449	16	2	18
	Nonmetals	12.352	119.198	5.873	29	46	43
	Services	23.906	134.79	5.268	55	52	39
	Totals	43.128	260.164	13.59			
P.D. 7							
	Metals	22.28	27.755	2.239	24	10	17
	Nonmetals	33.441	113.9872	6.719	35	40	51
	Services	38.85	140.534	4.306	41	50	32
	Totals	94.571	282.2762	13.264			
P.D. 4							
	Metals	22.805	23.091	8.452	29	26	47
	Nonmetals	45.723	63.212	8.527	58	71	47
	Services	10.55	3.352	1.096	13	4	6
	Totals	79.078	89.655	18.075			
P.D. 3							
	Metals	20.871	24.393	7.694	35	11	42
	Nonmetals	11.341	85.769	3.163	19	38	17
	Services	28.029	113.511	7.333	47	51	40
	Totals	60.241	223.673	18.19			
P.D. 1&2							
	Metals	16.559	10.169	3.645	26	6	24
	Nonmetals	10.775	49.739	2.389	17	28	16
	Services	35.771	119.844	9.08	57	67	60
	Totals	63.105	179.752	15.114			

the influence transmitted along subsidiary paths linked to paths that are intra-bloc is distinctly higher than such influence along subsidiary circuits linked to paths connecting the metals and nonmetals blocs. For example, in the U.S. model, 41 percent of tertiary level influence is induced by paths linking sectors within the nonmetals bloc (that is, intra-bloc paths).The paths from the sectors of the nonmetals bloc to the metals bloc, on the other hand, give rise to 13 percent of the total influence generated in the bloc. The pattern is similar in the case of all the other models, as is evident from column 7 of Table 5.2. Thus, the evidence in this case favors bloc independence. In all the cases, however, the influence along subsidiary circuits linked to paths connecting the metals bloc with the services bloc shows the highest levels, which is in accordance with the findings of Simpson and Tsukui.

To sum up the results, bloc independence, while present at the level of primary interactions, in the case of the metals bloc, does not appear to persist beyond this level to the secondary and tertiary interactions in the economy. In the case of the nonmetals bloc, however, bloc independence appears to be a much more deep rooted and persistent feature, being discernible even at tertiary levels of transactions in the economy. The technological relationships are such that, in the case of the sectors of the metals bloc, there is considerable input from the sectors of the nonmetals bloc that are needed in the manufacture of outputs. In the case of sectors of the nonmetals bloc, however, most of the input requirements are from sectors that are also in the nonmetals sector. Relatively few transactions with the sectors of the metals bloc are required.

5.3 The Analysis of Changes in Sectoral Linkages and Diversification

The Hypothesis: While Hirschman hypothesized that increasing diversification would lead to greater complexity in the network of linkages, the manner in which such increases occur has not been considered. Several questions may be raised in this regard: Does the increase in complexity occur uniformly over the entire economy? If this is not so, is the increase concentrated in some sectors in preference to others? For instance, with development, a sequential change in the activity dominating the economy has been postulated, with agriculture and primary activity in an underdeveloped economy giving way to a manufacturing economy which, in turn, gives rise to an economy in which the service sector dominates. How is this reflected in the network of linkages? Is there a corresponding change in the concentration of linkages? The expectation is that a region goes through a cycle of development that is reflected in the structure of its linkages. Thus, the primary industry dominated economy would have few linkages. As development occurred, and manufacturing activities began to grow, the number of linkages originating in the manufacturing activities would increase (as hypothesized by Hirschman), as a proportion of total linkages in the economy. As a result, the concentration of linkages would shift towards the manufacturing industries. The subsequent evolution to a services dominated economy would also be reflected in a majority of the linkages in the economy being related to the services sectors.

Since it would be cumbersome to examine each sector individually, especially in view of the large number of sectors in the models, it was decided to group sectors together, and compare the behaviour of these groups in the models representing the different economies. The grouping scheme chosen was the one used by Simpson and Tsukui in their study of the effects of triangularization of matrices.

The Method of Analysis: A way in which to test whether the sequence of changes in the economy outlined above is reflected in the linkages would be to examine the proportion of global linkages that is represented by the linkages originating in a particular bloc[18] and what changes, if any, occur in the proportion of linkages attributable to that particular bloc, as the economy diversifies. Based on the hypothesis stated above, a change in the proportion of linkages in a particular bloc is expected, relative to the total linkage in the economy. Thus the linkages of the services bloc for planning district 15 (a metroplitan area, presumably with high services demand) should constitute a much higher proportion of the total linkages in the economy, than it would in the case of planning district 1&2, which is a primary industry (coal mining) dominated economy.

5.3.1. Comparison of Linkages in Sectoral Blocs Across Economies

In order to ascertain whether a pattern of change existed and to enable comparison between economies, the total number of linkages in each bloc was calculated as a percentage of the total number of linkages in the economy. The results are shown in Figure 5.1 on page 125. As is evident from the figure, the calculation of the percentage representation of sectoral linkages reveals that, although the total paths in a particular sector vary widely in the different economies (from 429 to 3248 in the case of paths for example, as seen in Table 5.3 on page 126), the proportional representation of paths generated by a sector as a percentage of the global total is found to be similar across economies irrespective of the degree of diversification. As an examination of Figure 5.1 makes clear, the largest proportion, by far (80 to 90 percent), of the paths originate in the nonmetals bloc, with the metals bloc giving rise to between 5 and 15 percent of

[18] $L^{pg} = \frac{P_j}{P_{ij}}$ where i and j refer to blocs rather than sectors.

paths. Paths originating in the services bloc constitute the least share of the linkages in all the economies studied (between 4 and 8 percent).

The results indicate that the largest proportion of linkages developed in an economy originate in the nonmetals bloc. This is followed by the metals bloc, and the services bloc has the least number of backward linkages. This pattern is dictated by the technical relationships of the sectors in the blocs and is independent of changes in final demand. This would appear to rule out the occurrence of a life cycle, or an evolutionary sequence, in the development of an economy's structure.

5.4. The Measurement of Complexity

It was hypothesized in Chapter 1, in accordance with the arguments of Hirschman, that as an economy developed, its structure, as indicated by its linkages, became increasingly complex. In order to examine the models in the light of this hypothesis, several indices were utilised. These included the total paths/arcs in the matrix (in absolute terms, also referred to as the global totals), the average number of paths/arcs, and also the influence transmitted by the paths as the direct effect and the path multiplier. The last two indices were also computed in absolute terms and as averages. In addition, ratios of the path multiplier with respect to the number of paths as well as to the level of direct influence transmitted along these paths were used to analyse changes in complexity.

In order to provide a basis for assessment of the performance of the indices, a linkage-neutral index was first used to calculate an ordering for the models. The Zuchetto diversity index (equation 2.19, Chapter 2) was chosen for this purpose. The reason for this choice was that the index is based on the transactions matrix which, as

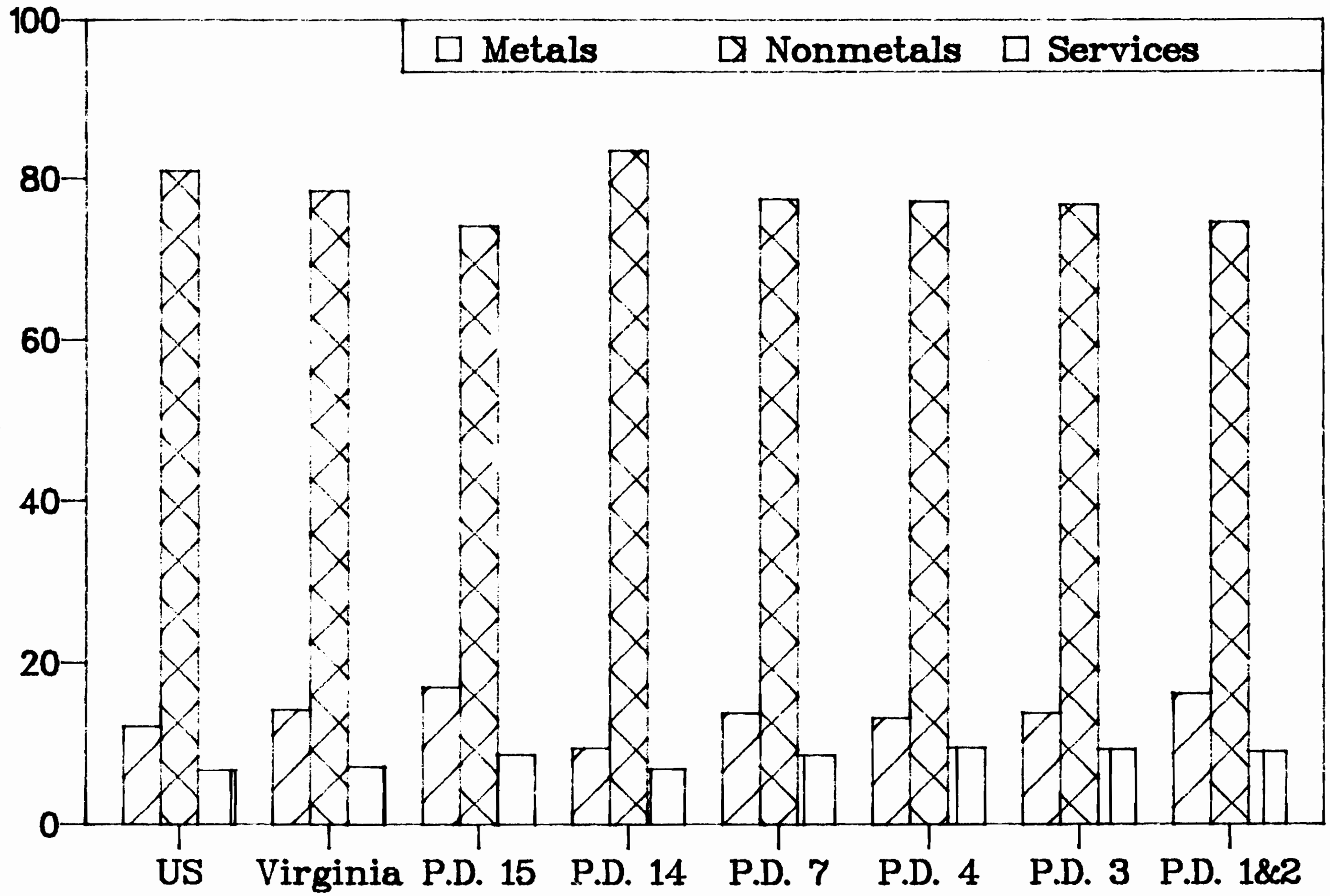

Figure 5.1. Intra-Bloc Linkages Depicted as Percentage of Global Linkages.

Table 5.3. Models Ranked in Order of Complexity on the Basis of Various Indices.

Index		Ranking							
		1	2	3	4	5	6	7	8
		Increasing Complexity→							
Zuchetto Index		15	1&2	VA	7	3	14	4	US
Global Paths									
	Total	1&2	14	15	3	7	4	VA	US
Global Arcs									
	Total	1&2	14	4	15	7	3	VA	US
Global Path Multipliers									
	Total	1&2	3	15	14	7	4	VA	US
Global Direct Effects									
	total	14	15	1&2	4	7	3	VA	US
Ratio: Path Multiplier/Paths		3	15	4	1&2	7	14	VA	US
Ratio: Path Multiplier/ Direct Effects		3	1&2	7	VA	15	14	4	US

described in Chapter 2, formed the basis for the development of several of the indices used to measure linkages. The results of the application of this index would, therefore, provide some idea of the performance of such indices, and enable a comparison with the results based on path analysis.

The application of the Zuchetto index gave rise to an ordering (Table 5.4 on page 128) of the models that, intuitively, appears to be unrealistic as an indicator of complexity. For example, the Virginia economy is portrayed as being less diversified than all the other regions with the exception of planning district 15. This would appear to be unlikely since the planning districts are part of the state economy. At the state level, the economy has a much broader spectrum of industries than any of its constituent planning districts. Hence the diversity of a planning district could not exceed that of the state. The results from linkage analysis, based on path analysis, which takes actual linkages into account, appear to be more realistic, as the following discussion indicates.

5.4.1. Total Index

The total number of paths/arcs and the total influence conveyed along these paths as path multipliers and as direct effects[19] (referred to as the respective global totals) may be used as a measure of the degree of complexity. According to Hirschman's hypothesis, the global linkages should show an increase in levels as economies with greater diversification are examined. The ordering of the models, on the basis of this index calculated with respect to the various forms of linkages (paths/arcs/path

[19] The indices used were $P_{ij} = \sum_{j=1}^{n} P_j$, and $A_{ij} = \sum_{j=1}^{n} A_j$, for paths and arcs, respectively.

Table 5.4. Results of Application of Various Indices.

Model 1	Zuchetto Index 2	Paths 3	Path Multip. 4	Arcs 5	Direct Effects 6	Mp/ Paths 7	Mp/DE 8
U.S.	3.934	3248	4425	5790	33.577	1.362	96.733
Virginia	1.758	833	947	1086	10.283	1.137	81.007
P.D. 15	1.333	498	542	613	6.087	1.088	81.814
P.D. 14	2.130	486	546	581	5.634	1.123	86.262
P.D. 7	1.909	554	615	689	7.206	1.11	76.88
P.D. 4	2.620	641	704	585	6.471	1.098	99.057
P.D. 3	1.932	506	540	820	8.927	1.067	56.682
P.D.1&2	1.605	429	474	530	6.245	1.105	68.695

multipliers/direct effects) can then be compared with each other and with the ordering arrived at by applying the linkage-neutral Zuchetto index described earlier.

The global totals and ratios derived from them are shown in Table 5.3. The ordering of the regions on the basis of complexity as revealed by the various forms of global linkages, is shown in Table 5.4 on page 128. The results of the calculation of global values, in terms of totals as well as averages, for paths, arcs, path multipliers, and direct effects, obtained from structural path analysis, are not identical. However, certain general patterns are evident. Thus, with the exception of the direct effects index, all indices indicate that planning district 1&2, which is dominated by the coal industry (a primary industry), occupies the lowest position in the ranking based on increasing complexity. However, planning district 1&2 shows a ranking above planning districts 14 and 15, when based on global direct effects, suggesting that the first order transactions in this economy are higher than those of the more diversified planning districts 14 and 15. This is in accordance with the expectation that direct transactions play a prominent role in a primary economy.

A second feature highlighted by the global totals is that the national and state models, and planning districts 3 and 4, in general, are within the first four positions in the complexity ordering based on global totals. These findings tend to support Hirschman's hypothesis of increasing complexity with increasing development, if global indices are assumed to be an adequate reflection of complexity in the economy. On the other hand, the position of planning district 15 in the ranking is somewhat unexpected. As indicated earlier, this metropolitan area, with its presumably service dominated economy, is be expected to occupy a high position in the ranking of the models. It ranks between the fifth and seventh positions in the order, suggesting that its economy has a low level of linkages. This suggests that service dominated industries induce lesser linkages in the economy than do manufacturing industries. An examination of Table 5.1 and Table 5.3 (column 5) supports this view. The services bloc, in the case of every model, gives rise to fewer paths/path multipliers than the manufacturing sectors. However, it should be pointed out that although few paths originate from the services bloc, this bloc plays a prominent role as the destination of paths originating in the metals and nonmetals blocs.

The inferences that can be drawn from the levels of indices based on global totals are limited. This is because an increase in global values with an increase in diversification is inevitable. There is no possibility of a decrease in global linkages as diversification increases.This is because the addition of a sector to an economy must give rise to more, rather than less, linkages. A more sensitive index of complexity would be the change in the average influence induced by a path (that is the level of the path multiplier) as diversification increases. The change in the average path multiplier per unit of direct effect would, similarly, be an index of the complexity of the economy.

5.4.2. The Path Multiplier/Paths Ratio

Two ratios of linkages were developed for analysis as indicated in Chapter 3. The first (MMG) looked at the path multiplier as a ratio of the number of paths, so that it indicated the average path multiplier per path in the regional economy being analysed. It is expected that, if increased diversity accompanied increases in complexity (as indicated by linkages), the increase should be manifested as greater levels of average influence being transmitted per path as a result of increases in the level of cycling. The second ratio developed (MPG) looked at the path multipliers with respect to the total direct influence. This expresses the average amount of tertiary level influence generated by a path (as path multipliers) in terms of a unit of direct influence along the path. It is postulated that, with increasing complexity (diversification) the average level of path multiplier per unit of direct effect will increase since there is increased scope for interactions to take place in the economy at the tertiary level. This is counter to the views of Ulanowicz and Yan and Ames who postulated a decrease in the interactions as diversification increased.

The ratio of path multipliers to the number of paths, calculated at the global level, furnishes the average cycling per path for the economy being analysed. The results of the application of this ratio to the global totals differ from the results of complexity based on absolute global totals. The results of the calculation of the ratios (Tables 5.3 and 5.4) indicate that the average global levels of cycling per path were highest in the case of the U.S. followed by the state economy. The ordering in respect of the planning districts is, however, very different from that obtained by using absolute global values. The economies presumed to be less diversified (planning districts 14, 7, and 1&2) have higher average levels of cycling per path (1.12, 1.11 and 1.105 respectively) than the more diversified economies represented by planning districts 4, 15, and 3 (1.098, 1.088 and 1.067, respectively). Planning district 4, which is highly industrialized, has one of the lowest average levels of cycling per path. The results suggest, (admittedly tentatively) that the economies which are mixed in terms of the representation of the agricultural, manufacturing and service sectors (planning districts 14 and 7), have higher levels of average cycling per path. The more specialized regions, in terms of sectoral representation, such as planning districts 4 and 15, representing respectively, manufacturing dominated and service dominated economies, show lower average levels of cycling per path. This evidence tends to negate the hypothesis that greater diversification gives rise to greater complexity, unless diversification is viewed in terms of greater variety in the sectoral representation in the economy. Based on this argument, the position of the national and state models at the top of the ranking is expected, since these economies show the greatest variety in sectoral representation with all (or almost all, in the case of the state economy) sectors being represented in the economy.

In the light of the above results it may be argued that high tertiary level interactions tend to occur when there is greater variety in the industrial mix. In the absence of such variety, the specialization that results is likely to lead to fewer linkages at deeper levels of transactions than the primary and secondary rounds. This supports, in a limited way, the arguments advanced by Ulanowicz and Yan and Ames regarding the simplifying effects (linkagewise) of specialization, although they had not taken variety in the industrial mix specifically into account when formulating their hypothesis.

5.4.3. The Path Multiplier/Direct Effect Ratio

The results of calculating the index based on the ratio of the global level path multiplier to the direct effects were mixed (Table 5.4, last row). This index[20], in which the numerator represents the tertiary level influences, and the denominator signifies the primary and secondary level influences in intersectoral transactions, derives the average level of cycling generated per unit of direct effect transmitted in the economy. It is evident from Table 5.4 that the ordering of the sectors shows no similarity with any of the earlier rankings. It may be pointed out that both the denominator and the numerator in this index are in terms of the magnitude of the influence transmitted along linkages

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[20] The index $MMG = \frac{\sum M_p^{ij}}{\sum D_{ij}}$ i,j = 1,...,n. was used.

and not in terms of the linkages themselves (that is, in terms of paths or arcs). The results of this index suggest that the industrialised planning districts (4 and 14) and the metropolitan planning district (15) are higher in the ranking than the other planning districts and the state. This suggests that these industrial and services dominated districts may have a larger amount of churning per unit of direct effect generated, than the other planning districts. The planning districts dominated by primary industries (planning districts 1&2, and 3) show low levels of the index. This is to be expected since the direct transactions are likely to be of greater importance in such economies than the secondary or tertiary linkages. As a result the denominator in the index is large relative to the other planning districts, resulting in lower ratios. Thus, in terms of the path multiplier/ direct effect ratio, there is support for the statement that as an economy diversifies, the complexity increases (that is, there is greater churning).

5.5. An Analysis of the Linkages in Agriculture

The methods and indices developed in the previous sections of this chapter offer a means to analyse, in greater detail, the linkages resulting from the agricultural industries. Accordingly, these methods were utilised to carry out a comparative analysis of the agricultural industries in Virginia with respect to these industries at the national level.

5.5.1. Paths

The index calculated in respect of linkages represented by paths in the state and national models was L^{PH}. This index, as explained in Chapter 2, was developed by Rasmussen.

Rasmussen had stated that where $L^{PH} > 1$, it indicated that the industry drew unevenly on the system of industries. Adapting this interpretation to linkages represented by paths, it may be considered to indicate whether the industry being analysed is linked homogenously with the other sectors in the economy or whether the linkages are skewed towards certain sectors or groups of sectors. The results of applying the index to the state and national models are shown in Figure 5.2 on page 135. All the agricultural industries, at both the national and state levels (when they are present) have values greater than one, indicating that the paths linking an agricultural industry with other industries are not evenly distributed across industries/sectors in the economy. This is intuitive. The national model, with its diversity and variety of linkages, is expected to have greater homogenity in its linkages, because there is more scope for each sector to develop linkages. The state model, on the other hand, has less variety and diversity, and is, therefore, expected to show greater heterogenity or skewness in its linkages.

In order to obtain some idea of the distribution of the linkages of the agricultural industries and the nature of the bias in linkages suggested by the above results, a procedure similar to that carried out in connection with the analysis of bloc independence was applied to the state and national path matrices. In this instance, however, the agricultural industries were grouped together to form one bloc, with the mining and manufacturing sectors forming the second bloc, and the services sectors constituting the third bloc. As before, the total linkages, in terms of paths, were calculated for the submatrices of each bloc and compared with each other.

The results of the analysis, at the national and state levels, are shown in Table 5.5 on page 137. The national model results show that the agricultural industries, considered as a group, have a greater percentage of paths linking them with the sectors of the

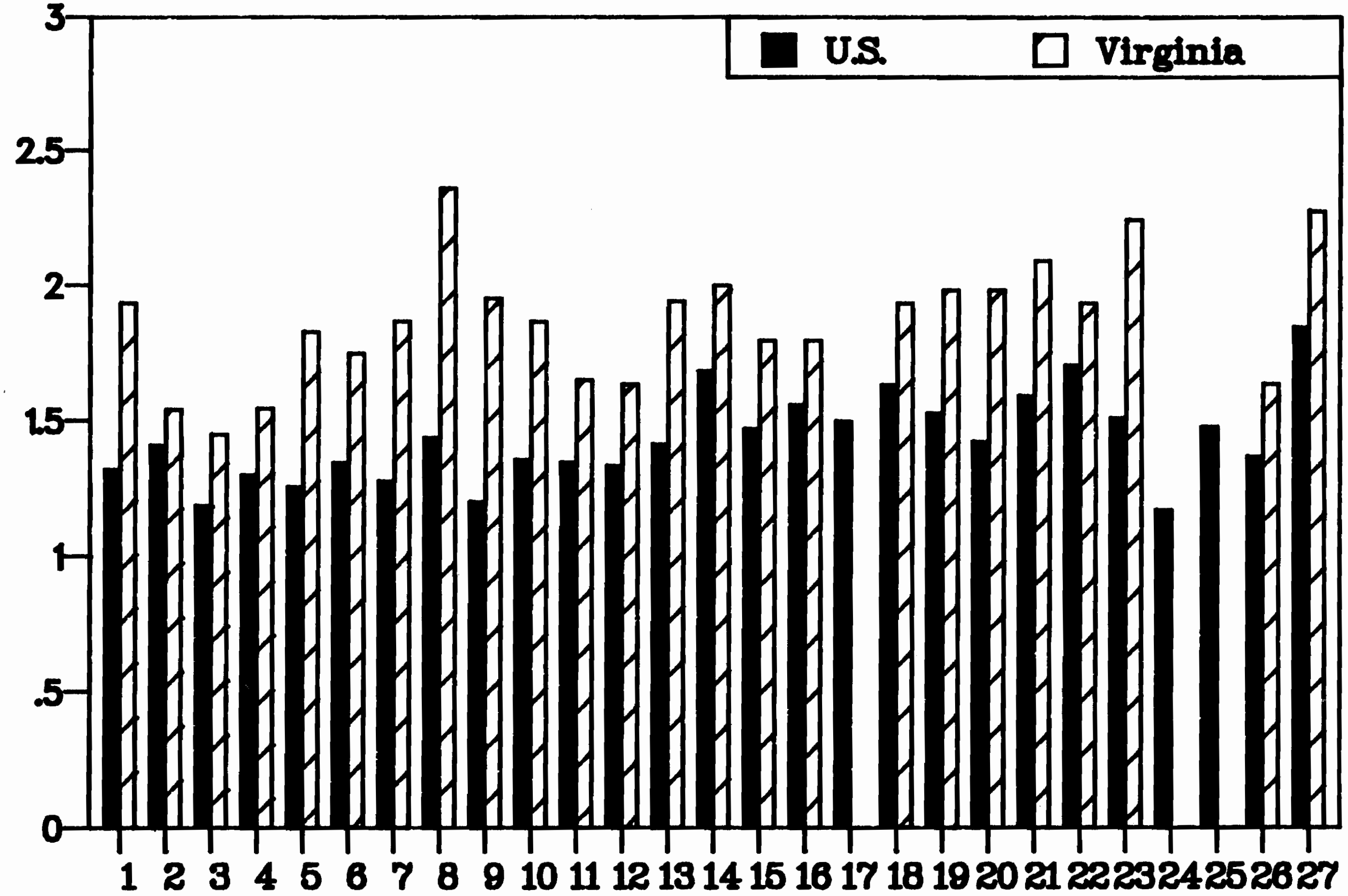

Figure 5.2. Results of Application of the Rasmussen Index to Agricultural Industries in the Virginia and U.S. Models: Key to Sector Numbers is Given in Table 7.1, Appendix B.

mining and manufacturing bloc (50%), and the services bloc (32%), than with other agricultural industries (19%). At the state level, there is a higher percentage of paths between the industries in the agricultural bloc (28%) and a greater interaction with the services bloc (40%), the latter probably reflecting the greater openness of the economy, relative to the national economy, and the consequential backward linkages of the agricultural industries to transportation and trade. Intuitively, the greater interaction of the agricultural sectors in the state with the services sectors rather than the manufacturing sectors is expected. The major manufactured goods used as inputs in agriculture (including fertilizers, machinery, feed, etc.) are not manufactured in Virginia. As a consequence, these are purchased through service agencies involved in trade and agribusinesses, giving rise to increased linkage with the service sectors.

5.5.2. Path Multipliers and Direct Effects

The above methods of analysis were also applied to the matrices of path multipliers and direct effects developed for the state and national models. The path multipliers and direct effects, unlike paths, represent actual levels of influence transmitted along the tertiary level network of paths (in the case of path multipliers) and along the primary and secondary network of linkages (that is, paths of length one and more than one respectively). An index $L^{PH} > 1$, for a particular sector would, therefore, indicate in the case of path multipliers, that the level of cycling generated by paths emanating from that sector is not homogenous with respect to all the sectors in the economy. The suggestion is that the influences due to cycling are more concentrated along paths linking some sectors than it is along others. In effect, therefore, this index indicates whether a sector has stronger tertiary level backward linkages with some sectors than with others.

Table 5.5. Comparison of Linkages in the Agricultural Sectors of the Virginia and U.S. Models Using Various Indices.

		BLOC TOTALS			PERCENTAGES		
Model	**Bloc**	**Agriculture(A)**	**Mfg. & Mining(M)**	**Services(S)**	**(A)**	**(M)**	**(S)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
PATHS							
U.S.							
	Agriculture	351	57	5	19	4	5
	Mfg. & Mining	926	744	73	50	59	67
	Services	591	470	31	32	37	28
	Virginia						
	Agriculture	119	24	0	28	6	0
	Mfg. & Mining	137	200	17	32	53	50
	Services	168	151	17	40	40	50
PATH MULTIPLIERS							
U.S.							
	Agriculture	456	81	6	19	4	4
	Mfg. & Mining	1241	1103	97	51	60	70
	Services	751	655	36	31	36	26
Virginia							
	Agriculture	135	26	0	28	6	0
	Mfg. & Mining	155	225	19	32	53	50
	Services	193	174	19	40	41	50
DIRECT EFFECTS							
U.S.							
	Agriculture	5.137	.789	.01	25	6	1
	Mfg. & Mining	8.068	6.558	.563	40	53	62
	Services	7.062	5.055	.335	35	41	37
Virginia							
	Agriculture	1.693	.242	0	29	6	0
	Mfg. & Mining	1.377	1.596	.115	24	38	41
	Services	2.763	2.329	.168	47	56	59

A qualifier to the above statement is required. The path multipliers used in this analysis indicate levels of influence transmitted along loops developed as ancillaries to paths linking sectors. The composition of the arcs composing the loop along which the influence is transmitted has not been taken into account. The path multiplier may (and in all likelihood will) encompass several sectors in the transmission of influence. Some of these sectors may lie outside the blocs linked by the path generating the path multiplier but this will not be indicated in the results obtained by analysis of the inter- and intra-bloc relationships.

The results of the analysis of path multipliers in terms of "blocs" at the national and state levels, are shown in Table 5.5. The examination of the submatrices, as was done in the case of paths, indicates that the major bias in the strength of tertiary level relationships of the agricultural bloc, at the national level, is towards the manufacturing bloc (51%) with the services bloc being next in order of importance (30%). This indicates that, at the tertiary level, the agricultural industries draw heavily on the manufacturing sector. The same analysis applied to the state model indicates that the major interaction, at the tertiary level, by the agricultural bloc, is with the services bloc (40%), with 32 percent of the total influence generated by the agricultural bloc being along linkages terminating at the mining and manufacturing bloc. Influence generated by intra-bloc transactions in the case of the agricultural bloc amounts to 28 percent and 19 percent of total tertiary level influence, in the case of agricultural industries at the state and national levels respectively.

The above analysis was also carried out for the direct effects matrices developed for the state and national models. As already mentioned, the direct effects represent primary (influence transmitted along paths of length 1) and secondary (influence transmitted along paths of length greater than 1) rounds of transactions between sectors/industries. The index L^{PH} when applied to direct effects, gave results similar to those obtained in the case of paths at both the national and regional levels and they are, therefore, not examined in detail here. The results of the analysis of the submatrices represented by the agricultural bloc (Table 5.5) indicate that, in the case of the state model, the agricultural industries draw more heavily, on average, on the services bloc (47%) and on the sectors of the agricultural bloc itself (29%), than on the manufacturing bloc (24%). The national model yielded results similar to those seen in the case of path multipliers.

The results of the analysis of path multipliers and direct effects would suggest that these backward linkages of the agricultural bloc, at the national level are skewed towards the mining and manufacturing bloc and then towards the services bloc. In the case of the state, however, the results suggest that the major primary and secondary relationships of the agricultural bloc are with the service sector, followed by interactions within the agricultural bloc itself. At the level of tertiary interactions (represented by path multipliers), however, while the major interactions are with the services bloc, there is a shift, from the intra-bloc linkages seen to be the second most important component of linkages at the secondary level, towards the mining and manufacturing bloc which is next in order of importance in terms of tertiary level transactions, followed by the intra bloc transactions of agricultural industries.

SUMMARY

The economic structures of the eight models chosen for analysis were examined in terms of the hypotheses set up in Chapter 1. The examination of the extent of penetration of the fundamental structure of production into the interactions between sectors revealed that, in terms of the metals bloc, in general bloc independence deteriorated within the second level of interaction in the economy. On reaching the tertiary level of interactions, bloc independence was usually diluted in this bloc of sectors. In the case of the nonmetals bloc, however, bloc independence persisted quite distinctly at both the secondary and tertiary level of interactions.

The analysis of the economies for changes in the concentration of linkages corresponding to changes in the sectors dominating the economy revealed that such changes did not occur. Notwithstanding the dominant sectors in the economy, in terms of demand, whether it was the services sector, the manufacturing sectors, or the primary sector, it was found in every case that the sectors of the nonmetals bloc contributed 80 to 90 percent of the linkages in the economy. The metals bloc gave rise to five to fifteen percent of the linkages. The services bloc invariably contributed the smallest proportion of backward linkages in the economy.

The changes in complexity in the network of linkages with diversification was analysed in order to see if Hirschman's hypothesis regarding the increase in linkages with increasing diversification was supported. As expected, absolute levels of linkages increased with increasing diversification. The results of calculation of the average influence transmitted by paths for the different economies, however, suggest that those economies which have variety in their sectoral representation, so that a broad spectrum of sectors are present in the economy, rather than a large number of sectors of one particular group (for instance, different sectors all of which could be classed as belonging to the metals bloc, in contrast to the same number of sectors distributed over the metals, nonmetals and services sectors), show higher average levels of influence transmitted per path in the economy.

The application of the linkage analogue of the Rasmussen index revealed that the agricultural sectors in the Virginia economy have the majority of their transactions with the sectors of the services bloc, followed by transactions among themselves. The least transactions are with the sectors of the mining and manufacturing bloc. This is in contrast to the pattern at the national level, where the majority of the interactions of the agricultural sectors are with the mining and manufacturing bloc, followed by the services bloc. The lowest number of interactions are among the agricultural sectors themselves at the national level. The above patterns are exhibited at both the the secondary and tertiary levels of interaction. The only exception to this is the fact that, at the tertiary level, the linkages for the agricultural sectors in the state are linked primarily to the services bloc, followed by the mining and manufacturing bloc. The least number of transactions are those among the agricultural sectors themselves.

Chapter 6

SUMMARY AND CONCLUSIONS

6.1. Major Findings

6.1.1. The Method

In Chapter 1, the need for understanding the regional economic structure and the changes that occur with diversification was indicated. The key to such an understanding involved the identification and development of appropriate tools of analysis. These tools could then be applied to answer questions regarding economic structure which were formulated as three hypotheses to be examined in the course of the study.

Accordingly, several indices were developed for application in the study. These were based on indices developed earlier in connection with the measurement of the contributions of sectors in the form of multipliers. However, they have not, to the author's knowledge, been applied to the results obtained from structural path analysis so as to get a detailed view of the interactions and changes in the structure of the economy. The procedures involving development of matrices, in which the data from structural path analysis were compiled and subjected to various analyses to ascertain the existence of patterns of linkages, does not appear to have been attempted before. The potential usefulness of structural path analysis for examining economic structure had, however, been suggested by Hewings *et al.*

Besides the novel application of the indices, a method was developed to ascertain the presence or absence of bloc independence, at levels beyond the first order transactions, by dividing the matrix into appropriate submatrices. This enabled analysis of the extent to which the phenomenon of bloc independence persisted among transactions in the economy. The use of submatrices also allowed a comparative study of the agricultural industries of the state of Virginia and of the U.S. to be made. At the same time the method yielded a means for tracing changes in the pattern of linkages at the primary, secondary and tertiary levels. These methods may be considered to be improvements on existing procedures for evaluation of economic structure and sectoral activity.

6.1.2. The Issues Examined

In terms of the results of the analysis that was carried out, three major issues, stated in Chapter 1, were examined in this study. The first major hypothesis examined related to the fundamental structure of production. Examination of regional transactions matrices confirmed the existence of bloc triangularity and bloc independence with respect to first order transactions at regional levels thus lending support to the view that a fundamental structure of production existed. However, at levels of secondary and tertiary rounds of transactions, the metals bloc displayed erratic bloc independence, although the tendency towards such independence was unambiguously present in the case of the nonmetals bloc. This implies that the fundamental structure of production extends deeper into the economic structure than the first round of interactions, in the case of the nonmetals bloc. Based on Simpson and Tsukui's interpretation of bloc independence, this would indicate that, with present technologies, industries of the nonmetals bloc, in general, have few backward linkages with the metals bloc, at any level of transactions. This finding may have some significance when key sectors are being sought. It suggests that, in general, the industries of the metals bloc may be expected to induce increased activity in the nonmetals bloc but the reverse may not be true.

Thus, if the policy objective of a regional planner is to choose a sector to focus on that will bring about growth in all three blocs of sectors in the economy (metals, nonmetals and services), then the above results suggest that the sectors of the metals bloc are more likely to bring about growth of all the sectors in view of their backward linkages with sectors in all three blocs at the secondary and tertiary levels. The nonmetals bloc, because of its strong tendency towards bloc independence, is less likely to affect the metals bloc through backward linkages. In such a situation, the preferred choice is likely to be for a sector belonging to the metals bloc. The sectors of the services bloc, had few backward linkages, in general and, therefore, are unlikely candidates in such a situation.

The second hypothesis concerned the question of whether the concentration of sectoral linkages shifted as economic structure changed. As indicated in Chapter 5, if sectoral activity is stated as a percentage of total activity in the economy, a similar distribution of linkages of the blocs, as a percentage of global linkages, is found irrespective of the extent of diversification in the economy. This similarity in sectoral proportions rules out any prospects of using changes in sectoral roles in the economy, in terms of sectoral percentages, as the basis of classification of economies with different structures. The highest percentage of linkages was found to originate in the nonmetals bloc. The role of the services sector, as an originator of linkages was found to be uniformly muted. The narrow range in variation in the distribution of linkages, in proportionate terms, across the different economies suggests that the intricate network of interrelationships imposed on a modern economy by the nature of its technology demands that a proportionate level of development of all three blocs occurs. This would tend to support the idea of the existence of a fundamental structure of production, reflecting technological relationships.

The findings in relation to the second hypothesis imply that the planner will have to facilitate the development of sectors belonging to all three blocs when considering the question of key sectors. The introduction of a key sector in the metals bloc will lead to development of sectors in the nonmetals and services blocs as well. This is intuitively obvious and has been recognized in key sector analysis. The uniformity in the proportionate development of sectors in the different blocs irrespective of the degree of diversification of the economy noted above, attests to the importance of facilitating the development of sectors in all three blocs in the economy. This feature suggests that specialized regions, dealing with one or only a few categories of manufacturing (such as iron and steel), while obtaining the benefits of specialization, may not be able to develop the full potential of the economy (in terms of linkages) unless sectors in all the blocs are allowed to develop.

The third hypothesis concerned the issue of increasing complexity in the economy as a function of diversification. The global totals, of the various linkage measures, support Hirschman's notion of an increase in complexity with diversification. However, such an increase in global totals is not an adequate indicator of increasing complexity. As mentioned in Chapter 5, an increase in diversification will inevitably result in an increase in total linkages in the economy and, as such, does not provide much indication of whether the magnitude of influence transmitted along each link has increased. An increase in the magnitude of average cycling per path would be a better index of increasing complexity. The average tertiary level influence transmitted by a path in the economy was, therefore, computed for each of the economies. The findings tend to confirm the views of several authors (Zuchetto; Yan and Ames; Ulanowicz) that average tertiary level influence would decrease with development.The cause of such a decrease could, as suggested by these authors, be due to the development of increased specialization leading to increased efficiency and decreased linkages.

The results of the examination of the three hypotheses when taken together, provide some insights into the development of linkages with diversification that may be useful in policy applications. The sectors of the metals bloc, in general, transmit higher levels of influence along their backward linkages. This is more likely when sectors from all three blocs are present in the economy. On the other hand, the largest proportion of transactions originates in the nonmetals bloc. These are, however, more or less confined to other sectors in the same bloc.

In view of these advantages (lack of bloc independence and high backward linkages) being found separately in the sectors of the metals and nonmetals blocs, respectively, the policy maker needs to choose the focus of sectoral development with care, keeping the resources of the region in mind. The decision to introduce a sector of the nonmetals bloc in a region with sectors belonging primarily to the metals bloc would lead to much of the nonmetals sectors transactions being confined to the trade sectors in order to import its inputs. This is implied from the finding that most of the transactions of the sectors of the nonmetals bloc are with other nonmetals sectors. While these relationships were intuitively known, the findings of this study have allowed a quantitative assessment of these patterns to be made.

The results of the analysis of the agricultural industries, grouped into blocs, indicate that in the national economy, the agricultural industries, in general, have a greater percentage of linkages with the mining and manufacturing sectors (50%), and that linkages with the services bloc are next in order of frequency (31%) so that intra-agriculture linkages at the national level constitute only 19 percent of total linkages. The above levels of interaction are true of linkages in physical terms (paths) and in terms of influence transmitted at the tertiary level (path multipliers).

The measures of activity of the agricultural activity at the state level reveal a high percentage of linkages with the services sector when linkages are measured in terms of both paths and path multipliers. However, the analysis of paths indicates that intra-agriculture linkages constitute the next most abundant form of linkage (28%) at the state level. The path multipliers, which represent tertiary levels of influence indicate that the mining and manufacturing sectors are second, in order of importance, in terms of linkages.

The pattern of linkages observed in the case of the agricultural industries at the state and national levels suggests that there exists potential for increasing the linkages of agricultural industries in the state economy. More specific analyses, looking at industries in the food processing sector, for example, may reveal more detail regarding the potential sources of such increases in linkages. The nature of the changes observed in the case of the agricultural industries suggest that they are most dependent on the services industries in economies that are relatively more open and in which sectoral representation is limited. As sectoral representation increases, and the economy becomes less open (this would be a natural consequence of greater sectoral representation), the dependence on the services sector is reduced and a greater proportion of interactions takes place with the mining and manufacturing sectors.

6.2. Further Work

The methods of analysis developed in this study show that it is feasible to analyse physical linkages, as well as the magnitude of the influence transmitted by such linkages. The methods also demonstrate that detailed levels of analysis can be performed to explore the behavior of particular segments of the economy, and their effects on other segments/sectors. The results of the application of the various indices suggest that indices developed earlier, such as the Zuchetto index, on the basis of multiplier levels, or from the transactions matrix, may not give an accurate portrayal of the linkages or the diversity in an economy.

These methods lay down a framework for the detailed analysis of various questions concerning the relationship between economic structure and income generation/ income inequality/ poverty. In order to perform such an analysis, the models used in this study would need to be extended from interindustry matrices to full fledged social accounting matrices. By taking the disaggregated household sector into account, based on such criteria as part time farmers/ farm size etc., and including the consumption patterns of the households, and carrying out a detailed analysis as was done in this study, significant insights into the process of income generation could be obtained.

The development of such social accounting matrices would provide a framework for examination of questions regarding income distribution, such as those raised by Williamson and Lindert, as to whether the consumer industries, by the nature of their employment, lead to lesser income inequality, whereas the capital intensive industries lead to greater inequality. Such questions have been examined previously (Bernat) using Boolian methods to simulate economies. The advantage of using the methods used in this study would be that the data used are not proxies, but an actual and accurate portrayal of the linkages in the economy in terms of both numbers and magnitude.

In addition, the procedure may be used to identify potential bottlenecks in the economy when identifying key sectors. Thus, a key ingredient in the inputs of several industries may be identified from the nature of the linkages. If the level of transactions (multiplier) is relied upon exclusively, the fact that the input is of importance to several industries may not be perceived as the multiplier level of the element of the matrix may not be an adequate indicator of its importance to the nexus of economic interrelationships. The prior identification of such important nodes in the matrix could guide policy so as to prevent the occurrence of bottlenecks.

A possible extension of the method to include a truly regional dimension would be to take into account spatial factors by including the distances involved in each input-output transaction (that is, each linkage between sectors). The availability of adequate spatial data would permit development of such a model on a regional level, which would have potential for explaining regional industrial location and development issues.

Another possible variant of this study may be carried out by analysing linkages in a matrix of value-added or employment multipliers. While the number of physical linkages would be the same as indicated in the case of output multipliers, the magnitude of value-added, or the level of employment generated, by each linkage would be clearly seen. This may have useful policy applications.

Finally, the effects of time on linkage patterns could be studied by analysing the linkage patterns of several input-output matrices of an economy representing several time periods. The results of such an analysis could clarify the manner in which regional development and growth takes place and how it is impacted upon by different policy measures.

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Appendix A.

Glossary of Selected Terms

Bloc: A grouping of industries developed by Simpson and Tsukui, based primarily on the physical characteristics of their outputs. Three types of blocs are recognized in this study: Metals, Nonmetals, and Services.

Bloc independence: Occurs when production relationships among the industries grouped together in a bloc are such that their transactions are confined to other industries in the same bloc. Few transactions occur with industries outside the bloc.

Bloc triangularity: Refers to the finding by Simpson and Tsukui of a triangular pattern of distribution of the non-zero elements of the Metals and Nonmetals blocs of industries in the input-output table.

Complexity: The extent of interactions that occur between industries in an economy especially at the second and third order levels of transactions. Complexity increases with greater interactions among industries at these levels.

Connectedness: This is a measure of the production relationships between sectors in terms of the magnitude of the transactions that occur between them. This contrasts with linkages which are measured in terms of a link between sectors irrespective of the magnitude of the transaction that the link represents.

Density: Refers to the number of linkages occurring among industries in an economy, taking into account the first, second and third order transactions. When two economies have the same number of industries (although the industrial mix may differ), the one with a larger number of linkages will be considered to have greater density than the other.

Diversification: Refers to the variety of industries that occur in a region. The larger the number of industries, the greater the diversification. In this study, the use of diversification as a proxy for development, reflects Hirschmans usage of the term. Since only inter-industry transactions are examined, none of the connotations of the term "development" as it relates to income, poverty, etc., is implied.

Structure: Economic structure, in this study, refers to the network of production relationships or transactions that take place between the industries in an economy. Each transaction constitutes a physical linkage between two sectors, and the level of the transaction in monetary terms constitutes the magnitude of the influence transmitted along the linkage.

Fundamental structure of production: A phrase coined by Simpson and Tsukui with reference to their finding that industries of modern economies have similar production relationships which can be highlighted in the input-output table in the form of bloc-triangularity and bloc-independence.

APPENDIX A

Table 7.1. The Aggregation Scheme Used in the Analyses.

1	DAIRY FARM PRODUCTS
2	POULTRY AND EGGS
3	RANCH FED CATTLE
4	RANGE FED CATTLE
5	CATTLE FEEDLOTS
6	SHEEP, LAMBS AND GOATS
7	HOGS, PIGS AND SWINE
8	OTHER MEAT ANIMAL PRODUCTS
9	MISCELLANEOUS LIVESTOCK
10	COTTON
11	FOOD GRAINS
12	FEED GRAINS
13	HAY AND PASTURE
14	GRASS SEEDS
15	TOBACCO
16	FRUITS
17	TREE NUTS
18	VEGETABLES
19	SUGAR CROPS
20	MISCELLANEOUS CROPS
21	OIL BEARING CROPS
22	FOREST PRODUCTS
23	GREENHOUSE AND NURSERY PRODUCTS
24	FORESTRY PRODUCTS
25	COMMERCIAL FISHING
26	AGRICULTURAL, FORESTRY, FISHERY SERVICES
27	LANDSCAPE AND HORTICULTURAL SERVICES
28	AGG Ferrous and Non Ferrous Mining
39	AGG Coal and Petroleum Extraction
44	AGG Non Metallic Minerals Mining
66	AGG Construction and Repairs
76	AGG Miscellaneous Mfg.
82	AGG Food Processing
127	AGG Tobacco Manufactures
131	AGG Fibres and Textiles
145	AGG Apparel
160	AGG Logging and Wood Products
174	AGG Furniture & Fixtures
187	AGG Pulp, Paper & Printing
215	AGG Chemicals
235	AGG Petroleum Products
240	AGG Rubber & Plastic Manufactures
246	AGG Leather Production & Manufacture
255	AGG Non Metallic Mineral Products
280	AGG Iron & Steel Mfg.
289	AGG Non Ferrous Metals Mfg.
303	AGG Fabricated Metal Products
330	AGG Machinery
371	AGG Electrical Equipment
401	AGG Transport Equipment

446 AGG Transportation & Warehousing Services
454 AGG Other Services
460 AGG Trade
516 AGG Government Services

Table 7.2. Breakdown of the Aggregation Scheme into its Constituent Industries.

28 Ferrous & Non Ferrous Mining
is an aggregate of the following original industries:
28 IRON ORES
29 FERROALLOY ORES, EXCEPT VANADIUM
30 COPPER ORES
31 LEAD AND ZINC ORES
32 GOLD ORES
33 SILVER ORES
34 BAUXITE AND OTHER ALUMINUM ORES
35 METAL MINING SERVICES
36 MERCURY ORES
37 URANIUM-RADIUM-VANADIUM ORES
38 METAL ORES, NOT ELSWHERE CLASSIF

39 Coal & Petroleum Extraction
is an aggregate of the following original industries:

39 ANTHRACITE AND ANTHRACITE MINING
40 BITUMINOUS AND LIGNITE MINING, S
41 NATURAL GAS
42 CRUDE PETROLEUM
43 NATURAL GAS LIQUIDS

44 Non Metallic Minerals Mining
is an aggregate of the following original industries:

44 DIMENSION STONE
45 CRUSHED AND BROKEN LIMESTONE
46 CRUSHED AND BROKEN GRANITE
47 CRUSHED AND BROKEN STONE, N. E.
48 CONSTRUCTION SAND AND GRAVEL
49 INDUSTRIAL SAND
50 BENTONITE
51 FIRE CLAY
52 FULLER'S EARTH
53 KAOLIN AND BALL CLAY
54 CLAY, CERAMIC, REFRACTORY MINERA
55 NONMETALLIC MINERALS (EXCEPT FUE
56 GYPSUM
57 TALC, SOAPSTONE, AND BORATE MINE
58 MISC. NONMETALLIC MINERALS, N.E.
59 BARITE
60 FLOURSPAR
61 POTASH, SODA, AND BORATE MINERAL
62 PHOSPHATE ROCK
63 ROCK SALT
64 SULFUR
65 CHEMICAL, FERTILIZER MINERAL MIN

66 Construction & Repairs

is an aggregate of the following original sectors:

66 NEW RESIDENTIAL STRUCTURES
67 NEW INDUSTRIAL AND COMMERCIAL BU
68 NEW UTILITY STRUCTURES
69 NEW HIGHWAYS AND STREETS
70 NEW FARM STRUCTURES
71 NEW MINERAL EXTRACTION FACILITIE
72 NEW GOVERNMENT FACILITIES
73 MAINTENANCE AND REPAIR, RESIDENT
74 MAINTENANCE AND REPAIR OTHER FAC
75 MAINTENANCE AND REPAIR OIL AND G

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76 Miscellaneous Mfg
is an aggregate of the following original industries:

76 COMPLETE GUIDED MISSILES
77 AMMUNITION, EXCEPT FOR SMALL ARM
78 TANKS AND TANK COMPONENTS
79 SMALL ARMS
80 SMALL ARMS AMMUNITION
81 OTHER ORDNANCE AND ACCESSORIES
416 ENGINEERING AND SCIENTIFIC INSTR
417 MECHANICAL MEASURING DEVICES
418 AUTOMATIC TEMPERATURE CONTROLS
419 SURGICAL AND MEDICAL INSTRUMENTS
420 SURGICAL APPLIANCES AND SUPPLIES
421 DENTAL EQUIPMENT AND SUPPLIES
422 WATCHES, CLOCKS, AND PARTS
423 OPTICAL INSTRUMENTS AND LENSES
424 OPHTHALMIC GOODS
425 PHOTOGRAPHIC EQUIPMENT AND SUPPL
426 JEWELRY, PRECIOUS METAL
427 JEWELERS MATERIALS AND LAPIDARY
428 SILVERWARE AND PLATED WARE
429 COSTUME JEWELERY
430 MUSICAL INSTRUMENTS
431 GAMES, TOYS, AND CHILDRENS VEHIC
432 DOLLS
433 SPORTING AND ATHLETIC GOODS, N.E
434 PENS AND MECHANICAL PENCILS
435 LEAD PENCILS AND ART GOODS
436 MARKING DEVICES
437 CARBON PAPER AND INKED RIBBONS
438 ARTIFICIAL TREES AND FLOWERS
439 BUTTONS
440 NEEDLES, PINS, AND FASTENERS
441 BROOMS AND BRUSHES
442 HARD SURFACE FLOOR COVERINGS
443 BURIAL CASKETS AND VAULTS
444 SIGNS AND ADVERTISING DISPLAYS
445 MANUFACTURING INDUSTRIES, N.E.C.

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82 Food Processing
is an aggregate of the following original industries:

82 MEAT PACKING PLANTS

83 SAUSAGES AND OTHER PREPARED MEAT
84 POULTRY DRESSING PLANTS
85 POULTRY AND EGG PROCESSING
86 CREAMERY BUTTER
87 CHEESE, NATURAL AND PROCESSED
88 CONDENSED AND EVAPORATED MILK
89 ICE CREAM AND FROZEN DESSERTS
90 FLUID MILK
91 CANNED AND CURED SEA FOODS
92 CANNED SPECIALTIES
93 CANNED FRUITS AND VEGETABLES
94 DEHYDRATED FOOD PRODUCTS
95 PICKLES, SAUCES, AND SALAD DRESS
96 FRESH OR FROZEN PACKAGED FISH
97 FROZEN FRUITS, JUICES AND VEGETA
98 FROZEN SPECIALTIES
99 FLOUR AND OTHER GRAIN MILL PRODU
100 CEREAL PREPARATIONS
101 BLENDED AND PREPARED FLOUR
102 DOG, CAT, AND OTHER PET FOOD
103 PREPARED FEEDS, N.E.C
104 RICE MILLING
105 WET CORN MILLING
106 BREAD, CAKE, AND RELATED PRODUCT
107 COOKIES AND CRACKERS
108 SUGAR
109 CONFECTIONERY PRODUCTS
110 CHOCOLATE AND COCOA PRODUCTS
111 CHEWING GUM
112 MALT LIQUORS
113 MALT
114 WINES, BRANDY, AND BRANDY SPIRIT
115 DISTILLED LIQUOR, EXCEPT BRANDY
116 BOTTLED AND CANNED SOFT DRINKS
117 FLAVORING EXTRACTS AND SYRUPS, N
118 COTTONSEED OIL MILLS
119 SOYBEAN OIL MILLS
120 VEGETABLE OIL MILLS, N.E.C
121 ANIMAL AND MARINE FATS AND OILS
122 ROASTED COFFEE
123 SHORTENING AND COOKING OILS
124 MANUFACTURED ICE
125 MACARONI AND SPAGHETTI
126 FOOD PREPARATIONS, N.E.C

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127 Tobacco Manufactures
is an aggregate of the following original industries:

127 CIGARETTES
128 CIGARS
129 CHEWING AND SMOKING TOBACCO
130 TOBACCO STEMMING AND REDRYING

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131 Fibres & Textiles
is an aggregate of the following original industries:

131 BROADWOVEN FABRIC MILLS AND FINI

132 NARROW FABRIC MILLS
133 YARN MILLS AND FINISHING OF TEXT
134 THREAD MILLS
135 FLOOR COVERINGS
136 FELT GOODS, N.E.C
137 LACE GOODS
138 PADDING AND UPHOLSTERY FILLING
139 PROCESSED TEXTILE WASTE
140 COATED FABRICS, NOT RUBBERIZED
141 TIRE CORD AND FABRIC
142 CORDAGE AND TWINE
143 NONWOVEN FABRICS
144 TEXTILE GOODS, N.E.C
152 CURTAINS AND DRAPERIES
153 HOUSEFURNISHINGS, N.E.C
154 TEXTILE BAGS
155 CANVAS PRODUCTS
156 PLEATING AND STITCHING
157 AUTOMOTIVE AND APPAREL TRIMMINGS
158 SCHIFFI MACHINE EMBROIDERIES
159 FABRICATED TEXTILE PRODUCTS, N.E

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145 Apparel
is an aggregate of the following original industries:

145 WOMENS HOSIERY, EXCEPT SOCKS
146 HOSIERY, N.E.C
147 KNIT OUTERWEAR MILLS
148 KNIT UNDERWEAR MILLS
149 KNITTING MILLS, N.E.C
150 KNIT FABRIC MILLS
151 APPAREL MADE FROM PURCHASED MATE

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160 Logging & Wood Products
is an aggregate of the following original industries:

160 LOGGING CAMPS AND LOGGING CONTRA
161 SAWMILLS AND PLANING MILLS, GENE
162 HARDWOOD DIMENSION AND FLOORING
163 SPECIAL PRODUCT SAWMILLS, N.E.C
164 MILLWORK
165 WOOD KITCHEN CABINETS
166 VENEER AND PLYWOOD
167 STRUCTURAL WOOD MEMBERS, N.E.C
168 PREFABRICATED WOOD BUILDINGS
169 WOOD PRESERVING
170 WOOD PALLETS AND SKIDS
171 PARTICLEBOARD
172 WOOD PRODUCTS, N.E.C
173 WOOD CONTAINERS

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174 Furniture & Fixtures
is an aggregate of the following original industries:

174 WOOD HOUSEHOLD FURNITURE
175 HOUSEHOLD FURNITURE, N.E.C

176 WOOD TV AND RADIO CABINETS
177 UPHOLSTERED HOUSEHOLD FURNITURE
178 METAL HOUSEHOLD FURNITURE
179 MATTRESSES AND BEDSPRINGS
180 WOOD OFFICE FURNITURE
181 METAL OFFICE FURNITURE
182 PUBLIC BUILDING FURNITURE
183 WOOD PARTITIONS AND FIXTURES
184 METAL PARTITIONS AND FIXTURES
185 BLINDS, SHADES, AND DRAPERY HARD
186 FURNITURE AND FIXTURES, N.E.C

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187 Pulp, Paper & Printing
is an aggregate of the following original industries:

187 PULP MILLS
188 PAPER MILLS, EXCEPT BUILDING PAP
189 PAPERBOARD MILLS
190 ENVELOPES
191 SANITARY PAPER PRODUCTS
192 BUILDING PAPER AND BOARD MILLS
193 PAPER COATING AND GLAZING
194 BAGS, EXCEPT TEXTILE
195 DIE-CUT PAPER AND BOARD
196 PRESSED AND MOLDED PULP GOODS
197 STATIONERY PRODUCTS
198 CONVERTED PAPER PRODUCTS, N.E.C
199 PAPERBOARD CONTAINERS AND BOXES
200 NEWSPAPERS
201 PERIODICALS
202 BOOK PUBLISHING
203 BOOK PRINTING
204 MISCELLANEOUS PUBLISHING
205 COMMERCIAL PRINTING
206 LITHOGRAPHIC PLATEMAKING AND SER
207 MANIFOLD BUSINESS FORMS
208 BLANKBOOKS AND LOOSELEAF BINDERS
209 GREETING CARD PUBLISHING
210 ENGRAVING AND PLATE PRINTING
211 BOOKBINDING AND RELATED WORK
212 TYPESETTING
213 PHOTOENGRAVING
214 ELECTROTYPING AND STEREOTYPING

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215 Chemicals
is an aggregate of the following original industries:

215 INDUSTRIAL INORGANIC, ORGANIC CH
216 NITROGENOUS AND PHOSPHATIC FERTI
217 FERTILIZERS, MIXING ONLY
218 AGRICULTURAL CHEMICALS, N.E.C
219 GUM AND WOOD CHEMICALS
220 ADHESIVES AND SEALANTS
221 EXPLOSIVES
222 PRINTING INK
223 CARBON BLACK
224 CHEMICAL PREPARATIONS, N.E.C

225 PLASTICS MATERIALS AND RESINS
226 SYNTHETIC RUBBER
227 CELLULOSIC MAN-MADE FIBERS
228 ORGANIC FIBERS, NONCELLULOSIC
229 DRUGS
230 SOAP AND OTHER DETERGENTS
231 POLISHES AND SANITATION GOODS
232 SURFACE ACTIVE AGENTS
233 TOILET PREPARATIONS
234 PAINTS AND ALLIED PRODUCTS

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235 Petroleum Products
is an aggregate of the following original industries:

235 PETROLEUM REFINING
236 LUBRICATING OILS AND GREASES
237 PETROLEUM AND COAL PRODUCTS, N.E
238 PAVING MIXTURES AND BLOCKS
239 ASPHALT FELTS AND COATINGS

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240 Rubber & Plastic Manufactures
is an aggregate of the following original industries:

240 TIRES AND INNER TUBES
241 RUBBER AND PLASTICS FOOTWEAR
242 RECLAIMED RUBBER
243 FABRICATED RUBBER PRODUCTS, N.E.
244 MISCELLANEOUS PLASTICS PRODUCTS
245 RUBBER AND PLASTICS HOSE AND BEL

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246 Leather Production & Manufacture
is an aggregate of the following original industries:

246 LEATHER TANNING AND FINISHING
247 FOOTWEAR CUT STOCK
248 SHOES, EXCEPT RUBBER
249 HOUSE SLIPPERS
250 LEATHER GLOVES AND MITTENS
251 LUGGAGE
252 WOMENS HANDBAGS AND PURSES
253 PERSONAL LEATHER GOODS
254 LEATHER GOODS, N.E.C

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255 Non Metallic Mineral Products
is an aggregate of the following original industries:

255 GLASS AND GLASS PRODUCTS, EXC CO
256 GLASS CONTAINERS
257 CEMENT, HYDRAULIC
258 BRICK AND STRUCTURAL CLAY TILE
259 CERAMIC WALL AND FLOOR TILE
260 CLAY REFRACTORIES
261 STRUCTURAL CLAY PRODUCTS, N.E.C
262 VITREOUS PLUMBING FIXTURES
263 VITREOUS CHINA FOOD UTENSILS
264 FINE EARTHENWARE FOOD UTENSILS

265 PORCELAIN ELECTRICAL SUPPLIES
266 POTTERY PRODUCTS, N.E.C
267 CONCRETE BLOCK AND BRICK
268 CONCRETE PRODUCTS, N.E.C
269 READY-MIXED CONCRETE
270 LIME
271 GYPSUM PRODUCTS
272 CUT STONE AND STONE PRODUCTS
273 ABRASIVE PRODUCTS
274 ASBESTOS PRODUCTS
275 GASKETS, PACKING AND SEALING DEV
276 MINERALS, GROUND OR TREATED
277 MINERAL WOOL
278 NONCLAY REFRACTORIES
279 NONMETALLIC MINERAL PRODUCTS, N.

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280 Iron & Steel Mfg
is an aggregate of the following original industries:

280 BLAST FURNACES AND STEEL MILLS
281 ELECTROMETALLURGICAL PRODUCTS
282 STEEL WIRE AND RELATED PRODUCTS
283 COLD FINISHING OF STEEL SHAPES
284 STEEL PIPE AND TUBES
285 IRON AND STEEL FOUNDRIES
286 IRON AND STEEL FORGINGS
287 METAL HEAT TREATING
288 PRIMARY METAL PRODUCTS, N.E.C

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289 Non Ferrous Metals Mfg
is an aggregate of the following original industries:

289 PRIMARY COPPER
290 PRIMARY LEAD
291 PRIMARY ZINC
292 PRIMARY ALUMINUM
293 PRIMARY NONFERROUS METALS, N.E.C
294 SECONDARY NONFERROUS METALS
295 COPPER ROLLING AND DRAWING
296 ALUMINUM ROLLING AND DRAWING
297 NONFERROUS ROLLING AND DRAWING,
298 NONFERROUS WIRE DRAWING AND INSU
299 ALUMINUM CASTINGS
300 BRASS, BRONZE, AND COPPER CASTIN
301 NONFERROUS CASTINGS, N.E.C.
302 NONFERROUS FORGINGS

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303 Fabricated Metal Products
is an aggregate of the following original industries:

303 METAL CANS
304 METAL BARRELS, DRUMS AND PAILS
305 METAL SANITARY WARE
306 PLUMBING FIXTURE FITTINGS AND TR
307 HEATING EQUIPMENT, EXCEPT ELECTR
308 FABRICATED STRUCTURAL METAL

309 METAL DOORS, SASH, AND TRIM
310 FABRICATED PLATE WORK (BOILER SH
311 SHEET METAL WORK
312 ARCHITECTURAL METAL WORK
313 PREFABRICATED METAL BUILDINGS
314 MISCELLANEOUS METAL WORK
315 SCREW MACHINE PRODUCTS AND BOLTS
316 AUTOMOTIVE STAMPINGS
317 CROWNS AND CLOSURES
318 METAL STAMPINGS, N.E.C.
319 CUTLERY
320 HAND AND EDGE TOOLS, N.E.C.
321 HAND SAWS AND SAW BLADES
322 HARDWARE, N.E.C.
323 PLATING AND POLISHING
324 METAL COATING AND ALLIED SERVICE
325 MISCELLANEOUS FABRICATED WIRE PR
326 STEEL SPRINGS, EXCEPT WIRE
327 PIPE, VALVES, AND PIPE FITTINGS
328 METAL FOIL AND LEAF
329 FABRICATED METAL PRODUCTS, N.E.C

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330 Machinery
is an aggregate of the following original industries:

330 STEAM ENGINES AND TURBINES
331 INTERNAL COMBUSTION ENGINES, N.E
332 FARM MACHINERY AND EQUIPMENT
333 LAWN AND GARDEN EQUIPMENT
334 CONSTRUCTION MACHINERY AND EQUIP
335 MINING MACHINERY, EXCEPT OIL FIE
336 OIL FIELD MACHINERY
337 ELEVATORS AND MOVING STAIRWAYS
338 CONVEYORS AND CONVEYING EQUIPMEN
339 HOISTS, CRANES, AND MONORAILS
340 INDUSTRIAL TRUCKS AND TRACTORS
341 MACHINE TOOLS, METAL CUTTING TYP
342 MACHINE TOOLS, METAL FORMING TYP
343 SPECIAL DIES AND TOOLS AND ACCES
344 POWER DRIVEN HAND TOOLS
345 ROLLING MILL MACHINERY
346 METALWORKING MACHINERY, N.E.C.
347 FOOD PRODUCTS MACHINERY
348 TEXTILE MACHINERY
349 WOODWORKING MACHINERY
350 PAPER INDUSTRIES MACHINERY
351 PRINTING TRADES MACHINERY
352 SPECIAL INDUSTRY MACHINERY, N.E.
353 PUMPS AND COMPRESSORS
354 BALL AND ROLLER BEARINGS
355 BLOWERS AND FANS
356 INDUSTRIAL PATTERNS
357 POWER TRANSMISSION EQUIPMENT
358 INDUSTRIAL FURNACES AND OVENS
359 GENERAL INDUSTRIAL MACHINERY, N.
360 CARBURETORS, PISTONS, RINGS, VAL
361 MACHINERY, EXCEPT ELECTRICAL, N.

362 ELECTRONIC COMPUTING EQUIPMENT
363 CALCULATING AND ACCOUNTING MACHI
364 SCALES AND BALANCES
365 TYPEWRITERS AND OFFICE MACHINES,
366 AUTOMATIC MERCHANDISING MACHINES
367 COMMERCIAL LAUNDRY EQUIPMENT
368 REFRIGERATION AND HEATING EQUIPM
369 MEASURING AND DISPENSING PUMPS
370 SERVICE INDUSTRY MACHINES, N.E.C

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371 Electrical Equipment
is an aggregate of the following original industries:

371 INSTRUMENTS TO MEASURE ELECTRICI
372 TRANSFORMERS
373 SWITCHGEAR AND SWITCHBOARD APPAR
374 MOTORS AND GENERATORS
375 INDUSTRIAL CONTROLS
376 WELDING APPARATUS, ELECTRIC
377 CARBON AND GRAPHITE PRODUCTS
378 ELECTRICAL INDUSTRIAL APPARATUS,
379 HOUSEHOLD COOKING EQUIPMENT
380 HOUSEHOLD REFRIGERATORS AND FREE
381 HOUSEHOLD LAUNDRY EQUIPMENT
382 ELECTRIC HOUSEWARES AND FANS
383 HOUSEHOLD VACUUM CLEANERS
384 SEWING MACHINES
385 HOUSEHOLD APPLIANCES, N.E.C.
386 ELECTRIC LAMPS
387 LIGHTING FIXTURES AND EQUIPMENT
388 WIRING DEVICES
389 RADIO AND TV RECEIVING SETS
390 PHONOGRAPH RECORDS AND TAPE
391 TELEPHONE AND TELEGRAPH APPARATU
392 RADIO AND TV COMMUNICATION EQUIP
393 ELECTRON TUBES
394 SEMICONDUCTORS AND RELATED DEVIC
395 ELECTRONIC COMPONENTS, N.E.C.
396 STORAGE BATTERIES
397 PRIMARY BATTERIES, DRY AND WET
398 X-RAY APPARATUS AND TUBES
399 ENGINE ELECTRICAL EQUIPMENT
400 ELECTRICAL EQUIPMENT, N.E.C.

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401 Transport Equipment
is an aggregate of the following original industries:

401 TRUCK AND BUS BODIES
402 TRUCK TRAILERS
403 MOTOR VEHICLES
404 MOTOR VEHICLE PARTS AND ACCESSOR
405 AIRCRAFT
406 AIRCRAFT AND MISSILE ENGINES AND
407 AIRCRAFT AND MISSILE EQUIPMENT,
408 SHIP BUILDING AND REPAIRING
409 BOAT BUILDING AND REPAIRING
410 RAILROAD EQUIPMENT

411 MOTORCYCLES, BICYCLES, AND PARTS
412 TRAVEL TRAILERS AND CAMPERS
413 MOBILE HOMES
414 MOTOR HOMES
415 TRANSPORTATION EQUIPMENT, N.E.C.

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446 Transportation & Warehousing Ser
is an aggregate of the following original industries:

446 RAILROADS AND RELATED SERVICES
447 LOCAL, INTERURBAN PASSENGER TRAN
448 MOTOR FREIGHT TRANSPORT AND WARE
449 WATER TRANSPORTATION
450 AIR TRANSPORTATION
451 PIPE LINES, EXCEPT NATURAL GAS
452 TRANSPORTATION SERVICES
453 ARRANGEMENT OF PASSENGER TRANSPO

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454 Other Services
is an aggregate of the following original industries:

454 COMMUNICATIONS, EXCEPT RADIO AND
455 RADIO AND TV BROADCASTING
456 ELECTRIC SERVICES
457 GAS PRODUCTION AND DISTRIBUTION
458 WATER SUPPLY AND SEWERAGE SYSTEM
459 SANITARY SERVICES AND STEAM SUPP
464 BANKING
465 CREDIT AGENCIES
466 SECURITY AND COMMODITY BROKERS
467 INSURANCE CARRIERS
468 INSURANCE AGENTS AND BROKERS
469 OWNER-OCCUPIED DWELLINGS
470 REAL ESTATE
471 HOTELS AND LODGING PLACES
472 LAUNDRY, CLEANING AND SHOE REPAI
473 FUNERAL SERVICE AND CREMATORIES
474 PORTRAIT AND PHOTOGRAPHIC STUDIO
475 ELECTRICAL REPAIR SERVICES
476 WATCH, CLOCK, JEWELRY AND FURNIT
477 BEAUTY AND BARBER SHOPS
478 MISCELLANEOUS REPAIR SHOPS
479 SERVICES TO BUILDINGS
480 PERSONNEL SUPPLY SERVICES
481 COMPUTER AND DATA PROCESSING SER
482 MANAGEMENT AND CONSULTING SERVIC
483 DETECTIVE AND PROTECTIVE SERVICE
484 EQUIPMENT REPAIR AND LEASING
485 PHOTOFINISHING, COMMERCIAL PHOTO
486 OTHER BUSINESS SERVICES
487 ADVERTISING
488 LEGAL SERVICES
489 ENGINEERING, ARCHITECTURAL SERVI
490 ACCOUNTING, AUDITING AND BOOKKEE
491 EATING AND DRINKING PLACES
492 AUTOMOBILE RENTAL AND LEASING
493 AUTOMOBILE REPAIR AND SERVICES

494 AUTOMOBILE PARKING AND CAR WASH
495 MOTION PICTURES
496 DANCE HALLS, STUDIOS AND SCHOOLS
497 THEATRICAL PRODUCERS, BANDS ETC.
498 BOWLING ALLEYS AND POOL HALLS
499 COMMERCIAL SPORTS EXCEPT RACING
500 RACING AND TRACK OPERATION
501 MEMBERSHIP SPORTS AND RECREATION
502 AMUSEMENT AND RECREATION SERVICE
503 DOCTORS AND DENTISTS
504 HOSPITALS
505 NURSING AND PROTECTIVE CARE
506 OTHER MEDICAL AND HEALTH SERVICE
507 ELEMENTARY AND SECONDARY SCHOOLS
508 COLLEGES, UNIVERSITIES, SCHOOLS
509 OTHER EDUCATIONAL SERVICES
510 BUSINESS ASSOCIATIONS
511 LABOR AND CIVIC ORGANIZATIONS
512 RELIGIOUS ORGANIZATIONS
513 OTHER NONPROFIT ORGANIZATIONS
514 RESIDENTIAL CARE
515 SOCIAL SERVICES, N.E.C.
523 SCRAP
524 USED AND SECONDHAND GOODS

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460 Trade
is an aggregate of the following original industries:

460 RECREATIONAL RELATED WHOLESALE T
461 OTHER WHOLESALE TRADE
462 RECREATIONAL RELATED RETAIL TRAD
463 OTHER RETAIL TRADE

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516 Government Services
is an aggregate of the following original sectors:

516 U.S. POSTAL SERVICE
517 FEDERAL ELECTRIC UTILITIES
518 OTHER FEDERAL GOVERNMENT ENTERPR
519 LOCAL GOVERNMENT PASSENGER TRANS
520 STATE AND LOCAL ELECTRIC UTILITI
521 OTHER STATE AND LOCAL GOVT ENTER
525 GOVERNMENT INDUSTRY

Table 8.1. Column Totals for Each Sector in the Paths Matrix.

	1&2	3	4	7	14	15	VA	US
Dairy Pr.	10	10	15	15	13	11	21	87
Poultry	12	13	20	16	16	13	25	105
Ranch Cat	10	11	17	16	19	12	27	108
Range Cat	13	13	19	16	19	12	28	106
Cattle Fe	16	16	24	24	22	13	30	105
Sheep	10	12	17	15	18	10	27	99
Hogs	12	12	18	17	17	12	26	98
Other Mea	8	9	11	12	10	6	14	47
Misc.Lvst	10	10	14	14	16	12	25	89
Cotton	0	0	0	0	0	0	14	72
Food Grns	10	13	16	13	12	10	18	69
Feed Grns	9	14	17	14	14	11	20	72
Hay/Pastu	12	11	15	11	12	9	17	70
Grass See	11	8	12	9	10	9	13	59
Tobacco	9	10	13	0	9	8	12	56
Fruits	9	12	19	12	13	9	12	67
Tree Nuts	0	0	0	0	0	0	0	55
Vegetable	8	9	13	10	11	7	11	50
Sugar Crp	4	8	7	3	3	6	12	55
Misc.Crps	11	8	15	6	9	6	12	50
Oil Crps.	6	10	11	9	9	6	10	37
Forest pd	4	6	12	7	6	5	11	39
Nursery P	9	12	14	13	8	8	14	57
Forestry	0	0	0	0	0	0	0	69
Comm.Fish	0	0	0	0	0	0	0	40
Ag.For.Se	9	14	15	14	0	11	16	67
Lndscape	9	8	10	8	9	8	9	40
Metal Min	15	12	17	12	9	10	17	50
Coal/Pet	9	9	10	0	0	7	11	33
Nonmet.Mn	9	9	12	11	7	9	13	45
Const/Rep	10	14	14	12	13	17	18	72
Misc.Mfg.	8	15	11	14	8	12	18	66
Food Proc	8	20	23	25	28	16	36	90
Tobac.Mfg	0	0	0	0	10	8	13	47
Fib.Texti	15	10	15	13	8	11	15	52
Apparel	7	9	14	13	8	8	17	50
Log/Wood	7	12	8	9	8	10	13	52
Furniture	11	13	17	12	10	14	20	72
Pulp/Pape	6	7	7	10	7	10	14	41
Chemicals	10	13	9	11	10	8	13	47
Petro.Pro	8	7	9	0	0	13	9	39
Rubber/Pl	0	13	15	13	10	14	20	62
Leather	0	0	0	26	6	12	13	57
Non.Met.P	12	14	15	11	9	10	16	59
Iron&Stee	16	0	13	0	0	14	20	55
NonFer.Mf	0	11	0	14	0	11	17	50
Fabr.Met.	9	9	12	9	11	13	15	60
Machinery	9	10	14	12	8	11	15	51

...contd.

	1&2	3	4	7	14	15	VA	US
ElectricE	8	13	13	14	8	9	13	53
Transport	11	13	14	14	9	14	19	68
Trans/War	6	5	9	6	7	6	11	38
OtherSer.	7	8	12	10	8	8	11	32
Trade	3	6	7	4	6	5	6	22
Govt.Ser.	4	5	7	5	3	4	6	1

Table 8.2. Column Totals for Each Sector in the Path Multipliers Matrix.

	1&2	3	4	7	14	15	VA	US
Dairy Pr.	10.3	10.2	15.6	14.9	13.4	11.5	22.7	108.7
Poultry	12.5	13.	20.9	16.7	16.4	13.6	27.4	133.1
Ranch Cat	10.3	11.2	17.7	16.8	19.7	12.6	30.9	135.5
Range Cat	13.4	13.3	19.9	16.8	19.7	12.5	30.2	132.2
Cattle Fe	16.3	16.3	24.9	25.0	22.7	13.5	32.7	129.1
Sheep	12.0	12.8	20.7	18.3	21.6	10.5	32.4	143.1
Hogs	12.8	11.3	18.8	18.9	19.2	12.9	29.6	133.3
Other Mea	16.8	13.1	19.2	23.5	22.5	9.3	26.4	126.3
Misc.Lvst	10.4	10.4	15.4	15.8	17.2	12.6	29.3	121.4
Cotton	0	0	0	0	0	0	14.9	86.4
Food Grns	11.4	13.6	17.5	14.5	13.6	11.0	20.2	90.8
Feed Grns	10.3	14.6	18.6	15.5	15.7	11.9	22.5	95.1
Hay/Pastu	12.4	11.2	15.9	11.5	12.6	9.3	18.4	85.9
Grass See	11.4	8.1	12.5	9.5	10.6	9.3	13.8	74.4
Tobacco	9.3	10.2	13.5	0	9.3	8.3	12.6	67.8
Fruits	9.3	12.5	19.9	13.7	14.0	9.3	12.9	81.8
Tree Nuts	0	0	0	0	0	0	0	66.2
Vegetable	8.3	9.2	13.5	10.5	11.5	7.3	11.7	61.9
Sugar Crp	4.1	8.1	7.4	3.2	3.0	6.3	12.7	70.0
Misc.Crps	11.6	8.1	15.8	6.3	9.2	6.3	12.9	62.6
Oil Crps.	7.2	10.5	12.1	10.3	12.0	7.0	12.4	52.7
Forest pd	4.0	6.1	12.6	7.2	6.1	5.1	11.6	45.5
Nursery P	9.6	12.8	15.6	13.9	8.6	8.6	16.1	76.3
Forestry	0	0	0	0	0	0	0	81.8
Comm.Fish	0	0	0	0	0	0	0	52.4
Ag.For.Se	10.2	14.9	15.5	15.6	0	11.9	17.7	84.8
Lndscape	9.2	8.2	10.7	8.3	9.2	8.3	9.5	46.8
Metal Min	16.1	12.6	18.2	12.6	9.6	10.7	18.8	63.6
Coal/Pet	10.9	9.5	10.4	0	0	7.5	12.8	44.1
Nonmet.Mn	9.5	9.4	12.8	11.7	7.3	9.5	13.8	56.4
Const/Rep	10.6	14.9	14.8	12.6	14.2	18.3	19.3	89.8
Misc.Mfg.	8.3	16.2	11.8	14.8	8.8	13.0	19.7	89.1
Food Proc	7.3	21.4	25.3	27.3	29.8	17.3	40.6	127.5
Tobac.Mfg	0	0	0	0	12.3	8.5	14.8	69.1
Fib.Texti	19.4	11.8	18.2	15.6	10.4	12.0	18.7	94.4
Apparel	7.8	10.4	16.6	16.2	9.2	8.5	20.5	85.1
Log/Wood	9.6	14.8	9.6	10.1	11.2	13.6	17.0	84.9
Furniture	11.8	13.9	18.6	12.8	11.4	15.7	22.7	93.1
Pulp/Pape	6.1	7.2	7.4	10.6	7.4	11.0	15.9	69.9
Chemicals	11.7	13.5	10.6	12.8	11.2	9.0	16.4	70.3
Petro.Pro	8.4	7.2	9.4	0	0	13.7	9.9	52.8
Rubber/Pl	0	13.5	16.1	13.9	10.8	15.0	22.6	86.6
Leather	0	0	0	28.8	6.2	12.8	15.2	85.1
Non.Met.P	13.3	15.2	16.3	11.8	9.6	10.7	17.4	81.1
Iron&Stee	17.2	0	13.9	0	0	14.7	21.3	76.7
NonFer.Mf	0	12.0	0	14.7	0	12.8	19.4	83.0
Fabr.Met.	9.7	9.4	12.7	9.5	12.1	14.4	16.2	81.7

	1&2	3	4	7	14	15	VA	US
Machinery	9.9	10.9	15.4	13.0	8.9	11.8	16.1	73.6
ElectricE	8.4	15.0	14.6	14.9	9.6	10.4	15.0	75.9
Transport	11.8	13.8	17.0	15.1	10.1	15.0	20.5	104.8
Trans/War	6.3	5.2	9.9	6.4	7.9	6.4	12.6	51.4
OtherSer.	7.6	8.6	13.4	11.3	8.5	9.0	12.7	39.8
Trade	3.1	6.2	7.2	4.2	6.5	5.2	6.3	27.6
Govt.Ser.	4.0	5.1	7.4	5.1	3.0	4.1	6.3	19.6

Table 8.3. Column Totals for Each Sector in the Arcs Matrix.

	1&2	3	4	7	14	15	VA	US
Dairy Pr.	14	13	20	21	20	16	32	179
Poultry	14	15	28	21	23	18	38	208
Ranch Cat	13	13	22	20	27	16	42	210
Range Cat	19	18	25	20	28	16	42	216
Cattle Fe	28	29	46	46	39	20	61	252
Sheep	12	14	21	18	24	12	40	189
Hogs	16	14	23	22	24	16	38	184
Other Mea	10	10	13	14	13	6	20	86
Misc.Lvst	13	13	19	18	25	16	40	173
Cotton	0	0	0	0	0	0	18	126
Food Grns	12	14	22	14	14	12	23	122
Feed Grns	10	16	22	16	17	12	26	126
Hay/Pastu	15	12	20	12	14	10	22	124
Grass See	13	9	15	10	11	10	16	106
Tobacco	10	11	16	0	10	9	13	97
Fruits	10	13	24	14	14	10	13	114
Tree Nuts	0	0	0	0	0	0	0	94
Vegetable	9	10	16	11	11	8	12	82
Sugar Crp	5	9	10	4	3	7	14	96
Misc.Crps	14	8	20	7	9	7	16	85
Oil Crps.	6	10	12	9	9	6	11	58
Forest pd	4	6	16	7	6	5	12	62
Nursery P	12	13	18	16	9	10	19	98
Forestry	0	0	0	0	0	0	0	121
Comm.Fish	0	0	0	0	0	0	0	67
Ag.For.Se	10	15	17	16	0	12	19	116
Lndscape	10	9	12	9	10	9	10	65
Metal Min	18	13	22	13	9	11	22	82
Coal/Pet	10	9	11	0	0	7	12	53
Nonmet.Mn	10	9	15	12	7	10	14	74
Const/Rep	11	16	16	14	15	19	20	126
Misc.Mfg.	9	16	14	16	8	13	21	112
Food Proc	9	27	33	35	46	19	50	158
Tobac.Mfg	0	0	0	0	15	9	16	80
Fib.Texti	23	11	19	18	9	13	20	89
Apparel	8	11	20	17	10	9	22	93
Log/Wood	8	13	9	10	9	11	14	86
Furniture	12	15	22	15	13	17	26	124
Pulp/Pape	7	8	8	11	7	11	17	72
Chemicals	13	14	10	12	12	9	14	77
Petro.Pro	10	8	10	0	0	14	10	71
Rubber/Pl	0	14	19	16	10	17	27	110
Leather	0	0	0	44	6	13	15	98
Non.Met.P	14	15	19	13	10	11	19	100
Iron&Stee	21	0	15	0	0	15	23	92
NonFer.Mf	0	12	0	16	0	12	20	81
Fabr.Met.	12	10	13	10	13	18	16	104

	1&2	3	4	7	14	15	VA	US
Machinery	10	11	16	13	9	12	17	85
ElectricE	9	14	14	15	9	10	14	88
Transport	13	15	15	15	10	15	21	117
Trans/War	8	6	12	7	9	8	14	62
OtherSer.	8	8	14	12	8	9	12	45
Trade	3	6	8	4	6	5	6	31
Govt.Ser.	5	6	9	6	3	5	7	24

Table 8.4. Column Totals for Each Sector in the Direct Effects Matrix.

	1&2	3	4	7	14	15		VA US
Dairy Pr.	.178	.194	.209	.215	.255	.176	.337	1.093
Poultry	.121	.132	.263	.176	.176	.177	.325	1.335
Ranch Cat	.166	.161	.224	.207	.219	.224	.367	1.311
Range Cat	.229	.231	.281	.265	.291	.243	.398	1.323
Cattle Fe	.693	.715	.727	.746	.787	.266	.811	1.695
Sheep	.165	.158	.258	.192	.2	.2	.308	1.021
Hogs	.169	.17	.216	.206	.224	.202	.33	1.084
Other Mea	.054	.064	.1	.075	.093	.061	.124	.441
Misc.Lvst	.143	.154	.177	.179	.211	.174	.323	1.113
Cotton	0	0	0	0	0	0	.179	.754
Food Grns	.134	.108	.249	.142	.128	.161	.227	.73
Feed Grns	.155	.125	.26	.163	.153	.165	.238	.73
Hay/Pastu	.156	.128	.272	.16	.153	.17	.251	.794
Grass See	.122	.087	.193	.118	.097	.127	.172	.625
Tobacco	.117	.107	.199	0	.111	.141	.181	.52
Fruits	.083	.09	.194	.122	.1	.1	.134	.584
Tree Nuts	0	0	0	0	0	0	0	.456
Vegetable	.08	.072	.15	.088	.07	.086	.116	.39
Sugar Crp	.078	.073	.147	.102	.068	.111	.146	.502
Misc.Crps	.185	.057	.249	.105	.066	.116	.171	.592
Oil Crps.	.055	.047	.095	.058	.046	.065	.085	.277
Forest pd	.043	.055	.098	.058	.042	.059	.081	.294
Nursery P	.138	.08	.235	.16	.081	.118	.214	.429
Forestry	0	0	0	0	0	0	0	.703
Comm.Fish	0	0	0	0	0	0	0	.481
Ag.For.Se	.121	.114	.178	.152	0	.146	.212	.683
Lndscape	.08	.088	.104	.072	.071	.089	.103	.307
Metal Min	.159	.106	.215	.116	.086	.133	.193	.476
Coal/Pet	.089	.074	.106	0	0	.057	.103	.305
Nonmet.Mn	.109	.071	.148	.086	.055	.089	.139	.501
Const/Rep	.116	.158	.203	.167	.122	.197	.271	.752
Misc.Mfg.	.091	.11	.154	.093	.069	.141	.156	.59
Food Proc	.095	.213	.326	.37	.406	.144	.313	.799
Tobac.Mfg	0	0	0	0	.286	.078	.116	.523
Fib.Texti	.381	.072	.265	.425	.06	.147	.245	.475
Apparel	.071	.1	.192	.137	.125	.076	.161	.532
Log/Wood	.057	.137	.115	.114	.075	.119	.146	.44
Furniture	.119	.218	.247	.177	.246	.178	.278	.686
Pulp/Pape	.075	.077	.105	.097	.067	.124	.18	.408
Chemicals	.138	.145	.143	.126	.11	.087	.135	.519
Petro.Pro	.094	.068	.113	0	0	.117	.102	.683
Rubber/Pl	0	.082	.273	.108	.084	.193	.358	.688
Leather	0	0	0	.417	.038	.112	.112	.414
Non.Met.P	.164	.099	.191	.169	.101	.122	.199	.574
Iron&Stee	.24	0	.184	0	0	.143	.176	.508
NonFer.Mf	0	.074	0	.174	0	.139	.168	.416
Fabr.Met.	.104	.085	.124	.095	.082	.195	.14	.595

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	1&2	3	4	7	14	15	VA	US
Machinery	.115	.103	.141	.105	.082	.109	.136	.484
ElectricE	.139	.103	.154	.158	.083	.096	.138	.447
Transport	.108	.116	.121	.099	.094	.099	.202	.587
Trans/War	.138	.067	.111	.067	.086	.066	.109	.416
OtherSer.	.066	.058	.073	.05	.032	.045	.068	.244
Trade	.044	.047	.077	.056	.038	.06	.078	.15
Govt.Ser.	.068	.041	.068	.039	.018	.028	.028	.098

Table 8.5. Global Ratios and Rasmussen Indices Calculated for Paths in the Virginia and U.S. Models.

	Global Ratios		Rasmussen Index	
	Virginia	U.S.	Virginia	U.S.
Dairy Pr.	1.286	1.446	1.935	1.319
Poultry	1.531	1.746	1.542	1.409
Ranch Cat	1.653	1.796	1.450	1.186
Range Cat	1.714	1.762	1.547	1.3
Cattle Fe	1.837	1.746	1.829	1.257
Sheep	1.653	1.646	1.750	1.346
Hogs	1.592	1.629	1.869	1.278
Other Mea	.857	.781	2.360	1.439
Misc.Lvst	1.531	1.48	1.954	1.202
Cotton	.857	1.197	1.868	1.358
Food Grns	1.102	1.147	1.654	1.349
Feed Grns	1.224	1.197	1.638	1.336
Hay/Pastu	1.041	1.164	1.944	1.416
Grass See	.796	.981	2.002	1.686
Tobacco	.735	.931	1.799	1.473
Fruits	.735	1.114	1.799	1.561
Tree Nuts	0	.914	0	1.500
Vegetable	.673	.831	1.936	1.635
Sugar Crp	.735	.914	1.985	1.53
Misc.Crps	.735	.831	1.985	1.425
Oil Crps.	.612	.615	2.093	1.594
Forest pd	.673	.648	1.936	1.707
Nursery P	.857	.948	2.245	1.512
Forestry	0	1.147	0	1.172
Comm.Fish	0	.665	0	1.48
Ag.For.Se	.980	1.114	1.640	1.37
Lndscape	.551	.665	2.277	1.847
Metal Min	1.041	.831	1.944	1.464
Coal/Pet	.673	.549	1.936	1.502
Nonmet.Mn	.796	.748	1.678	1.485
Const/Rep	1.102	1.197	1.346	1.67
Misc.Mfg.	1.102	1.097	1.560	1.637
Food Proc	2.204	1.496	1.426	1.63
Tobac.Mfg	.796	.781	2.150	1.527
Fib.Texti	.918	.865	2.098	1.491
Apparel	1.041	.831	1.944	1.761
Log/Wood	.796	.865	1.678	1.537
Furniture	1.224	1.197	1.556	1.516
Pulp/Pape	.857	.682	2.005	1.732
Chemicals	.796	.781	1.678	1.731
Petro.Pro	.551	.648	2.277	1.814
Rubber/Pl	1.224	1.031	1.703	1.51
Leather	.796	.948	1.847	1.487
Non.Met.P	.980	.981	1.977	1.654
Iron&Stee	1.224	.914	1.393	1.72
NonFer.Mf	1.041	.831	1.655	1.58
Fabr.Met.	.918	.998	1.473	1.599

...contd.

	Global Ratios		Rasmussen Index	
	Virginia	U.S.	Virginia	U.S.
Machinery	.918	.848	1.616	1.543
ElectricE	.796	.881	1.678	1.743
Transport	1.163	1.131	1.271	1.631
Trans/War	.673	.632	2.508	1.536
OtherSer.	.673	.532	1.936	1.139
Trade	.367	.366	2.598	1.802
Govt.Ser.	.367	.283	3.102	2.115

Table 8.6. Global Ratios and Rasmussen Indices Calculated for Path Multipliers in the Virginia and U.S. Models.

	Global Ratios		Rasmussen Index	
	Virginia	U.S.	Virginia	U.S.
Dairy Pr.	1.224	1.327	1.962	1.333
Poultry	1.479	1.625	1.566	1.439
Ranch Cat	1.666	1.654	1.401	1.189
Range Cat	1.628	1.614	1.562	1.311
Cattle Fe	1.765	1.576	1.823	1.252
Sheep	1.751	1.747	1.778	1.352
Hogs	1.596	1.627	1.918	1.28
Other Mea	1.422	1.541	2.386	1.418
Misc.Lvst	1.583	1.482	1.896	1.187
Cotton	.807	1.055	1.873	1.413
Food Grns	1.092	1.109	1.674	1.329
Feed Grns	1.215	1.161	1.684	1.337
Hay/Pastu	.994	1.049	2.014	1.436
Grass See	.749	.908	2.01	1.716
Tobacco	.683	.828	1.821	1.521
Fruits	.696	.999	1.816	1.599
Tree Nuts	0	.808	0	1.541
Vegetable	.633	.756	1.958	1.698
Sugar Crp	.685	.855	2	1.542
Misc.Crps	.7	.765	1.992	1.487
Oil Crps.	.672	.644	2.125	1.6
Forest pd	.627	.556	1.96	1.742
Nursery P	.868	.932	2.302	1.528
Forestry	0	.999	0	1.22
Comm.Fish	0	.64	0	1.484
Ag.For.Se	.957	1.035	1.641	1.37
Lndscape	.516	.572	2.303	1.87
Metal Min	1.013	.777	1.985	1.408
Coal/Pet	.692	.538	1.95	1.483
Nonmet.Mn	.749	.688	1.697	1.492
Const/Rep	1.045	1.096	1.372	1.618
Misc.Mfg.	1.067	1.088	1.622	1.651
Food Proc	2.191	1.556	1.451	1.635
Tobac.Mfg	.801	.844	2.182	1.534
Fib.Texti	1.01	1.153	2.111	1.483
Apparel	1.105	1.039	2.025	1.837
Log/Wood	.916	1.037	1.7	1.516
Furniture	1.227	1.136	1.639	1.526
Pulp/Pape	.86	.853	2.066	1.647
Chemicals	.889	.858	1.701	1.752
Petro.Pro	.534	.645	2.315	1.768
Rubber/Pl	1.22	1.057	1.755	1.528
Leather	.822	1.039	1.908	1.522
Non.Met.P	.943	.99	2.036	1.649
Iron&Stee	1.151	.936	1.408	1.724
NonFer.Mf	1.045	1.014	1.717	1.589
Fabr.Met.	.878	.997	1.49	1.592

....contd.

	Global Ratios		Rasmussen Index	
	Virginia	U.S.	Virginia	U.S.
Machinery	.871	.899	1.635	1.536
ElectricE	.809	.927	1.701	1.734
Transport	1.105	1.279	1.284	1.617
Trans/War	.68	.628	2.543	1.466
OtherSer.	.687	.487	1.923	1.133
Trade	.342	.337	2.6	1.854
Govt.Ser.	.34	.24	3.076	2.092

Table 8.7. Global Ratios and Rasmussen Indices Calculated for Direct Effects in the Virginia and U.S. Models.

	Global Ratios		Rasmussen Index	
	Virginia	U.S.	Virginia	U.S.
Dairy Pr.	1.671	1.758	3.445	2.804
Poultry	1.612	2.147	3.024	2.463
Ranch Cat	1.82	2.108	2.672	2.298
Range Cat	1.974	2.128	2.823	2.289
Cattle Fe	4.022	2.726	4.335	2.753
Sheep	1.528	1.642	2.657	2.22
Hogs	1.637	1.743	2.521	2.229
Other Mea	.615	.709	2.985	2.552
Misc.Lvst	1.602	1.79	2.693	2.273
Cotton	.888	1.213	3.592	2.776
Food Grns	1.126	1.174	3.154	2.734
Feed Grns	1.18	1.174	2.784	2.51
Hay/Pastu	1.245	1.277	3.04	2.617
Grass See	.853	1.005	3.466	2.697
Tobacco	.898	.836	3.523	2.703
Fruits	.665	.939	2.554	2.008
Tree Nuts	0	.733	0	2.232
Vegetable	.575	.627	3.155	2.466
Sugar Crp	.724	.807	3.488	2.858
Misc.Crps	.848	.952	4.244	3.568
Oil Crps.	.422	.445	3.692	3.071
Forest pd	.402	.473	3.366	2.529
Nursery P	1.061	.69	3.79	2.311
Forestry	0	1.131	0	2.234
Comm.Fish	0	.774	0	2.493
Ag.For.Se	1.051	1.098	3.123	2.609
Lndscape	.511	.494	3.577	2.290
Metal Min	.957	.766	3.226	2.712
Coal/Pet	.511	.491	3.149	3.507
Nonmet.Mn	.689	.806	3.349	3.140
Const/Rep	1.344	1.209	3.106	1.939
Misc.Mfg.	.774	.949	2.631	1.989
Food Proc	1.552	1.285	1.957	1.462
Tobac.Mfg	.575	.841	3.022	2.774
Fib.Texti	1.215	.764	4.262	2.640
Apparel	.799	.856	3.08	3.266
Log/Wood	.724	.708	3.072	2.069
Furniture	1.379	1.103	3.217	1.947
Pulp/Pape	.893	.656	2.744	2.596
Chemicals	.67	.835	3.012	2.434
Petro.Pro	.506	1.098	2.929	4.204
Rubber/Pl	1.776	1.106	4.301	2.811
Leather	.555	.666	2.615	2.062
Non.Met.P	.987	.923	2.477	2.396
Iron&Stee	.873	.817	2.982	2.147
NonFer.Mf	.833	.669	3.079	2.236
Fabr.Met.	.694	.957	2.906	2.329

...contd.

	Global Ratios		Rasmussen Index	
	Virginia	U.S.	Virginia	U.S.
Machinery	.675	.778	3.375	2.117
ElectricE	.684	.719	3.581	2.212
Transport	1.002	.944	2.749	1.89
Trans/War	.541	.669	3.218	3.012
OtherSer.	.337	.392	2.655	1.861
Trade	.387	.241	5.258	2.511
Govt.Ser.	.139	.158	3.722	3.074

Vita

Rathin Basu was born in Calcutta, India, on June 3, 1948. His schooling was primarily in Bangalore, India. After graduating from high school, Rathin attended the University of Calcutta, where he obtained his buccalaureate and Master's degrees in Geology. He subsequently joined the State Bank of India, and served in its junior and middle management levels for ten years.

Rathin came to the United States in 1982 and obtained a Master's degree in International Administrative Studies from the School of International Studies, Ohio University, Athens, Ohio, prior to his joining the doctoral program at Virginia Tech.