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DEVELOPMENT OF REGIONAL INPUT-OUTPUT MODELLING:

PAST ACHIEVEMENTS, FUTURE PROSPECTS

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Abstract

Since the initial development of input-output modelling, the technique has been widely used in regional planning, and a considerable variety of models has emerged. Regional input-output research has hitherto focused on three aspects: dynamic multi-regional input-output modelling, spatial input-output modelling of cities using multiple sectors, multiple multiple zones; and dynamic multi-urban modelling.

In this paper, the authors attempt to track trends in the increasing refinement of the technique through reviewing the development of input-output modelling research.

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1. Introduction

Since the pioneering work of Leontief(1936), many models using input-output analysis have emerged. Isard (1951) was one of the first to attempt the development of regional and urban input-output models. Since then regional and urban modelling has become the major concern of input-output analysis.

Many scholars have applied the models to real world situation such as Emerson's model of Kansas in 1969, Isard, Langford, and Romanoff's survey based models of Philadelphia in 1966, 1967, and 1969, and Artle's Stockholm input-output model in 1959. This empirical work highlighted data problems and attempts to solve this problem, and has resulted in the emergence of numerical models. In this paper, an attempt is made to spell out the continuity and discontinuity that exist in the development of regional and urban input-output modelling by dividing the discussion into four parts: firstly, the introduction which includes the definitions of input-output analysis, region and city; secondly, the paper traces the chronological development of input-output research through three phases and some typical models characteristerising each phase are described; thirdly, major themes in the evolution of input-output modelling are identified and the need for future development is disscussed; finally, in the conclusion suggestions are made about how the gaps in input-output research might be bridged in future research.

But first, it is important to define what is meant by input-output analysis, region and city. A variety of definitions are available.

Input-output analysis

---- Leontief's definition in 1966 argued that:

> "The input-output method is an adaptation of the neo-classical theory of general equilibrium to the empirical study of the quantitative interdependence between interrelated economic activities."
> (p.134)

---- Wilson gave the follow definition in his "Urban and Regional Models in Geography and Planning" (1974):

> "The input-output model, as the name implies, is

> concerned with the inputs and outputs of each industry and their interrelationships. The products of an industry can be used as industrial inputs (in other industries, or in that in which it was produced) or can be consumed by what is defined to be the final demand sector....."
>
> (p.112)

---- Again, Jensen's definition (1979) states:

> "An input-output table represents the economy to be studied in terms of aggregated industrial or commodity groups or sectors. They trace out transactions in dollar terms between the sectors for a given year. Industries sell goods and services to other industries and to final users or 'final demand' and buy their inputs from other industries and primary sectors....."
>
> (p.18)

---The most recent definition appeared in Field and MacGregor's "Forecasting Techniques for Urban and Regional Planning" (1987):

> "Input-output analysis is often referred to as inter-industry accounting. Because it deals explicitly with the inter-industry transactions that arise from the demand for final products, it differs from other forms of accounting which exclude these transactions for intermediate goods to avoid double counting....."
>
> (p.85)

Although there are different definitions, a reasonably comprehensive one should possess the following characteristics:

1. It should reflect the supply (or output or sale) direction

and quantity of each sector or group or industry (X_i).

2. It should reflect the demand or input, or purchase direction and quantity of each sector or group, or industry (X_j).

3. Transactions exist to elaborate the supply or demand flow from industry to industry (x_{ij}). From the supply or output, or sales point of view, it means that some goods are produced in sector, or industry i, and supplied or sold to industry j. From the demand or input or purchase point of view, X_{ij} implies that the goods produced in industry or sector i were demanded or purchased or consumed by industry j. Alternatively, X_{ij} can be regarded as an expression of the structural characteristic of any two individual sectors or industries i and j of the economy.

4. It should identify the whole production process from initial production to final demand, an aspect of input-output modelling that is disscussed further in Chapter 3.

5. There should be a balance between requirements: the value of the combined inputs of each commodity or service must be equal to its total output.

As input-output analysis has many merits, and is potentially an excellent descriptive device and a powerful analytical technique (Jensen 1979), it has been widely applied in more than 100 countries (Zhang 1986), and in many fields in both region and city, capitalist and socialist countries.

Region and city

Every economic activity has a locational characteristic. An input-output method, which is used to describe and analyse economic activities has to refer to a defined area. According to Goodall's definition:

> "a region is any area of the earth's surface with distinct and internally consistent patterns of physical features or of human development which give it a meaningful unity and distinguishes it from surrounding areas" (Goodall 1987).

The city is a spatial concept. The term is used to denote any urban form but is applied particularly to large urban settlements. There is a scale on which urban can be measured based on population size varing from the metropolis with for example, 1,000,000 people to a town with a population of 50,000 to 100,000 people.

There is both heterogeneity and homogeneity between region and city. In a broad sense, the city is a region, it has various zones , each of them is a small area. In a narrow sense, the city is different from the region since a region is a plain, whilst the city is a point; the region is large, even relatively infinite, whilst the city is a small, finite entity; the region may have relatively rich natural resources, whilst a city will provide labour, and capital resources. Nevertheless, very little input-output research has hitherto considered big cities. Regional input-output analysis has occupied the majority of research effort.

2. Looking backword: history of regional input-output analysis

As Richardson suggests (1985), the history of regional input-output analysis falls into three major phases:

1. The first phase (1950-1960) was one of interregional input-output modelling.
2. The second phase (1950-1970) was concerned with survey-based input-output modelling.
3. The third phase (1970-onwards) focused on nonsurvey-based input-output modelling.

2.1 The first phase: Model development

In the first phase, the main contributions included the work of Isard (1951), Leontief (1953), Chenery(1953), Kuenne (1953), and later Miller (1957).

2.1.1 The Isard input-output model

Isard's initial thinking was that the region could be subdivided into different relatively small regions, for example, east, south , north and west. Flows ocurred between sectors within subregions, and trade (imports and exports) occurred between subregions. In an input-output formation, the interregional and regional input-output table takes the form illlustrated table 1.

	Region	East	South	West	Total		Subtotals
Region	Sector	1...20	1... 20	1...20	Export	Output	1 ... 20
East	1 : : 20						
South	1 : : 20						
West	1 : : 20						
Impotts (nat)							
Total input							
Sub-total	1 : : 20						

Table 1: Interregional and regional input-output table

Source: Isard (1951)

Hartwick (1971) demonstrated how Table 1 can be simplified and modified into Table 2.

	REGION 1	...	REGION l	...	REGION m	FINAL DEMAND	TOTAL
REGION 1	X^{11}	...	X^{1l}	...	X^{1m}	y^{1}	x^{1}
:	.		.		.	.	.
:	.		.		.	.	.
REGION k	X^{k1}	...	X^{kl}	...	X^{km}	y^{k}	x^{k}
:	.		.		.	.	.
:	.		.		.	.	.
REGION M	X^{m1}	...	X^{ml}	...	X^{mm}	y^{m}	x^{m}
PRIMARY INPUTS	$g^{1'}$	...	$g^{l'}$	...	$g^{m'}$		
TOTAL	$x^{1'}$	...	$x^{l'}$	...	$x^{m'}$		

Table 2 :Regional accounts for Isard interregional input-output model after Hartwick (1971)

In Table 2, there are m regions, and in each of them, n sectors are included. Hence, there are mxm interregional trade flows and nxn intersectoral commodity or service flows in each region, therefore, Table 2 contains nmxmn intersectoral and interregional trade flows.

Using the notation used in Table 2, x^{kl} is an nxn matrix of intersectoral flows moving from region k to region l, For example x^{11} is an nxn matrix in which each component is a flow from one of the n sectors to another of the n sectors in region 1, y^{k} is final demands in region k, which contain n components; x^{k} is a column vector of n components defining the sum by sector of intermediate outputs originating in region k plus final demands in region k, that is , all of region k's exports to its related regions are included in x^k, so, $x^k = \Sigma x^{kl} + y^k$. $g^{l'}$ and $x^{l'}$are row vectors of n components defining the primary inputs by sector flowing into region $\bar{l}$, and total input by sector for region l respectively. Apparently $x^{l'}$ or total inputs is defined to equal X^k or total output. Futher, supposing i is an output sector, j is an input sector, then x^{kl}_{ij} means the goods or services flow from sector i in region k into sector j in region l, a^{kl}_{ij} is the technical coefficient showing how many goods or services of sector i in region k are used by sector j in region l per unit, Thus,

$$a^{kl}_{ij} = \frac{x^{kl}_{ij}}{\sum_k \sum_i x^{kl}_{ij} + g^l_j} \qquad (1)$$

Where x^{kl}_{ij} is total input in sector j in region l, a^{kl}_{ij} is an element of the nmxnm matrix which is denoted as A.

Hartwick drew our attention to the fact that one of the drawbacks of the Isard interregional input-output model procedure for defining the coefficients of A^{kl} is that the coefficients contain elements of both interregional trade characteristcs and technical production characteristics. The coefficients a^{kl}_{ij} are imprecisely related to the technical coefficient Thus, if the coefficients change over time we cannot say whether there has been a simple rearrangement of trading patterns, a change in technology, or both. (Hartwick 1971)

2.1.2 The Chenery-Moses input-output model

For a variety of reasons the sector of destination of the flows in the real world, is usually unknown. For instance, we may know that 20 million tons of steel flow from sector i in region k to region l, but we do not know how the 20 million tons of steel is distributed into each sector in region l. Chenery and Moses hence developed an interregional input-output model which differs from that of the Isard model in the respect that the sector of destination is explored. In the Chenery-Moses interreginal input-output account table (Table 3) interpretation of each "cell" has different meaning.

	Region 1		Region l		Region m	Final Demand	Total
Region 1	x^{11}	...	x^{1l}	...	x^{1m}	y^{1}	x^{1}
Region k	x^{k1}	...	x^{kl}	...	x^{km}	y^{k}	x^{k}
Region m	x^{m1}	...	x^{ml}	...	x^{mm}	y^{m}	x^{m}
Primary Inputs	$g^{1'}$	...	$g^{l'}$	...	$g^{m'}$		

Table 3:Chenery Moses interregional account table

In the Chenery-Moses input-output model, x^{kl} is a column vector with n, not nxn, components; x^{kl}_i, i=1,2,...n, where x^{kl}_i is the flow of commodity i from region k to region l. In addition, it is assumed that a matrix X^{kk} is known for each region k = 1, 2, ... m , which contains intersectoral flows from each of n sectors to each of n sectors aggregated to include all competitive imports. Then, x^{kk}_{ij}, the component of X^{kk} describes the total amount of i including imports required to produce an observed flow of i, so , the coefficient a^l_{ij} is expressed in the following equation.

$$a^l_{ij} = \frac{x^{ll}_{ij}}{\sum_i x^{ll}_{ij} + g^l_j} \quad (2)$$

Where x^{ll}_{ij} is the i,jth component of X^{ll} and $g^{l'}_j$ is the jth component of $g^{l'}$. Equation (2) forms a nmxnm matrix. In Isard's model, the technical coefficient is a^{kl}_{ij} which means the quantity that is required from sector j in region l when one unit of output is derived from sector i in region k. In the Chenery-Moses model, the technical coefficients, a^l_{ij} define the total amount of flow from i required per unit output of j in region l. During this period, Kuenne (1953) and later Miller (1957) developed their own interregional models, which put more weight on the techniques for measuring the impact of expansion in a major industry on a region.

However, models cannot be used to analyse and predict a region's economy unless they have available the appropriate data. Input-output studies, particularly interregional input-output analyses are without question among the most data-ravenous economic models that have been developed. Vast quantities of information must be obtained in order to produce the desired table. Thus, the second phase, empirical implementation of interregional input-output models using surveyed data, began in 1960. Theoretical interregional input-output modelling research, however, was continued, for example, Leontief and Strout developed an interregional input-output gravity model to allow for a cross-hauling, where it occurs (Leontief and Strout, 1963; Yan, 1969. pp 117-20; Wilson 1970).

2.2 The second phase: Empirical implementation using surveys

In fact, empirical implementation of interregional input-output models can be traced back as early as 1955, when Moses constructed the first empirical interregional model to be published. This was an eleven sector , three region model based on a highly restrictive set of assumptions. He later developed a more elaborate model consisting of nine census regions and sixteen manufacturing sectors. This model is a blend of linear programming and input-output analysis designed to allow for substitution in an effort to obtain optimal trade patterns (Moses 1960). Following Moses's model in 1960, lots of survey-based interregional input-output models began to appear, such as the model of Washington State (Bourgne et al 1967), Emerson's model of Kansas in 1969, the model of Boulder (Miernyk et al 1967) and Isard, Langford, and Romanoff's survey-based model of Philadelphia in 1966 1967, and 1968.

2.2.1 Isard, Longford's model of Philadephia

Take Isard and Longford's model as an example. It was confined to the Philadephia Standard Metropolitian Statictical Area which included 8 subregions: Bucks, Chester, Delaware, Montgomery, and Philadephia in Pennsylvania; and Barlington, Camden, and Gloucester in New Jersey. SIC (Stardard Industrial Classification) was used to define the sectors in the model, about 86 sectors were involved. The use of multi-regions and multi-sectors made data collection more difficult.

The data required by the Philadelphia input-output model were collected by the following methods: census, sampling, interviewing and questionaires sent by mail. Sampling techniques were more commonly used than census because for a large region such as Philadelphia , the cost of obtaining a complete census as well as editing and processing all the responses would be tremendous and in the Philadelphia study, the limited resources relative to the size of the region made it absolutely necessary to sample establishments by sectors (Isard and Langford 1971). The survey, involving the collection of a large quantity of primary data, was conducted by interviewing in person, mailing and using some combination of the two methods. Personal interviews are the only method of collecting quality data. However, personal interviews are expensive and frequently, because of limited funds, the investigator must employ mail survey for supplementary purpose" (Isard 1981)

Although, the data collected by survey were dominant in the second phase in the development of interregional input-output research, the shortcomings were revealed also. Again, take Isard and Langford's (1971) Philadelphia interregional input-output model as an example, in which the drawbacks of survey methods can be identified. Firstly, a census has the advantage of a higher degree of accuracy and the investigator is able to construct a flow table that is "inherently" in balance and internally consistent, but has the major and overpowering disadvantages of high cost, long duration and tedious editing of the responses. Secondly, sampling can avoid these shortcomings, but it is difficult to decide upon the sample's size and coverage. Thirdly, interviewing to get quality data would encounter problems such as the difficulty of choosing proper and effective interviewers because most of them "had insufficient knowledge of the establishment to be interviewed and of manufacturing processes in general; and that our questionaires for many establishments were improperly structured", so the interviewers had to be trained beforehand. In addition to the problems of interviewers, it is very desireable to have the proper letters of introduction from a high public office which enthusiastically spells out the importance of the survey. Fourthly, mailing questionaires faces the problems of size and content. If the questionaires are too long, the response rate will be low thus choosing the questions carefully and technically is very important. Sometimes, stamping the word CONFIDENTIAL prominently in red ink over the first page of the questionaire can increase the response rate.

Survey data are ususally limited in their usefulness. Leontief stressed the need for improved regional data :"... highest priority should be assigned to improvement of the basic data. For statistics which are collected on a national level, a systematic, regional breakdown becomes more and more important .

On the other hand, most data collected by local and state organizations ..... are limited in their usefulness because of lack of comparability with other regional and national statistics." (Leontief et al 1965 pp228). There was a strong need to look for another short, accurate and economic way to 'collect ' interregional data which led to research during the third phase.

2.2.2 Artle's Stockholm input-output modelling

One of the most important uses of input-output modelling is that it can be used to predict total production by assuming that $(1-a)^{-1}$ is a matrix multiplier, and the final demand (Y) is given. However, the final demand (Y) is usually very difficult to forecast. To address this problem, Artle developed an input-output model in 1957 in which he estimated final demands through subclassing household income groups. He argued (1959):

> "Thus, the idea is to classify households into more homegeneous subcategories so that forecasts of total consumer demand and its components are faciliated and improved."

He assumed there are three household categories, for example, low-income, middle-income, high-income households which are symbolized as 'h' to refer to a particular household category, and 'n' sectors by using the symbols i and j ($i,j = 1,2,..,n$). Considering the income accruing to household category 'h' from industry 'j' as being a linear function of the level of activity 'j' and of time, then the income accruing to household category 'h' from industry 'j' during a given year(y_{hj}) can be expressed as:

$$y_{hj} = (w_{hj} + \overline{w}_{hj} t) x_j \qquad (h = 1,2,3) \quad (j = 1,2,...,n) \qquad (3)$$

where x_j is total value of output of the local sector 'j' during the given year, 't' is time, and $\overline{w}_{hj}$ and $w_{hj}t$ are constants.

Artle implemented those ideas in an analysis of the Stockholm economy. The models he built included 62 sectors and four subcategories (84-87) of household. The large amount of data which was required for the models was based on the 1951 CPDS (Census of Production, Distribution and Service) conducted by the Kommerskollegium (Board of Trade). Wilson (1974) appraised Artle's achievement in building the input-output model of Stockholm in late 50s highly:

"Artle made particularly important advances in relation to the final demand sector, particularly in introducing a number of categories of household by income".

Artle further explored his model in 1961 by firstly, defining the matrices: A_{nxn} is the square matrix of production coefficients; B_h as a set of a square matrices, refering to different subclasses or sector of household, where 'h' varies from n+1 to p; C_h, a further set of square matrices, denoting the consumption structure in each of the subclasses of households where h varies from n+1 to p; 'I' is the identity matrix. Secondly, he formulated a system whose equations state that the output of a sector minus the intermediate demand for its output minus the consumption demand for its output equals the exogenous demand for its output, so the symbolized equation will be:

$$x - Ax - C_{n+1} (B_{n+1} x - A B_{n+1} x) -\ldots- C_p (B_p x - A B_p x) = y \qquad (4)$$

If equation (4) is factored out the 'x' and '(I-A)' and to solve 'x', we can get

$$x = (1 - A)^{-1}[1-\sum_{h=n+1}^{p} C_h (I - A) B_h (I - A)^{-1}]^{-1}y \qquad (5)$$

2.3 The third phase: Data estimation from non-survey techniques

The third phase, starting around 1970, emphasised nonsurvey methods which used national data to estimate regional data. In fact, the first attempt to adjust national coefficients to derived regional coefficients had already been made by Moore and Peterson in 1955, although the major search for alternatives to the survey-based model gained momentum in the 1970s. From 1970 onwards, a variety of appproaches and models were developed as contributions to the research effort in interregional input-output modelling. These approaches were summarised and categorised into three sets of techniques by Richardson in 1985: conversion of national coefficients, shortcut, and hybrid methods.

2.3.1 Conversion of National coefficients model

Suppose we have two input-output tables: a national input-output table (table 4) and a regional input-output table(table 5)

	INTER-MEDIATE	FINAL DEMAND	GROSS OUTPUT
INTER-MEDIATE	A	Y	X
PRIMARY INPUT	M		
TOTAL INPUT	X		

Table 4:National input-output table

	INTER-MEDIATE	FINAL DEMAND	GROSS OUTPUT
INTER-MEDIATE	a	y	x
PRIMARY INPUT	m		
TOTAL INPUT	x		

Table 5:Regional input-output table

The notations used above are defined as follows: Xi and xi are national and regional total output of each sector; Xj and xj are national and regional total input of each sector; M and m are national and regional primary input; Yi and yi are national and regional final demand; Aij and aij are national and regional technical coefficient.

In the national input-output table, the relationships among intermediate coefficients, final demand and total output can be interpreted by equation(6)

$$AX + Y = X \qquad (6)$$

then $(1 - A)^{-1}Y = X$. The same equation can be derived only the capital letters are changed into small letters as

$$(1-a)^{-1}y = x \qquad (7)$$

where "a" is the regional coefficient matrix. The relationship between the national coefficient and the regional coefficient looks like

$$a_{ij} = k_{ij} A_{ij} \qquad (8)$$

National input-output tables, fortunately, are more readily available, for example national input-output tables for the UK were published 1953, 1958, 1963, 1968, 1979, 1984. They provide the possibility using national tables, particularly the national technical coefficients (A) to estimate the regional input-output technical coefficient matrix (a). In equation (8), Aij is known and kij is the multiplier. The conversion of the national coefficient model is primarily concerned with how to use the national coefficient matrix to estimate the regional coefficients matrix, and this necessitates focusing is on the multiplier, kij.

Almost all the nonsurvey models, such as supply-demand pools, location quotient, or regional weights were aimed at estimating the multiplier, k_{ij}.

2.3.1.1 (1) Pool techniques (Regional Commodity Balance or Supply-Demand Pools)

This techniques was firstly created by Moore and Peterson in 1955, it was later developed by Kokat in 1966, Nevin, Roe and Round in 1966, Schaffer and Chu in 1969, Vamwynsberghe in 1976, and Alward and Palmer in 1981. The procedure of constructing a regional interindustry table from this technique may be treated quite briefly as follows:

Firstly, using national production coefficients and local output estimates, it is possible to derive the initial cell values for a table of total input requirements.

$$r_{ij} = x_j * A_{ij} \quad (9)$$

$$cij = (y_r/Y_t)\ Y_{ir} \quad (10)$$

Where r_{ij} is regional intermediate requirements and c_{ij} is the estimated final demand vector of the region's share of national final vectors.

Secondly, the commodity balance for each industry i can be computed as the difference between input requirement and produced supply. Therefore, r_i the total regional requirements of products i, and bi the commodity balance will be

$$r_i = r_{ij} + c_{ir} \quad (11)$$

$$b_i = x_i - r_i \quad (12)$$

Finally, b_i can be calculated. It is clear there are two possibilities that is $b_i > 0$ or $b_i < 0$

If bi is positive ($b_i > 0$) , it means that supply is larger than demand (input requirement of the region), and no imports are needed; on the other hand, export exists which is equal to the difference between input requirement and produced supply, and the multiplier k's value is equal to 1

$$a_{ij} = 1 \times A_{ij} \qquad (13)$$

If bi is negative (b_i <0) it means that supply is less than demand, and import becomes necessary, export is equal to zero.

$$m_{ij} = r_{ij} - x_{ij} \qquad (14)$$

$$m_{ir} = c_{ij} - y_{ir} \qquad (15)$$

Thus the multiplier k's value here is x_i/r_i. That is

$$a_{ij} = k\, A_{ij} = (x_i/r_i)\, A_{ij} \qquad (16)$$

A modified version of the technique developed by Kokat(1966) and Neven, Roe and Round (1966) constructs regional final demands from both regional output and requirements when there is a net commodity deficit, therefore assuming that imports enter the region as imports but never as final demand. More recent variants have been proposed by Vanwynsberghe(1976) and Alward and Palmer(1981)

2.3.1.2 Location quotient

The location quotient (LQ) , as Morrison and Smith defined it in 1974, is a measure designed to reflect the relative importance of an industry in a region as compared to its importance in the nation, this relative value can be judged either in terms of the level of output or the size of employment. The key idea is to use LQ_{ij} as a proxy for the multiplier k_{ij} in equation (5) when $LQ_{ij} < 1$, and to assume that all the inputs i for sector j are supplied locally if $LQ_{ij} > 1$, various modifications of the location quotient have been proposed, such as SLQ (the simple location quotient), POLQ (the purchases-only location quotient), SLLQ (the semi-logarithmic location quotient), CILQ (the crossed industry location quotient) and CBLQ (the consumption-based location quotient) [Schaffor and Chu (1969), Tiebout (Consad Research Corporation), Harrigan, McGilray, and McNicoll (1980), Morrison and Smith (1974), Norcliffe (1983), Richardson (1982), Round (1972), Round (1978a), Hewings (1970a, 1970b)].

(a) Simple location quotient (SLQ)

This method uses the location quotient directly as the multiplier k . Schaffer and Chu gave the equation as:

$$LQ_i = (x_i/x)/(X_i/X) \qquad (18)$$

LQ_i here is a number comparing the relative importance of an industry in a region to its relative importance in the nation. In the same year, Hewings modified the model as in equation (19):

$$\left[\left(x^r_i / \sum_j^m a^n_{ij} x^r_j\right) / \left(x^n_i / \sum_j^m a^n_{ij} x^n_j\right)\right] a^n_{ij} = a^r_{ij} \qquad (19)$$

Where x^n_i, x^r_i refer to national and regional total outputs for industry i; a^n_{ij}, a^r_{ij} refer to national and regional technical coefficient and the equation is subject to the constraint that $a^n_{ij} > a^r_{ij}$. This method simply attempts to measure the relative supply of and demand for industry i's output by industries k (j = 1,2,....m) in the region vis-a-vis the nation.

(b) POLQ (the Purchases-Only Location Quotient approach)

Schaffer and Chu developed this approach in 1969, and gave the notation x_i and X_i as regional and national total output of sector i; the primed x', X' indicate that the summation includes only the outputs of those industries which purchase from industry i. Thus,

$$x'/X' = [x - (x_j^{*} + ...)] / (X - (X_j^{*} + ...)] \qquad (20)$$

This difference depends on the relative sizes of purchasing industries excluded from the computation (x_j, X_j ...). So, the location quotient looks like:

$$k_{polqij} = LQ_i = (x_i/x') / (X_i/X') \qquad (21)$$

(c) CILQ (the Cross-industry location quotient approach)

The approach compares the proportion of national output of selling (supplying or outputting) industry i in the region to that for purchasing (demanding or inputting) industry j.

$$k_{cilq} = (x_i/X_i) / (x_j/X_j) \qquad (22)$$

If K_{cilqij} >1, which means that selling is larger than purchasing, the regional coefficient is equal to the national coefficient.

If k_{cilqij} <1, then

$$a_{ij} = K_{cilqij} * A_{ij} = \frac{x_i / X_i}{x_j / X_j} * \frac{x_{ij}}{X_j}$$

$$= \frac{X_{ij}}{X_i} * \frac{x_i}{x_j} \qquad (23)$$

This procedure leaves exports and imports to be computed as remainders,

$$\text{Imports} \qquad m_{ij} = A_{ij}\, x_j - a_{ij}\, x_j \qquad (24)$$

$$\text{Exports} \qquad e_i = x_i - x_{ij} - y_{if} \qquad (25)$$

2.3.1.3 Test and RAS (Bi-proportional approach)

Both Schaffer and Chu (1969), and Morrison and Smith (1974) carried out statistical tests on these various location quotient approaches. Morrison and Smith's results are listed in the Table 4.

Table 4 <u>Evaluation of simulated tables: Methods ranked for each test</u>

Rank	Test				
	Mean Absolute Difference	Correlation Coefficient	Mean Similarity Index	Information Content	Chi-Square
1	RAS	RAS	RAS	RAS	RAS
2	SLQ	SDP	SLQ	SLQ	CMOD
3	POLQ	SLQ	POLQ	POLQ	RMOD
4	RMOD	POLQ	SDP	CMOD	SLQ
5	CMOD	RMOD	RMOD	RMOD	POLQ
6	SDP	CMOD	RND	RND	RND
7	RND	RND	CMOD	CILQ	CILQ
8	CILQ	CILQ	CILQ	SDP	SDP

Note: Key initials of nonsurvey methods:

SLQ - simple location quotient

POlQ - purchase-only location quotient

CILQ- Cross-industry location quotient

CMUD - Modified cross-industry quotient

RND - Logarithmic cross quotient

RMOD - Modified logarithmic cross -quotient

SDP - Supply-demand pool

RAS - Bi-proportional model

Source: Morrison and Smith (1974)

It is immediately apparent from Table that the biproportional approach (RAS) produces a superior simulation when judged by the five measures of distance. As Morrison and Smith pointed out:

> ".... Of course, this is not entirely surprising, given that the technique employs a certain amount of survey material....".

A detailed description of RAS models is provided in Morrison and Smith(1974). They decribe the RAS method of estimating input-output coefficients as assuming that the deviation of regional coefficients from their national counterparts is explained by the simultaneous operations of a row and column vector upon an initial estimate of the regional coefficients. These regional coefficients are provided by

$$\underline{a}^{r} = \underline{R}\,\underline{a}^{n}\,\underline{S} \qquad (26)$$

Where $\underline{R}$ is now a row vector of K elements, one for each industrial sector of the economy: $\underline{S}$ is a column vector of k elements, one for each industrial sector: a^r is the regional coefficients matrix; and a^n is the national coefficients matrix.

It is clear that the model is developed for the purpose of projecting input-output tables, using a base period matrix and projection period row and column totals introduced as constraints. In setting up these constraints, a surveyed element is almost inevitably introduced into the analysis, in the sense that setoral data on intermediate input and output are not generally available at the local or regional level. Therefore, a process is adapted that firstly, treats the national input-output matrix as an estimate of the regional table and is combined with the vector of regional gross output to yield an estimated vector of intermediate outputs, secondly, the matrix is adjusted to conform with the row constraint, thirdly, a vector of intermediate inputs is estimated by using the result of step 2, and fourthly the matrix is adjusted to conform with the column constraint..... Then steps are repeated until the matrix converges to a state in which both row and column constraints are satisfied. This is the reason that RAS is called a biproportional model since it implements a mixture of methods, surveying and estimating. The degree of superiority is hence, noteworthy. For instance, the Morrison and Smith test shows that the size of mean absolute difference for the best nonsurvey method (SLQ) is almost three times that produced by RAS.

Although the conversion nonsurvey methods clearly have many advantanges, they also have their shortcoming, ie, they are too mechanical to satisfy all the required conditions. For example, the regional coefficients can be examined provided that national coefficients exist. So, research on data estimation began to shift to new approaches such as short cut and hybrid methods.

2.3.2 Short-cut approach

The first short cut method did not appear until Drake's RIMS (regional industrial multiplier system) technique was developed in 1979, subsequently followed by Latham and Montgomery in 1979 and Cartwright, Beamillor and Gustely in 1981. This method involves computing the direct component of the regional multiplier by applying the location quotient to adjust the national input-output coefficient, and using this along with data on proportions of earnings derived from agriculture and manufacturing in the region to estimate the indirect component of the multiplier.

An alternative short cut approach, what might be called a column sum multiplier, was developed by Burford and Katz (Burford and Katz 1987, Katz and Burford 1981a). It is not a substitute for an input-output model, but rather is a good estimator of the output multiplier for a firm or industry given its proportion of interindustry expenditures over all the industries in the region. The formula proposed by Burford and Katz is

$$U_j = 1 + \frac{w_j}{1 - \bar{w}} \qquad (27)$$

Where u_j is the estimated gross output multiplier for sector j, w_j is the column sum of the domestic trade coefficient matrix for sector j ($w_j = \sum_i^n a_{ij}$), and w is the mean columm sum of A matrix ($\bar{w} = (1/n) \sum_i^n w_j$).

These short cut approaches are superficially attractive (Richardson 1985), if only regional multipliers are needed, rather than a full regional input-output model and the construction of the complete table. However, they were soon found to be inadequate. The multiplier derived by RIMS, remain "at best very crude approximations of industry-specific output multipliers" (Latham and Montgomery (1979 p.6) and the column-sum multiplier, neglects the fact that most matrices can be triangularized and the estimated coefficients are thus less reliable, and, moreover, the column-sum is redundant because the column sums of intermediate requirements are difficult to obtain without a full input-output table (Richardson 1974). In other words, if we have a full input-output table, the intermediate requirements will be easy to get, and the value of this method will be lost.

2.3.3 Hybrid approaches

Embryonic hybrid approaches, in fact, appeared as early as 1963 when Hanson and Tiebout, and later Schaffer (1976) developed the exports only model . This model was first used to overcome the inadequacy of the SDP (Supply-Demand Pool technique). As Schaffer argued in his Georgia model in 1972, the commodity balance is equal to b_i($b_i=x_i-r_i$). If b_i is positive, x_{ij} is equal to r_{ij}, $e_i = b_i$, $a_{ij} = A_{ij}$. If b_i is negative, $a_{ij} = A_{ij}$ * bri, where br_i is defined as x_i/r_i, which is called the 'balance ratio', and $m_{ij} = r_{ij} - a_{ij}.x_j$. However, if the export of industry i is now assigned and making a clear claim on supply (x_i), the regional commodity balance should equal zero or less. But in actual practice this condition is not necessarily met. So, the balance ratio of SDP is now modified as

$$br^e_i = (x_i - e_i) / (r_i) \qquad (28)$$

Since exports have a predetermined value, the local trade can be estimated as a residual in proportion to needs:

$$x_{ij} = r_{ij}\, br^e_i = (x_{ij}/r_j)\,(x_i-e_i) \qquad (29)$$

$$y_{ij} = c_{if}\, br^e_i \qquad (30)$$

If $br^e_i<0$, then a_{ij} and m_{ij} will be computed as in the SDP procedure.

Parallel to the exports-only model, an imports only survey approach, which estimates the regional input-output coefficients residually, was developed by Su in 1970. At the same time, Williamson developed his so-called hybrid model and the TAP (Technique For Area Planning) approach. The GRIT (Generation of Regional Input-Output Tables) approach was developed as a true mongrel in its mix of nonsurvey and survey techniques by Jensen, Mandeville, and Karunaratne(1979). West(1981), Phibbs and Holsman(1982), have developed another alternative model abbreviated as GRITSSIC (Generalized Regional Input-output Tables with Survey-based Sums of Intermediate Coefficients)

An important version of the hybrid is the reconciliation technique. According to Jensen's definition(1976, 1977), rows-only table is a table of intersectoral transactions based on estimates of sector sales. The elements of this table are notated as r_{ij}; the columns-only table is a table of intersectoral transactions based on estimates of sector purchases, and representing sector cost structure. The elements of this table are notated as the cij. No matter whether we use the rows-only or columns-only model, the descrepanices between sale and purchase estimates of regional transactions may be large, even in its most detailed and thorough input-output survey. Therefore, the row and column coefficients have to be reconciled. This technique met that need.

Jensen and McGaurr (1976,1977) assumed that there existed a matrix of single-value estimates [m_{ij}] of actual inter-sectoral transaction [x_{ij}] which could be calculated from [r_{ij}] and [c_{ij}] and which could satisfy the requirements that $m_{ij}=x_i$, and $m_{ij}=x_j$, and certainly, that $x_i=x_j$, for i=j. Six methods are described to produce the matrix [mij]:

(1) Arithmetic Mean; the arithmetic mean of the r_{ij} and c_{ij} in each cell was taken as the appropriate transaction flow. [$(r_{ij}+c_{ij})/2$]

(2) Geometric Mean; the geometic mean of the r_{ij} and c_{ij} in each cell was taken as the appropriate transaction flow.

(3) Weighted Averages-True Sector Totals; reliability weights, summing to unity were attached to the rij and cij in each cell. However, it is unavoidable that these weights would reflect the subjective view of the analyst.

(4) Weighted Averages-Own Totals; weighted averages were derived as in (3) above.

(5) Weighted Friedlander.

(6) Weighted RAS.

Detailed description and exploration of these methods are also provided by Round (1986), Miernyk (1976, 1976), and Gerking (1976, 1979).

Two other hybrid approaches that have been developed are the MRIO (Multiregional input-output) model and the aggregation method.

The MRIO model, as Polenske defined it in 1980, is a comprehensive, multipurpose tool that can be used for systematic studies of many regional economic policies. The model developed for the United States combines a set of input-output tables for each of 51 states (including the District of Columbia) with a set of regional trade flow tables for each of 79 goods and services, and 1 total final demand, the systems of equations are be specified in general terms for m industries, n regions, and k final users. If x is the supply of output industries, y is total demand, then the supply of output of each industry in each region is equal to the amount of output demanded by all intermediate and final users in all regions.

$$x^{go}_{oj} = x^{gh}_{ij} + y^{gh}_{ik} \quad (i,j=1,\dots,m;\ h=1,\dots,n;\ k=1,\dots,p) \qquad (31)$$

As each technical coefficient, a^{oh}_{ij}, can be derived by the equation $a^{oh}_{ij} = x^{oh}_{ij} / x^{go}_{oj}$, which decribes the amount of commodity i purchased by industry j in region h, the equation above could be rewritten as

$$X = \hat{A} X + Y \qquad (32)$$

which is almost the same as Leontief's equation. Considering the trade coefficient matrix C which is a set of n x n diagonal matrices, in which the entry (c^{rs}_{io}) measures the proportion of good i available in region s that was imported from region r. The equation will be

$$X = (C \hat{A}) X + C Y \qquad (33)$$

$$(1 - C \hat{A}) X = C Y \qquad (34)$$

$$X = (I - C \hat{A}) C Y \qquad (35)$$

So, the regional outputs can be obtained from the calculations above. The merits of MRIO, according to Polenske, are of

> " an accounting tool, a policy analysis tool, and planning (forecasting) tool".

Other MRIO models are discussed in Gordon(1976), Round (1978a, 1978b), Polenske (1980), Miller and Blair(1983).

The aggregation approach includes sectoral aggregation methods developed by Williamson,(1970) Hewings (1982), Jensen and West (1980), and spatial aggregation methods developed by Miller and Blair (1981), whereby the data assembly task of regional input-output analysts could be simplified For example, Williamson(1970) aggregated a 12-sector model to 6 sectors and found that the long range (20-year) employment forecast increased by less than 5 percent. Also, tests with the nine-region Japanese model and a hypothetical five-region model suggested that for most purposes (eg. all single-region questions and interregional system outputs) a two-region model is more than adequate (Richardson,1985).

2.4 Evaluation of the techniques

Although we have reviewed the conversion of national coefficients, short cut and hybrid approaches, it is still very difficult to be clear which technique is most suitable for a particular task. The reason that we cannot reach a sound decision as Sawyer and Miller show us(1981) is that there is a wide variety of standard testing measures such as the Theil information index, the chi-square statistics, and mean absolute percentage error. Furthermore, Richardson makes the point that the determination of the boundary line between acceptable and unacceptable levels of error is subjective. Also, Jensen (1980) and Hewing (1984) draw our attention to the problem that if the input-output matrix itself is being evaluated, there is a choice between partitive accuracy (ie, the precision of each coefficient estimate) and holistic accuracy (ie, the consistency of the overall matrix with individual cell errors permitted if they tend to cancel each other out). Thus the approaches described above have both advantages and disadvantages; on the one hand they can solve certain problems in certain circumstances; on the other hand they have many deficiencies, in particular that the conversion of national coefficients is too mechanical to use flexibly, and the short cut method is ingenious but not reliable. It is the hybrid methods which are currently receiving the most attention.

Table 5 attempts to summarize the main contributions towards regional input-output research.

CONTRIBUTIONS	MODEL	EXPLANATION
I. Regional I-O analysis		
(1) <u>Interregional models</u>		
Isard (1951)	$a^{kl}_{ij} = x^{kl}_{ij} / (\sum_k \sum_i x^{kl}_{ij} + g^{l}_{j})$	Model tries to elaborate relationships by small scale subdivision, eg m small regions, each with n sectors. So, the total cells in the table will be nm x nm.
Chenery (1953) Moses (1955)	$a^{l}_{ij} = x^{ll}_{ij} / (\sum_i x^{ll}_{ij} + g^{l}_{j})$	Model treats each region independently, and imports are included.
Leontief and Strout (1966) Wilson (1971)		Uses gravity theory to estimate interregional flow.
(2) <u>Dynamic regional models</u>		
Leontief (1953)	$x_i - \sum_j^n x_{ij} - \sum_j^n I_{ij} = y_i^{(2)}$ as, $I_{ij} = b_{ij}\ x_j$ so, $I_{ij} = b_{ij}\ (d(x_j) / d_t)$	Increasing and decreasing investment cause technical coefficients and total output to change.
Burgur (1969) Miernyk (1970) Richardson (1972) Lundquist (1981)	$x_i - \sum_j^n x_j - \sum_j^n b_{ij} \dfrac{d(x_j)}{d_t} = y^{(2)}$	Investment has to be separated from final demand and treated independently
II. Metropolitan Models		
Artle (1961)	$x = (1-A)^{-1}\ [I-\sum_{h=n+1}^{p} C_h(I-A)\ B_h(I-A)^{-1}]^{-1}\ y$	This model made particularly important advances in relation to final demand sectors, introducing a number of categories of household by incomes. It enables better estimates of final demand to be made, since the form of demand functions will certainly vary with income Wilson (1974).
III. Non-survey techniques		
(1) <u>Conversion of national Coefficients</u>		
(a) Location quotient	SLQ	
Schaffer & Chu (1969) Morrison & Smith (1974) Round (1978a) Harrigan, McGilvray & McNicoll (1980a)	$SLQ_i = (x_i / x) / (X_i / X)$	LQi here is a number comparing the relative importance of an industry in a region to its relative importance in the nation.
	POLQ $POLQ_i = (x_i / x') / (X_i / X')$	LQj concerned with summation including the output of those industries which purchase from industry i.
	CILQ $CILQ_{ij} = (x_i / X_i) / (x_j / X_j)$	Compares the proportion of national output of selling industry in the region to that for purchasing industry j.
(b) Pool techniques (Supply Demand pools)	when $CILQ_{ij} > 1$, then $a_{ij} = A_{ij}$ $CILQ_{ij} < 1$, then $a_{ij} = CILQ_{ij} * A_{ij}$	
Moore & Peterson (1955) Kokat (1966) Nevin, Roe & Round (1966) Vanwynsberghe (1976) Alward & Palmer (1981)	$r_i = \sum_j^{s} r_{ij} + \sum_f^{t} C_{if};\ \ b_i = x_i - r_i$ If $b_i > 0,\ a_{ij} = A_{ij},\ e_i = b_i$ $b_i < 0,\ a_{ij} = A_{ij} * (x_i / r_i),\ b_i = 0$ $m_{ij} = r_{ij} - x_{ij};\ \ m_{if} = c_{if} - y_{if}$	Estimates the technical coefficient and import and exports coefficients by computing commodity balance for each industry i as the difference between requirement and produced supply (bi)
(c) RAS (Biproportional approach)		
Morrison & Smith (1974) Czamanski & Malizia (1969) Malizia (1969) McMenamin & Harrigan (1974)	$\underline{a}^{=} = \underline{R}\ \underline{a}^{n}\ \underline{S}$	The RAS method employs a certain amount of survey material such as the initial row and column vectors.
(d) Regional weighs		

(2) <u>Short Cuts</u>		
Drake (1976) Burford & Katz (1977) Latham & Montgomery (1979) Harrigan (1982)	$u_j = 1 + \dfrac{v_j}{1 - \bar{v}}$	A column-sum multiplier, by which the gross output multiplier for a sector can be estimated. W is the mean of the column sums of the A matrix.
(3) <u>Hybrids</u>		
(a) Mongrels TAP Bonner & Fable (1967) Fahle (1967) Williamson (1970) Su (1974) Schaffer (1976) Hewings (1977)	Export Only $\dot{b}_{ri} = (x_i - e_i) / r_i$ $x_{ij} = r_{ij} - \dot{b}_{ri}$ $y_{ij} = c_{ir} * \dot{b}_{ri}$	This model supposes that regional exports, have predetermined value. After bri is derived the procedure is the same as Supply-Demand Pool method.
GRIT Jensen, Mandeville and Karuneratne (1979)		GRIT = generation of regional input-output analysis. Five phases and fifteen steps.
GRITSIC Phibbs & Holsman (1982)		Generalized regional input-output tables with survey-based sums of intermediate coefficients.
(b) Reconciliation Techniques Gerking (1976,1979) Jensen & McGaurr (1976,1977)		
(c) Aggregation Sectoral Williamson (1970) Doesen & Little (1968) Hewings (1972) Jensen and West (1980) Katz and Burford (1981) Miller & Blair (1981)		
(d) MRIO Models Polenske (1980) Miller & Balir (1983) Gordon (1976) Round (1978a, 1978b) Batten (1982)	$x_{oj}^{go} = x_{ij}^{gh} + y_{ik}^{gh}$ (i,j=1,...m; h = 1,...,n; k = 1,...,p) $X = (I-C\hat{A})\ CY$	MRIO = Multiple Regional Input-Output.

Table 5: Summary of research contributions via input-output modelling.

Sources based on Richardson (1985), Smith and Leigh (1977), Morrison and Smith (1974).

3. Looking forward: trends of regional input-output research

2.1 Trends of regional input-output research

Smith and Leigh(1977) made an attempt to portray some of the interrelationships of input-output modelling by using figure 1.

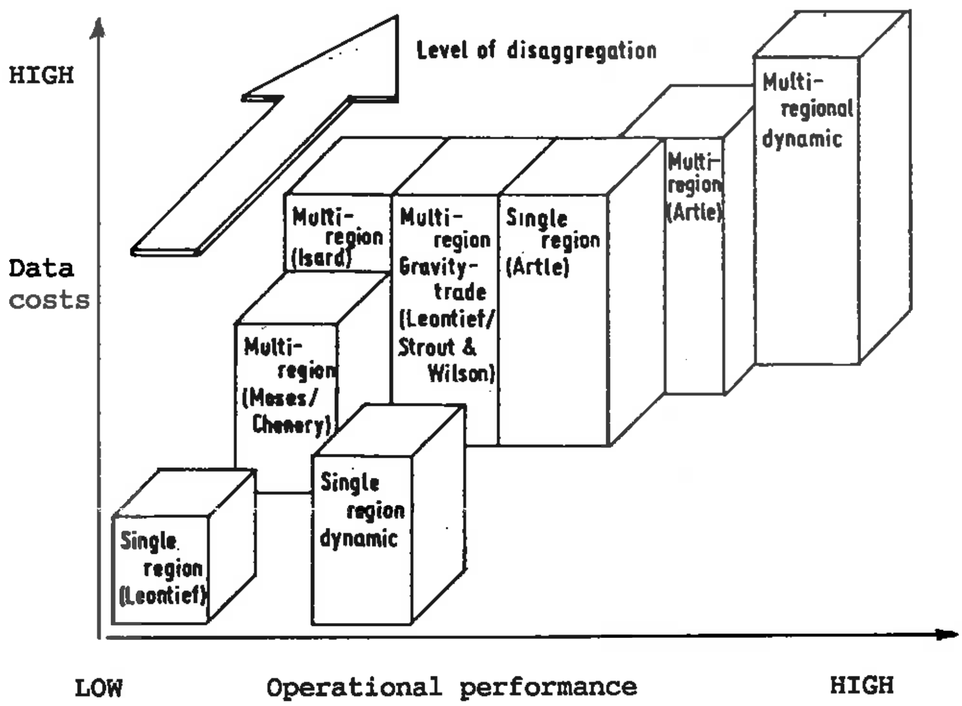


Figure 1: input-output modelling: the relationships between data requirements, level of disaggregation and operational performance.

Source: T.B. Smith and C.M Leigh (1977)

In this figure, the axis labelled data costs represents the relative quantities of data required by the model shown; the axis labelled operational performance refers to the level of improvement of each model which includes more reliable aggregate forecasts, more stable disaggregated forecasts and tractibility of solution method, and the axis labelled level of disaggregation refers mainly to the spatial refinement of the models, ie, the size of the economy under study (Smith and Leigh 1977). The figure shows that the development of regional input-output modelling developed from a single region to multi-region, from multi-region to multi-regional dynamic input-output, with the net benefits from each model development becoming greater, but the data cost at the same time are higher. This conceptulization simply made the interrelationships between various forms of a input-output modelling more explicit, it does not make any contribution to input-output development. From the literature review, we think, that future trends in input-output research may focus on the following fields: the development of multi-region tables, input-output modelling in cities, refering data collection techniques, and dynamic modelling which is related to input-output models both of the region and the city.

(1) Multiple regional input-output table

It would appear that the development of a regional or interregional or multiple regional input-output table had already been solved in the first stage of input-output research. It is true that many examples are available, for example, Isard's model in 1951, Miernyk's model in 1970, and many empirical models have been attempted since a number of questions, however, still need to be addressed, for instance, how to reflect the intermediate flows and trade flows between each region and each sector more accurately; how to divide a region into subregions, and how to reaggregate them; how to use the regional model to predict; how to change the two critical assumptions of input-output viz that one sector can only produce a product, and the product connot produced by any other sectors; and the technical coefficients connot changed; and how to make the model more dynamic.

(2) Dynamic regional input-output modelling

It is commonly admitted that the input-oputput model is a static one It assumed that the technical coefficients between each sector are firstly unchanged, and secondly, that each sector can only produce one product, which cannot be substituted by the product produced by any other sector. In the real world, technical innovation and time will cause the coefficients to change more or less. Moreover, a sector usually can produce many products, and can also substitute products from other sectors. Thus the input-output model is less reliable if it does not reflect the time factor. This problem was realised as early as 1953 when Leontief proposed his dynamic input-output model in "American Economic Structure", later developed by Bargur (1969), Miernyk (1970) Richardson (1972) and Lundgvist (1981). They argued that investment will lead to a change in the coefficients, thus investment should be seperated from final demand. Investment can be reproduced by a nxn matrix. So,

$$x_i = x_{ij} - s_{ij} = y_i^{(1)} \quad (i=1,2...,n) \qquad (36)$$

where, $y_i = y_i^{(1)} + y_i^{(2)}$, which leads to equatio

$$X^t = (I-A)^{-1} Y^t + (I-A)^{-1} S \quad I \qquad (37)$$

where, I measures the difference between required capacity in year t and actual year t-1, and S is an investment coefficient matrix, sij =Iij/xj. However, the approach is very complicated, so there are few cases where it has been implemented.

(3) Data estimation by nonsurvey method

Figure 1 above shows that the more complicated the input-output model becomes, (both in spatial disaggregation and operational performance), the more difficult the data collection will be, which leads to high data cost. True, if the data cost is high, it is difficult to collect the data, thus to finish the input-output table, but this is not insurmountable. Another approach can be substituted. This is why the nonsurvey method came into being. In future, it seems likely that nonsurvey techniques will be dominant because they are fast, economical and increasingly accurate.

(4) Input-output model of cities

Regional input-output modelling, we can see, has played a major part in input-output research over the last 30 years. In contrast, the input-output relationships cities has been given much less attention. Since Artle's Stockholm input-output model in 1950, there has not been a urban model which has treated different zones of a city as seperate regions, though some miniregional models have been constructed. Recently, some spatial models of inter-sectoral relationships, which are concerned wtih the flows (money, commuters) between sectors in different zones in a city have been developed, for example Wilson (1985). However, these models have a limited set of spatial linkage structures(Wilson 1985), because of the limitation of the scale of the models. Therefore the relationshop between sectors and those in different zones of the city, and the relationship between city and region and further between city and the rest of the world remain to be explored. The input-output model may have a valuable role to play in the exploration of both spatial relationship and sectorally disaggregated relationships within and between cities which will promise interesting future lines of investigation.

We are now in a position to refere to the Smith and Leigh's figure which can be modified to describe a more detailed classification of input-output research as Figure 2.

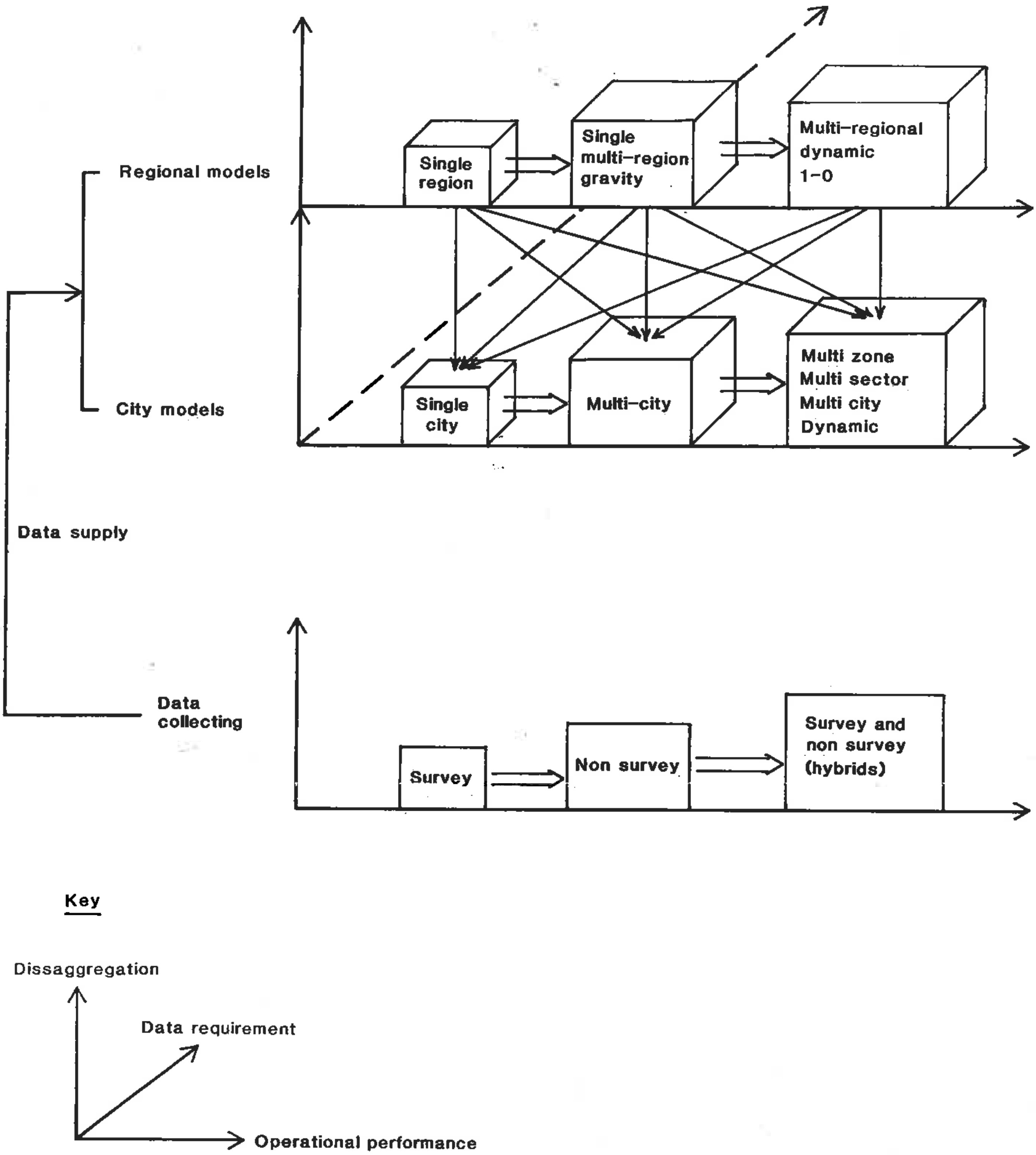
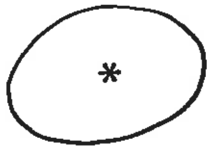


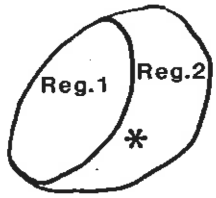
Figure 2. Relationships between Regional 1-0 models

Nine Relationships

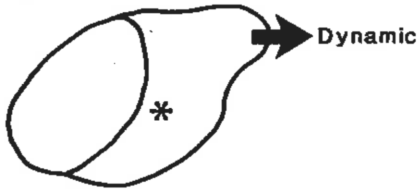
(1) Single city ——— Single region



(2) Single city ——— Multi-region

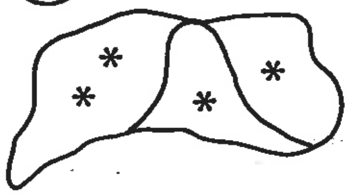


(3) Single city ——— Multi-regional dynamic

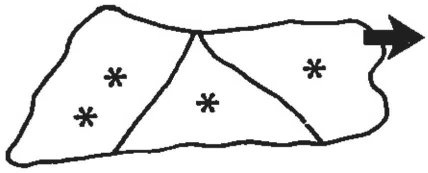


(4) Multi-city ——— Single region

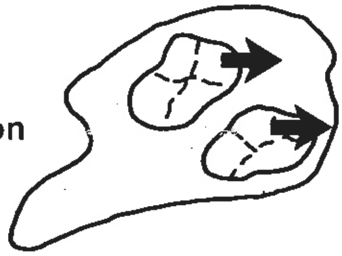
(5) Multi-city ——— Multi-region



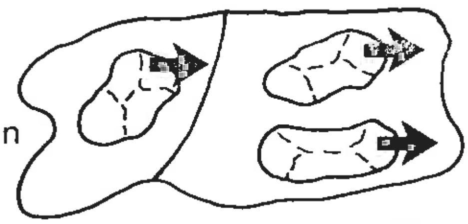
(6) Multi-city ——— Multi-regional dynamic



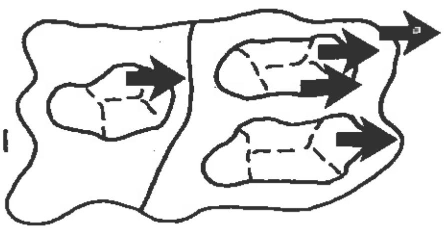
(7) Multi-zone Multi-city
Multi-sector dynamic ——— Single region



(8) Multi-zone Multi-city
Multi-sector dynamic ——— Multi-region



(9) Multi-zone Multi city
Multi-sector dynamic ——— Multi-regional dynamics



Region * City Zone of City

4. Conclusion

The most fascinating direction for future research lies perhaps in the development of urban input-output modelling --- a area which is under-researched, but in which there is a need to explore not only the complex relationships between sectoral of detail components of the city but also to develop a close understanding of the structure and functioning of local economics as a dynamic integrated system, needed from the intra-urban zone through to urban-rural relationships and beyond. The potential of a powerful tool like input-output to contribute to such an understanding is considerable.

Future research might most probably focus on the followings:

(1) To develop the theoretical explanation of a hierachy of models from the intraurban (relationships between functional zones in a city) to interurban (relationships between cities in a region). This set of models will be different from other regional input-output models as described in Part 2.1 in which the assumption of the number of input regions have to be equal to the number of output regions a constraint that cannot be met in

practice. Urban input-output models do not divide the urban zones in the models using functional variables so that the relationships between functional zones (for example, the residential and industrial zone) cannot be reflected in the model. In fact very few models are concerned with urban zones at all.

(2) A set of revelant data collection techniques may have to be developed in order to operationalize this hierachy of models.

(3) Dynamic factors should be incorporated into the model in order to approach realistic simulations of the real world. So the plausible model to be developed in the future might be a multisector, multizone, multiregion, dynamic input-output model of cities (MSMZMRDIMC) which is identified as the ninth type relationship in Figure 2.

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