CHINESE GEOGRAPHICAL SCIENCE
Volume 2, Number 4, pp.337–356, 1992
Science Press, Beijing, China

TECHNIQUES OF CONSTRUCTING REGIONAL INPUT–OUTPUT TABLES: ACHIEVEMENTS

Jin Yuxian (金玉献) Christine M Leigh
(School of Geography, the University of leeds, leeds LS2 9JT England)

ABSTRACT: The development of any analytical method should have to experience at least four stages: its initial status, growth, mature and declining. However, although the regional input–output analysis has been widely applied for more than forty years, it is still one of the most important approach in regional economic analysis and forecast at present in the world. This is due to the never ended modifications and its great potentials. In this paper, we review the historical development of the regional input–output analysis.

KEY WORDS: Input–output, regional research, regional input–output, models

I. INTRODUCTION

A basic regional input–output table usually consists of five interrelated components: the intermediate transactions that are occurred between sectors, final demand, total output product, primary input and total input product, among which the final demand and primary input are exogenously determined, and both total output and input are unknown variables which needed to be predicted. The intermediate transaction flows are the major concern in constructing an input–output table. The national input–output tables are usually available, for example, the national input–output table of China in 1983[1] and the national input–output tables of the UK that are published in every five years, e.g. the input–output table in 1984.[2] The reparation of regional input–output tables, however, is usually seriously disadvantaged both with respect to data availability and access to research resources.[3] The regional transactions have to be derived using one or a combination of the following approaches: surveying, modelling and non–survey estimation methods. In this paper, the advantages of each approach, together with the construction of extended input–output frameworks will be reviewed, the history of regional input–output analysis is outlined. The history of regional input–output analysis, as Richardson[4] suggests, falls into three major phases:(1) The first phase (1950–1960) was dominated by the development of regional input–output model. (2) The second phase (1960–1970) was concerned with survey–based input–output modelling. (3) The third phase (1970–onwards) focused on non–survey based input–output modelling.

II. THE FIRST PHASE: DEVELOPMENT OF REGIONAL INPUT–OUTPUT MODELLING FRAMEWORKk

In the first phase, the main contributions included the work of Isard,[5] Leontief,[6] Chenery,[7] Kuenne,[8] and later Miller,[9] among which the most typical one is the Isard's interregional input–output model.

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 occurred between sectors within subregions, and trade (imports and exports) occurred between subregions. In an input–output formulation, the interregional and regional input–output table takes the form illustrated in Table 1.

Table 1 Interregional and regional input–output table (After Isard 1951)

	Region	East	South	West	Total		Subtotal
Region	Sector	1…20	1…20	1…20	Export	Output	1…20
East	1 : 20						
South	1 : 20						
West	1 : 20						
Imports (nat)							
Total input							
Subtotal	1 : 20						

In Table 1, assuming that there are Rregions ($r=1, ..., R$), i.e. rather than the East, West and South, and in each of which, S sectors ($n=1, ..., S$), i.e. rather than 20 sectors, are included, then, there will be R^2 interregional trade flows and S^2 inter—sectoral commodity flows in each region, and Table 1 will contain R^2XS^2 intersectoral and interregional trade flows. Supposing n is an output sector, n is an input sector, then $X_{rr'}^{nn'}$ shows the goods or service flow from sector n in region r into sector n' in region r', $h_{rr'}^{nn'}$ is the technical coefficient showing the amount of goods or service of sector n in region r are used by one unit product in sector n' in region r, thus,

$$h_{rr'}^{nn'} = \frac{x_{rr'}^{nn'}}{\sum_n \sum_r x_{rr'}^{nn'} + g_{r'}^{n}} \quad (1)$$

Hartwick[10] drew our attention to the fact that one of the drawbacks of the Isard interregional input—output model procedure for defining the coefficients of $h_{rr'}^{nn'}$ is that the coefficients contain elements of both interregional trade characteristics and technical production characteristics, and they 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. And he illustrated that the coefficient is the product of both the trade and technical coefficient.

During this same period, Chenery[7] and Moses[11] developed a model that is similar to the Isard's interregional model but requires considerably less data in order to statistically applied, and Kuenne[8] and later Miller[9] 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 analyze and predict a region's economy unless the appropriate data is available. Input—output studies, particularly interregional input—output analyses are, without question, among the most data—ravenous economic models that have been developed. A vast quantity of information must be obtained in order to produce the desired table. Theoretical interregional input—output modelling research basing on Newton's gravity inverse square law, was thus developed. For example, Leontief and Strout developed an interregional input—output gravity model to allow for cross—hauling where it occurs.[12,13,14,15] Tentative inter—regional models using linear programming were also developed. The basic structures of linear programming transportation models together with the gravity models are simply demonstrated below.

2. Linear Programming Transportation model (LPT)

LPT modelling is an appropriate technique for the derivation of interregional commodity flow (Q_{ij}^{rsg}) provided the regional consumption of each commodity (D_{ij}^{rsg}) and the average transport cost per unit of commodity g from sector r to s between region i and region j (T_{ij}^{rsg}) are given. If regional trade is assumed to take place so as to minimize total transport cost, the LPT transport model can thus be derived as:

$$Min\sum_r\sum_s\sum_i\sum_j T_{ij}^{rsg} Q_{ij}^{rsg} \tag{2}$$

subject to

$$\sum_r\sum_s\sum_j Q_{ij}^{rsg} = Q_j^g \tag{3}$$

$$\sum_r\sum_s\sum_i Q_{ij}^{rsg} = D_i^g \tag{4}$$

where $Q_{ij}^{rsg} > 0$.

The advantage of the LPT model is that it is relatively easy to operate, and an optimal pattern of interregional trade can be obtained. The shortcomings however are also very clear: firstly, the trade flows derived from LPT are irrelevant to the real world since not all trade patterns are, or have to be, optimal; secondly, the data problems are still serious, i.e. it is not easy to obtain transport data; and finally, the conclusion can be drawn that 'the LPT model is a most unsatisfactory way of distributing trade'.[16]

3. Gravity models

The gravity models arise from an analogy with Newton's inverse square law, that is, the 'force' varies positively with the 'masses' and negatively with the distance. In regional science, the transaction flow of a commodity between two regions is supposed to be the same to the 'force'; the two 'masses' are replaced by the supply and demand (or origin and destination of a commodity); and the 'distance' is replaced by the travel cost. Gravity models are therefore used to analyse and predict interregional commodity flows and are particularly incorporated into input–output frameworks. The basic gravity model can be expressed as:

$$Q_{ij}^{rsg} = K_1^g O_i^g D_j^g d_{ij}^{rs(-a)_1^g} \tag{5}$$

subject to

$$\sum_r\sum_s\sum_j Q_{ij}^{rsg} = O_i^g \tag{6}$$

$$\sum_r\sum_s\sum_i Q_{ij}^{rsg} = D_j^g \tag{7}$$

where k^g is a constant; a^g is an exponential parameter to be fitted; and D_j^g is demand for commodity g in region j; O_i^g is the supply of commodity g in region i, and Q_{ij}^{rsg} represents the transaction flow of commodity g from sector r to sector s between region i and region j. O'Sullivan[17] argued that both the constant (k^g) and parameter (a^g) can be estimated from regression analysis. Equation (5) can then be changed into a linear programming form:

$$Y = a + bX \tag{8}$$

where:

$$a = k_1^g \tag{9}$$

$$b = - a_i^g \tag{10}$$

$$X = log d_{ij}^{rsg} \tag{11}$$

$$Y = log Q_{ij}^{rsg} - log Q_i^g - log D_j^g \tag{12}$$

Wilson[15] suggests that the parameter (a^g) can be obtained by calibration, 'which is the process of comparing (Q_{ij}^{rsg}) predicted by the model with a set of observations of the same array, perhaps from a sample survey, ..., and finding the a^g which gives the best fit between predicted and observed'. Compared to LPT modelling, the merit of the gravity model is the fact that it gives a more realistic simulation of interregional trade with two way flows between regions and with the pattern of trade reflecting actual, empirically observed behaviour rather than optimizing principles.

III. THE SECOND PHASE: EMPIRICAL APPLICATION USING SURVEYS

In fact, empirical implementation of interregional input—output models can be traced back as early as 1955, when Moses constructed an empirical interregional model. 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.[18] Following Moses's model in 1960, lots of survey—based interregional input—output models began to appear, such as the model of Washington State,[19] Emerson's model of Kansas in 1969, the model of Boulder[20] and Isard, Langford, and Romanoff's survey—based model of Philadelphia in 1966, 1967 and 1968.

1. Isard, Longford's model of Philadelphia

Take Isard and Longford's model as an example. It was confined to the Philadelphia Standard Metropolitan Statistical Area which included 8 subregions: Bucks, Chester, Delaware, Montgomery, and Philadelphia in Pennsylvania; and Barlington, Camden, and Gloucester in New Jersey. SIC (Standard Industrial Classification) was used to define the sectors in the model, about 86 sectors were involved. The use of several regions and many 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 questionnaires 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.[21] 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.

Although the data collected by survey were dominant in the second phase in the development of interregional input—output research, the shortcomings were also revealed. Again, take Isard and Langford's[21] 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 questionnaires for many establishments were improperly structured", so the interviewers had to be trained beforehand. In addition to the problems of interviewers, it is very desirable to have the proper letters of introduction from a high public office which enthusiastically spells out the importance of the survey. Fourthly, mailing questionnaires faces the problems of size and content. If the questionnaires 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 questionnaire can increase the response rate.

2. Artle's Stockholm input—output modelling

One of the most important uses of input—output models is that it can be used to predict total production by assuming that $(1-H)^{-1}$ is a matrix multiplier, and the final demand (F) is given. However, the final demand (F) is usually very difficult to be forecasted. To address this problem, Artle developed an input—output model in 1957 in which he estimated final demands through subclassifying household income groups. He argued:[22] "Thus, the idea is to classify households into more homogeneous subcategories so that forecasts of total consumer demand and its components are facilitated 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 (F_{hj}) can be expressed as:

$$F_{hj} = (w_{hj} + w^{t}_{hj})x_{j} \qquad h = 1,2,3 \qquad j = 1,...,n \tag{13}$$

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

Artle implemented those ideas in an analysis of the Stockholm economy. The models he built included 62 sectors and four subcategories 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 Board of Trade. Wilson[23] appraised Artle's achievement in building the input—output model of Stockholm in late 1950s 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: H_{nxn} is the square matrix of production coefficients; B_h as a set of a square matrices, referring 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:

$$X - HX - C_{n+1}(B_{n+1}X - HB_{n+1}X) - ... - C_p(B_pX - HB_pX) = F \tag{14}$$

If equation (14) is factored out the 'X' and '$(I-H)$' and to solve 'X', we can get:

$$X=(I-H)_1^{-1}(I-\sum_h C_h B_h)^{-1}F \tag{15}$$

However, the construction of regional input—output tables by surveying are too expensive in terms of time and cost. There was a strong need to look for another short, accurate and economic way to collect interregional data which led to the third phase research — non—survey estimation techniques that will be discussed in subsection 3.

IV. THE THIRD PHASE: ESTIMATION FROM NON—SURVEY TECHNIQUES

The third phase, starting around 1970, emphasized non—survey methods which employed 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 approaches and models were developed as contributions to the research effort in interregional input—output modelling. These approaches were summarized and categorized into three sets of techniques by Richardson in 1985: conversion of national coefficients, shortcut, and hybrid methods.

1. Conversion of National Coefficients Model

National input—output tables, fortunately, are readily available. They provide the possibility using national tables, particularly the national technical coefficients (H_{ij}) [NB. national variables are denoted by capital letters, e.g. H, as the national technical coefficient matrix; X, national gross output. Regional variables are represented by the lower case letters, e.g. h, regional coefficient matrix; x, regional gross output; and f, regional final demand] to estimate the regional input—output technical coefficient matrix (h_{ij}). Suppose, H_{ij} is known and k_{ij} is the multiplier then $k_{ij}=h_{ij}/H_{ij}$. The conversion of the national coefficient model is primarily concerned with how to use the national coefficient matrix to estimate the regional coefficient matrix, and this necessitates focusing on the multiplier, k_{ij}.

Almost all the non—survey models, such as supply—demand pools, location quotients, or regional weights were aimed at estimating the multiplier, k_{ij}.

(1) Pool techniques (Supply—Demand Pools)

This technique was first created by Moore and Peterson in 1955, it was later developed by Nevin, Roe and Round in 1966,[24] Schaffer and Chu in 1969,[25] Vanwynsberghe in 1976,[26] and Alward and Palmer in 1981. The procedure for 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.

$$r_{ij} = x_j \times H_{ij} \quad (16)$$

$$C_i = (f_i / F_i) F_i \quad (17)$$

where r_{ij} is regional intermediate requirements, and f_i and F_i are regional and national final demands respectively, Ci is the estimated final demand vector of the region's share of national final demand vector.

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

$$r_i = \sum_j r_{ij} + c_i \quad (18)$$

$$b_i = x_i - r_i \quad (19)$$

Finally, b_i is calculated from equation (19). It is clear there are two possibilities, that is, $b_i > 0$ or $b_i < 0$. If b_i is positive ($b_i > 0$), it means that the supply (production of the region) 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 actually equal to 1, and the regional coefficient (h_{ij}) is then equal to the national coefficient:

$$h_{ij} = k_{ij} \times H_{ij} = 1 \times H_{ij} \quad (20)$$

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

$$m_{ij} = r_{ij} - x_{ij} \quad (21)$$

$$m'_i = c_i - f_i \quad (22)$$

where m'_i is the import for the final demand i. Thus the multiplier k's value here is x_i / r_i, and the regional technical coefficient is equal to equation (23).

$$h_{ij} = k_i H_{ij} = (x_i / r_i) H_{ij} \quad (23)$$

A modified version of the technique has been developed by Neven, Roe and Round,[24] and more recent variants have been proposed by Vanwynsberghe[26] and Alward and Palmer.[27]

(2) Location Quotient

The location quotient (LQ), as what Morrison and Smith defined in 1974,[28] 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} 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).[16,25,28–32]

(a) Simple location quotient (SLQ)

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

$$LQ_i = (x_i / x) / (x_i / x) \tag{24}$$

LQ_i is a set of multipliers derived by 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 (25):

$$[(x_i^r / \sum_j H_{ij}^n x_j^r) / (x_i^n / \sum_j H_{ij}^n x_j^n)] h_{ij}^n = H_{ij}^r \tag{25}$$

where x_i^n and x_i^r refer to national and regional total outputs for industry i; H_{ij}^n and h_{ij}^r refer to national and regional technical coefficient and the whole equation is subject to the constraint that $H_{ij}^n > h_{ij}^r$. This method simply attempts to measure the relative supply of and demand for industry i's output by industries j 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 the regional and national total output of sector i; primed x' and x' indicate that the summation includes only the outputs of those industries which purchase from industry i. Thus,

$$x'_i / X'_i = (x_i - \sum_j x_{ij}^{\bullet}) / (X_i - \sum_j X_{ij}^{\bullet}) \tag{26}$$

where $x_j^{\bullet}$ and $X_j^{\bullet}$ indicate regional and national no purchase industries respectively. This difference in equation (26) depends on the relative sizes of purchasing industries excluded from the computation. So, the location quotient looks like:

$$LQ_i = (x_i / X') / (X_i / X') \tag{27}$$

(c) CILQ (the Cross–industry Location Quotient approach)

The approach compares the proportion of national output of selling industry i in a region to that for purchasing industry j.

$$LQ_{ij} = (x_i / X_i) / (x_j / X_j) \tag{28}$$

When $LQ_{ij} > 1$, it means that selling is larger than purchasing, and the regional coefficient is equal to the national coefficient.

$$h_{ij} = LQ_{ij} \times H_{ij} = \frac{x_{ij} / X_i}{x_j / X_j} \times \frac{X_{ij}}{X_j} \tag{29}$$

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

Imports $\quad m_{ij} = H_{ij} x_j - h_{ij} x_j \quad (30)$

Exports $\quad e_i = x_i - \sum_j x_{ij} - f_i \quad (31)$

(3) Test and RAS (Bi–proportional approach)

Both Schaffer and Chu,[25] and Morrison and Smith[28] carried out statistical tests on these various location quotient approaches. Morrison and Smith's results are listed in Table 2.

It is immediately apparent from Table 2 that the bi–proportional approach [it is also named RAS because matrix elements are 'proportional' (i.e. adjusted) to two constraints–row and column totals], produces a superior simulation when judged by the above measures.

As Morrison and Smith[28] 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.[28] They describe the RAS method of estimating input–output coefficients as one which assumes 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

$$a^r = R a^n S \tag{32}$$

where R is a row vector of S elements, each of which represents an industrial sector of the economy: S is a column vector of S 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

Table 2 Evaluation of simulated tables: methods ranked for each test

Rank	Test			
	Mean absolute difference	Correlation coefficient	Mean similarity index	Chi-Square
1	RAS	RAS	RAS	RAS
2	SLQ	SDP	SLQ	CMOD
3	POLQ	SLQ	POLQ	RMOD
4	RMOD	POLQ	SDP	SLQ
5	CMOD	RMOD	RMOD	POLQ
6	SDP	CMOD	RND	RND
7	RND	RND	CMOD	CILQ
8	CILQ	CILQ	CILQ	SDP

Note: Key initials of non-survey methods:

SLQ—Simple location quotient;

POLQ—Purchase-only location quotient;

CILQ—Cross-industry location quotient;

CMOD—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[28]

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 sectoral data on intermediate input and output are not generally available at the local or regional level. Therefore, a process is adopted 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 these steps are repeated until the column constraint. Then these steps are repeated until the matrix converges to a state in which both row and column constraints are satisfied. This is the reason why the RAS method is called a bi-proportional 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 non-survey method (SLQ) is almost three times that produced by RAS.

Although the conversion non-survey methods clearly have many advantages, they also have their shortcomings, i.e. they are too mechanical to satisfy all the required conditions. For example, the regional coefficients can only 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. Shortcut Approach

The first shortcut method did not appear until Drake's RIMS (Regional Industrial Multiplier System) technique was developed in 1976,[33] subsequently followed by Latham and Montgomery in 1979[34] and Cartwright, Beamillor and Gustely in 1981.[35] 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 shortcut approach, what might be called a column-sum multiplier, was developed by Burford and Katz.[36] It is not a substitute for an input-output model, but rather a good estimator of the output multiplier for a firm or industry given its proportion of of interindustry expenditures over all the industries in the region. The formula proposed by Burford and Katz is:

$$u_j = 1 + \frac{\hat{u}_j}{1} - \hat{u} \qquad (33)$$

where u_j is the estimated gross output multiplier for sector j, $\hat{u}_j$ is the column sum of the domestic trade coefficient matrix for sector j ($\hat{u}_j = \sum_i h_{ij}$), and $\hat{u}$ is the mean column sum of matrix h ($\hat{u} = (1/n)\sum_j \hat{u}_j$).

These shortcut approaches are superficially attractive,[4] if only regional multipliers only are needed, rather than a full regional input-output model or 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*" and the column-sum multiplier, neglects the fact that most matrices can be triangulated[34] 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.[16] 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.

3. Hybrid Approaches

Embryonic hybrid approaches, in fact, appeared as early as 1963 when Hanson and Tiebout, and later Schaffer[37] 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} , $e_i=b_i$ and $h_{ij}=H_{ij}$. If b_i is negative, $h_{ij}=H_{ij}\times br_i$, where br_i is defined as x_i / r_i, which is called the 'balance ratio', and $m_{ij}=r_{ij}-h_{ij}$. 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 to zero or less. But in practice this condition is not necessarily met. So, the balance ration of SDP is now modified as

$$br_i^e=(x_i-e_i)/(r_i) \tag{34}$$

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

$$x_{ij}=r_{ij}br_i^e=(x_{ij}/r_j)(x_i-e_i) \tag{35}$$

If $br_i^e< 0$, then h_{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 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 non–survey and survey techniques by Jensen, Mandeville, and Karunaratne.[3] West,[38] Phibbs and Holsman[39] 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 and MacGaurrs'definition,[40,41] a rows–only table is a table of inter–sectoral 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 c_{ij}. No matter whether we use the rows–only or columns–only model, the differences between the estimates of sale and purchase in regional transactions may be large, even in the most detailed and thorough input–output survey. Therefore, the row and column coefficients have to be reconciled. This technique meets this need. Detailed description and exploration of these methods are also provided by Round,[30,42] Miernyk,[43,44] and Gerking.[45]

Two other hybrid approaches that have been developed are the MRIO (Multiregional input—output) model and the aggregation method. Most of the literature on MRIO models are discussed in Round,[30,42] Polenske,[46] Miller and Blair.[47] The aggregation approach includes sectoral aggregation methods developed by williamson,[48] Hewings,[32] Jensen and West,[49] and spatial aggregation methods developed by Miller and Blair,[47] whereby the data assembly task of regional input—output analysts could be simplified. For example, Williamson[48] aggregated a 12—sector model to 6 sectors and found that the long range (20—year) employment forecast only increased by less than 5 percent. Aslo, tests with the nine—region Japanese model and a hypothetical five—region model suggested that for most purposes (e.g. all single—region model is more than adequate.[4]

V. DEVELOPMENT OF THE EXTENDED INPUT—OUTPUT FRAMEWORKS

We have so far reviewed the development of 'pure' regional input—output analysis. In this section, we will trace the development of 'extended' input—output modelling. 'Extended' input—output modelling has enlarged the concept of conventional input—output analysis either by the extension of the input—output model per se, or by linking it with much more extensive modelling systems. The first of these, was attempted by Miyazawa.[50] This notion continues to demand attention in the literature, as evidenced in, for instance, Shinnar,[51] Isard and Anselin,[52] Batey and Madden,[53,54] Isard,[55] Anselin and Rey.[56] These works may be categorized as using either an embedding or a connection approach. The embedding approach incorporates all systems into one methodological framework and operates the model using one calculation system. A typical example can be found in Batey and Madden's models. The connection approach attempts to link input—output model with much more extensive modelling systems. The Isard—Anselin framework developed in 1982 is one of the best examples. Each of these approaches will now be elaborated.

1. The Batey—Madden extended input—output framework

One of the limitations of the conventional input—output model is that it can only reflect economic relationships via demand and supply. It cannot show the operation of the whole economic system if other subsystems such as demographic, transportation, or land—use systems are to be considered, although the Type II multipliers of employment and income can to some extent demonstrate aspects of the whole system. The Batey—Madden framework based on the earlier work of Shinnar[50] is a good attempt to allow such problems to be addressed. Batey and Madden[57] suggest that the principal economic and demographic relationships can be obtained by partitioning the matrix of coefficients into four quadrants.

Based on this figure and the notation inside it, if the V_{11}, V_{12}, V_{21} and V_{22} denote the inverse matrices of A_{11}, A_{12}, A_{21} and A_{22} respectively, the activity level X_1 and X_2 will be equal to:

$$X_1 = V_{11} Y_1 + V_{12} Y_2 \tag{36}$$

$$X_2 = V_{21} Y_1 + V_{22} Y_2 \tag{37}$$

From equation (35), the first term of the right–hand side, $V_{11}Y_1$, represents that part of gross output is due to final demand. The second term, $V_{12}Y_2$, can be interpreted as that component of gross output which is due entirely to demographic inputs. In equation (36), as V_{21} is assumed to zero in their analysis, level X_2 will then be determined by the interaction between demographic activities and commodities.

2. Isard and Anselin's integration model

Differing from the Batey–Madden framework, i.e. where the input–output model is enlarged from 'inside' or by 'embedding', the Isard–Anselin framework is derived by connecting six modules; (1) a national econometric module (NATLEC); (2) an integrated comparative cost, industrial complex, input–output programming module (CICIOP); (3) a transportation module (TRANS); (4) a demographic module (DEMO); (5) a multiregional econometric module (REGLEC); and (6) a factor demand–investment supply econometric module (FACTIN). The characteristics of Isard–Anselin's model can be summarized as follows:

(1) as the framework is concerned with as many vital systems as possible, it can, in the sense of regional analysis, reflect 'global' relationships which thus make the model more general and systematic.

(2) The framework adopted in the connection approach links different existing methodologies, for instance: input–output model by Polenske, Miernyk, Isard and other; transportation models by Boyce and Hewings;[31] and multiregional economic modules heavily relying on Fromm et al.[58]

(3) It does not come as a surprise that there is considerable difficulty in implementation since the demand for data is massive. A similar version has been experimentally tried in California by Anselin and Rey in 1989, the subsystems considered in this case were much reduced, and only three modules including LPT, demo–labour modules and I–O model were taken into account.

VI. EVALUATION OF THE TECHNIQUES

Although we have reviewed the conversion of national coefficients, shortcut, hybrid approaches and interregional modelling methods, 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[59] show us 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[4] points out that the determination of the boundary line between acceptable and unacceptable levels of error is subjective. Also, Jensen[60] and Hewings[61] draw our attention to the problem that if the input–output matrix itself is being evaluated, there is a choice between partitive accuracy (i.e. the precision of each coefficient estimate) and holistic accuracy (i.e. 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 be flexibly used, and the shortcut method is ingenious but not reliable. It is the hybrid methods which are currently receiving the most attention.

ACKNOWLEDGEMENTS

The authors would like to thank Prof. Alan Wilson for his invaluable comments on a early draft of this paper.

REFERENCES

[1] CSICSC. Input–output tables of China, Beijing & Häwaiil.1987.

[2] CSO, (1988) Input–output tables for the United Kingdom, 1984, Longdon.

[3] Jensen, R.C. Mandeville, T.D. and Karunaratne, N.D. (1979) Regional economic planning: Generation of regional input–output analysis. London: Croom Helm.

[4] Richardson, H.W. (1985) "Input–output and economic base multipliers: Looking backward and forward", Journal of Regional Science, Vol. 25, No.4.

[5] Isard, W. (1951) "Interregional and regional input–output analysis: A model of space economy, " Review of Economics and Statistics, 33, 318–376.

[6] Leontief, W.W. (1953) "International theory", in Leontief, W.W. et al. (eds.), Studies in the structure of the American Economy. New York: Oxford University Press.

[7] Chenery, H.B. (1953) "Regional analysis," in H.B. Chenery, P.C. Clark, and V. Cao–Pinna (eds.), The structure and growth of the Italian economy. Rome: U.S. Mutual Security Agency, 1053, pp 97–116.

[8] Kuenue, R.E. (1953) Walras, Leontief, and the interdependence of economic activities, Quarterly Journal of Economics, 68, pp. 323–54.

[9] Miller, R.E. (1957) "The impact of the aluminium industry on the Pacific Northwest: A regional input–output analysis," Review of Economics and Statistics, 39, 200–209.

[10] Hartwick, J.M. (1971) "Notes on the Isard and Chenery–Moses interregional input–output models, " Journal of Regional Science, Vol. 11, 73–97.

[11] Moses, L. (1955) "The stability of interregional trading patterns and input–output analysis", American Economic Research, 45.

[12] Leontief, W.W. and Strout, A.A. (1963) "Multiregional input–output analysis," in T. Barna (ed.), Structural Independence and economic development. London: Macmillan, pp. 119–149.

[13] Polenske, K.R. (1970) " An empirical test of the interregional input–output models: Estimation of 1963 Japanese production," American Economic Review, 60, 76–82.

[14] Wilson, A.G. (1968) " Interregional Commodity Flow: Entropy Maximizing Approaches" , Centre for Environmental Studies, WP 19.

[15] Wilson A.G. (1981) Geography and the Environment, London: John Wiley and Sons.

[16] Richardson, H.W. (1972) Input–output and regional economics. New York: Halsted Press.

[17] O'Sullivan, P. (1970) "Forecasting interregional freight flows in Great Britain", Colston Symposium on Regional Forecasting, Bristol, UK.

[18] Moses, L. (1960) "A general equilibrium model of production, interregional trade, and location of industry", Review of Economics and Statistics, 42, 373–97.

[19] Bourque, P.J. and Conway, R.S. (1977) The Washington input–output study. Seattle: University of Washington, Graduate School of Business Administration.

[20] Miernyk, W.H. et al (1967) Impact of the Space Program on a Local Economy, West Virginia University Press.

[21] Isard, W. and Langford, T.W. (1971) Regional input–output study: Recollections, Reflections, and Diverse notes on the Philadelphia experience. Cambridge, Mass.: M.I.T.Press.

[22] Artle, R. (1959) The structure of the Stockholm economy towards a framework for projecting metropolitan community development, New York: Cornell University press.

[23] Wilson, A.G. (1974) Urban and regional models in geography and planning, London: John Wiley and Sons.

[24] Nevin, E.t. Roe, A.R. and Round, J.I. (1966) The structure of the Welsh economy. Cardiff: University of Wales Press.

[25] Shaffer, W.A. and Chu, K. (1969) "Nonsurvey techniques for constructing interindustry models," Papers, Regional Science Association, 23, 83–89.

[26] Vanwynsberghe, D. (1976) "An operational nonsurvey technique for estimating a coherent set of interregional input–output tables," in Polenske K.R and Sholka, J.V (eds.), Advances in input–output analysis. Cambridge, Mass.: Ballinger, 279–294.

[27] Alward, G.S. and Palmer, C.J. (1981) IMPLAN: An input–output analysis system for forest service planning. Fort Collins: U.S. Forest Service.

[28] Morrison, W.I. and Smith, P. (1974) " Nonsurvey input output techniques at the small area level: An evaluation," Journal of Regional Science, 14, 1–14.

[29] Round, J.I. (1972) "Regional input–output models in the U.K.: A reappraisal of some techniques," Regional Studies, 6, 1–9.

[30] Round, J.I. (1978a) "An interregional input—output approach to the evaluation of nonsurvey methods," Journal of Regional Science, 18, 179—194.

[31] Hewings, G.J.D. (1980) "The identification of key sectors in an economy: a regional perspective. The Developing Economics, 20, 173—195.

[32] Hewings, G.J.D. (1982) "Regional and interregional interdependence: Alternative accounting systems, " Environment and Planning A, 14, 1469—1478.

[33] Drake, R.E. (1976) " A shortcut to estimates of regional input—output multipliers: methodology and evaluation," International Regional Science Revies, 1,1—17.

[34] Latham, W.R. and Montgomery, M. (1979) "Methods for calculating regional industry impact multipliers," Growth and Change, 10, 2—9.

[35] Cartwright, J.V, Beemiller, R.M. and Gustely, R.D. (1981) Regional input—output modelling systems. Washington, D.C.: U.S.Department of commerce, Bureau of Economic Analysis.

[36] Burford R.L. Katz J.L. (1977) "Regional input—output multipliers without full I—O table" Annals of Regional Science, 11, p21—38.

[37] Shaffer, W.A. (1976) On the use of input—output models for regional planning. Leiden: Martinus Nijhoff.

[38] West, G.R. (1981) "An efficient approach to the estimation of regional input—output multipliers," Environment and Planning A, 13, 857—867.

[39] Phibbs, P.J. and Holsman, A.J. (1982) "Estimating input—output multipliers—A new hybrid approach", Environment and Planning A, 14 335—42.

[40] Jensen, R.C. and McGaurr, A.D. (1976) "Reconciliation of purchases and sales estimates in input—output tables," Urban Studies, 13, 59—65.

[41] Jensen, R.C. and McGaurr, A.D. (1977) "Reconciliation techniques in input—output analysis: Some comparisons and implications," Urban Studies, 14, 327—337.

[42] Round, J.I. (1978b) "On estimating trade flows in interregional input—output models," Regional Science and Urban Economics, 8, 284—302.

[43] Miernyk, W.H. (1976) "Comments on recent developments in regional input—output analysis," International Regional Science Review, 1, 47—55.

[44] Miernyk, W.H. (1979) "Reconciling reconciliation procedures in Regional input—output analysis: Comment," International Regional Science Review, 4, 36—38.

[45] Gerking, S. (1979) "Reconciling reconciliation procedures in regional input—output analysis," International Regional Science Review, 21, 451—467.

[46] Polenske, K.E. (1980) The United States Multiregional input—output Accounts and Model. Lexington, Mass: Health.

[47] Miller, R.E. (1966) Interregional feedbacks in input—output models: Some preliminary results, " Western Economic Journal, 17, 106—164.

[48] Williamson, R.B. (1970) "Simple input—output models for area economic analysis," Land Economics, 46, 333—338.

[49] Jensen, R.C. and West, G.R. (1980) "The effect of relative coefficient size on input—output multipliers," Environmental and Planning A, 12, 659—670.

[50] Miyazawa, K. (1976) " Input—output analysis and the structure of Income distribution." Berlin: Springer Verlag.

[51] Shinnar, A.P. (1976) " A multidimensional accounting model for demographic an economic planning interactions", Environment and Planning A, 8, p455—475.

[52] Isard, W. and Anselin, L. (1982) "Integration of multiregional models for policy analysis, " Environment and Planning A, VOL. 14, 359—376.

[53] Batey, P.W.J and Madden, M. (1983) "The modelling of demographic—economic change within the context of regional decline: analytical procedures and empirical Results", Socioeconomic Planning Sciences, 17, 315—328.

[54] Batey, P.W.J and Madden, M. eds. (1986) Integrated Analysis of Regional System, Pion, London.

[55] Isard, W. (1986) "Reflections on the relevance of integrated multiregional models". Regional Science and Urban Economics, 16: 165—180.

[56] Anselin, L. and Rey, S. (1989) Issues in the specification of an integrated multiregional model for a system of small regions, Paper presented at the 29th European RSA conference, Cambridge, UK.

[57] Batey, P.W.J and Madden, M. (1981) " Demographic—economic forecasting within an activity commodity framework" Environment and planning A, 1981, Vol. 13. pp 1067—1083.

[58] Fromm, D. Loxley, C.J. McCarthy, M. (1980) "The Wharton EFA multiregional econometric model: a bottom up approach top—down approach to constructing a regional model of national economy", in Modelling the Multiregional Economic Systems. Eds F, G Adams, N J Glickman (Lexington Books, Lexington, MA) pp 89—106.

[59] Sawyer, C.H. and Miller, R.E. (1983) "Experiments in regionalisation of a national input—output table", Environment and Planning A, 15, 1501—1520.

[60] Jensen, R.C. (1980) The concept of accuracy in regional input—output models, International Regional Science Review, 5, 139—154.

[61] Hewings, G.J.D. (1984) " The role of prior information in updating regional input—output models" , Socioeconomic Planning Sciences, 18, 319—336.