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Applicability and Limitations in the Use of National Input-Output Tables for Regional Studies

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APPLICABILITY AND LIMITATIONS IN THE USE OF NATIONAL INPUT-OUTPUT TABLES FOR REGIONAL STUDIES

by

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I. Introduction

One of the major limitations in the use of input-output analysis in regional studies is the considerable cost and effort involved in the construction of inter-industry flow tables. The regional economist, therefore, is often inclined to use either national coefficients or coefficients originally derived for other regions as a short-cut method to avoid the substantial field work. The drawbacks of using surrogate coefficients are rather obvious, and this crude method is rarely effectively used.

There were numerous attempts over the past years at assessing the feasibility of using national coefficients for regional studies. One of the most rigorous examinations is contained in Shen /13/. He derived an estimate of input-output coefficients for New England from the 1947 U.S. table. The national manufacturing sectors were grouped into a 20 x 20 matrix covering the two digit S.I.C. manufacturing groups. Value added by New England manufacturing industries provided the weights for the grouping process. In the absence of a regional input-output study based on direct field surveys he could not assess the ensuing errors.

The sources of divergence between national and regional input-outout coefficients have been abundantly discussed in the literature. The most important ones appear to be related to differences industrial mix and in the relative importance and structure of foreign trade. Foreign trade is an especially sensitive issue at the regional level because of the notorious lack of reliable data on interregional flows. In addition, the surrogate tables of coefficients are often several years old which further impairs their value.

Whether on the other hand differences in technology and in the relative prices of inputs between regions within a country as economically integrated as the United States are important is not intuitively obvious.

The major objectives of the research described here were the following:

1. To develop and test a model for adjusting national input-output coefficients so as to eliminate all or part of the differences due to (i) changes in the relative level of prices over time, (ii) degree of fabrication, (iii) composition of demand, (iv) industry mix, and (v) structure of imports.
2. Determine which sectors could be handled by short-cut methods without destroying the analytic and forecasting value of the input-output table and which sectors would have to be covered by a field study.
3. Analyze the probable errors introduced by the use of the model and compare these with savings in cost and time.

A case study approach was used. We tried to construct with the help of national input-output coefficients and such information as is readily available from Regional Income and Product Accounts the Washington State Input-Output Table for 1963 [2]. We then compared our results with the Washington State table based on direct field data.

By what method?

II. The Model

The first task confronting us was to attempt to develop regional input-output coefficients using as the only source of information regional income and product accounts disaggregated by sectors. This amounts to the knowledge of the bill of goods and of the row and column totals and is by

Why not follow the L Q approach: this at least permits adjustment downward?

itself insufficient for reconstructing the intersectoral flows. The problem has too many degrees of freedom. In order to reach a solution, we need an additional source of information and, in our case we used the national technical input-output coefficients. These had to be adjusted to yield the regional row and column totals when multiplied by total regional output. These adjustments require the following assumptions:

1. Price differences operate uniformly along rows; whenever there is a difference in the average price of the products of a sector, it is charged in the same proportion to all users.

2. Whenever there is substitution of one product for another due to differences in demand or in industry mix, it affects all users to the same extent.

3. Wherever there is a change in the degree of fabriaction it uniformly affects all productive processes.

The corollary of the last two assumptions is that differences in selling patterns and/or differences in technology operate uniformly along rows and columns, respectively.

In order to explain the model,[1] let us introduce the following definitions:

A = national (1958) input-output coefficients matrix.

B = regional (Washington State 1963) input-output coefficients matrix.

x = regional vector of gross outputs by sector.

t = regional vector of intermediate outputs (row totals)

z = regional vector of intermediate inputs (column totals)

G = grouping matrix.

1. Our model is an adaptation of a model presented by Richard Stone and Alan Brown and used by them in order to adjust for changes in national input-output tables over time [15], [14].

G_W = weight matrix, where $g_{w.ij} = 0, 1, w_{ij}$;

$$0 \leq g_{w.ij} \leq 1 \text{ and } \sum_{i=1}^{n} g_{w.ij} = 1.$$

p = vector of price ratios $\frac{1963}{1958}$;

i = identity vector.

Capital letters refer to matrices.
Lower case letters refer to vectors.
Capped letters refer to diagonal matrices obtained from vectors.
Superscripts: T = transpose
r = regional
-1 = inverse or, in case of a diagonal matrix, another diagonal matrix whose non-zero elements are reciprocals of the original matrix.
Subscripts: 1, 2, 3... n refer to successive estimates.
The equation numbers and steps in the computer program are synonymous.

First we adjust the national matrix for differences in relative price levels between 1958 and 1963 and reduce both the national and regional matrix to the same dimensions.

$$A_1 = \hat{p} A \hat{p}^{-1}; \qquad (1)$$

$$A_2 = G A_1 G_W^T; \qquad (2)$$

$$B_1 = G^r B G_W^{r.T} \qquad (3)$$

Next, it is obviously true that

$$t_2 = A_2 x; \qquad (4)$$

where t_2 is an estimate of the known t.

Ordinarily $t_2 \neq t$, however,

$$\hat{t}\,\hat{t}_2^{-1}\,\hat{t}_2 = \hat{t}\,\hat{t}_2^{-1} A_2 \hat{x}; \qquad (5)$$

Hence,

$$\hat{t} = \hat{t}\,\hat{t}_2^{-1} A_2 \hat{x} \qquad (6)$$

$$A_3 = \hat{t}\,\hat{t}_2^{-1} A_2; \qquad (7)$$

is an improved estimate of B adjusted for row totals, but not for column totals. Now,

$$z_3 = i\,\hat{x}\,A_3^{T}; \qquad (8)$$

$$\hat{z}\,\hat{z}_3^{-1}\,\hat{z}_3 = \hat{z}\,\hat{z}_3^{-1}\,\hat{x}\,A_3^{T} \qquad (9)$$

$$z = i\,\hat{x}\,(A_3\, z\, z_3^{-1})^{T}; \qquad (10)$$

and

$$A_4 = A_3\,\hat{z}\,\hat{z}_3^{-1}; \qquad (11)$$

is a new improved estimate of B now adjusted for column totals but no longer for row totals. One can use, however, A_4 in equation (4) and obtain A_5 in equation (7) which then can be used in equation (8) and so on. In our computer program this forms a loop.

The only remaining problem is to find out whether the process converges, at what speed and whether the limit towards which it converges is the B matrix of true regional coefficients.

The above model was used for testing six different cases in order to isolate the effects of (1) degree of aggregation (size of the matrix of coefficients), (2) differences in the relative level of prices between 1958 and 1963, and (3) differences in the relative size and structure of Washington State and U.S. imports. More specifically, the following cases were studied.

Case I: Both the U.S. and the 54 x 54 Washington State input-output coefficients matrices were aggregated to size 43 x 43 by the use of appropriate grouping and weighting matrices in steps (2) and (3) of the program. The relative importance of the various sectors in the national and Washington State economy provided the respective weights.

No adjustments were made for differences and changes in the relative price levels, i.e. step (1) of the program was omitted.

Case II: Repeated Case I except that both the U.S. and Washington State matrices were aggregated to size 36 x 36.

Case III: Both matrices were aggregated to size 43 x 43. The U.S. matrix was adjusted for changes in the relative price levels between 1958-1963. This was accomplished in step (1).

Case IV: Repeated case III except that both the U.S. and Washington State matrices were aggregated to size 36 x 36.

Case V: Both matrices were aggregated to size 36 x 36. The Washington State matrix was adjusted by including domestic imports into the appropriate sectors. The input-output coefficients obtained by applying our model to the U.S. input-output matrix were now compared with Washington State coefficients which included inputs per dollar of output imported from the rest of the U.S. as well as those obtained from other industries in the State.

Case VI: Repeated Case V except that the U.S. matrix was adjusted for changes in the relative price levels between 1958-1963.

III. Measurement of Errors

In order to assess the validity of the results we first calculated the absolute deviations between the Washington State coefficients estimated from national coefficients with the help of the model and the "true" coefficients. These deviations were next transformed into percentages and the mean, standard deviation and distribution by deciles of errors were derived. More formally the program covered the following steps:

$$D_1 = B_1 - A_4 ; \qquad (12)$$

$$d_1^* = \left[\frac{d_{1 \cdot ij}}{b_{1 \cdot ij}}\right] ; \qquad \text{where } b_{ij} \neq 0; \qquad (13)$$

$$\text{Mean of } D_1^* = \frac{\sum_i \sum_j d_{1 \cdot ij}^*}{m} ; \qquad (14)$$

$$\text{Standard deviation of } D_1^* = \sqrt{\frac{\sum_i \sum_j d_{1 \cdot ij}^{*2}}{m} - \left(\frac{\sum_i \sum_j d_{1 \cdot ij}^*}{m}\right)^2} \qquad (15)$$

where

D_1 = matrix of absolute deviations between the calculated and real coefficients

D_1^* = matrix of deviations between the calculated and real coefficients expressed as percentages of the real coefficients.

$d_{1 \cdot ij}$ = elements of the D_1 matrix

b_{ij} = elements of the B matrix

$d_{1 \cdot ij}^*$ = elements of the D_1^* matrix

m = number of entries in the D_1^* matrix.

These calculations were repeated after each iteration of the model. Together with the distribution of percentage deviations by deciles they enable a crude assessment of the relative value of the various approaches and hypotheses tested. The major drawback appears to be, however, the way in which the deviations have been implicitly weighted. Notice that a deviation from a small "true" coefficient affects far more the end result than an equal deviation from a large coefficient. Weighting the deviations by the absolute size of the flows would not serve our purpose. Since these flows would refer to one particular region only they would not necessarily help to test the basic assumptions of the method used.

Obviously, size of flows and of sectors varies greatly from one region to another.

In order to overcome, at least partly, this shortcoming we used also the information theory approach to measuring the accuracy of input-output coefficients.[2] We now considered our estimated Washington State Input-Output table (A_n) as a forecast of the "true" table (B). In other words the two tables A_n and B were treated as two consecutive messages, the first containing a forecast of the second. The value of this second message may be viewed as a function of the accuracy of the predictions contained in the first message. Obviously, if the predictions contained in the first (A_n) table were correct, the information content of the second message would be small. The information content of the "true" table may be defined as

$$I\,(B : A_n) = \sum_i \sum_j \left| b_{ij} \log_2 \frac{b_{ij}}{a_{n.ij}} \right| ; \qquad (16)$$

where each estimate is weighted by the "true" coefficient, b_{ij}.
In accordance with information theory practice we used logs to base 2. Logs are used because of their additive properties and the standard information "bit" is expressed as log to base 2 because of its convenience in cases of 50:50 alternatives. Obviously, the smaller "I" values correspond to better estimates.

IV. Sources of Data

The case study involved the use of the following sources of data:

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2. The information theory approach used by us was largely developed and extensively used by H. Theil [1], [16], [17].

1. United States Input-Output Coefficients Table, 1958, which is a (77 x 77) matrix [11]. This table was enlarged to an 89 x 89 table by including additional information provided by the Office of Business Economics [12].

More specifically, three sectors were expanded: (1) Food and kindred products to nine separate sectors; (2) Primary nonferrous metals manufacturing to three sectors; (3) Electric, gas, water, and sanitary services also to three sectors. For more detail on the sectors used, see Appendix I.

2. The Washington State Input-Output Tables, for 1963 which included a gross flows table and a 54 x 54 table of coefficients [2], [10].[3]

3. Washington State Input-Output Technical Coefficients Table for 1963 calculated by us in the following way. We first reduced the Washington State gross flows table to size 46 x 46. Next we added the gross flows to the distribution of Washington State imports from the rest of the U.S. by receiving sectors. Finally, we converted the flow table into a technical coefficients table.

4. Wholesale price indexes for 89 sectors showing average changes from 1958 to 1963 [8], [9].

5. Sales, receipts, value-added and value of shipments data for the U.S. and Washington State which were used to calculate the weights needed for aggregating coefficients. They became the elements of the weighting matrices [3], [4], [5], [6], [7].

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3. The authors are deeply indebted to Charles M. Tiebout for providing the working tables for the Washington State Input Output Study.

V. Results

With the help of our computer program we examined six different cases. The results are summarized in the following Table and Appendix II.

Deviations Between Estimated and "True" Regional
Input-Output Coefficients

Case	I	II	III	IV	V	VI	VII*
Matrix Size	43 x 43	36 x 36	43 x 43	36 x 36	36 x 36	36 x 36	28 x 28
Price Adjustments	No	No	Yes	Yes	No	Yes	No
Domestic Imports Adjustments	No	No	No	No	Yes	Yes	No
Mean percentage error of coefficients	58.65	71.73	59.03	69.92	80.81	79.20	38.93
Standard Deviation of Percentage Error	2.211	3.716	2.202	3.378	6.314	6.177	2.160
"I" Values**	9.085	6.279	9.266	6.408	54.169	54.262	0.779

* Repeats II after removing "problem" sectors (1, 2, 3, 4, 8, 14, 16, 24).

** $I\,(B_1 : A_{10}) = \sum_i \sum_j \left| b_{ij} \log_2 \frac{b_{ij}}{a_{n.ij}} \right|$

This case eliminates the six "problem" sectors given on P. 14 & aggregates 7 [illegible] sectors into 2. (P. 13) Doesn't this throw the baby completely out & only retain the tepid bath water.

this is the one which include imports in the A matrix - and should be used.

The results presented in the above table were obtained after ten iterations of the process.[4] The striking fact is that the process converges extremely rapidly. As a matter of fact, the differences in the results obtained after ten iterations and those obtained after the first iteration were never nearer than in the fourth or fifth decimal place. In most cases, there were no differences whatsoever.

The results gave rise to different interpretations depending on whether one considers the mean percentage errors or the "I" values. This was almost invariably the case. The mean percentage errors, however, were implicitly weighted inversely to the size of the coefficients. Hence our analysis was based mainly on the "I" values.

The first six cases summarized in the table above show very wide deviations between the estimates obtained with the help of our program and the real matrix. Whichever way one looks at them, they seem to exceed by far any tolerance limits.

The adjustment for domestic imports has clearly increased the errors and diminished the value of the estimates. This rather surprising result seems to have something to do with the differences in routing used in the U.S. and Washington tables. how?

We next proceeded to a detailed examination of errors by sector. On purely theoretical grounds one would expect the greatest deviations to occur in sectors strongly affected by (1) differences in routing practices, (2) fundamental differences in natural conditions, and (3) sectors in which the regional economy is highly specialized.

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4. Supra., p. 5.

* I would have been surprised if the results were not made worse by including imports in the A matrix

Differences in the routing practices would be particularly significant in the tertiary sectors. In our study, the errors in the seven tertiary sectors, Communications, Electric companies, Gas companies, Water services, Wholesale and retail trade, Finance and insurance, Real estate, Business services, and Personal services, were particularly large. The grouping of the seven tertiary sectors into two considerably improved the results.[5] Of the six cases examined, Case II in which both matrices had been aggregated to order 36 x 36 through grouping of the tertiary sectors and without adjustments for prices or domestic imports, yielded the best results.

Primary activities which on theoretical grounds were expected to yield poor results were represented in our matrix by four sectors: Agricultural crops, Livestock products, Forestry and fishing, Mining. The errors in these sectors were over two standard deviations larger than the mean errors of the whole array.

It can be safely assumed that these high errors can be largely explained by the wide range of activities. Agricultural crops in Washington State, for example, would include different activities from the U.S. average. This will be even more true of Mining, Livestock products, or Forestry and fishing. Many types of mining included in the U.S. sector do not exist in Washington State.

The last group of sectors in which large deviations were expected to occur were those in which the regional economy is highly specialized. Measuring the degree of specialization by location quotients[6] we found

5. Compare case I to II and III to IV which are otherwise identical.
6. The location quotients were compiled by taking the ratio $L = \frac{E_{ir}}{E_r} \div \frac{E_{i.us}}{E_{us}}$
   where L = location quotient
   E_{ir} = employment in industry i in Washington, 1963
   E_r = total employment in Washington State, 1963.
   E_{us} = total employment in the U.S., 1963.
   $E_{i.us}$ = employment in industry i in U.S., 1963.

that six out of the thirty-six sectors had location quotients of 2.0 or more:

3)	Forestry and fishing	(5, 15)	3.1
8)	Canning and preserving	(8)	2.5
14)	Lumber and wood products	(16, 17, 18, 19)	5.1
16)	Paper products	(21, 22, 23)	2.0
24)	Non-ferrous metals manufacturing	(31)	2.4
31)	Aerospace industry	(39)	7.7

Of the six sectors, Forestry and fishing, a primary industry, has been explained above while Aerospace industry is a case apart.

It seems that sectors in which the regional economy is highly specialized have a different technology from the national average and their input-output coefficients cannot be estimated by short-cut methods. This is not true, however, for the Aerospace industry. In this case, the coefficients estimated on the basis of the U.S. table were quite close to actual. This is undoubtedly due to the fact that Aerospace industry in Washington State forms an important part of the national total and, hence, does influence the structure of national coefficients. In fact, on the basis of employment it would appear that 11% of the U.S. aerospace industry is concentrated in this state.

By removing eight sectors (four primary industries and four industries in which Washington State is specialized) from the 36 x 36 table, we obtained a considerable decrease in the "I" value. Notice that in our table the "I" value becomes 0.779 after removing the eight sectors, certainly an acceptable level of error by any standard.

But is the basic table good anyway??

VI. Some Tentative Conclusions

It appears, thus, that while national input-output tables cannot be used for purposes of regional studies without considerable adjustments, acceptable results can be achieved by the methods tried on the Washington State table.

In order to obtain acceptable results it seems important to (1) exclude the tertiary sectors through aggregation; to (2) use field surveys in order to obtain input-output coefficients for (a) primary industries, and (b) industries in which the regional economy is specialized. Price adjustments and adjustments for domestic imports do not seem to add anything to the quality of results. Neither do successive iterations after the first one.

If you have to survey firms in the region's specialty you'll obtain much useful data on the outputs of trade & service to them!

Doubt that they are "acceptable." Would probably get much closer by LQ x a_{ij} national

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APPENDIX I

SECTOR RECONCILIATION

Final Sector Number	General Name of Sector	Washington State Sector No.	Name of Sector Washington State Table	U.S. Sector No.	Name of Sector United States Table
1	Agricultural crops	1 2 4	Field crops Vegetables Other agriculture	2	Other agricultural products
2	Livestock products	3	Livestock & products	1	Livestock & livestock products
3	Forestry and fishing	5	Fishing	3	Forestry & fishery products
		15	Forestry	4	Agriculture, forestry & fishery services
4	Mining	14	Mining	5-10	Various types of mining
5	Construction	48	Construction	11	New construction
				12	Maintenance & repair construction
6	Meat products	6	Meat products	14.1	Meat products
7	Dairy products	7	Dairy products	14.2	Dairy products
8	Canning & preserving	8	Canning & preserving	14.3	Canning & preserving
9	Grain mill products	9	Grain mill products	14.4	Grain mill products
10	Beverages	10	Beverages	14.8	Beverage industries
11	Other foods	11	Other foods	14.5	Bakery products
				14.6	Sugar
				14.7	Confectionary & retail products
				14.9	Miscellaneous food & kindred products

Final Sector Number	General Name of Sector	Washington State Sector No.	Name of Sector Washington State Table	U.S. Sector No.	Name of Sector United States Table
12	Textiles	12	Textiles	16	Broad and narrow fabrics, yarn
				17	Miscellaneous textile goods & floor covering
13	Apparel	13	Apparel	18	Apparel
				19	Miscellaneous fabricated textile products
14	Lumber & wood products	16	Logging	20	Lumber & wood products
		17	Saw mills		
		18	Plywood		
		19	Other wood	21	Wooden containers
15	Furniture & fixtures	20	Furniture & fixtures	22	Household furniture
				23	Other furniture & fixtures
16	Paper products	21	Pulpmills	24	Paper & allied products
		22	Paper mills		
		23	Paperboard mills		
				25	Paperboard containers & boxes
17	Printing & publishing	24	Printing & publishing	26	Printing & publishing
18	Industrial chemicals	25	Industrial chemicals	27	Chemicals & selected chemical products
19	Other chemicals	26	Other chemicals	28	Plastics & synthetic materials
				29	Drugs, cleaning & toilet
				30	Paints & allied products
20	Petroleum refining	27	Petroleum refining	31	Petroleum refining & related industries

Final Sector Number	General Name of Sector	Washington State Sector No.	Name of Sector Washington State Table	U.S. Sector No.	Name of Sector United States Table
21	Glass, stone, & clay products	28 29	Glass & stone Cement, clay products	35	Glass & glass products
				36	Stone & clay products
22	Iron & steel manufacturing	30	Iron and steel	37	Primary iron & steel manufacturing
23	Aluminum manufacturing	32	Aluminum	38.2	Aluminum manufacturing
24	Non-ferrous metals manufacturing	31	Non-ferrous metals	38.1	Copper manufacturing
				38.3	Other non-ferrous metal manufacturing
25	Metal products	33 34	"Heavy" metal products "Light" metal products	39	Metal containers
				40	Heating, plumbing & structure
26	Nonelectric motive equipment	35	Nonelectric motive equipment	43	Engines & turbines
				44	Farm machinery & equipment
				45	Construction, mining, oil machinery
				46	Materials handling machinery & equipment
27	Machine tools & shops	36	Machine tools & shops	47	Metal working machinery & equipment
				50	Machine shop products
28	Nonelectric industrial equipment	37	Nonelectric industrial equipment	48	Special industry machinery & equipment

Final Sector No.	General Name of Sector	Washington State Sector No.	Name of Sector Washington State Table	U.S. Sector No.	Name of Sector United States Table
				49	General industry machinery & equipment
				51	Office, computing & accounting machines
				52	Service industry machines
29	Electric machinery	38	Electric machinery	53	Electric industry equipment
				54	Household appliances
				55	Electric lighting & wiring
				56	Radio & TV
				57	Electrical components
				58	Miscellaneous electrical equipment
30	Motor vehicles	40	Motor vehicles	59	Motor vehicles & equipment
31	Aerospace	39	Aerospace	60	Aircraft & parts
32	Other transportation	41	Shipbuilding	61	Other transportation equipment
33	Other manufacturing	42	Other manufacturing	13	Ordnance & accessories
				15	Tobacco manufacturing
				32	Rubber & plastic
				33	Leather & tanning
				34	Footwear & other leather
				62	Scientific & controlling equipment

Final Sector No.	General Name of Sector	Washington State Sector No.	Name of Sector Washington State Table	U.S. Sector No.	Name of Sector United States Table
				63	Optical, photographic equipment
				64	Miscellaneous manufacturing
34	Transportation	43	All transportation	65	Transportation and warehousing
35))35	Communications	47	Communications	66	Other communications
)				67	Radio & TV broadcasting
36)	Electric companies	44	Electric companies	68.1	Electric utilities
37)	Gas companies	45	Gas companies	68.2	Gas utilities
38)	Water services	46	Water services	68.3	Water & sanitary services
39)	Wholesale & retail trade	49	Wholesale & retail	69	Wholesale & retail trade
40)	Finance & insurance	50	Finance	70	Finance & insurance
)		51	Insurance		
41)	Real estate	52	Real estate	71	Real estate & rental
42))36	Business services	53	Business services	73	Business services
)				74	Research & development
43)	Personal services	54	Personal services	72	Hotels, personal & repair services
				75	Automobile repair services
				76	Amusements
				77	Medical, educational & nonprofit organizations

APPENDIX II

Distribution of Percentage Errors by Deciles

After the Tenth Iteration

	%	CASES					
		I	II	III	IV	V	VI
1	0-10	57	36	47	31	16	14
2	11-20	46	36	47	43	31	34
3	21-30	53	52	60	43	25	21
4	31-40	60	38	54	39	32	29
5	41-50	54	40	55	41	30	31
6	51-60	75	46	65	39	36	42
7	61-70	67	40	76	48	41	46
8	71-80	71	32	75	35	41	34
9	81-90	66	37	65	35	54	54
10	91-100	127	85	132	85	248	251
11	100+	149	103	149	106	71	69
		825	545	825	545	625	625
B(i,j)=0		1024	751	1024	751	671	671
m =		1849	1296	1849	1296	1296	1296