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INTERREGIONAL INPUT-OUTPUT STUDY FOR THE LEEDS METROPOLITAN DISTRICT

Yu-xian Jin and Mark Birkin

School of Geography
University of Leeds
Leeds LS2 9JT

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CONTENTS

ABSTRACT

This paper outlines the procedures for constructing an interregional input-output table for Leeds Metropolitan District using available but limited data. Interregional Input-output coefficient models associated with the conditions of the availability of trade figures in terms of origin and destination are firstly described; and the possibilities for employing the travel-to-work flows to estimate the trade flows and the RAS approach to estimate technical coefficients are then attempted. In addition, the aggregation of urban zones, which may embody the features of the urban spatial structure, together with those derived results such as the interregional intermediate transactions and multipliers are reported.

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LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Interregional Input-output
Study for the Leeds Metropolitan District

Yu-xian Jin and Mark Birkin

I. Introduction

The interregional input-output study has a quite long history in regional analysis. In regional economic analysis, analysts employ the concept to describe the economic relationships between one region and another, or between one region and the rest of the world. If an interregional table for a group of identified regions is constructed, both the regional and interregional multipliers can then be calculated so that the differences between regional and interregional economic impacts can be distinguished. The crucial point, however, is how to construct such a table. Due to difficulties and expense of data collection, the construction of the ideal interregional input-output table developed by Isard in 1953 has never been completely achieved.

One of the critical arguments is that both the origin and destination of trade between any pair of regions which are assumed to be known are rarely met in the real world. A model based on the assumption that only the origin of the trade is known is thus proposed by both Moses (1955) and Chenery (1953). Diverse interregional input-output models which focus on the derivation of trade flows have been developed (Leontief and Strout, 1963, Riefler and Tiebout, 1970). The conditions on which these models are based can probably be categorised into following groups: (i) when both the origin and destination are known; (ii) when only the origin is known and destination is unknown; (iii) when only the destination is known but the origin is unknown; (iv) when both the origin and destination are unknown. From the current literature, little work concerned with the third and fourth conditions can be found. In this paper, we attempt to describe interregional input-output coefficient models which are based on third condition, i.e. when only destination of trade is know but the origin of trade is unknown. In addition, we assume that there are close relationships between trade flows and travel-to-work flows(TTW), and the TTW flows can be employed to estimate the trade flows. Such an assumption is then used to derive interregional input-output intermediate transaction flows for the Leeds Metropolitan District.

In regional empirical studies, much interregional input-output research has aimed to describe economic at a regional scale. Very few studies, however, have focused on urban analysis(Richardson 1972). Some urban input-output analyses merely take large metropolitan regions as a whole. Consequently, much is known about the metropolitan region as a point economy but little is known about how the metropolitan region functions as a spatial system composed different areas, such as inner core and outer periphery (Dolenc, 1967). The purpose of this paper is to analyse and describe this set of economic relationships between inner and outer Leeds.

The structure of this paper is as follows: firstly, in section II, we demonstrate four circumstances under which an interregional input-output model may be constructed, and specify the model based on the assumption that only destination of trade is available; in section III, we present the procedures that allow the interregional input-output table for the Leeds metropolitan District to be constructed. The output information from the table such as the regional and interregional output multipliers and impacts is presented in section IV. Information on both sectoral and spatial aggregation, together with the data demand by the model, is given in Appendices.

II. The interregional input-output models

The general formula of an interregional input-output model is the same as a national input-output model with the exception that the former has been defined spatially. The gross product for a specific sector in region i can be broken into two components, i.e. the intermediate transactions to other sectors in other regions and products produced for final demand. The interregional interindustry transactions for each industry in each region can be written as:

$$X_i^m = \Sigma_n \Sigma_j a_{ij}^{mn} X_j^n + \Sigma_j Y_{ij}^m \tag{1}$$

where $X^m{}_i$ indicates the output product of industry m in region i and $Y^m{}_{ij}$ is the output of industry m produced in region i to the final demand in region j. $a^{mn}{}_{ij}$ is the interregional interindustry coefficients which are defined as

$$a_{ij}^{mn} = X_{ij}^{mn}/X_j^n = X_{ij}^{mn}/(\Sigma_i \Sigma_m a_{ij}^{mn} X_j^n + \Sigma_i Y_{ij}^n) \tag{2}$$

Suppose both the origin and destination of trades between any pair of regions are given. The coefficients ($a^{mn}{}_{ij}$) can be redefined as the product of the trade coefficients ($t'^{mn}{}_{ij}$) and the technical coefficients for region i ($a^{mn}{}_i$)

$$a_{ij}^{mn} = t'^{mn}_{ij} a_i^{mn} \tag{3}$$

The trade coefficients indicate the product of industry m produced in region i required as an input by industry n in region j, and the technical coefficients simply indicate the amount of product m required when a unit of product n in region j is produced.

This general description of an interregional input-output model is illustrated widely (eg.Isard, 1953; Hewings, 1985). Due to the difficulties of collecting data for such a model, other models that focus on modifying the trade coefficients

(t'^{mn}_{ij}) according to the availability of data have been developed. The conditions of the availability of trade data can be grouped under four headings:

(i) when both the origin and destination of trade are known. In this case, equation (3) can be applied directly;

(ii) when the origin of trade is known but the destination of trade is unknown. Both Chenery and Moses, and Riefler and Tiebout suggest that the trade coefficients can be modified and interregional interindustry coefficients can then be derived by multiplying the modified trade coefficients and the relevant technical coefficients. In the Chenery and Moses model, the trade coefficients take the form of t^m_i, i.e. the figures of the total product of industry m in region i required by other regions are known. But the requirement by which industry by which region is unknown. In the Riefler and Tiebout model, the trade coefficients is regarded as t^m_{ij}, i.e. the figure of the total product of industry m produced in region i required by region j is known, but the destination to which sectors in region j remains unknown.

In practice, there may exist the third condition, i.e. when only destination of requirement by industry n in region j is known, but the origin of trade is unknown. The unknown origin of trade can be further considered under two situations: first, the origin of neither industry nor region is unknown; and second, the origin of region is known but the industry is unknown. In the former case, we suggest that the trade coefficients in equation (3) can be modified into t'^{n}_{j}, and equation (3) can be rewritten as equation (4)

$$a^{mn}_{ij} = t'^{n}_{j}\, a^{mn}_{i} \tag{4}$$

In the latter case, equation (3) can be expressed as

$$a^{mn}_{ij} = t'^{n}_{ij}\, a^{mn}_{i} \tag{5}$$

where the trade coefficients t'^{n}_{ij} indicate the amount produced in region i destined to industry n in region j. For clarity, suppose we have, say two regions and two industries, the partitioning of the total interregional interindustry coefficients assumes the form:

$$a^{mn}_{ij} = t'^{n}_{ij} * a^{mn}_{i} = \left[\begin{array}{cc|cc} t'^{1}_{11}a^{11}_{1} & t'^{2}_{11}a^{12}_{1} & t'^{1}_{12}a^{12}_{2} & t'^{12}_{12}a^{12}_{2} \\ t'^{1}_{11}a^{21}_{1} & t'^{2}_{11}a^{22}_{1} & t'^{1}_{12}a^{21}_{2} & t'^{2}_{12}a^{22}_{2} \\ \hline t'^{1}_{11}a^{21}_{1} & t'^{2}_{11}a^{22}_{1} & t'^{1}_{12}a^{11}_{2} & t'^{2}_{12}a^{12}_{2} \\ t'^{1}_{11}a^{21}_{1} & t'^{2}_{11}a^{22}_{1} & t'^{1}_{12}a^{21}_{2} & t'^{2}_{12}a^{22}_{2} \end{array}\right] \tag{6}$$

The fourth condition is that when both the origin and destination of trade in terms of industry and region are unknown. From the current available literature, there has been no progress made under this condition. Further discussion must be the subject of another article. These four conditions associated with the relevant interregional input-output models are described in Figure 1.

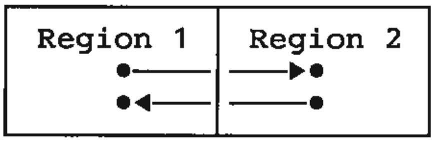
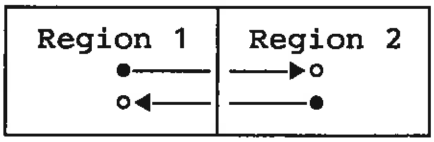
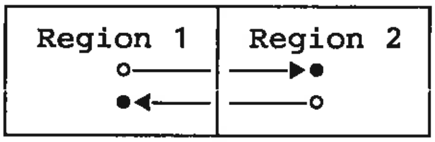
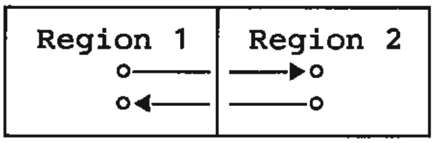
Conditions	Illustrations	Models for interregional I-O coefficients
(1) Both origin and destination are known		$a_{ij}^{mn} = t'^{mn}_{ij}\ a_i^{mn}$ (Isard,1953)
(2) Origin known destination unknown		(1) $a_{ij}^{mn} = t'^{m}_{ij}\ a_i^{mn}$ (Chenery, Moses) (2) $a_{ij}^{mn} = t'^{m}_{i}\ a_i^{mn}$ (Riefler,Tiebout)
(3) Origin unknown destination known		(1) $a_{ij}^{mn} = t'^{n}_{j}\ a_i^{mn}$ (2) $a_{ij}^{mn} = t'^{n}_{ij}\ a_i^{mn}$
(4) Neither origin nor destination is known		$a_{ij}^{mn} = ?$

Figure 1: Models under four conditions of the availability of origin and destination of trade.

In Figure 1, the black circle '•', denotes that either origin or destination is known, and the white circle 'o' denotes the neither origin nor destination is known; the arrow '—▶', reflects the trade direction between region i and j.

III. Construction an interregional Input-output table for the Leeds Metropolitan region

The Leeds metropolitan region is located in the north-east part of the UK, within the region of Yorkshire and Humberside. It can be actually disaggregated into 33 electoral / census wards. However, it is neither possible nor necessary to construct an interregional input-output table between any pair of these districts. This paper is mainly concerned with the urban economic structure between inner Leeds and outer Leeds, the economic structure of inner Leeds and its economic relationships to outer Leeds and to the rest of the world.

The interregional input-output model is constructed under the third condition for the two zones (inner Leeds and outer Leeds), together with the rest of the world. The reasons that only the third condition is considered are: (a) there are no relevant data available for the first two conditions; and (b) some data from the census, such as the travel-to-work flow, can be modified to fit the third condition. Since the TTW flow indicates the number of employees from a social class in a residential zone go to work in an industry in an industrial zone, this flow can then be aggregated across the social classes. The result will be the number of employees from one of the urban zones go to work in an identified industry in an industrial zone. Obviously, it is similar to the third condition, i.e, when the destination by industry by zone is known. However, to what extent that the TTW flow is related to the trade flow also needs further research in the future.

The interregional input-output model for the Leeds Metropolitan District is graphically shown in Figure 3, in which both inner and outer Leeds consist of seven industries. The rest of the world is an aggregate vector that include the shipment to the rest of the Leeds, rest of the Yorkshire and rest of the UK. The shipment also implies that the total product produced in the inner and outer Leeds required by the rest of the world either as an intermediate input or final demand.

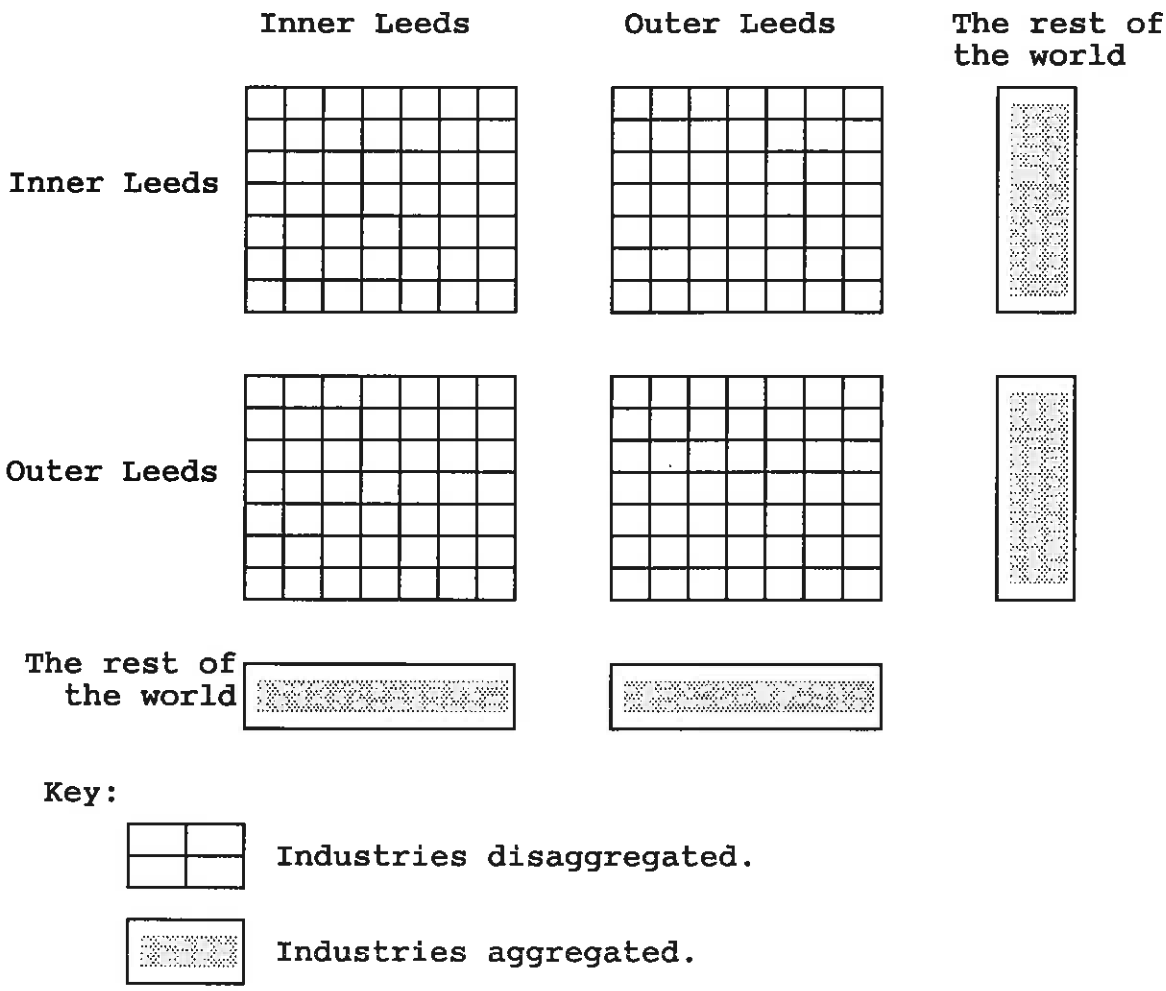


Figure 2: A graphic illustration of the interregional Input-output model for the city of Leeds

The following features can be identified:

(a) The sale direction (across the columns) represent the spatial output structure, for example, the structure of the amount of output product produced in the Inner Leeds allocated to it *per se* and to the Outer Leeds.

(b) The purchase direction (down the rows) reflects the spatial input structure, for example, the amount of products required from inner Leeds purchased from the industries in the zone, in Outer Leeds and the rest of the world.

(c) The spatial output and input structure by industry of the rest of the world are aggregated in the study.

The next step is to expose both the spatial and sectoral aggregations for the interregional input-output model. The purposes of the spatial aggregation are to reflect the economic relationships as well as the travel-to work movements between the Inner and outer Leeds. We assume that the population density is the key role that characterised the urban structure, and aggregate those districts whose population densities are over 1850 (people/per sq km) into the Inner Leeds and those are below the figure into the Outer Leeds. The spatial aggregation based on population density is illustrated in Figure 3. The Inner Leeds consists of 17 districts, and the Outer Leeds consists of 16 districts(see Appendix 1). Some general comparisons listed in Table 1 show the distinctions between Inner and Outer Leeds. The percentage of the total area of Inner Leeds is only 18%, but it takes about 70% of the employment, and 50% of the total population.

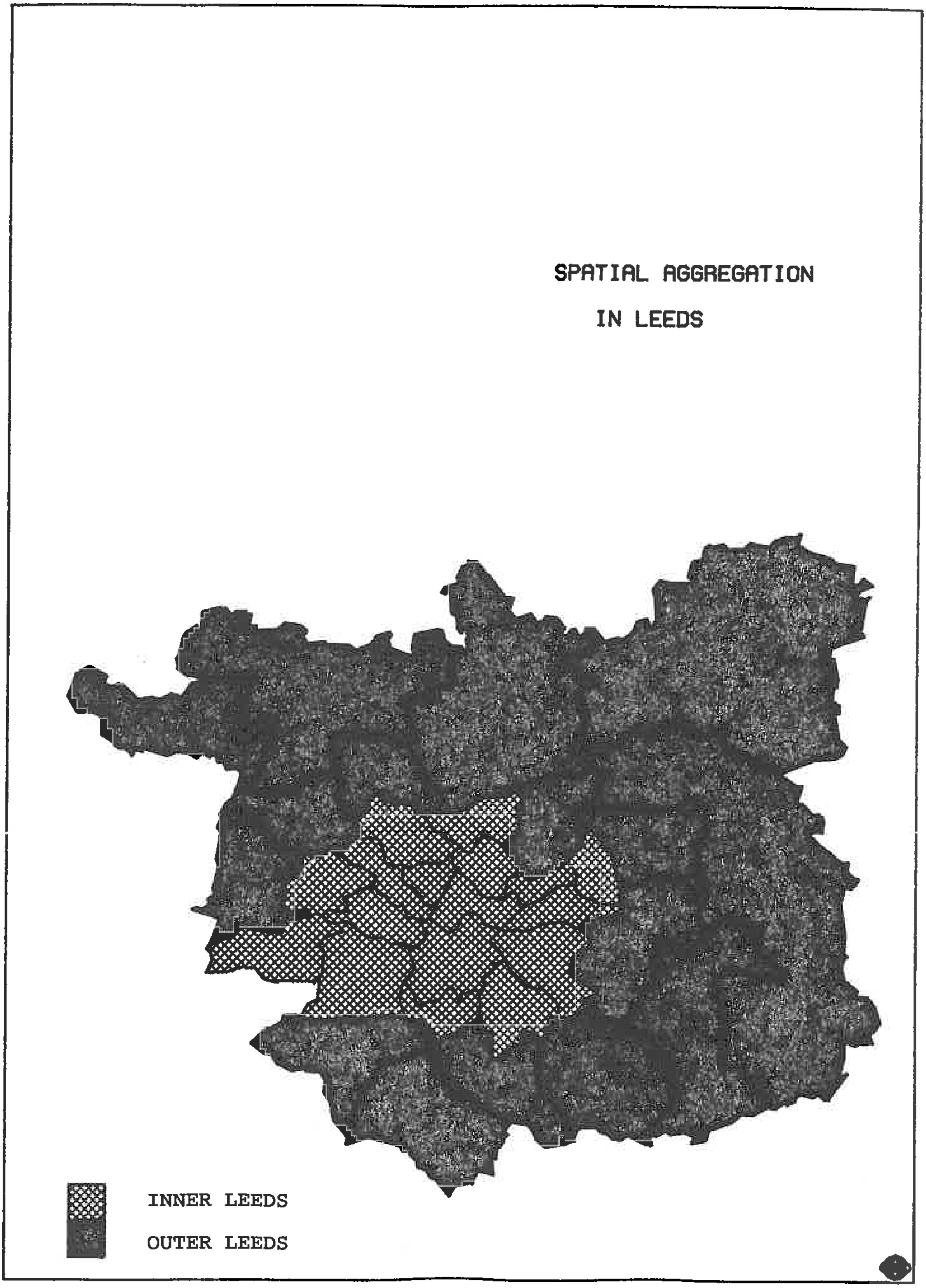


Figure 3: Spatial aggregation in Leeds

Table 1: Comparisons between the Inner and Outer Leeds

Inner Leeds	Area		Employment		Population	
	km^2	%	1000	%	1000	%
Inner Leeds	104.72	18.75	186.23	69.78	345.202	50.13
Outer Leeds	453.84	81.25	80.66	30.22	343.353	49.87
Total	558.56	100.00	266.89	100.00	688.555	100.00

The sectoral aggregation is based on the SIC system. In our study, only 7 industries are considered. The detail contents in each industry are given in Appendix II.

The construction of the Leeds interregional input-output model is based on the third condition when only the destination of trade is known. The travel-to-work coefficient ($\underline{t}'^{n}_{ij}$) in this case is then taken as a surrogate for the trade coefficient (t'^{n}_{ij}). The travel-to-work coefficient is derived by dividing the number of employments in inner Leeds destined to each industry in inner and outer Leeds by the total employment destined to both inner and outer Leeds(see Appendix 3(2): the trade coefficients).

The treatment of the technical coefficients for both Inner and Outer Leeds is fairly complicated. The RAS approach is applied. The derivation of the technical coefficients for inner and outer Leeds, however, is not estimated from the national table directly because there are big differences, in economic structure, between a city and a region, let alone the difference between a city and a nation. Multiple estimation methodology is therefore adopted. Firstly, the technical coefficients for the region of Yorkshire and Humberside is estimated; secondly, by employing the regional estimates as both the constraints and basic coefficients, the technical coefficient for the city of Leeds as a whole is estimated; thirdly, the technical coefficients for both Inner and Outer Leeds are derived from the coefficients from the city of Leeds. By this way, the estimating errors may be lessened. The detailed estimating procedures and estimates for both the region of Yorkshire and Humberside and the city of Leeds are provided in Jin, 1991, and Jin, Leigh and Wilson in 1991.

The Leeds interregional interindustrial coefficients are calculated by equation (7)

$$\underline{a}_{ij}^{mn} = \underline{t}'^{n}_{ij}\ \underline{a}_{i}^{mn} \tag{7}$$

in which $\underline{t}'^{n}_{ij}$ is the Leeds trade coefficient derived by modifying the travel-to-work coefficient. The number of different entries in it is I*J*N. $\underline{a}^{mn}_{i}$ the technical coefficients for inner(i=1) and outer Leeds(i=2) which are estimated from the RSA approach. The technical coefficients are detailed in Appendix 3(2).

IV. Analysis of Results

The constructed interregional input-output table for the Leeds Metropolitan District can provide at least two pieces of important information for urban planners when certain policies on urban development are to be made, firstly, the output and input structures by industry by region which may expose the 'black box' of Leeds as a point; secondly, both the regional and interregional output impact multipliers for industries in a particular region. By comparing the different impact multipliers in inner and outer Leeds, policy of industrial location can be properly made.

Table 2 shows the output structure for 7 industries for both the inner and outer Leeds. The interregional coefficients represent the output shares from industries in inner and outer Leeds to Leeds and to the rest of the world. For instance, about 20.32% of total manufacturing products produced in inner Leeds are consumed locally, and 5.41% are sold to outer Leeds. 74.27% are output to the rest of the World. However, about 17.56% of energy products produced in outer Leeds are consumed locally, and 36.63 and 51.81% are sold to inner Leeds and the rest of the world respectively. The rest of the world takes the largest output share of the products produced in inner Leeds and outer Leeds.

Table 2: Interregional Output Coefficients for the Leeds Metropolitan District

Industries	Inner Leeds	Outer Leeds	Rest of the World
I.Inner Leeds			
Agriculture	0.000	0.7471	0.2529
Energy	0.3158	0.2472	0.4370
Manufacture	0.2023	0.0541	0.7447
Construction	0.3343	0.0966	0.5691
Distribution	0.1446	0.0408	0.8146
Transportation	0.2611	0.0446	0.6943
Service	0.0733	0.0207	0.9060
II.OuterLeeds			
Agriculture	0.0000	0.5083	0.4917
Energy	0.1482	0.1217	0.7301
Manufacture	0.3063	0.1756	0.5181
Construction	0.4283	0.2683	0.3134
Distribution	0.2395	0.1572	0.6033
Transport-tion	0.4267	0.3234	0.2499
Service	0.2750	0.1757	0.5493

Table 3 is about the input structure by industry by region. The interregional coefficients describe the shares of inputs or purchases in the two regions in the city of Leeds and the rest of the world. For example, 18.9% of the required input products of the manufacturing industry in inner Leeds are met locally, and 13.3% are purchased from outer Leeds. 67.8% have to be imported from the rest of the world. In outer Leeds, 9.9% of the manufacturing products are input from inner Leeds and 17.8% are met locally. 73.2% are purchased from the rest of the world. In the input structure, the rest of the world also takes the biggest share. This may result from the differences between a region and a city, and the trades of a city to and from the rest of the world are usually larger than that of a region.

Table 3: Interregional Input Coefficients for the Leeds Metropolitan District

Industries	Inner Leeds	Outer Leeds	Rest of the World
I.Inner Leeds			
Agriculture	0.000	0.619	0.381
Energy	0.239	0.306	0.445
Manufacture	0.189	0.133	0.678
Construction	0.188	0.131	0.681
Distribution	0.166	0.110	0.724
Transportation	0.248	0.187	0.565
Service	0.111	0.108	0.781
II.OuterLeeds			
Agriculture	0.153	0.365	0.482
Energy	0.066	0.134	0.800
Manufacture	0.104	0.171	0.725
Construction	0.093	0.113	0.794
Distribution	0.082	0.160	0.758
Transporttion	0.197	0.290	0.513
Service	0.124	0.250	0.626

Table 4 presents both the regional and interregional output multipliers for inner Leeds and outer Leeds. The regional multipliers indicate the total impacts (direct and indirect) on all the industries in a certain region due to a unit increase in the sales to the final demand. In this case, the interregional effects are excluded. The interregional output multipliers for an indicated region show the total impacts on all the industries in a certain region due to an increase in the sales to the final demand in which the interregional effects are considered. In Table 4, the first data column shows the regional impacts in the industries in inner Leeds and outer Leeds. The second column expresses the interregional impacts. The third column shows the interregional feedback impacts which are calculated as the differences between the regional and interregional impact multipliers. In inner Leeds the regional impact for the service industry is 1.231, and the interregional impact multiplier is 1.412, and the interregional feedback impact is 0.181 which is about 13% of the total interregional impacts. In outer Leeds, the regional impact multiplier for the service industry is 1.310, and the total interregional impact multiplier is 1.625, and the interregional feedback is 0.315 which is about 19.39% of the total impacts. Obviously, the interregional impacts and feedback effect cannot be ignored when a development policy on a single region is to be made, otherwise, '*due to the neglect of the interregional feedback effects, viz the affect that has on itself via its interindustry relations with other regions, multipliers derived from the regional interindustry model will understate the local impact of regional activities*'(Greytak

1970). The detail information about the interpretation of the regional, interregional and interregional feedback impacts can be referred to Miller in 1966, Madden and Batey in 1983. The interregional interindustrial coefficients and the regional and interregional impact multipliers are detailed in Appendix 4(2).

Table 4: Interregional Impact multipliers for the Leeds Metropolitan District

Industries	Regional impact multipliers	Interregional feedback multipliers	Interregional impact multipliers
I. Inner Leeds			
Agriculture	1.004	0.083	1.087
Energy	1.133	0.097	1.230
Manufacture	1.726	0.491	2.217
Construction	1.244	0.185	1.429
Distribution	1.157	0.126	1.283
Transporta-tion	1.218	0.116	1.334
Service	1.231	0.181	1.412
II. OuterLeeds			
Agriculture	1.191	0.009	1.200
Energy	1.196	0.233	1.429
Manufacture	1.667	0.705	2.372
Construction	1.309	0.359	1.668
Distribution	1.242	0.330	1.572
Transport-tion	1.209	0.317	1.525
Service	1.319	0.315	1.634

V. Summary and conclusion

In this paper, we illustrate the four conditions under which the main current interregional models are constructed. The model of interregional I-O coefficients is described. In the Leeds interregional input-output study, the travel-to-work coefficients are employed to modify the trade coefficients. The drawbacks of using the travel-to-work coefficients as surrogate coefficients for the trade flow are clear. The TTW flow cannot be exactly equal to the trade coefficient, although they are highly correlated with each other. And a weighting matrix(m) which is based on the regression analysis should be considered to modify the TTW flow. However, this idea may enlighten the future interregional input-output analysis, particularly when the trade data are not available. In addition, this crude study does provide a wealth of information for further research on the interregional interindustry for the Leeds Metropolitan District. The economic relationships between inner and outer Leeds are to some extent exposed.

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Appendix 1: the composed wards in inner and outer Leeds

INNER LEEDS	OUTER LEEDS
L2 : ARMLEY	L1 : AIREBOROUGH
L4 : BEESTON	L3 : BARWICK & KIPPAX
L5 : BRAMLEY	L9 : COOKRIDGE
L6 : BURMANTOFTS	L10: GARFORTH & SWILLINGTON
L7 : CHAPEL ALLERTON	L11: HALTON
L8 : CITY & HOLBECK	L14: HORSFORTH
L12: HAREHILLS	L17: MIDDLETON
L13: HEADINGLEY	L19: MORLEY NORTH
L15: HUNSLET	L20: MORLEY SOUTH
L16: KIRKSTALL	L21: NORTH
L18: MOORTOWN	L22: OTLEY & WHARFEDALE
L24: PUDSEY SOUTH	L23: PUDSEY NORTH
L25: RICHMONDHILL	L26: ROTHWELL
L28: SEACROFT	L27: ROUNDHAY
L29: UNIVERSITY	L31: WETHERBY
L30: WEETWOOD	L32: WHINMOOR
L33: WORTLEY	

Appendix 2: Classification of industry I-O groups

Group	industry/Commodity	SIC Activity Heading
I.	Agriculture	0100 - 0300
II.	Energy	1113 - 1700
III.	Manufacture	2100 - 4959
IV.	Construction	5000 - 5040
V.	Distribution	6100 - 6670
VI.	Transportation	7100 - 7700
VII.	Services	7901 - 9900

Source: <<Indexes to the SIC>>(Revised 1980)

Appendix 3: Data requirements

(1) Trade coefficient

The trade coefficient indicates the amount of products produced in zone i required by per unit product n produced in zone j. It is based on the TTW data which is obtained from the census data.

$$\underline{t}'^{n}_{ij} =$$

$$\begin{array}{c c}
\text{Industry} & \begin{array}{ccccccc} \text{I} & \text{II} & \text{III} & \text{IV} & \text{V} & \text{VI} & \text{VII} \end{array} \\
\underline{t}^{n}_{1j} & \begin{bmatrix} 0.0000 & 0.3874 & 0.5858 & 0.5879 & 0.6049 & 0.5571 & 0.5040 \\ 1.0000 & 0.6126 & 0.4142 & 0.4121 & 0.3951 & 0.4429 & 0.4960 \end{bmatrix}
\end{array}$$

$$\begin{array}{c c}
\text{Industry} & \begin{array}{ccccccc} \text{I} & \text{II} & \text{III} & \text{IV} & \text{V} & \text{VI} & \text{VII} \end{array} \\
\underline{t}^{n}_{2j} & \begin{bmatrix} 0.2941 & 0.3272 & 0.3766 & 0.4550 & 0.3141 & 0.3453 & 0.3055 \\ 0.7059 & 0.6728 & 0.6234 & 0.5450 & 0.6859 & 0.6547 & 0.6945 \end{bmatrix}
\end{array}$$

(2) Technical coefficient

The technical coefficient is derived by the RAS approach. Detailed information can be referred to Jin in 1991.

$$\underline{a}_i^{mn} =$$

Industry	I	II	III	IV	V	VI	VII
Inner Leeds (i=1)	0.002	0.000	0.000	0.000	0.000	0.000	0.000
	0.037	0.207	0.005	0.001	0.006	0.019	0.003
	0.164	0.226	0.208	0.062	0.124	0.181	0.081
	0.142	0.010	0.007	0.183	0.030	0.013	0.053
	0.160	0.066	0.032	0.007	0.022	0.065	0.012
	0.091	0.090	0.023	0.003	0.037	0.140	0.014
	0.093	0.015	0.046	0.063	0.057	0.028	0.056

Industry	I	II	III	IV	V	VI	VII
Outer Leeds (i=2)	0.209	0.000	0.013	0.000	0.002	0.000	0.000
	0.032	0.104	0.007	0.001	0.011	0.051	0.011
	0.073	0.057	0.169	0.040	0.119	0.247	0.150
	0.063	0.003	0.006	0.117	0.029	0.017	0.098
	0.071	0.017	0.026	0.005	0.021	0.089	0.021
	0.026	0.015	0.012	0.001	0.023	0.124	0.017
	0.043	0.004	0.039	0.042	0.057	0.039	0.107

Appendix 4: Output results

(1) The interregional interindustry coefficients

The interregional interindustry coefficient is the product of the modified trade coefficient ($\underline{t}$) and the regional direct coefficient ($\underline{a}$). It shows the amount of product m in zone i required to produce a unit of output product n in zone j.

$$\underline{a}_{1j}^{mn} =$$

$$
\begin{array}{cc}
\text{Industry} & \begin{array}{ccccccc} \text{I} & \text{II} & \text{III} & \text{IV} & \text{V} & \text{VI} & \text{VII} \end{array} \\
a_{11}= & \begin{bmatrix}
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.000 & 0.080 & 0.003 & 0.000 & 0.003 & 0.011 & 0.002 \\
0.000 & 0.088 & 0.122 & 0.037 & 0.075 & 0.101 & 0.041 \\
0.000 & 0.004 & 0.004 & 0.108 & 0.018 & 0.007 & 0.027 \\
0.000 & 0.026 & 0.019 & 0.004 & 0.013 & 0.036 & 0.006 \\
0.000 & 0.035 & 0.014 & 0.002 & 0.022 & 0.078 & 0.007 \\
0.000 & 0.006 & 0.027 & 0.037 & 0.035 & 0.015 & 0.028
\end{bmatrix}
\end{array}
$$

$$
a_{12}= \begin{bmatrix}
0.003 & 0.000 & 0.000 & 0.000 & 0.001 & 0.000 & 0.000 \\
0.009 & 0.034 & 0.003 & 0.000 & 0.003 & 0.018 & 0.003 \\
0.021 & 0.019 & 0.064 & 0.018 & 0.037 & 0.085 & 0.046 \\
0.019 & 0.001 & 0.002 & 0.053 & 0.009 & 0.006 & 0.030 \\
0.021 & 0.006 & 0.010 & 0.002 & 0.007 & 0.031 & 0.007 \\
0.008 & 0.005 & 0.005 & 0.001 & 0.007 & 0.043 & 0.005 \\
0.013 & 0.001 & 0.015 & 0.019 & 0.018 & 0.014 & 0.033
\end{bmatrix}
$$

$$\underline{a}^{mn}_{2j} =$$

$$\begin{array}{cc}
\text{Industry} & \begin{array}{ccccccc} \text{I} & \text{II} & \text{III} & \text{IV} & \text{V} & \text{VI} & \text{VII} \end{array} \\
a_{21} = & \left[\begin{array}{ccccccc}
0.002 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.037 & 0.127 & 0.002 & 0.000 & 0.002 & 0.008 & 0.001 \\
0.094 & 0.068 & 0.086 & 0.026 & 0.049 & 0.070 & 0.040 \\
0.142 & 0.006 & 0.003 & 0.075 & 0.012 & 0.006 & 0.026 \\
0.160 & 0.041 & 0.013 & 0.003 & 0.009 & 0.029 & 0.006 \\
0.091 & 0.055 & 0.010 & 0.001 & 0.015 & 0.062 & 0.007 \\
0.093 & 0.009 & 0.019 & 0.026 & 0.023 & 0.012 & 0.028
\end{array}\right]
\end{array}$$

$$a_{22} = \left[\begin{array}{ccccccc}
0.148 & 0.000 & 0.008 & 0.000 & 0.001 & 0.000 & 0.000 \\
0.023 & 0.070 & 0.005 & 0.000 & 0.007 & 0.033 & 0.008 \\
0.051 & 0.038 & 0.106 & 0.022 & 0.062 & 0.081 & 0.074 \\
0.045 & 0.002 & 0.004 & 0.064 & 0.020 & 0.011 & 0.068 \\
0.050 & 0.011 & 0.016 & 0.003 & 0.015 & 0.058 & 0.015 \\
0.018 & 0.010 & 0.008 & 0.001 & 0.016 & 0.081 & 0.011 \\
0.030 & 0.003 & 0.024 & 0.023 & 0.039 & 0.026 & 0.074
\end{array}\right]$$

(2) The inverse interregional interindustry multipliers

The inversed interregional interindustry multiplier is derived by the following equation:

$$b^{mn}_{ij} = (I - a^{mn}_{ij})^{-1}$$

It demonstrates the total requirements, eg. first round, second round, ... and so forth, of product n in zone j when a unit product m in zone i is produced.

$$\underline{b}_{i1}^{mn} =$$

Industry I II III IV V VI VII

$$a_{11}=\begin{bmatrix} 1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.006 & 1.096 & 0.005 & 0.001 & 0.005 & 0.017 & 0.003 \\ 0.044 & 0.144 & 1.160 & 0.059 & 0.105 & 0.154 & 0.061 \\ 0.018 & 0.011 & 0.009 & 1.130 & 0.025 & 0.014 & 0.036 \\ 0.009 & 0.039 & 0.026 & 0.007 & 1.019 & 0.048 & 0.009 \\ 0.010 & 0.051 & 0.021 & 0.005 & 0.028 & 1.094 & 0.010 \\ 0.017 & 0.019 & 0.038 & 0.049 & 0.044 & 0.029 & 1.036 \end{bmatrix}$$

$$a_{12}=\begin{bmatrix} 0.006 & 0.002 & 0.002 & 0.001 & 0.001 & 0.002 & 0.001 \\ 0.048 & 0.155 & 0.005 & 0.001 & 0.005 & 0.016 & 0.003 \\ 0.151 & 0.124 & 0.123 & 0.048 & 0.078 & 0.120 & 0.061 \\ 0.169 & 0.015 & 0.010 & 0.096 & 0.020 & 0.015 & 0.035 \\ 0.176 & 0.058 & 0.020 & 0.007 & 0.015 & 0.043 & 0.010 \\ 0.107 & 0.076 & 0.017 & 0.004 & 0.022 & 0.080 & 0.011 \\ 0.122 & 0.025 & 0.031 & 0.039 & 0.034 & 0.028 & 0.037 \end{bmatrix}$$

$$\underline{b}_{i2}^{mn} =$$

Industry I II III IV V VI VII

$$a_{21}=\begin{bmatrix} 0.004 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.015 & 0.041 & 0.005 & 0.001 & 0.005 & 0.025 & 0.005 \\ 0.054 & 0.037 & 0.092 & 0.032 & 0.060 & 0.138 & 0.076 \\ 0.034 & 0.003 & 0.007 & 0.066 & 0.016 & 0.014 & 0.044 \\ 0.030 & 0.010 & 0.015 & 0.004 & 0.011 & 0.043 & 0.012 \\ 0.016 & 0.010 & 0.010 & 0.003 & 0.011 & 0.057 & 0.010 \\ 0.026 & 0.005 & 0.023 & 0.026 & 0.026 & 0.028 & 0.046 \end{bmatrix}$$

$$a_{22}=\begin{bmatrix} 1.177 & 0.001 & 0.020 & 0.001 & 0.006 & 0.003 & 0.002 \\ 0.034 & 1.082 & 0.009 & 0.001 & 0.010 & 0.045 & 0.012 \\ 0.093 & 0.058 & 1.138 & 0.036 & 0.088 & 0.135 & 0.109 \\ 0.067 & 0.005 & 0.011 & 1.077 & 0.029 & 0.022 & 0.086 \\ 0.067 & 0.017 & 0.023 & 0.005 & 1.021 & 0.073 & 0.022 \\ 0.030 & 0.016 & 0.014 & 0.003 & 0.022 & 1.100 & 0.017 \\ 0.050 & 0.008 & 0.035 & 0.031 & 0.050 & 0.044 & 1.091 \end{bmatrix}$$