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Regional input-output models and the treatment of imports in the European System of Accounts (ESA)

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Abstract

Input-output models are often used in regional science due to their versatility and their ability to capture many of the distinguishing features of a regional economy. Input-output tables are available for all EU member countries, but they are hard to find at the regional level, since many regional governments lack the resources or the will to produce reliable, survey-based regional input-output tables. Therefore, in many cases researchers adopt nonsurvey techniques to derive regional input-output tables (RIOT) on their own.

The earliest applications of this type relied on the commodity balance (CB) method, and the simple location quotient (SLQ) method. Over time, numerous variations therefore have been introduced. The latest proposals have been the FLQ method (Flegg and Webber, 2000; Flegg *et al.*, 1995) and the CHARM approach (Kronenberg, 2009). This increasing variety of methods has spawned a stream of literature comparing the relative performance of nonsurvey regionalisation methods.

The present paper contributes to that literature by examining a largely neglected problem of nonsurvey techniques: the allocation of imports. In the European System of Accounts (ESA) there are two ways of allocating imports: inside the interindustry transactions matrix or outside. In the latter case, imported products are allocated to the sector that uses them (direct allocation). In the former case, they are allocated as imports in the sector that produces similar goods and as a delivery from that sector to the sector which uses them (indirect allocation).

The present paper argues that the choice of a nonsurvey method should depend on the way in which imports are allocated. The argument is explained with reference to the theoretical and empirical literature. It is shown that if the nonsurvey method is not properly chosen the results of the procedure may be misleading and implausible. These findings suggest that LQ methods are better suited for regionalising input-output tables with directly allocated imports, whereas commodity-balance methods like CHARM are better suited for regionalising input-output tables with indirectly allocated imports.

Keywords: Regional input-output model, nonsurvey method, location quotient, commodity balance.

Topic: 1. Construction and adjustment of input-output tables

1. Introduction

Input-output analysis is widely used by authors working in the fields of regional science or regional economics. It is also becoming increasingly popular in environmental and ecological economics (Los, 2011). Naturally, some ecological economists are also interested in conducting environmental impact studies for individual regions. Therefore, it is likely that regional input-output models will be frequently used for environmental impact studies in the future.

When studying a particular region, analysts often have to construct a regional input-output table (RIOT), since many statistical offices provide only national input-output tables (NIOT). Fortunately, there are established methods for regionalising the NIOT and adapting it to regional characteristics (nonsurvey methods). A large and growing literature discusses the strengths and weaknesses of these methods (Bonfiglio and Chelli, 2008; Morrison and Smith, 1974; Richardson, 1985; Schaffer and Chu, 1969; Tohmo, 2004). However, the focus of the present paper is a different one.

This paper aims at drawing attention to a crucial issue whose importance has not yet been realised in the literature on nonsurvey regionalisation methods: There are different variants of the symmetric input-output table (SIOT), and the choice of the nonsurvey method should depend on the type of SIOT that is to be regionalised. The most important difference between the SIOT variants lies in the treatment of imported products. The United Nations handbook on input-output analysis identified four different variants, labelled alphabetically from “A” to “D” (United Nations, 1973). This convention is also adopted in the present paper, and an additional variant “E” (for “Eurostat”) is introduced to describe the tables based on the European System of Accounts (ESA 95).

A crucial finding of this paper is that location quotient (LQ) methods are suitable for variant B tables, whereas commodity balance (CB) methods are suitable for variant A and E tables. The existing literature has not paid much attention to this issue because regional economists mostly use variant B tables. Ecological economists, by contrast, are more likely to use variant A or E tables.

The paper proceeds as follows: Section 2 introduces definitions of variables and conventions on mathematical notation. Section 3 explains the various variants of the SIOT, largely following the exposition in the UN manual (United Nations, 1973). Section 4 describes the interpretation of the coefficients derived from different tables. Section 5 identifies the implications that follow for those who want to construct RIOT using nonsurvey methods. Finally, Section 6 provides some concluding remarks and suggests avenues for future research.

2. Definitions and conventions

Table 1 shows the basic data which is needed to construct input-output tables of the sort that will be discussed below.

Table 1: Basic data

$\mathbf{Z}_{i,j}^d$	\mathbf{y}_i^d	\mathbf{e}_i^d	\mathbf{u}_i^d
$\mathbf{Z}_{i,j}^m$	\mathbf{y}_i^m	\mathbf{e}_i^m	\mathbf{u}_i^m
\mathbf{v}_j			
\mathbf{x}_j			

Source: author's illustration

The following conventions will be used: The subscript i stands for products or commodities, the subscript j stands for industries or homogeneous branches. A superscript d or m is used to indicate the origin of products (domestically produced or imported). Matrices are denoted by capital letters, vectors by lower case letters. Both are printed in bold type. The individual elements of a matrix are printed in italics. Thus, for example, $Z_{i,j}$ is element i, j of matrix $\mathbf{Z}_{i,j}$. It reports the total amount of product i used by industry j . The amount of this which originates from domestic production is $Z_{i,j}^d$, and the amount which was imported is $Z_{i,j}^m$. Naturally, $Z_{i,j}^d + Z_{i,j}^m = Z_{i,j}$.

In addition to $\mathbf{Z}_{i,j}^d$ and $\mathbf{Z}_{i,j}^m$, the basic data table contains the following elements. The vector \mathbf{v}_j reports value added (i.e. primary inputs) by industry, and the vector \mathbf{x}_j reports output (i.e. production) by industry. The vectors \mathbf{y}_i^d and \mathbf{y}_i^m contain domestic final use of products, respectively. Domestic final use is defined as the sum of private consumption expenditure, public consumption expenditure, and gross capital formation. The vector \mathbf{e}_i^d reports exports of domestically produced commodities, whereas \mathbf{e}_i^m reports exports of imported commodities (i.e. re-exports). It should be noted that re-exports are normally not included in input-output tables, so \mathbf{e}_i^m will usually contain only zeroes. Finally, the vectors \mathbf{u}_i^d and \mathbf{u}_i^m describe the total use of domestically produced and imported commodities. Total use is defined as the sum of intermediate use, final domestic use, and exports. Mathematically:

$$u_i = \sum_j^n Z_{i,j} + y_i + e_i \quad (1)$$

where n is the number of products and. Naturally, this relationship also holds for only domestically produced products or imported products:

$$u_i^d = \sum_j^n Z_{i,j}^d + y_i^d + e_i^d \quad (2.A)$$

$$u_i^m = \sum_j^n Z_{i,j}^m + y_i^m + e_i^m \quad (2.B)$$

Table 1 shows which data are needed for simple applications of input-output analysis. The big advantage of input-output tables is that they arrange these data in a straightforward manner that is consistent with standard bookkeeping procedures. Table 2 shows how this can be done by showing a comprehensive input-output table containing all the relevant information.

Table 2: The comprehensive input-output table

		Homogeneous branches			Final uses		Total	
		1	...	n	Total	Domestic	Exports	Total
<i>Domestically produced products</i>		1	2	3	4	5	6	7
1	1	$Z_{1,1}^d$	...	$Z_{1,n}^d$	r_1^d	y_1^d	e_1^d	u_1^d
2	...	...	...	...	...	...	...	...
3	n	$Z_{n,1}^d$	...	$Z_{n,n}^d$	r_n^d	y_n^d	e_n^d	u_n^d
4	Subtotal	z_1^d	...	z_n^d	$z^d = r^d$	y^d	e^d	u^d
<i>Imported products</i>								
5	1	$Z_{1,1}^m$	...	$Z_{1,n}^m$	r_1^m	y_1^m	e_1^m	u_1^m
6	...	...	...	...	...	...	...	...
7	n	$Z_{n,1}^m$	...	$Z_{n,n}^m$	r_n^m	y_n^m	e_n^m	u_n^m
8	Subtotal	z_1^m	...	z_n^m	$z^m = r^m$	y^m	e^m	u^m
9	Total interm. cons. / final use	z_1	...	z_n	$z = r$	y	e	u
10	Value added (i.e. primary inputs)	v_1	...	v_n	v			
11	Output (i.e. production)	x_1	...	x_n	x			

Source: author's illustration

The first column of Table 2 refers to the first industry (henceforth ‘industry 1’). In the first three rows (with row 1 referring to product 1, row 3 to product n , and row 2 to “all products between 1 and n ”), the elements of $Z_{i,j}^d$ concerning industry 1 are reported. Row 4 contains a subtotal, denoted by z_1^d . This is the sum of all domestically produced products that were used as intermediate inputs by industry 1. Below that, the relevant elements of $Z_{i,j}^m$ are reported. Rows 5 to 7 show the use of imported products as intermediate inputs by industry 1, and row 8 contains the sum of these, z_1^m . In row 9, we find the sum of z_1^d and z_1^m . z_1 is the value of all intermediate inputs used by industry 1. Using these intermediate inputs, industry 1 generates a certain amount of value added, reported in row 10 and denoted by v_1 . This value added can be interpreted as the value of primary inputs (labour, capital, and land). Taxes on products, which drive a wedge between basic prices and purchasers’ prices and divert a share of value added to government, are ignored here for the sake of simplicity. Depreciation (i.e.

consumption of fixed capital) and taxes on production are also ignored. Under these assumptions, value added is simply the sum of compensation of employees (wages plus social security contributions, the reward for labour services) and net operating surplus (the remuneration of capital).

The following relationship holds by definition:

$$x_j = \sum_i^n Z_{i,j}^d + \sum_i^n Z_{i,j}^m + v_j \quad (3)$$

In words, (3) states that the value of output produced by industry j is equal to the value of intermediate products used by that industry and the value added by that industry. This definition is in accordance with the classical theory of value, where firms buy inputs (commodities) of a certain value and generate additional value in the course of the production process. The added value is then distributed to the primary inputs labour, capital and land (although capital and land are unfortunately not displayed separately in the input-output tables).

Moving along the first row of Table 2, we can see how and where products of type 1 that are produced domestically are used. The first three columns show the amounts of product 1 that are used by industries 1 to n as intermediate inputs, and column 4 shows the sum of these. Column 5 shows the domestic final use (final consumption expenditure by households, NPISH, and government as well as gross capital formation including stock formation) of product 1. In column 6 we observe the amount of product 1 that is exported to other countries. Finally, column 7 reports total use (i.e. the sum of intermediate use and final use). Rows 2 and 3 show the same for all other domestically produced commodities, and row 4 shows the sum of rows 1 to 3. Rows 5 through 8 show the same thing but for *imported* products. Thus, the comprehensive input-output table allows us to trace the use of domestically produced products (rows 1 through 4) separately from the use of imported products (rows 5 through 8). Row 9 is the sum of intermediate respectively final use. Row 10 reports value added by each industry, and row 11 reports the value of output of each industry.

Eurostat does not supply comprehensive input-output tables as shown in Table 2. However, it does provide all the data that is required to produce such a table. For

(almost) every EU member country, there is an input-output table containing only domestically produced products, which contains data for $\mathbf{Z}_{i,j}^d$, \mathbf{y}_i^d , \mathbf{e}_i^d , \mathbf{u}_i^d , \mathbf{v}_j , and \mathbf{x}_j . Furthermore, there is an ‘import matrix’, which contains data for $\mathbf{Z}_{i,j}^m$, \mathbf{y}_i^m , \mathbf{e}_i^m , and \mathbf{u}_i^m . Thus, with the available data we can produce a comprehensive input-output table. However, this is usually not done. Most input-output modellers prefer working with a symmetric input-output table (SIOT). What complicates the matter is the fact that there are different variants of how to construct a SIOT. These are discussed in the following section.

3. Variants of the symmetric input-output table

Table 3 reports what we will call the SIOT Variant A¹. At the core of the SIOT Variant A is an interindustry transactions matrix \mathbf{Z} , which reports the entire intermediate consumption of products (domestically produced and imported). Mathematically, $\mathbf{Z} = \mathbf{Z}^d + \mathbf{Z}^m$. Taking column sums of this matrix yields total intermediate consumption by industry, denoted by \mathbf{z} . Taking row sums yield total intermediate consumption by product, denoted by \mathbf{r} . By definition, summing \mathbf{z} over j must yield the same result as summing \mathbf{r} over i , so $z = r$ (but $\mathbf{z} = \mathbf{r}$ will usually not be true; it is possible but extremely unlikely).

Table 3: Symmetric input-output table, variant ‘A’

Products	Homogeneous branches				Final uses		Imports	Output
	1	...	n	Total	Domestic	Exports		
1	$Z_{1,1}$	...	$Z_{1,n}$	r_1	y_1	e_1	$-m_1$	x_1
...
n	$Z_{n,1}$	...	$Z_{n,n}$	r_n	y_n	e_n	$-m_n$	x_n
Total interm. use / final use	z_1	...	z_n	$z = \mathbf{r}$	y	e	$-m$	x
Value added	v_1	...	v_n	v				
Output	x_1	...	x_n	x				

Source: author’s illustration

In each homogeneous branch, intermediate consumption plus value added is equal to output:

¹ This is what Holub and Schnabl (1994) call „Variante A1“. At the regional level, it is closely related to what Stäglin (2001) calls the “technological version”.

$$\mathbf{x} = \mathbf{z} + \mathbf{v} \quad (4)$$

The bottom row of the SIOT variant A reports output by industry x_j . Total output is the sum of x_j over all j : $x = \sum_j^n x_j$.

Each row can be understood as a representation of the commodity balance. If a country uses more of product i than it produces, it must be a net importer of that product, and vice versa. In other words, net exports of product i must be equal to domestic output minus domestic use of that product. Mathematically:

$$e_i - m_i = x_i - r_i - y_i \quad (5)$$

Rearranging terms yields:

$$r_i + y_i + e_i - m_i = x_i \quad (6)$$

Going through row i of the SIOT variant A means going through equation (6). This is why imports are entered with a negative sign in the table.

The symmetry of SIOT variant A is captured by the following condition:

$$x_i = x_j \text{ if } i = j. \quad (7)$$

Table 4: Symmetric input-output table, variant ‘B’

Products	Homogeneous branches				Final uses		Output
	1	...	n	Total	Domestic	Exports	
1	$Z_{1,1}^d$	...	$Z_{1,n}^d$	r_1^d	y_1^d	e_1^d	x_1
...
n	$Z_{n,1}^d$	...	$Z_{n,n}^d$	r_n^d	y_n^d	e_n^d	x_n
Imported products	z_1^m	...	z_n^m	z^m	y^m	e^m	m
Total interm. use / final use	z_1	...	z_n	$z = r$	y	e	u
Value added	v_1	...	v_n	v			
Output	x_1	...	x_n	x			

Source: author’s illustration

Table 4 shows the symmetric input-output table, variant B². This variant is based on a different way of recording imports. In variant A, imports are allocated by

² This is what Holub and Schnabl (1994) call „Variante B“ and Stäglin (2001) calls “regional version”.

product and the vector \mathbf{m} consists of the m_i 's. In variant B, by contrast, imports are allocated by use, i.e. homogeneous branches and final users. z_j^m denotes the column sums of matrix \mathbf{Z}^m . Thus, z_j^m is the value of imported products which were used as intermediate inputs by industry j . Accordingly, z^m denotes the value of total imports used as intermediate inputs. y^m denotes the value of products that were consumed by final users in the country, and e^m denotes the value of imported products used for exports (re-exports). m denotes the total value of imports.

It is important to realize that \mathbf{z}^m is very different from \mathbf{m} . The latter is a column vector of length n (the number of different products), and element m_i is interpreted as “imported products of type i ”. The former is a row vector of length n , and element z_j^m is interpreted as “products of all types imported for use by industry j ”. Moreover, the sum of all elements is not equal – vector \mathbf{m} contains all imported products, but vector \mathbf{z}^m contains only those products imported for intermediate, as imported products for final use are recorded elsewhere.

Table 5: Symmetric input-output table, variant ‘E’

Products	Homogeneous branches				Final uses			Total use
	1	...	n	Total	Domestic	Exports	Total	
1	$Z_{1,1}$	...	$Z_{1,n}$	r_1	y_1	e_1	f_1	u_1
...
n	$Z_{n,1}$	...	$Z_{n,n}$	r_n	y_n	e_n	f_n	u_n
Total interm. use / final use	z_1	...	z_n	$z = r$	y	e	f	u
Value added	v_1	...	v_n	v				
Output	x_1	...	x_n	x				
Imports of similar goods	m_1^E	...	m_n^E	m				
Total supply	s_1	...	s_n	s				

Source: author's illustration

Table 5 shows how Eurostat currently compiles its input-output tables according to the ESA 95 guidelines. This variant is called variant ‘E’ for ‘Eurostat’.

The total supply of a commodity is equal to domestic production plus imports of similar commodities:

$$\mathbf{s} = \mathbf{x} + \mathbf{m}^E \quad (8)$$

The row vector \mathbf{m}^E refers to imports by commodity. \mathbf{m}^E stands for ‘vector of imports constructed the Eurostat way’. m_j^E is the value of imports of commodity j , not the value of products imported by industry j . This is a crucial difference, as we will see below. Mathematically, \mathbf{m}^E is the transpose of \mathbf{m}^A .

At the core of Variant E is the interindustry transactions matrix \mathbf{Z} , as in variant A. Taking column sums of this matrix yields total intermediate consumption by industry, denoted by \mathbf{z} . Taking row sums yield total intermediate consumption by product, denoted by \mathbf{r} . By definition, summing \mathbf{z} over j must yield the same result as summing \mathbf{r} over i , so $z = r$ (but $\mathbf{z} = \mathbf{r}$ will usually not be true; it is possible but extremely unlikely).

Total final use is defined as the sum of domestic final use and exports:

$$\mathbf{f} = \mathbf{d} + \mathbf{e} \quad (9)$$

Total use is equal to the sum of intermediate use (by product) and final use:

$$\mathbf{u} = \mathbf{r} + \mathbf{f} \quad (10)$$

Finally, it is true by definition that

$$\mathbf{s} = \mathbf{u} \quad (11)$$

Thus, the IOT is symmetric in the sense that $s(j) = u(i)$ when $i = j$.

What is the difference from variants A and B? There is a great difference between variants E and B, because import allocation is very different. There is not a big difference between variants A and E, and actually variant A can easily be converted into variant E by simply transposing the import vector and adding/subtracting things.

4. Interpretation of coefficients

The most important implication of the different variants is the careful interpretation of the Leontief matrix and the coefficients used for multiplier analysis.

In variant A, we have:

$$a_{i,j}^A = \frac{Z_{i,j}}{x_j} \quad (12)$$

These coefficients describe how many units of input i were used/needed to produce one unit of output j . Therefore, they can be interpreted as *technological coefficients*.

In variant B, we have:

$$a_{i,j}^B = \frac{Z_{i,j}^d}{x_j} \quad (13)$$

These coefficients do not tell us how many units of input i were used to produce one unit of output j , because they refer only to those inputs that were produced domestically. Imported inputs are ignored. To make this point clearer, let's define a trading coefficient $t_{i,j}$ as:

$$t_{i,j} = \frac{Z_{i,j}^d}{Z_{i,j}} \quad (14)$$

In words, $t_{i,j}$ is the share of input i used by industry j that originates from domestic production. Conversely, $(1 - t_{i,j})$ can be interpreted as the import share. Using equations 12, 13, and 14, we can write the relationship between $a_{i,j}^A$ and $a_{i,j}^B$ as:

$$a_{i,j}^B = t_{i,j} a_{i,j}^A \quad (15)$$

Thus, $a_{i,j}^B$ will generally be smaller than $a_{i,j}^A$. The $a_{i,j}^B$ coefficients differ from the true technological coefficients ($a_{i,j}^A$) due to international trade. Therefore, they cannot not be interpreted as technological coefficients. They are a mixture of technology and trade.

Finally, what do we have in variant E? This depends on what we put in the denominator – output or supply. If we put output in the denominator, we are performing exactly the same calculation as in (12). Mathematically:

$$a_{i,j}^E = \frac{Z_{i,j}}{x_j} = a_{i,j}^A \quad (16)$$

Thus, variant E also allows the computation of technological coefficients.

If we divide $Z_{i,j}$ by s_j , we get a different kind of coefficients, which we will call $b_{i,j}$:

$$b_{i,j}^E = \frac{Z_{i,j}}{s_j} = \frac{Z_{i,j}}{x_j} \frac{x_j}{s_j} = a_{i,j}^E \frac{x_j}{s_j} \quad (17)$$

Thus, there is a close relationship between $b_{i,j}^E$ and the technological coefficient $a_{i,j}^E$. The factor of proportionality is (x_j/s_j) . This is the share of total supply of product j which is provided by domestic output x_j . If the country does not import product j , we have $x_j = s_j$. In this case, the two coefficients coincide. Whenever imports of product j are larger than zero, $b_{i,j}^E$ will be smaller than $a_{i,j}^E$. The difference between the two can be interpreted as an indicator of self-sufficiency or import dependence. It is clear, however, that $b_{i,j}^E$ cannot be interpreted as a technological coefficient. The only technological coefficient is $a_{i,j}^E$, which is equal to $a_{i,j}^A$.

5. Implications for regional input-output modellers

The very technical discussion of the previous sections has important implications for regional input-output modellers. The reason for this is that regional input-output models are often constructed on the basis of regionalisation methods that adjust the national input-output table to regional conditions by applying mechanistic rules. These methods are laid out in the following³.

A variety of methods is based on a popular concept of regional science, the location quotient (LQ), which is generally interpreted as an indicator of an industry's relative over- or underrepresentation within a region (compared to the national average). The LQ is computed by using data that happens to be available. Preferable is a direct

³ For a more extensive explanation of these methods, see Miller and Blair (2009, pp. 349-359).

measure of an industry's relative importance, such as the share of its output in total regional output. If such data are not available (at a satisfactory level of disaggregation), researchers often resort to employment data. The LQ of industry j is then computed according to following formula:

$$LQ_j = \frac{L_j^R / \bar{L}^R}{L_j^N / \bar{L}^N} \quad (17)$$

In words, the LQ as computed by equation (17) is equal to the share of industry j in regional employment divided by the share of industry j at the national level. If $LQ_j > 1$ (i.e. the employment share of industry j at the regional level is larger than at the national level) industry j is said to be overrepresented. Conversely, if $LQ_j < 1$ industry j is said to be underrepresented. This procedure of describing the economic structure of a region, in comparison with other regions or the national average, has been standard practice in regional science for a long time.

The LQ has found use in the input-output literature as a tool for constructing regional input-output tables when detailed data is not available for the region to be studied. The idea is to regionalise the national input-output table by applying the LQ as correction factor of the A matrix. In the seminal paper by Schaffer and Chu this is formulated as follows: "A location quotient of less than one means that the region imports some of its needs of output i . A location quotient greater than one means that the region exports some of output i " (Schaffer and Chu, 1969, p. 85). Following this line of reasoning, Schaffer and Chu then explain what to do when the location quotient is greater or smaller than one: "If $LQ_i \geq 1$, we set $a_{i,j} = A_{i,j}$, where $a_{i,j}$ is the regional production coefficient (defined as $x_{i,j}/x_j$) and $A_{i,j}$ is the national production coefficient ($X_{i,j}/X_j$). Knowing regional industry outputs, x_j , and having established $a_{i,j}$, we may easily compute regional interindustry flows" (Schaffer and Chu, 1969, p. 85). They then propose the following formula for computing $x_{i,j}$:

$$x_{i,j} = a_{i,j} x_j = X_{i,j} \frac{x_j}{X_j} \quad (18)$$

In other words, this procedure boils down to assuming that if $LQ_i \geq 1$ the “regional production coefficient”, $a_{i,j}$, is equal to its national counterpart. In the other case, Schaffer and Chu propose the following procedure: “If $LQ_i < 1$, local production is assumed to be inadequate to supply local needs – no exports can be made and imports are necessary. The regional production coefficient in row i may now be computed as $a_{i,j} = LQ_i A_{i,j}$ ” (Schaffer and Chu, 1969, p. 86). Thus, in this case the “regional production coefficient” will be smaller than its national counterpart.

This approach is called the “simple location quotient” (SLQ) method. Since it has a number shortcomings, various alternatives have been proposed. For a survey, see Miller and Blair (2009, pp. 349-359). However, in this paper the focus is not on the particular shortcomings of the SLQ method; it is on the structure of the input-output table and the proper interpretation of the interindustry transactions matrix.

The input-output table used by Schaffer and Chu (1969) looks like this:

Table 6: the input-output table of Schaffer and Chu

TABLE 1
SIMPLIFIED REGIONAL TRANSACTIONS

Outputs		Selling Industries					Local Final Demand		Exports	Total Sales	
		1	2	3	...	s	1	...			t
Purchasing Industries	1	x_{11}	x_{12}	x_{13}	...	x_{1s}	y_{11}	...	y_{1t}	e_1	x_1
	2	x_{21}	x_{22}	x_{23}	...	x_{2s}	y_{21}	...	y_{2t}	e_2	x_2
	3	x_{31}	x_{32}	x_{33}	...	x_{3s}	y_{31}	...	y_{3t}	e_3	x_3
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	s	x_{s1}	...			x_{ss}	y_{s1}	...	y_{st}	e_s	x_s
Value Added		v_1	v_2	v_3	...	v_s	u_1	...	u_t		
Imports		m_1	m_2	m_3	...	m_s	n_1	...	n_t		
Total Inputs		x_1	x_2	x_3	...	x_s	y_1	...	y_t		

Source: Schaffer and Chu (1969), Table 1

Obviously, this table is of the SIOT Variant B format. This means that, for example, m_1 must be interpreted as “intermediate products imported for use by industry 1”. It must *not* be interpreted as “imported products of type 1” (that would be the correct interpretation for Variant E tables). Thus, the reasoning behind the SLQ method (and, as

remains to be shown, that of all other LQ methods) is based on an input-output table of the SIOT Variant B layout. The purpose of the present paper is to convince you, the reader, that this has important implications for those who work with other variants of the SIOT.

In the context of a SIOT Variant B table, the reasoning behind the LQ methods is perfectly valid. Let us assume an extreme case: Industry 1 is coal, and the regional economy happens to have no coal mines at all. Consequently, $LQ_1 = 0$. When equation (18) is applied, all entries in row 1 will be zero. If the other industries in the region need coal as an intermediate input, they will import coal, and these imports will be recorded in the row labelled “imports”, but not in the X matrix. Thus, the reasoning of Schaffer and Chu is perfectly valid.

However, in the context of a SIOT Variant A or E this is not the case. Let us consider again Table 5, the SIOT Variant E. The application of equation (18) would mean that the first row of the Z matrix contains only zeroes. But the Z matrix in Table 5, unlike the X matrix of Schaffer and Chu, refers not only to intraregional transactions; it refers to the intermediate use of products, including imported products. Setting the first row of the Z matrix equal to zero would mean that none of the regional industries use any coal whatsoever. What’s worse is that the SLQ procedure does not even ensure that the first column of the Z matrix contains only zeroes (but it should, for if industry 1 is not present in the region it does not use any inputs and consequently the first row of the Z matrix must contain only zeroes). This example shows that the SLQ method is not well-suited for regionalising SIOT of Variant A or E.

What about other LQ methods? Let us take the CILQ method, which is based on the following formula (again taken from Schaffer and Chu):

$$CILQ_{i,j} = \frac{x_i / X_i}{x_j / X_j} \quad (19)$$

The CILQ method has the advantage that it does not only consider the relative size of industry i but also sets this in relation with industry j . However, this does not make it immune to the problem identified above. Once again, if industry i is coal mining, and coal mining does not exist in the region to be studied, all cells in row i will

be equal to zero. This is perfectly reasonable for SIOT Variant B, but it does not make sense for SIOT Variant A or E. Thus, the CILQ method is subject to the same limitation as SLQ – it is not applicable for tables of SIOT Variant A or E.

What, then, can be done if a regional SIOT of Variant A or E is required? The present paper argues that for these SIOT variants, the preferable regionalisation method should be based on the commodity balance (CB) approach (also known as supply-demand pool approach). This approach is based on the following equation, which is true by definition:

$$x_i + m_i^E = r_i + f_i. \quad (20)$$

In words, equation (20) states that the sum of regional production and imports (the supply pool) must be equal to the sum of intermediate use and final use (the demand pool). Final use in turn can be decomposed into regional final use (regional consumption and capital formation) and exports, which yields:

$$\mathbf{x} + \mathbf{m} = \mathbf{r} + \mathbf{d} + \mathbf{e}. \quad (20)$$

Note that the vector \mathbf{m} which appears in (20) is the column vector of imports by product as displayed in the SIOT Variant A (Table 3). Its transpose is the row vector \mathbf{m}^E as displayed in the SIOT Variant E (Table 5). It is very different from the vector of imported intermediate products \mathbf{z}^m as displayed in the SIOT Variant B (Table 4).

It is assumed that regional output x_i and regional final use d_i can somehow be estimated or measured. The next task is to estimate r_i . In order to do this, the “equal technology assumption” is invoked. This means that each industry in the region is assumed to operate with the same technological coefficients as on the national level. The technological coefficients can be calculated from the national input-output table according to (12) or (16)⁴. Then, the same equations can be used to compute the \mathbf{Z} matrix for the RIOT. Taking the row sum of \mathbf{Z} yields the vector of intermediate use \mathbf{r} . Thus, the remaining task is to compute estimates for e_i and m_i . To do this, the trade balance b_i has to be computed. It is defined as:

$$\mathbf{b} = \mathbf{e} - \mathbf{m} \quad (21)$$

Solving (21) for \mathbf{e} or \mathbf{m} and substituting it into (20) yields:

$$\mathbf{b} = \mathbf{x} - \mathbf{r} - \mathbf{d} \quad (22)$$

Since data or estimates of \mathbf{x} , \mathbf{r} , and \mathbf{d} are available, \mathbf{b} can be computed from (22). However, it is not possible to compute actual exports and imports; (22) allows us only to compute the eponymous commodity balance. If we want to compute actual exports and imports, additional assumptions are required. For SIOT Variant A this step is not very important, because the columns labelled “exports” and “imports” may simply be subsumed by a column labelled “net exports”. This is a way of evading the problem but not solving it. If the goal is to construct a SIOT Variant E, this problem cannot be circumvented.

A very simple solution that has often been applied relies on the assumption that for each product the region is either import-dependent or not. That is, whenever the trade balance is positive, imports are assumed to be zero, and if the trade balance is negative, exports are assumed to be zero. This assumption rules out the possibility of cross-hauling (the simultaneous exporting and importing of similar products) and has been heavily criticised (Richardson, 1985). A more advanced treatment is possible with the Cross-Hauling Adjusted Regionalisation Method (CHARM), which estimates the amount of cross-hauling based on the heterogeneity of products (Kronenberg, 2009). Either way, some estimate of \mathbf{e} and \mathbf{m} will be produced, and a SIOT Variant E can be constructed.

The CB method solves the problem outlined above, as can be seen with respect to the coal mining example. By multiplying the technological coefficients derived from the national IOT with the regional production vector, the matrix \mathbf{Z} will be correctly estimated (subject to the drawbacks of the “equal technology assumption”, of course). That is, column 1 of the matrix \mathbf{Z} will contain only zeroes, because industry 1 (coal mining) does not exist and hence does not use any intermediate inputs. The entries in row 1, by contrast, will not be forced to equal zero, so the coal use of other industries is

⁴ Note that technological coefficients as defined in the present paper cannot be computed from SIOT Variant B tables.

correctly respected. Given that regional production of coal is zero the application of (22) will yield a negative trade balance for coal, and this will be reflected in the first element of the import vector \mathbf{m} . In a Variant A table, the required imports of coal will be recorded in row 1, column “imports”, and in the Variant E table they will be recorded in row “imports”, column 1. All this is absolutely correct.

On the other hand, neither the CB method nor the CHARM extension should be applied to SIOT Variant B tables. Aside from producing false results, there is also a logical contradiction. Setting up a commodity balance is possible only if the vector \mathbf{m} is known. In a SIOT Variant B there is no such vector, therefore it is not possible to apply a CB method to such a table without using additional information.

6. Concluding Remarks

The present paper shows that LQ methods can be applied to national input-output of the SIOT Variant B type, but they should not be applied to tables of Variant A or E. Conversely, CB methods including CHARM can be applied to Variant A or E tables, but not to type B tables. Applying LQ or CB methods to tables for which they are not suitable may result in misleading and implausible results.

The discussion of the previous sections is based purely on definitions and logical considerations. The information on which the discussion is based has been available for a long time. However, the following implications of the differences between the SIOT variants for regional input-output models have not yet been fully acknowledged in the literature on regional input-output modelling. The reason for this is that much of that literature was written by authors based in the United States, where SIOT Variant B appears to be much more common than the other variants. Being used to working with this particular version of the SIOT, these authors did not devote much attention to the possible complications of working with other SIOT variants. This explains why neither Schaffer and Chu (1969) nor Miller and Blair (2009) discuss this problem.

Furthermore, in regional economics it often makes sense to use the SIOT Variant B, as researchers are mostly interested in the effects of a certain final demand

impulse on output, value added, and employment within the region of study. These questions coincide with the concerns of regional policymakers. When they decide, for example, on a particular investment project, they want to know how many jobs are generated in the region for which they are responsible. In recent years, however, input-output models are increasingly used in the fields of environmental and ecological economics (Los, 2011). Researchers from those fields are mostly interested in energy use, material consumption, greenhouse gas emissions and so on. For such research topics, SIOT Variant A or E is more useful. If you are concerned about climate change, you want to know the impact of final demand on, for example, electricity consumption, because electricity production is closely associated with greenhouse gas emissions. It does not matter much whether the electricity is produced in region A or region B (unless the electricity generation mix differs significantly). Therefore, you want to know how much electricity is actually used, and not whether it comes from domestic production or import. This is why ecological economists tend to prefer the allocation of imports according to Variant E. In the past, most of these studies have been undertaken for national economies. More recently, however, there seems to be a growing interest in sustainable development and environmental policy at the regional level. As more and more researchers conduct environmental impact studies for individual regions, they will need to construct regional input-output models. Therefore, they need to be aware of the complications that stem from the different allocation of imports.

Future work should aim at illustrating these problems by means of an empirical application. The author intends to do this in the near future. Another question to be addressed is whether the arguments hold for all the variants of the LQ method. Above, only SLQ and CILQ have been explicitly discussed. It remains to be shown that the same arguments apply to other variants such as PLQ, RLQ and FLQ.

7. Appendix

Table A1: List of symbols

e_i	Exported products of type i
s_j	Total supply of products of type j
u_i	Total use of products of type i
u_i^d	Total use of domestically produced products of type i
u_i^m	Total use of imported products of type i
v_j	Value added in industry j
x_j	Total output of industry j
y_i^d	Domestic final use of domestically produced commodities of type i
y_i^m	Domestic final use of imported commodities of type i
$Z_{i,j}^d$	Intermediate use of domestically produced products of type i in industry j
$Z_{i,j}^m$	Intermediate use of imported products of type i in industry j

Source: author's imagination

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