8 Nonsurvey and Partial-Survey Methods: Extensions

8.1 Introduction

Regional input–output tables share with their national counterparts the problem of becoming outdated simply because of the passage of time. But smaller geographic scale introduces other problems. For example, if the only automobile assembly plant in Michigan closes and its replacement opens (as the only such plant) in Tennessee, a "national" table would still reflect automobile assembly (although perhaps under more modern methods in the new plant) whereas that activity would disappear entirely from a Michigan table and appear as a completely new activity in a Tennessee table. In addition, states or counties or even smaller economic areas may have fewer resources available for the kinds of data collection needed for survey-based input–output tables – although since the economy is smaller (in terms of number of square miles covered, numbers of active plants, etc.) the effort involved in surveying may be less. In addition, when one is concerned with models in which two or more regions are connected (or a single region and the rest of the country) shipments out of and into the regions assume a much more important role – the former providing inputs to production and the latter representing markets for outputs. Consequently, considerable effort has been devoted to estimation of interregional flows of goods in an effort to construct approximations to and estimates of the a_{ij}^{rs} or $c_{i\cdot}^{rs}$ coefficients of the IRIO or MRIO models (Chapter 3).

As noted in Chapter 3, some of the earliest attempts at estimating interindustry relationships at a regional level employed national input coefficients along with estimates of regional supply percentages showing, for each supplying sector, the proportion of total regional requirements of that good that could be expected to originate within the region. One procedure for obtaining this estimate for sector i was to find the ratio of total regional output, less exports, of sector i, to the total output, less exports, plus imports, of sector i. As in Chapter 3, for a particular region r,

$$p_i^r = \frac{x_i^r - e_i^r}{x_i^r - e_i^r + m_i^r}$$

Thus, when none of good i was imported, $p_i^r = 1$, and the assumption is that all of the region's needs for i can be supplied internally. The regional input coefficient matrix is then estimated as

$$\mathbf{A}^{rr} = \hat{\mathbf{p}}\mathbf{A}^{n}$$

where $\mathbf{p} = [p_i^r]$ and $\mathbf{A}^n$ is the national technical coefficients matrix. As we saw in Chapter 3, this represents a uniform alteration of each of the coefficients in row i of $\mathbf{A}^n$ by p_i^r.

As we saw in section 3.2, a regional input coefficient, a_{ij}^{rr}, is defined as the difference between a regional technical coefficient, a_{ij}^{r}, and a regional import coefficient, a_{ij}^{sr}, where s indicates "outside of r." (When it is clear what particular region is intended, the simpler notation $r_{ij} = a_{ij} - m_{ij}$ is used.) If we have available a complete set of intra- and interregional data (as is needed in constructing an interregional input–output model, for example), then we observe the a_{ij}^{rr}'s (and a_{ij}^{sr}'s) directly. However, if we are trying to estimate a_{ij}^{rr} from national data, the estimation problem can be posed in the following way: (1) estimate a regional technical coefficient, a_{ij}^{r}, from the corresponding national coefficient, a_{ij}^{n}, and then (2) estimate the regional input coefficient, a_{ij}^{rr}, as some proportion of the regional technical coefficient; that is, $a_{ij}^{rr} = p_{ij}^{r} a_{ij}^{r}$ (where $0 \leq p_{ij}^{r} \leq 1$). Instead of estimating, a_{ij}^{r} and a_{ij}^{sr} we estimate a_{ij}^{r} and p_{ij}^{r}. The two steps in this procedure for estimating a_{ij}^{rr} from a_{ij}^{n} would therefore be: (1) find $\alpha_{ij}^{r} \geq 0$ such that

$$a_{ij}^{r} = (\alpha_{ij}^{r})(a_{ij}^{n}) \tag{8.1}$$

and (2) find β_{ij}^{r} ($0 \leq \beta_{ij}^{r} \leq 1$) such that

$$a_{ij}^{rr} = (\beta_{ij}^{r})(a_{ij}^{r}) \tag{8.2}$$

[Of course, if we indeed can find α_{ij}^{r} and β_{ij}^{r} for every i and j, this is equivalent to finding $a_{ij}^{rr} = (\gamma_{ij}^{r})(a_{ij}^{n})$ where $\gamma_{ij}^{r} = (\alpha_{ij}^{r})(\beta_{ij}^{r})$].

The basic point is that in general there is not enough regional information to find the α_{ij}^{r} and β_{ij}^{r}. For example, in the simple procedure described at the beginning of this section, we see that (1) a_{ij}^{r} was assumed equal to a_{ij}^{n}; in terms of (8.1), $\alpha_{ij}^{r} = 1$ for all i and j (region r and national production recipes are identical) and (2) each regional purchaser, j, of input i was assumed to buy the same proportion of those inputs from within the region; in terms of (8.2), $\beta_{ij}^{r} = p_i^r$ for all i.

In the absence of specific survey information, it is customary, at least initially, to invoke assumption (1). This overlooks probable regional differences in product mixes within a sector (as discussed in Chapter 3), especially at anything but the finest level of disaggregation; it also ignores relative sizes and ages of firms within a particular regional sector (with differing efficiencies, for example), differences in quality of capital stocks, etc. The prevalent view in the mid-1980s was

> … in the absence of any information about many of these characteristics, one is left with very few options but to adopt a very conservative strategy, namely, one in which a minimum of speculation is applied to the modification process. (Hewings, 1985, p. 47.)

We will now explore a number of nonsurvey techniques for regionalization of national coefficients – through adjustments based entirely on published information on regional employment, income, or output, by industry – and see where they fit in the general scheme given by (8.1) and (8.2). Later we will examine more recent and more comprehensive "regionalization" approaches; but since, historically, the techniques discussed in section 8.2 have been used in a great many regional studies, it is imperative that we understand them.

8.2 Location Quotients and Related Techniques

8.2.1 Simple Location Quotients

Let x_i^r and x^r denote gross output of sector i in region r and total output of all sectors in region r, respectively, and let x_i^n and x^n denote these totals at the national level. Then the simple location quotient for sector i in region r is defined as

$$LQ_i^r = \left(\frac{x_i^r/x^r}{x_i^n/x^n}\right) \tag{8.3}$$

(often in the literature these are denoted by SLQ_i). In cases where regional output data are not consistently available, or where analysts feel it is appropriate, other measures of regional and national economic activity are often used – including employment (probably the most popular), personal income earned, value added, and so on, by sector.

The interpretation of this measure is straightforward. The numerator in (8.3) indicates the proportion of region r's total output that is contributed by sector i. The denominator represents the proportion of total national output that is contributed by sector i, nationally. If $LQ_i^r = (0.034)/(0.017) = 2$, sector i's output represents 3.4 percent of all regional gross output while, at the national level, sector i's output represents only 1.7 percent of the total national output. In a case like this – in fact, whenever $LQ_i^r > 1$ – sector i is more localized, or concentrated, in the region than in the nation as a whole. Conversely, if $LQ_i^r = (0.015)/(0.045) = 0.33$, we understand that while sector i's output is 4.5 percent of the total national gross output, it represents only 1.5 percent of the gross output in the region. In this situation, sector i is less localized, or less concentrated, in region r than in the nation as a whole.

Note that simple algebra generates an alternative expression, namely

$$LQ_i^r = \left(\frac{x_i^r/x_i^n}{x^r/x^n}\right)$$

This tells a somewhat different "story." The numerator measures the proportion of total national output of commodity i that is produced in region r. The denominator is the proportion of total national output of all commodities that is produced in region r. But the interpretation is much the same; $LQ_i^r > 1$ indicates a commodity whose production is relatively localized in region r.

The simple location quotient has been viewed as a measure of the ability of regional industry i to supply the demands placed upon it by other industries (and by final demand) in that region, in the following way. If industry i is less concentrated in the region than in the nation ($LQ_i^r < 1$), it is seen as less capable of satisfying regional demand for its output, and its regional direct input coefficients, $a_{ij}^{rr}(j = 1, \ldots, n)$ are created by reducing the national coefficients, a_{ij}^{n}, by multiplying them by LQ_i^r. However, if industry i is more highly concentrated in the region than in the nation ($LQ_i^r > 1$), then it is assumed that the national input coefficients from industry i, a_{ij}^n $(j = 1, \ldots, n)$, apply to the region, and the regional "surplus" produced by i will be exported to the rest of the nation. Thus, for each row i of an estimated regional table,

$$a_{ij}^{rr} = \left\{ \begin{array}{cl} (LQ_i^r)a_{ij}^n & \text{if } LQ_i^r < 1 \\ a_{ij}^n & \text{if } LQ_i^r \geq 1 \end{array} \right\} \tag{8.4}$$

[If a national sector is not present in the region ($LQ^r = 0$), that row and column are simply deleted from $\mathbf{A}^n$.]

In terms of the general scheme in (8.1) and (8.2), we see that this procedure is equivalent to (1) assuming $\alpha_{ij}^r = 1$ for all i and j and (2) letting $\beta_{ij}^r = LQ_i^r$ when $LQ_i^r < 1$ and $\beta_{ij}^r = 1$ when $LQ_i^r \geq 1$. Note that there is a distinct asymmetry in this approach. When a sector is import-oriented ($LQ_i^r < 1$), the modification of the national coefficient varies with the strength of the import orientation – $a_{ij}^{rr} = (LQ_i^r)a_{ij}^n$. When a sector is export-oriented ($LQ_i^r > 1$), the strength of that orientation is not reflected in the modification – $a_{ij}^{rr} = (1)a_{ij}^n$.

A complication arises if the estimates of regional industry output that are obtained using LQ coefficients exceed actual output for some industries. In this event, coefficients developed by this method have often been "balanced" to ensure that they do not overestimate the regional output of each sector. The notion of a balancing method is simply that if estimated coefficients generate a regional output for sector i ($\tilde{x}_i$) that is too large (meaning $\tilde{x}_i^r > x_i^r$), then the row-i estimates, a_{ij}^{rr} (for all j), should be uniformly reduced – multiplied by $(x_i^r/\tilde{x}_i^r)$.

For example, calculate estimated sector i output on the basis of actual regional industry outputs (these are necessary data for this correction) and the LQ-estimated regional input coefficients (and regional final-demand purchase coefficients). For sector i, this is

$$\tilde{x}_i^r = \sum_j a_{ij}^{rr} x_j^r + \sum_f c_{if}^{rr} f_f^r \tag{8.5}$$

where

$\tilde{x}_i^r$ = estimated regional output of sector i,
f_f^r = total regional final demand of final-demand sector f, and
c_{if}^{rr} = estimated regional final-demand purchase coefficient of regional final-demand sector f from industry i.

The c_{if}^{rr} elements reflect purchases of regionally produced output i by regional final-demand sector f. Typically, the regional final-demand sectors will be personal consumption expenditures, investment, state and local government, as well as both foreign and rest-of-the-country exports (a part of which will be federal government purchases, except for those purchases made by federal installations located in the region). These estimates are found in much the same manner as were the a_{ij}^{rr}; that is, using national data and the region-specific location quotients. In particular,

$$c_{if}^{rr} = \begin{Bmatrix} (LQ_i^r)c_{if}^n & \text{if } LQ_i^r < 1 \\ c_{if}^n & \text{if } LQ_i^r \geq 1 \end{Bmatrix} \tag{8.6}$$

where

$$c_{if}^n = f_{if}/f_f,$$

f_{if} = national sales of industry i to final-demand sector f, and
f_f = total national purchases of final-demand sector f.

Thus, when $LQ_i^r \geq 1$, it is assumed that purchases of good i by final-demand sector f are the same proportion of total sector f purchases in the region as in the nation. For example, if purchases of electricity (sector i) by consumers (final-demand sector f) constitute 3 percent of total consumer expenditures nationally ($c_{if}^n = 0.03$), and if $LQ_i^r \geq 1$, then it is assumed that 3 percent of the total expenditures by consumers in region r will be on electricity produced in region r; $c_{if}^{rr} = 0.03$. When $LQ_i^r < 1$, then the national proportion is modified downward. If $LQ_i^r = 0.67$, then it would be assumed that only 2 percent of the total expenditures by consumers in region r will be on electricity produced in region r; $c_{if}^{rr} = 0.02$.

The next step in the balancing procedure is to calculate the ratio of estimated to actual regional output; denote this by Z_i^r. Then

$$Z_i^r = x_i^r/\tilde{x}_i^r \tag{8.7}$$

Each row of estimated regional input coefficients for which Z_i^r is less than one is adjusted downward. That is, adjusted ("balanced") regional input coefficients are estimated as

$$\bar{a}_{ij}^{rr} = \begin{Bmatrix} Z_i^r a_{ij}^{rr} & \text{if } Z_i^r < 1 \\ a_{ij}^{rr} & \text{if } Z_i^r \geq 1 \end{Bmatrix} \tag{8.8}$$

As noted above, in this LQ and other quotient approaches, $\alpha_{ij}^r = 1$ is assumed. The observed national technology is uniform across regions; regional input coefficients vary only because of varying regional capacities to satisfy own-region demand. For some kinds of production, this is quite reasonable; for others it is not. Coca Cola made in Boston probably has the same production "recipe" as Coca Cola made in San Francisco (even though local ability to supply any given input may vary). However, an "airplane" made in Seattle (for example, a Boeing commercial airliner with two jet engines) is quite a different product from an airplane made in Wichita (for example, a Cessna private aircraft with one propeller engine). So in a model with a highly aggregated "aircraft" sector, there is clearly non-uniformity in production recipes for "aircraft" across states in the USA, and the $\alpha_{ij}^r = 1$ assumption is invalid. This is the product-mix issue, and the

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level of aggregation is decisive. In a model with a sector labeled "Commercial aircraft, 2 jet engines" it is apparent that wherever produced, two jet engines will be used per aircraft. Similarly, for the "Private aircraft, one propeller engine" sector, one propeller engine will be required per aircraft. At that level of disaggregation, the assumption of constant (national) technology across regions ($\alpha_{ij}^r = 1$) may be reasonable.

Another complaint made about this approach (and many of its variants, to be examined below) is that it underestimates regional trade since it ignores cross-hauling – the situation in which a region exports and imports the same goods. Cross-hauling is a generally observed phenomenon, but it is also difficult to capture in an estimation technique. To take a very simple illustration, at a level of aggregation that includes a sector labeled "agriculture," a specific region (say Washington State) exports peaches (to California, for example) and imports avocados (from California); both are products of the "agriculture" sector. Using an LQ approach, a specific sector in a specific region must be either a net exporter or a net importer of any particular good. When $LQ_i^r > 1$, industry i is seen as producing more than its share of the national output of i, and region r is assumed to be a net exporter of the "excess" output of i. Conversely, if $LQ_j^r < 1$, the region is less than self-sufficient in good j and will therefore be a net importer of that good. (When $LQ_k^r = 1$, the region would neither import nor export good k.) This quirk of the location quotient approach thus leads to a tendency for underestimation of interregional trade (agricultural products cannot be shipped from Washington to California and also from California to Washington) and thus for overestimation of intraregional economic activity, and therefore it also tends to generate regional multipliers that are too large.[1] Later in this section we will examine an approach that attempts to overcome this problem.

There are several variants of the simple location quotient approach, all of which are used in the same general way in adjusting national to regional coefficients. We examine some of these in what follows. Since the LQ approach in (8.4) will never increase a national coefficient (they are either left unchanged or made smaller), this procedure is also called *reducing* the national coefficients table, and hence these are sometimes referred to as *reduction* techniques.

This $a_{ij}^{rr} \le a_{ij}^n$ characteristic of the LQ approach has also been called into question (see, for example, McCann and Dewhurst, 1998). A producer in sector j might use relatively fewer imported inputs than is reflected in the national coefficients for sector j, and thus at least some regionally supplied inputs *could* be larger, per unit of output j in that region than in the nation as a whole. And in general, if the national coefficient is an average of observed regional coefficients, then some coefficients in some regions should be expected to be above average while others in other regions would necessarily be below average. One of the variants to be examined below (section 8.2.4) allows for $a_{ij}^{rr} > a_{ij}^n$.

[1] Robison and Miller (1991) calculate the amount of overestimation of intraregional trade in a model for a small multicounty area in Idaho.

8.2.2 Purchases-Only Location Quotients

The purchases-only location quotient (PLQ) for sector i in region r relates regional to national ability to supply sector i inputs, but only to those sectors that use i as an input. That is,

$$PLQ_i^r = \left(\frac{x_i^r / x^{*r}}{x_i^n / x^{*n}} \right) \tag{8.9}$$

where x_i^r and x_i^n are regional and national output of good i, as before, and where x^{*r} and x^{*n} are total regional and national output of only those sectors that use i as an input. The idea here is simply that if input i is not used by sector k, then the size of sector k's output is not relevant in determining whether or not the region can supply all of its needs for input i. [For example, whether or not region r can supply all of its needs for potatoes (sector i) is probably not affected by the amount of automobiles produced (sector k) in region r, since potatoes are not a direct input to automobile manufacturing.] PLQ_i^r is used in the same way as LQ_i^r to uniformly adjust the elements in row i of a national coefficients table, as in (8.4).

8.2.3 Cross-Industry Quotients

Another variant is the cross-industry quotient (CIQ). This allows for differing modifiers within a given row of the national matrix; that is, it allows for differing cell-by-cell adjustments within $\mathbf{A}^n$ rather than uniform adjustments along each row. What is now of interest is the relative importance of both selling sector i and buying sector j in the region and in the nation. Specifically,

$$CIQ_{ij}^r = \left(\frac{x_i^r / x_i^n}{x_j^r / x_j^n} \right) \tag{8.10}$$

Then

$$a_{ij}^{rr} = \begin{Bmatrix} (CIQ_{ij}^r) a_{ij}^n & \text{if } CIQ_{ij}^r < 1 \\ a_{ij}^n & \text{if } CIQ_{ij}^r \geq 1 \end{Bmatrix} \tag{8.11}$$

The idea is that if the output of regional sector i relative to the national output of i is larger than the output of regional sector j relative to the national output of sector j ($CIQ_{ij}^r > 1$), then all of j's needs of input i can be supplied from within the region. Similarly, if sector i at the regional level is relatively smaller than sector j at the regional level ($CIQ_{ij}^r < 1$), then it is assumed that some of j's needs for i inputs will have to be imported. Note that $CIQ_{ij}^r = LQ_i^r / LQ_j^r$. Note also that $CIQ_{ii}^r = 1$ (along the main diagonal, when $i = j$), and hence this technique would make no adjustments to on-diagonal coefficients. This has been called into question, and often the diagonal elements are adjusted using their associated LQ_i's in place of CIQ_{ii}^r (Smith and Morrison,

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1974; Flegg, Webber and Elliott, 1995). More completely, then,

$$a_{ij}^{rr} = \begin{Bmatrix} (CIQ_{ij}^r)a_{ij}^n & \text{if } CIQ_{ij}^r < 1 \\ a_{ij}^n & \text{if } CIQ_{ij}^r \geq 1 \end{Bmatrix} \quad \text{for } i \neq j$$

$$a_{ij}^{rr} = \begin{Bmatrix} (LQ_i^r)a_{ij}^n & \text{if } LQ_i^r < 1 \\ a_{ij}^n & \text{if } LQ_i^r \geq 1 \end{Bmatrix} \quad \text{for } i = j$$

8.2.4 The Semilogarithmic Quotient and its Variants, FLQ and AFLQ

Rewrite LQ_i in (8.3) as $LQ_i^r = (x_i^r/x_i^n) \div (x_r/x_n)$. This clearly distinguishes the measure of the relative size of the regional (selling) sector (x_i^r/x_i^n) and the relative size of the region (x_r/x_n), but the sizes of buying sectors are ignored. The cross-industry quotient includes relative sizes of both selling (x_i^r/x_i^n) and buying (x_j^r/x_j^n) sectors but contains no x_r/x_n term. In the 1970s, Round conjectured that an appropriate approach should include all three measures. He proposed, among others, a "semilogarithmic quotient (SLQ)" which he defined (Round, 1978a, p. 182) as

$$SLQ_{ij}^r = LQ_i^r / \log_2(1 + LQ_j^r)$$

suggesting that it "... was devised simply to account for all three ratios in a way which maintains the basic properties of both the LQ and CIQ methods."[2] Notice that $\log_2(1+LQ_j^r) = 1$ when $LQ_j^r = 1$ and so in that case $SLQ_{ij}^r = LQ_i^r$; for $LQ_j^r > 1$, $\log_2(1+LQ_j^r) > 1$ and the adjustment means that $SLQ_{ij}^r < LQ_i^r$ and the reverse is the case when $LQ_j^r < 1$. Rewriting SLQ_{ij}^r we have

$$SLQ_{ij}^r = [(x_i^r/x_i^n) \div (x^r/x^n)] / \log_2\{1 + [(x_j^r/x_j^n) \div (x^r/x^n)]\}$$

and we see that along with relative sizes of both industries, i and j, this includes the regional size component in both numerator and denominator but not in such a way that the terms cancel out.

Perhaps surprisingly, applications using this *SLQ* generally failed to demonstrate any particular improvement over simpler measures like *LQ* and *CIQ*.[3] This spurred attempts to include these three factors in a measure that might perform better. One approach was developed in several articles by Flegg and others – hence the acronym *FLQ*. (See, for example, Flegg, Webber and Elliott, 1995; Flegg and Webber, 1997, 2000, and references cited in those articles.) This measure is generated by modifying the CIQ_{ij}^r to incorporate an additional measure of the relative size of the region; namely,

$$FLQ_{ij}^r = (\lambda)CIQ_{ij}^r$$

[2] "The semilogarithmic form is arbitrary, but is among the simplest functions which maintains basic properties of the [quotient] values without further parameterization." (Round, 1978a, p. 182, note 4.) The first mention of this quotient seems to be in Smith and Morrison (1974, p. 43); they indicate that it was suggested in a personal communication from Round dated 1971. See also Flegg, Webber and Elliott (1995).

[3] For example, in Smith and Morrison (1974) and Harrigan, McGilvray and McNicoll (1981).

where $\lambda = \{\log_2[1 + (x_E^r/x_E^n)]\}^\delta, 0 \le \delta < 1$.[4] Then

$$a_{ij}^{rr} = \begin{Bmatrix} (FLQ_{ij}^r)a_{ij}^n & \text{if } FLQ_{ij}^r < 1 \\ a_{ij}^n & \text{if } FLQ_{ij}^r \ge 1 \end{Bmatrix}$$

Flegg *et al.*, as well as many other regional analysts, use employment rather than output as the relevant measures of regional and national activity; these are x_E^r and x_E^n for the region and the nation, respectively, so x_E^r/x_E^n provides an alternative to the output ratio (x^r/x^n) as a measure of relative regional size. They also use employment as the measure of sector i and j activity (output). The general idea is to reduce national coefficients less for larger regions – on the belief that larger regions import (relatively) less than smaller ones.[5] The problem, however, is that the analyst must specify a value of δ in advance (β in the earlier formulation in footnote 5), and it is not at all clear what this value (or range of values) should be. Empirical work has suggested that $\delta = 0.3$ seems to work well in a variety of situations (see the articles by Flegg and associates cited above). The approach has been shown to be an improvement in at least one study that compared LQ, CIQ and (the earlier version of) FLQ for a region in Finland for which there were also survey-based coefficients to serve as a standard against which to measure the estimates (Tohmo, 2004). (Problem 8.4 asks the reader to examine the behavior of λ for various values of x_E^r/x_E^n and δ to see how this adjustment might work.)

An additional variant of the FLQ is designed to reflect regional specialization (Flegg and Webber, 2000). This was developed in response to the observation (McCann and Dewhurst, 1998) that such specialization might lead to increased intraregional purchases (by the specialized industry) and hence to intraregional input coefficients that were larger than their national counterparts. As noted earlier, national coefficients can never be increased by any of the quotient techniques examined thus far. In this case, the proposed augmentation of the FLQ (termed $AFLQ$) is

$$AFLQ_{ij}^r = \begin{Bmatrix} [\log_2(1 + LQ_j^r)]FLQ_{ij}^r & \text{if } LQ_j^r > 1 \\ FLQ_{ij}^r & \text{if } LQ_j^r \le 1 \end{Bmatrix}$$

and so

$$a_{ij}^{rr} = \begin{Bmatrix} (AFLQ_{ij}^r)a_{ij}^n & \text{if } LQ_j^r > 1 \\ (FLQ_{ij}^r)a_{ij}^n & \text{if } LQ_j^r \le 1 \end{Bmatrix}$$

This adjustment term, $[\log_2(1 + LQ_j^r)]$, is the modifier used for Round's SLQ_{ij}^r, only now it appears as a multiplier and not a divisor. Now FLQ is increased in those cases (only) in which sector j is relatively specialized in region r (when $LQ_j^r > 1$, so $[\log_2(1 + LQ_j^r)] > 1$). For example, as LQ_j^r increases from 1 to 5, $\log_2(1 + LQ_j^r)$ goes from 1 to 2.585. (There are some issues regarding the possibility of a national coefficient being

[4] Flegg and Webber (1997) use λ^* in their formulation because they used λ in an earlier and less successful version of their formula – $FLQ_{ij}^r = (\lambda^\beta)CIQ_{ij}^r$ where $\lambda = (x_E^r/x_E^n)/\{\log_2[1 + (x_E^r/x_E^n)]\}$.

[5] This logic has been questioned. See Brand (1997), McCann and Dewhurst (1998) and replies from Flegg and Webber (1997 and 2000, respectively).

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increased to more than 1.0.) The argument is that a large industry (j) in a particular region may attract in-movement to the region of firms in other sectors that supply j; hence j's *intra*regional input purchases may be larger than the national coefficient would suggest. However, limited empirical evidence suggests that not much is gained in performance over *FLQ* by this augmentation (Flegg and Webber, 2000).

8.2.5 Supply–Demand Pool Approaches

The supply–demand pool (*SDP*) technique estimates regional from national coefficients in much the same way as the procedure that was used to balance the regional coefficients estimated by the simple location quotient technique. National technical coefficients are taken as the first approximation to regional coefficients. Regional output by sector is then found, as above, by multiplying each of these coefficients by the appropriate actual regional output of that sector (and similarly for final-demand sectors, but using the *national* final-demand input proportions, c_{if}^n) and summing:

$$\tilde{x}_i^r = \sum_j a_{ij}^n x_j^r + \sum_f c_{if}^n f_f^r \tag{8.12}$$

Then the regional commodity balance, b_i^r, is calculated for industry i as $b_i^r = x_i^r - \tilde{x}_i^r$.

If this balance is positive (or zero), using national coefficients as estimates of regional coefficients does not generate an overestimate of regional production and so $a_{ij}^{rr} = a_{ij}^n$ and $c_{if}^{rr} = c_{if}^n$ are acceptable estimates. However, if the balance is negative, national coefficients are too large, in the sense that they generate unrealistically high regional outputs, by sector, so $a_{ij}^{rr} = a_{ij}^n(x_i^r/\tilde{x}_i^r)$ and $c_{if}^{rr} = c_{if}^n(x_i^r/\tilde{x}_i^r)$ – the national coefficients are reduced by the amount necessary to make the regional balance for that sector exactly zero. Summarizing,

$$a_{ij}^{rr} = \begin{Bmatrix} (x_i^r/\tilde{x}_i^r)a_{ij}^n & \text{if } b_i^r < 0 \\ a_{ij}^n & \text{if } b_i^r \geq 0 \end{Bmatrix} \tag{8.13}$$

In terms of the general approaches in (8.1) and (8.2), we see that the supply-demand pool technique assumes that $\alpha_{ij}^r = 1$, as do all of the quotient techniques mentioned above. Further, $\beta_{ij}^r = x_i^r/\tilde{x}_i^r$ when $x_i^r - \tilde{x}_i^r < 0$ and $\beta_{ij}^r = 1$ when $x_i^r - \tilde{x}_i^r \geq 0$. As with the *LQ*-based techniques, only reductions of national coefficients are possible and cross-hauling is not captured.

8.2.6 Fabrication Effects

Round (1972, 1978a, 1983) has suggested an adjustment to account for differing regional "fabrication" effects that reflect differing value-added/output ratios for a specific sector across regions. Define the regional fabrication effect for sector j in region r as

$$\rho_j^r = \frac{1 - (w_j^r/x_j^r)}{1 - (w_j^n/x_j^n)} \tag{8.14}$$

In the numerator, w_j^r is total value-added payments by sector j in region r and x_j^r is, as usual, gross output of sector j in r. Thus (w_j^r/x_j^r) is the proportion of the total output of sector j in region r accounted for by value-added elements, and $1-(w_j^r/x_j^r)$ is the proportion of total output that is due to interindustry inputs from the processing sectors (including imports). Roughly, then, the numerator represents the relative dependence of sector j in region r on inputs from itself and all other sectors. For example, if $w_j^r = \$400$ and $x_j^r = \$1000$, then $1-(w_j^r/x_j^r) = 0.6$; 60 percent of the value of sector j's total output is derived from inputs from producing sectors. The denominator in (8.14) is this same measure of industrial dependence for sector j nationally. Suppose $w_j^n = \$300{,}000$ and $x_j^n = \$1{,}000{,}000$, so that the denominator in (8.14) is 0.7; at the national level sector j is relatively more dependent on industrial inputs and relatively less dependent on value-added inputs. For this example, $\rho_j^r = 0.6/0.7 = 0.857$.

Round suggests that ρ_j^r be used as α_{ij}^r in (8.1), so that the estimate of a_{ij}^r (for $i = 1, \ldots, n$) is found as

$$a_{ij}^r = (\rho_j^r)(a_{ij}^n)$$

This is a column modification, as opposed to the row modifications of the quotient-like techniques – the entire jth column of $\mathbf{A}^n$ is multiplied by ρ_j^r to generate an estimate of the jth column of $\mathbf{A}^r$. The idea is that since interindustrial inputs are relatively less important to industry j's production in region r than at the national level, national input coefficients for sector j should be scaled down. Similarly, if $\rho_k^r > 1$, then all of the elements in the kth column of $\mathbf{A}^n$ would be scaled upward, to generate the estimates of $a_{ik}^r (i = 1, \ldots, n)$. Unlike most LQ-based techniques, national coefficients can be increased with this approach.[6] This a_{ij}^r can then be further adjusted to create an estimate of a_{ij}^{rr} via a quotient-like modification.

8.2.7 Regional Purchase Coefficients

Work at the Regional Science Research Institute (as discussed, for example, in Stevens and Trainer, 1976, 1980 and in Stevens *et al.*, 1983) concentrated on estimation of what are essentially the regional supply proportions, p_i^r, that were mentioned in section 8.1 (and earlier in Chapter 3). These were termed *regional purchase coefficients* (RPCs) in the RSRI work; they operate uniformly across rows, as do LQ-based methods. In terms of (8.1), $\alpha_{ij}^r = 1$ and, in (8.2), $\beta_{ij}^r = p_i^r$ $(= RPC_i^r)$.

The regional purchase coefficient for a sector is defined as the proportion of regional demand for that sector's output that is fulfilled from regional production. Formally, for region r and good i,

$$\mathrm{RPC}_i^r = z_i^{rr}/(z_i^{rr} + z_i^{sr})$$

[6] This "fabrication" adjustment is similar in spirit to the column adjustments (the s's) in the RAS updating procedure, which multiply all elements in the kth column of the coefficient matrix by s_k. This is what Stone termed the "fabrication effect" – the possibility that there is a change in the proportion of value-added inputs in a sector's output over time.

where, as in Chapter 3, z_i^{rr} accounts for shipments of good i from producers in r to all buyers in r and z_i^{sr} represents imports of i from outside r to buyers in r.[7] Dividing numerator and denominator by z_i^{rr},

$$\mathrm{RPC}_i^r = 1/[1 + 1/(z_i^{rr}/z_i^{sr})]$$

Effort was concentrated on estimating the magnitude of the *relative shipments* term, z_i^{rr}/z_i^{sr}. Assuming that *relative* terms designate ratios of values in region r to national values, relative shipments are estimated as a function of relative delivered costs (made up of relative unit production costs and relative unit shipment costs). These, in turn, depend on relative wages, relative output levels, and average shipping distances from producers within and outside region r. Various relationships between RPC_i^r and proxies for these relative terms have been proposed and fitted by regression techniques to data that are available in US published sources such as *County Business Patterns*, *Census of Transportation*, and *Census of Manufactures*, as well as a national input–output technical coefficients table. Comparisons with LQ-based approaches suggest the superiority of this method (Stevens, Treyz and Lahr, 1989). An alternative approach to estimation of RPCs (at the county level in the USA) is suggested by Lindall, Olson and Alward (2006) in the context of a gravity model for estimating intercounty commodity flows.[8]

8.2.8 "Community" Input–Output Models

In section 3.6 we cited Robison and Miller (1988, 1991) and Robison (1997) as examples of "regional" input–output modeling at a very small spatial scale:

> Our greatest departure from the traditional I-O approach stems from a fundamental redefinition of region. The traditional I-O approach models uniform regions, e.g., counties and multicounty areas, states, and so on. In contrast, we build models for punctiform regions, i.e., models constructed for individual cities, towns, and hamlets. (Robison, 1997, p. 326.)

Robison and Miller (1991) introduce ideas from Central Place Theory in modeling such small area economies – here a small Idaho timber (logging/sawmills) economy, the "rural West-Central Idaho Highlands Highway 55 economy" (six communities, five containing sawmills, with a combined population around 20,000). The authors suggest that principles from that theory can help to guide construction of such "intercommunity" input–output models. For example, they consider an intra- and intercommunity coefficients matrix of the sort $\mathbf{A} = \begin{bmatrix} \mathbf{A}_{11} & \cdots & \mathbf{A}_{1m} \\ \vdots & \ddots & \vdots \\ \mathbf{A}_{m1} & \cdots & \mathbf{A}_{mm} \end{bmatrix}$, where communities $1, \ldots, m$

[7] In the context of the multiregional input–output model (Chapter 3), these coefficients are the c_i^{rr} – for example, as in (3.27). However, in the MRIO model, they are used to modify a *regional* matrix, $\mathbf{A}^r$, that is not assumed simply to be the same as $\mathbf{A}^n$, the national table. In terms of equations (8.1) and (8.2), in the MRIO model $a_{ij}^r \neq 1$, at least for some i, j and r, and $\beta_{ij}^r = c_i^{rr}$ for all i.

[8] Since these authors use a gravity model formulation, there is further discussion of their work below in section 8.6.1.

are arranged from upper left to lower right in descending hierarchical (rank) order. Then strict hierarchical trade (meaning that goods flow primarily from higher- to lower-order places) would be reflected in an **A** matrix that is (close to) upper-triangular (zeros below the main diagonal).[9] In such multiregional economies cross-hauling is much less likely to be present, and hence estimation techniques that fail to account for cross-hauling (such as *LQ* and *SDP* approaches, as noted above) may be acceptable regionalization approaches.

Robison (1997) discusses hybrid procedures to estimate trade among such places in a set of hierarchically structured areas (the upper-right off-diagonal elements in **A**) as well as other special features of small-area rural economies such as their extreme openness and the importance of transboundary income and expenditure flows. In this case the application was for a rural two-county region in central Idaho (total population less than 12,000) which was disaggregated into seven community-centered sub-county regions.

County-level data from IMPLAN ("impact analysis for planning") form a basis for much of the estimation, but further disaggregation to subcounty community level regions is required. For some data, surveys were used; for others, published sources contribute information (for example, business listings in local telephone directories); in still others, *SDP* and/or *LQ* estimates were generated. Other applications of these ideas can be found in Hamilton *et al.* (1994).

8.2.9 Summary

It is worth noting that these approaches (or variants) are frequently used in applied regional analysis. Even the straightforward location quotients of section 8.2.1 are often employed. For example, in the USA, multipliers for any selected single- or multi-county region can be purchased from the Bureau of Economic Analysis of the US Department of Commerce through their *Regional Impact Modeling System* (RIMS II).[10] This system uses location quotients to derive estimates of intraregional input coefficients. As noted earlier, these intraregional coefficients will tend to be overestimated; in fact, Robison and Miller (1988) advise caution in using either RIMS or IMPLAN estimates in small area studies – specifically:

> We argue that pool and quotient techniques, used in nonsurvey models such as IMPLAN and RIMSII, should not be applied to a single county situation, or to any aggregation of counties that is not, in some sense, a functional economic area [p. 1523] . . . Because of the likelihood of cross-hauling when state and functional economic boundaries diverge, we suspect that many of these models of states [e.g., RIMSII] possess overstated multipliers . . . There could be large errors in reported RIMSII multipliers for states [p. 1529].

[9] The authors recognize that there can be shipments up the hierarchy: "What about trade in the opposite direction, from lower to higher-order places? Examples from rural regions would include agricultural and other raw materials shipped to higher-order places for processing. Rural economies are simple and normally raw materials trade will have to be obtained from observation rather than technique" (Robison, 1997, pp. 335–336).

[10] Currently these are based on 2004 national input–output accounts and 2004 regional economic accounts. See US Department of Commerce (1997); also www.bea.gov.

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As another example, the bulk of the discussion in Gerking *et al.* (2001) deals with imaginative ways of filling in for "suppressed" data at the county level (due to disclosure concerns), in order to estimate industry-specific employment at the county level. These employment data are used to calculate county-level location quotients which are then used in the usual way to regionalize (down to the county level) a national direct coefficients table. The authors argue that estimating at the lowest possible level of sectoral aggregation has the effect of minimizing the consequences of the no cross-hauling feature of location quotient reduction techniques. The approach is illustrated with an economic impact analysis of an energy project for a county in Wyoming.

It is generally recognized that the reduction techniques discussed above are less than totally successful. Yet the need for input–output data at a regional level continues to increase and has stimulated much discussion and many approaches. Often, these are *hybrid* techniques which include use of the RAS procedure (originally devised for updating national input–output information) along with additional information. We turn to some of these developments next, looking first at the use of RAS for regionalization of a national input–output table.

8.3 RAS in a Regional Setting

As we saw in section 7.4, the RAS technique generates a coefficient matrix for a particular year, $\mathbf{A}(1)$, given observations on total outputs, total interindustry sales, and total interindustry purchases for that year – $\mathbf{x}(1)$, $\mathbf{u}(1)$, and $\mathbf{v}(1)$, and using as a starting point an earlier coefficient matrix, $\mathbf{A}(0)$. While it is inherently a mathematical technique, we have also seen that the economic notions of uniform substitution and fabrication effects are compatible with the procedure. Since coefficient tables for regional input–output models are essential for regional analysis, one way to have a wider variety of tables available for various regions of a nation is to apply the same RAS principles, where we utilize a (relatively up-to-date) *national* input–output table, $\mathbf{A}^n$, and current marginal information about *regional* economic activity – $\mathbf{x}^r$, $\mathbf{u}^r$, and $\mathbf{v}^r$. Or, for that matter, instead of $\mathbf{A}^n$, one may have a current input–output table for some *other* region in the country, s, and then use the known $\mathbf{A}^s$ as the matrix to be adjusted to satisfy the observed marginal information for region r. Thus, instead of using the RAS procedure to adjust coefficient matrices across time (the updating problem), it has also been used to adjust coefficient matrices across space (the regionalization problem). To the extent that a national table, $\mathbf{A}^n$, reflects an average of input–output relationships in various regions of the nation, the minimization of "information distance" or "surprise" that is inherent in the RAS technique may also be appropriate at the regional level. Or if there is an input–output coefficient table for a region, s, that is thought to be economically similar to the region in question, r, then this same "minimal surprise" characteristic of the RAS procedure is possibly an attractive one.

On the (different) problem of updating an existing regional table via RAS-like techniques, see, among others, the early work of McMenamin and Haring (1974) (and also the Giarratani, 1975, comment on this work)[11] and Malizia and Bond (1974). Many studies have compared results from the RAS approach with one or more of the reduction techniques in section 8.2 for deriving a regional from a national input–output table. We illustrate this kind of comparison in the following section. More recently, analysts have combined both kinds of techniques into hybrid approaches. We examine a few examples in section 8.5. Later, in section 8.7, we consider the additional problem of estimating interregional flows in order to create a model for two or more connected regions.

8.4 Numerical Illustration

In Table 8.1 we present illustrative results from application of some of these techniques to estimate matrices for Region 1 (North China) from the three-region, three-sector data set for China for 2000. (These were used for illustration in Chapter 3, section 3.4.6.) More detailed results – for example, the complete 3×3 coefficients matrices and their associated Leontief inverses, are shown in Web Appendix 8W.1 for the interested reader. This is done in part because, as always when comparing matrices, a good deal of individual detail is inevitably lost when summary measures are used. Coefficients and inverse matrices were estimated using *LQ*, *CIQ*, *FLQ*, *AFLQ*, *RPC*, and *RAS* techniques, first on an unadjusted national table, $\mathbf{A}^n$, created by spatial aggregation of the data in Chapter 3, and then on a regional technical coefficients table, $\mathbf{A}^r$, created using Round's fabrication effect adjustment, where $\mathbf{A}^r = \mathbf{A}^n\hat{\rho}^r$.

Differences between survey-based total intraregional intermediate inputs and those in each of the estimated matrices (column sums of $\mathbf{A}^{rr}$ and each estimate, $\tilde{\mathbf{A}}^{rr}$) are one way to condense n^2 pieces of information (here 9) into n. Differences in column sums of each of the Leontief inverses, $\mathbf{L}^{rr}$ and each of the $\tilde{\mathbf{L}}^{rr}$ (intraregional output multipliers) are another (and more frequently used) summary measure. Both of these mask individual cell differences in the process of summation down the columns. We also include one additional measure, the mean absolute percentage error (MAPE), already used in section 7.4.2. This is the average of the percentage differences in corresponding cells of $\mathbf{A}^{rr}$ and $\tilde{\mathbf{A}}^{rr}$ or of $\mathbf{L}^{rr}$ and $\tilde{\mathbf{L}}^{rr}$ (irrespective of whether positive or negative), so it too masks a wide variety of individual differences.

Notice that *RAS* always estimates total intraregional intermediate inputs correctly. In this small set of examples *RPC* was the best of the quotient techniques and *RAS* performed best overall, on the basis of either intermediate inputs or multipliers. The fabrication adjustment suggested by Round appeared to be a significant help for *RPC* only, and only when assessed on the basis of the average percentage difference. It made no difference for *RAS* because the initial matrices (with and without the fabrication adjustment) were very close. These results pertain only to this one small illustration.

[11] A particular feature of the McMenamin–Haring approach is that it employs the RAS technique on an entire transactions table, including the sales to final-demand sectors and the purchases from value-added sectors. That is, $\mathbf{u}^r$ and $\mathbf{v}^r$ are not needed; only $\mathbf{x}^r$ is used. This relaxes the data requirements but imposes the biproportionality assumption on not only the interindustry transactions but also on final-demand and value-added data. This is the basic point raised by Giarratani (1975).

Table 8.1 Total Intraregional Intermediate Inputs and Intraregional Output Multipliers for Region 1 (North China) Calculated from Several Regionalization Techniques

	Total Intraregional Intermediate Inputs			Percentage Differences[a]			Average Percentage Difference[b]	MAPE[c]
Survey	0.2891	0.5781	0.3466					
Using $\mathbf{A}^n$								
LQ	0.3166	0.6774	0.4019	9.54	17.19	15.96	14.23	12.41
CIQ	0.3169	0.6717	0.4022	9.64	16.20	16.03	13.96	12.54
FLQ	0.2541	0.5189	0.3113	−12.10	−10.23	−10.18	−10.84	13.04
AFLQ	0.2541	0.5290	0.3113	−12.10	−8.50	−10.18	−10.26	12.49
RPC	0.2827	0.5850	0.3495	−2.19	1.19	0.84	1.41[d]	7.17
RAS	0.2891	0.5781	0.3466	0	0	0	0	6.94
Using Round's $\mathbf{A}^r = \mathbf{A}^n\hat{\rho}^r$								
LQ	0.3222	0.6720	0.3943	11.45	16.24	13.75	13.82	12.17
CIQ	0.3225	0.6663	0.3945	11.56	15.27	13.82	13.55	12.31
FLQ	0.2585	0.5148	0.3054	−10.57	−10.95	−11.90	−11.14	13.33
AFLQ	0.2585	0.5247	0.3054	−10.57	−9.23	−11.90	−10.57	12.79
RPC	0.2877	0.5803	0.3429	−0.48	0.38	−1.08	0.65[d]	7.11
RAS	0.2891	0.5781	0.3466	0	0	0	0	6.94
	Intraregional Output Multipliers			**Percentage Differences[e]**			**Average Percentage Difference**	**MAPE[f]**
Survey	1.5311	2.1115	1.6620					
Using $\mathbf{A}^n$								
LQ	1.6765	2.5684	1.9201	9.50	21.63	15.53	15.55	25.06
CIQ	1.6734	2.5480	1.9148	9.29	20.67	15.21	15.06	23.74
FLQ	1.4309	1.9294	1.5515	−6.55	−8.63	−6.65	−7.28	15.93
AFLQ	1.4353	1.9590	1.5578	−6.26	−7.22	−6.27	−6.58	14.81
RPC	1.5108	2.1318	1.6700	−1.33	0.96	0.48	0.92[d]	3.50
RAS	1.5219	2.1145	1.6618	−0.60	0.14	−0.01	0.25[d]	2.79
Using Round's $\mathbf{A}^r = \mathbf{A}^n\hat{\rho}^r$								
LQ	1.6841	2.5425	1.8933	9.99	20.41	13.92	14.77	23.76
CIQ	1.6810	2.5226	1.8882	9.79	19.47	13.61	14.29	22.46
FLQ	1.4369	1.9172	1.5375	−6.15	−9.20	−7.49	−7.62	16.45
AFLQ	1.4413	1.9463	1.5436	−5.87	−7.82	−7.12	−6.94	15.35
RPC	1.5179	2.1163	1.6524	−0.86	0.23	−0.58	0.56[d]	3.13
RAS	1.5219	2.1145	1.6618	−0.60	0.14	−0.01	0.25[d]	2.79

[a] This is $\{[(\mathbf{i}'\tilde{\mathbf{A}} - \mathbf{i}'\mathbf{A}) \oslash \mathbf{i}'\mathbf{A}] \times 100\}$, where "$\oslash$" indicates element-by-element division.

[b] This is a simple, unweighted average. Various kinds of weightings (e.g., using some measure of the size of each sector) are frequently used.

[c] Calculated as $\left(\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{|a_{ij}-\tilde{a}_{ij}|}{a_{ij}}\right) \times 100$.

[d] This is the average of the absolute values of the differences, so that the negatives and positives do not cancel out.

[e] Calculated as $\{[(\mathbf{i}'\tilde{\mathbf{L}} - \mathbf{i}'\mathbf{L}) \oslash \mathbf{i}'\mathbf{L}] \times 100\}$.

[f] Calculated as $(\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{|l_{ij}-\tilde{l}_{ij}|}{l_{ij}}) \times 100$.

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Other applications (and other measures of error) could easily generate different outcomes in terms of rankings of the techniques. Problem 8.9 asks the reader to create similar results for either (or both) of the other two regions, the South and the Rest of China, in the Chinese data in Chapter 3. Results for those exercises are shown in the Solutions, for those who want to bypass the work. As can be seen, the sizes of errors vary a great deal across the three region results, and in one case *FLQ* and *AFLQ* perform very badly. Generally, *RAS* is seen to provide the best results.

Over the years there have been many empirical studies, generally much larger than the illustration in Table 8.1, in which various location quotient approaches to regional coefficient estimation, often along with RAS, have been compared, and, not unexpectedly, the results have varied. Examples include (but are not limited to) Czamanski and Malizia (1969), Schaffer and Chu (1969), Hewings (1969, 1971), Round (1972), Morrison and Smith (1974), Smith and Morrison (1974), Eskelinen and Suorsa (1980), Cartwright, Beemiller and Gusteley (1981), Alward and Palmer (1981), Harrigan, McGilvray and McNicoll (1981), Sawyer and Miller (1983), Stevens, Treyz and Lahr (1989), Flegg and Webber (2000), Tohmo (2004) and Riddington, Gibson and Anderson (2006). As always, the results often depend on the statistic(s) used to rate the techniques.

8.5 Exchanging Coefficients Matrices

Early in applied regional input–output work it was thought that an alternative to adapting a national table to reflect the economic characteristics of a particular region might be to adapt an existing table for some other region or, indeed, simply to use a table for one region as representing another region as well. For example, a coefficients table for a particular wheat-growing county in North Dakota might reflect very well the economic interrelations in another wheat-growing county in North Dakota, or probably also in South Dakota or Nebraska. However, less plausible would be the use of a survey-based table for Philadelphia to represent interrelations in the Boston or, less likely, San Francisco economy. How much and what kind of modifications would be necessary are much more complicated questions. In this regard, one can only make very broad and general statements; for example, if in the opinion of experts, two regions are very similar economically, then it is possible that a coefficients table for one of them may prove to be useful for the other also. Or it may be useful with appropriate modification; the problem is always how to decide what needs to be modified and how to go about doing it.

As an example of coefficient exchange at the regional level, Hewings (1977) used a survey-based table for Washington State for 1963 (Bourque and Weeks, 1969) to estimate Kansas interindustry structure in 1965; he also used a survey-based Kansas table for 1965 (Emerson, 1969) to estimate Washington's structure in 1963. After appropriate classification of the two tables into a comparable set of sectors, it was clear from inspection that there were many individual coefficients that were vastly different in the two tables. In a simple coefficient change, estimating Washington output with Kansas technology, as $\mathbf{x}^W = (\mathbf{I}-\mathbf{A}^{KK})^{-1}\mathbf{f}^W$ and similarly, estimating Kansas output with Washington technology, $\mathbf{x}^K = (\mathbf{I}-\mathbf{A}^{WW})^{-1}\mathbf{f}^K$, it was found that aggregate errors (for total

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output, summed over all sectors) were 4.8 percent (overestimate) for Washington and −12.6 percent (underestimate) for Kansas. However, as usual with aggregate measures of error, individual sector estimates were often very far off; the worst in Washington was overestimated by 336 percent and the worst in Kansas was overestimated by 114 percent. Thus, straightforward coefficient exchange could not be considered a success.

However, using the RAS procedure in conjunction with Kansas survey-based information on total intermediate outputs, total intermediate inputs, and total output, by sector, produced far superior results. That is, the Washington table (instead of a national table) was "balanced" by the RAS technique to conform to the observed Kansas marginal information. With the modification, total estimated Kansas output was underestimated by only 0.008 percent, and the largest error for an individual sector's output was only 0.195 percent.

To emphasize the relative importance of the marginal information in the RAS procedure, Hewings also "balanced" an artificial coefficient matrix made up of random numbers (but with column sums less than one). That is, the "base" matrix was a totally artificial one, which did not correspond to any national or regional table. Using a randomly generated new final-demand vector, he compared "true" gross outputs (using the actual Kansas table) with the RAS-adjusted Washington table and the RAS-adjusted random table. In these two cases, the total Kansas output, summed over all sectors, was overestimated by only 0.028 percent and underestimated by 0.192 percent, respectively. The worst errors in individual sector outputs were 3.7 percent (Washington table) and 5.6 percent (random table). The main lesson from this experiment appears to be that information on region-specific sectoral total intermediate outputs, $\mathbf{u}$, and inputs, $\mathbf{v}$, along with sectoral gross outputs, $\mathbf{x}$, are of dominant importance (as opposed to the base matrix) in an RAS adjustment procedure. (For a comment on the Hewings study and a reply, see Thumann, 1978 and Hewings and Janson, 1980. Also, see Szyrmer, 1989, for a discussion of experiments that indicate the importance of correct target-year marginal information in an RAS procedure.)

8.6 Estimating Interregional Flows

Earlier in this chapter, we examined some techniques that have been proposed and used to estimate regional input coefficients from existing regional or national tables. If two or more regions are to be connected in the model, then interregional coefficients are also needed. In Chapter 3 we saw what data are necessary in both the interregional and multiregional cases, and an example was provided from multiregional data for China in 2000 (in section 3.3.5).

Because of the extremely detailed data that are necessary for a full interregional model and because the US multiregional model was itself an extremely ambitious and time-consuming project, there are not many existing tables of interregional commodity flows or their associated coefficients that can be used as "base" tables to be updated, projected, or exchanged. Rather, a number of proposals have been explored for estimating these flows between sectors and regions. The techniques are sometimes relatively advanced,

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and a thorough survey is beyond the scope of this book. We indicate only some of the broad ideas that have been used.

8.6.1 Gravity Model Formulations

Many versions of gravity model formulations have been proposed and explored for estimating commodity flows between regions. The basic idea is that the flow of good i from region r to region s can be looked upon as a function of (1) some measure of the total output of i in $r, x_i^{r\cdot}$, (2) some measure of the total purchases of i in $s, x_i^{\cdot s}$, and (3) the distance (as a measure of "impedance") between the two regions, d^{rs}. One straightforward function, taking inspiration from Newton's observations on gravity (and hence the name for this class of models), would involve the product of the two "masses" ($x_i^{r\cdot}$ and $x_i^{\cdot s}$) divided by the square of the distance. A bit more generally,

$$z_i^{rs} = \frac{(c_i^r x_i^{r\cdot})(d_i^s x_i^{\cdot s})}{(d^{rs})^{e_i}} = (k_i^{rs}) \frac{x_i^{r\cdot} x_i^{\cdot s}}{(d^{rs})^{e_i}} \tag{8.15}$$

where c_i^r, d_i^s (alternatively, k_i^{rs}) and e_i are parameters to be estimated. (In the strictest Newtonian form, $e_i = 2$.)

As noted in Chapter 3, the gravity approach was suggested initially in an input–output context in Leontief and Strout (1963); it was also explored in Theil (1967). Leontief and Strout suggested the relatively simplified form

$$z_i^{rs} = \frac{x_i^{r\cdot} x_i^{\cdot s}}{x_i^{\cdot\cdot}} Q_i^{rs} \tag{8.16}$$

where $x_i^{r\cdot}$ is labeled the "supply pool" of good i in region r, $x_i^{\cdot s}$ is labeled the "demand pool" of good i in region s, $x_i^{\cdot\cdot}$ is the total production of commodity i in the system and Q_i^{rs} is a parameter. The authors write:

> The multiplicative form in which the total output of good i in the exporting and its total input in the importing regions enter into [(8.15)] permits us to characterize it as a special type of Gravity or Potential Model. It implies that there can be no flow from region r to region s if either one of those two magnitudes is equal to zero. The introduction of the aggregate output of good i into the denominator implies that, if the aggregate output [$x_i^{\cdot\cdot}$], as well as output [$x_i^{r\cdot}$] in region r and total input [$x_i^{\cdot s}$] in region s, double, the flow of that good from region r to region s will double too. [Leontief (1966) p. 226. The authors use g and h in place of r and s.]

Notice that the denominator in this formulation [(8.16)] is aspatial; that is, its magnitude is unrelated to any measure of "distance" between r and s. Rather, it provides the flexibility necessary so that if, for good i, the supply pool in r, the demand pool in s and total output all increase by p percent, then z_i^{rs} increases by that same percent (assuming $Q_i^{rs} > 0$). So the Q_i^{rs} term has something of the look of $\frac{k_i^{rs}}{(d^{rs})^{e_i}}$ from (8.15).

An important feature of this kind of formulation is that cross-hauling is allowed; that is, good i can be shipped simultaneously from r to s and from s to r. Specifically, if $x_i^{r\cdot}, x_i^{\cdot r}, x_i^{s\cdot}$, and $x_i^{\cdot s}$ are all nonzero, and if $Q_i^{rs} > 0$ and $Q_i^{sr} > 0$, then both $z_i^{rs} > 0$ and $z_i^{sr} > 0$.

Miller, Ronald E.; Blair, Peter D.. Input-Output Analysis : Foundations and Extensions.
Cambridge, , GBR: Cambridge University Press, 2009. p 365.
http://site.ebrary.com/lib/mitlibraries/Doc?id=10329730&ppg=399

The most optimistic scenario is that values of $x_i^{r\cdot}, x_i^{\cdot s}, x_i^{\cdot\cdot}$, and z_i^{rs} are known from some base period or for some subset of transportation data. In that case, one can evaluate the parameter Q_i^{rs} from those data, as

$$Q_i^{rs} = \frac{\bar{z}_i^{rs}\bar{x}_i^{\cdot\cdot}}{\bar{x}_i^{r\cdot}\bar{x}_i^{\cdot s}}$$

where overbars indicate known values. Leontief and Strout also discuss a number of alternative ways of estimating the Q_i^{rs} in cases where there is no base-case information.

Polenske (1970a) tested the Leontief–Strout gravity approach, using Japanese interregional flow data. She also compared the gravity formulation with the Chenery–Moses MRIO model (section 3.4) and one other alternative, known as a "row-coefficient" version of the MRIO model. The gravity and MRIO estimates were about equally good and far better than those obtained from the row-coefficient model (Polenske, 1970b). Estimates based on gravity models have also appeared in Uribe, de Leeuw and Theil (1966) and Gordon (1976) among others. Lindall, Olson, and Alward (2006) use a gravity formulation to estimate gross trade flows for some 509 commodities and 3140 counties in the USA. One outcome is that their results allow for estimation of a set of regional purchase coefficients (RPCs) for each county, using their results for each county's commodity i trade with itself divided by total county demand for i.

The gravity approach was embedded in a general entropy-maximizing framework in a number of papers by Wilson. An overview is provided by Wilson (1970, especially Chapter 3).[12] Connections with information theory have been suggested, and this has been thoroughly explored by Batten (1982, 1983) and applied in Snickars (1979). Batten's empirical studies combine iterative (RAS-like) methods with a maximum entropy formulation and, if required, additional variations ("minimum information gain" procedures). (See Batten, 1983, especially Chapter 5 and Appendix E.) Batten and Boyce (1986) review gravity-based and other spatial interaction models.

8.6.2 *Two-Region Interregional Models*

A number of estimation methods for interregional models are simplifications or variants of the quotient techniques discussed above. Essentially, they use some measure of a region's import or export orientation with respect to each good; and if region r is found to be an exporter of good i, then it is assumed that all the requirements for i in region r will be met by local production and hence there will be no imports of i to region r (no cross-hauling). One important feature in a two-region interregional model is that one region's (domestic) exports of a particular good are the other region's (domestic)

[12] A compact discussion of MRIO, gravity, and entropy-maximizing models can also be found in Toyomane (1988). He also develops and applies two alternative multinomial logit models of trade coefficients to an Indonesian example. Amano and Fujita (1970) combine MRIO and econometric models to allow both input coefficients and trade coefficients to change over time. Details of these models are beyond the scope of this book.

imports. From (8.4), since

$$a_{ij}^{rr} = \begin{Bmatrix} (LQ_i^r)a_{ij}^n & \text{if } LQ_i^r < 1 \\ a_{ij}^n & \text{if } LQ_i^r \geq 1 \end{Bmatrix}$$

then, in a two-region interregional model (with regions r and s),

$$a_{ij}^{sr} = \begin{Bmatrix} (1 - LQ_i^r)a_{ij}^n & \text{if } LQ_i^r < 1 \\ 0 & \text{if } LQ_i^r \geq 1 \end{Bmatrix}$$

For example, if $LQ_i^r = 0.65$, then the assumption is that 35 percent of the needs of input i by sectors in region r will be met by imports from region s.

A simple procedure of this sort was used in early studies by Nevin, Roe and Round (1966) for a two-region model in the United Kingdom and by Vanwynsberghe (1976) for a three-region Belgian model. Examination of a wide variety of nonsurvey techniques in an (especially two-region) interregional setting is contained in a series of papers by Round (1972, 1978a, 1978b, 1979, and 1983), to which the interested reader is referred. An alternative approach used in several Swedish regional studies is outlined in Andersson (1975) and modifications are suggested in Bigsten (1981). As we will see below, there have been attempts to modify the two-region approach for cases in which more than two regions are present.

8.6.3 Two-Region Logic with more than Two Regions

The logic of the "balancing" inherent in two-region models – where one region's (domestic) exports of i are the other region's (domestic) imports of i – appears to have first been extended to more than two regions by Hulu and Hewings (1993; five regions); later examples include Hewings, Okuyama and Sonis (2001; four regions) and Bonet (2005; seven regions). The essential idea is to use location quotients, a sequence of two-region models, and an RAS balancing approach. A three-region setting is adequate to illustrate the process.

1. Consider a two-region context where regions 2 and 3 have been aggregated; let r = region 1 and $\tilde{r}$ = the rest of the economy (the remaining two regions). Use location quotients for r to estimate $\mathbf{A}^{rr} = [a_{ij}^{rr}]$ in the usual way from a known national coefficient matrix, $\mathbf{A}^n$; $a_{ij}^{rr} = \begin{Bmatrix} (LQ_i^r)a_{ij}^n & \text{if } LQ_i^r < 1 \\ a_{ij}^n & \text{if } LQ_i^r \geq 1 \end{Bmatrix}$. Then import coefficients from the rest of the economy to r, $\mathbf{A}^{\tilde{r}r} = [a_{ij}^{\tilde{r}r}]$, are found as $a_{ij}^{\tilde{r}r} = a_{ij}^n - a_{ij}^{rr}$.

Similarly, find $\mathbf{A}^{\tilde{r}\tilde{r}} = [a_{ij}^{\tilde{r}\tilde{r}}]$ using location quotients for the aggregate "rest of the economy" region (regions 2 and 3 in this case). Finally, imports from region 1 to the rest of the economy, $\mathbf{A}^{r\tilde{r}} = [a_{ij}^{r\tilde{r}}]$, are found as $a_{ij}^{r\tilde{r}} = a_{ij}^{n} - a_{ij}^{\tilde{r}\tilde{r}}$. The result is $\begin{bmatrix} \mathbf{A}^{11} & \mathbf{A}^{1\bar{1}} \\ \mathbf{A}^{\bar{1}1} & \mathbf{A}^{\bar{1}\bar{1}} \end{bmatrix}$.

2. Repeat this procedure for each of the other possible two-region partitions ($r = 2, \tilde{r} = 1, 3$ and $r = 3, \tilde{r} = 1, 2$), giving $\begin{bmatrix} \mathbf{A}^{22} & \mathbf{A}^{2\bar{2}} \\ \mathbf{A}^{\bar{2}2} & \mathbf{A}^{\bar{2}\bar{2}} \end{bmatrix}$ and $\begin{bmatrix} \mathbf{A}^{33} & \mathbf{A}^{3\bar{3}} \\ \mathbf{A}^{\bar{3}3} & \mathbf{A}^{\bar{3}\bar{3}} \end{bmatrix}$.

   This information can be arranged as in the table below. Missing, of course, are the interregional coefficients (shaded areas).

$\mathbf{A}^{11}$			$\mathbf{A}^{1\bar{1}}$
	$\mathbf{A}^{22}$		$\mathbf{A}^{2\bar{2}}$
		$\mathbf{A}^{33}$	$\mathbf{A}^{3\bar{3}}$
$\mathbf{A}^{\bar{1}1}$	$\mathbf{A}^{\bar{2}2}$	$\mathbf{A}^{\bar{3}3}$	

3. Convert coefficients to flows. For example, using known outputs $\mathbf{x}^1$ and $\mathbf{x}^{\bar{1}}$, find $\begin{bmatrix} \mathbf{A}^{11} & \mathbf{A}^{1\bar{1}} \\ \mathbf{A}^{\bar{1}1} & \mathbf{A}^{\bar{1}\bar{1}} \end{bmatrix} \begin{bmatrix} \hat{\mathbf{x}}^1 & \mathbf{0} \\ \mathbf{0} & \hat{\mathbf{x}}^{\bar{1}} \end{bmatrix} = \begin{bmatrix} \mathbf{Z}^{11} & \mathbf{Z}^{1\bar{1}} \\ \mathbf{Z}^{\bar{1}1} & \mathbf{Z}^{\bar{1}\bar{1}} \end{bmatrix}$. Similar calculations can be made for $r = 2$ and 3, producing

$\mathbf{Z}^{11}$			$\mathbf{Z}^{1\bar{1}}$
	$\mathbf{Z}^{22}$		$\mathbf{Z}^{2\bar{2}}$
		$\mathbf{Z}^{33}$	$\mathbf{Z}^{3\bar{3}}$
$\mathbf{Z}^{\bar{1}1}$	$\mathbf{Z}^{\bar{2}2}$	$\mathbf{Z}^{\bar{3}3}$	

   (The three $\mathbf{Z}^{\tilde{r}\tilde{r}}$ matrices that are generated in these calculations are ignored.)

4. The (shaded) off-diagonal flow matrices remain to be estimated. If these empty cells are filled with initial estimates, an RAS procedure can be applied. The extremely simplifying assumption is made that imports to any particular (on-diagonal) region come equally from all other (here both) regions; e.g., $\mathbf{Z}^{21} = \mathbf{Z}^{31} = (1/2)\mathbf{Z}^{\bar{1}1}$. Thus all cells now contain initial estimates.

Miller, Ronald E.; Blair, Peter D.. Input-Output Analysis : Foundations and Extensions.
Cambridge, , GBR: Cambridge University Press, 2009. p 368.
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$\mathbf{Z}^{11}$	$\mathbf{Z}^{12}$	$\mathbf{Z}^{13}$	$\mathbf{Z}^{1\bar{1}}$
$\mathbf{Z}^{21}$	$\mathbf{Z}^{22}$	$\mathbf{Z}^{23}$	$\mathbf{Z}^{2\bar{2}}$
$\mathbf{Z}^{31}$	$\mathbf{Z}^{32}$	$\mathbf{Z}^{33}$	$\mathbf{Z}^{3\bar{3}}$
$\mathbf{Z}^{\bar{1}1}$	$\mathbf{Z}^{\bar{2}2}$	$\mathbf{Z}^{\bar{3}3}$	

5. Eliminate the on-diagonal matrices. Given the row and column margins, which account only for interregional flows (the shaded portions), use RAS to create a balanced table. (The table conforms to the column sums by the way in which it was constructed, but not to the row sums.)

$\mathbf{0}$	$\mathbf{Z}^{12}$	$\mathbf{Z}^{13}$	$\mathbf{Z}^{1\bar{1}}$
$\mathbf{Z}^{21}$	$\mathbf{0}$	$\mathbf{Z}^{23}$	$\mathbf{Z}^{2\bar{2}}$
$\mathbf{Z}^{31}$	$\mathbf{Z}^{32}$	$\mathbf{0}$	$\mathbf{Z}^{3\bar{3}}$
$\mathbf{Z}^{\bar{1}1}$	$\mathbf{Z}^{\bar{2}2}$	$\mathbf{Z}^{\bar{3}3}$	

If the presence of null matrices creates convergence problems (as it did in the articles cited), reintroduce the on-diagonal matrices, alter the margins accordingly, and reapply RAS.

8.6.4 Estimating Commodity Inflows to a Substate Region

Liu and Vilain (2004) start with known commodity flow data for US states from the 1993 US Commodity Flow Survey (US Department of Commerce, 1993) and national commodity-by-industry input–output data. They derive commodity inflows to a substate region using features of a supply-side, commodity-by-industry model and secondary data on the region's industrial structure. Their two-step procedure first scales each commodity's national "output coefficients" (using the terminology of the supply-side input–output model which is discussed in Chapter 12) to a state level. These coefficients are commodity sales to industries as a proportion of the selling sector's output, rather than commodity purchases as a proportion of the buying sector's output; they represent the distribution across buyers instead of across sellers in the usual input–output model. The second step then scales the state-level coefficients to a regional (substate) level. In both cases, the scaling is done using location quotients, but on these output coefficients, rather than on input coefficients as in the approaches of section 8.2.

Given a national Use matrix, $\mathbf{U}^N$, and total commodity outputs, $\mathbf{q}^N$, find $\mathbf{B}^N = (\hat{\mathbf{q}}^N)^{-1}\mathbf{U}^N$, where b_{ij}^N indicates the share of total commodity i output that is sold to industry j.[13] Convert these national output shares to the state-level shares using state-specific location quotients. [The authors use industry earnings as the basis for their location quotients but recognize that other alternatives (e.g., employment) are possible.] That is, create $\mathbf{B}^S = \mathbf{B}^N \langle \mathbf{lq}^S \rangle$ where $\mathbf{lq}^S = [LQ_i^S]$ and LQ_i^S is the earnings-based location quotient for sector i in the state.[14] In contrast to the way in which location quotients are used for regionalizing national input coefficients (sections 8.2.1–8.2.4), if a given $LQ_i^S > 1$ then the associated b_{ij}^N (for all j) are increased. Next, normalize the elements in each row of $\mathbf{B}^S$ by dividing by the row sum (so that all row sums in the normalized matrix will equal 1) – $\tilde{\mathbf{B}}^S = \mathbf{B}^S \langle \mathbf{B}^S \mathbf{i} \rangle^{-1}$, so $\tilde{b}_{ij}^S = b_{ij}^S / \sum_j b_{ij}^S$. Each $\tilde{b}_{ij}^S$ is an estimate of the proportion of commodity i shipped into the state that will be used by industry j in the state.[15] Let $\mathbf{m}^S$ be a vector of inflows to the state of the m commodities (known from the Commodity Flow Survey). Then the matrix $\boldsymbol{\rho}^S = \hat{\mathbf{m}}^S \tilde{\mathbf{B}}^S$ apportions the inflows of the m commodities among the n industries (including households); ρ_{ij}^S is the amount of commodity i flowing to industry j in the state. (In the notation of Chapter 3, this is an estimate of $z_{ij}^{\cdot S}$, an element in the MRIO model.)

The next step moves to the regional (substate) level. Estimate another matrix of location quotients, $\mathbf{LQ}^R$, this time for the region, measuring the relative representation of each industry in the region. Then define $\boldsymbol{\rho}^R = \boldsymbol{\rho}^S \langle \mathbf{lq}^R \rangle = \hat{\mathbf{m}}^S \tilde{\mathbf{B}}^S \langle \mathbf{lq}^R \rangle$; ρ_{ij}^R is an approximation of the amount of commodity i shipped to the state that is used by industry j in the region in question.[16] In terms of transportation planning, row sums of $\boldsymbol{\rho}^R$ may also be of interest; they are estimates of the total amount of each commodity that is shipped to the region – $\boldsymbol{\varphi}^R = \boldsymbol{\rho}^R \mathbf{i} = [\phi_i^R]$, where ϕ_i^R is the total regional inflow of commodity i.

The authors apply the method to commodity inflow to seven states and compare their results with known inflows (from the 1993 Commodity Flow Survey; that is, they assume the "regions" are in fact states in order to have data with which to compare their estimates). For six of the seven states, mean absolute percentage errors (MAPEs) were between 16 and 30 (with large variation among commodities) and for one state, the MAPE was 71. This method is compared with results from the Jackson *et al.* approach, discussed immediately below.

[13] We use upper-case superscripts "N," "S," and "R" to denote nation, (subnational) state and (substate) region, respectively, since lower-case superscripts are generally reserved for individual and distinct regions (e.g., "r" and "s").

[14] This notation is a bit unconventional. The vector of location quotients for the state is denoted by lower-case bold letters, $\mathbf{lq}^S$ (our convention for vectors throughout this book), but its elements are upper-case, LQ_i^S, to conform with the usual convention for representing location quotients, as in section 8.2.1, even though the usual notation for elements of the $\mathbf{lq}^S$ vector would be lq_i^S.

[15] The normalization is done so that 100 percent of the inflow of each commodity will be used up by purchasing sectors in the state. The authors work with a closed model, so household consumption of imported commodities is accounted for.

[16] Notice that these are akin to the *regional sales coefficients* of Oosterhaven and his colleagues in the Netherlands (section 8.7.2).

8.6.5 Additional Studies

Commodity Flows among US States

Interregional Social Accounts Model (ISAM). In two articles (Jackson *et al.*, 2006; Schwarm, Jackson and Okuyama, 2006) single-state SAMs are constructed using data derived from IMPLAN. (In the second article, the acronym *ISAG* is used, for *Interregional Social Accounts Generator*.) The authors estimate interregional commodity-by-industry flows connecting the states in an attempt to improve on the commodity flow survey (CFS) data from the Bureau of Transportation Statistics. The system consists of 51 regions (states plus DC), 54 industry/commodity sectors, 4 factors of production, and 18 institutions. The primary effort is to derive an estimating equation to distribute known regional domestic exports (from the single-region SAMs) from each region to each other domestic region in the model. (Intraregional flows are generated in the construction of each of the single-region SAMs, and they are assumed to be correct.) The authors assume that distributions of exports from one region to all others are fixed, while export levels vary with regional production.

The preferred estimating equation is a function of transportation costs (interregional distances) and region-specific commodity demand. It has the form

$$z_i^{rs} = \frac{(w_i^s)^{\alpha_i} \exp(-\beta_i d^{rs})}{\sum\limits_s (w_i^s)^{\alpha_i} \exp(-\beta_i d^{rs})} z_i^{r\cdot}$$

where w_i^s is a measure of region s's demand for imports of commodity i and d^{rs} is some measure of the distance between r and s, and where α and β are elasticities on commodity demand and distance, respectively. These elasticities are estimated in an optimization model in which a measure of total absolute deviation between estimated flows and their associated observed benchmark flows is minimized. (The many details, including how a set of benchmark figures is generated, are relatively complex. The interested reader is referred to Jackson *et al.*, 2006.) At various points, biproportional (RAS) adjustments are required to ensure consistency with known national figures.

National Interstate Economic Model (NIEMO). An ambitious project to revitalize the US MRIO model is underway at the University of Southern California in its Center for Risk and Economic Analysis of Terrorism Events (CREATE). This effort updates the outdated US MRIO models for 1963 and 1977 (Chapter 3) in a framework of 47 sectors and 52 regions (50 states, the District of Columbia and the Rest of the World) and uses the model in many empirical applications. There are numerous publications, beginning around 2005, that discuss the derivation of the model and various extensions and applications; these include Park *et al.* (2004) and Richardson, Gordon and Moore (2007, especially the chapters by Park *et al.* and Richardson *et al.*).

The basic model-building idea is to integrate data from 2001 IMPLAN state-level input–output models (for intrastate coefficients) with commodity flow data from the US Department of Transportation's 1997 Commodity Flow Survey (for interregional coefficients) in an MRIO framework. There are many issues with the data sets alone – for example, reconciling the 509 IMPLAN sectors with the 43 sectors in the CFS data and dealing with the absence of interstate trade in services and many other empty cells in the CFS data. Instead of a gravity-model approach (as in the work of Jackson *et al.*, above), NIEMO uses a doubly constrained Fratar model (a biproportional matrix balancing technique – similar to RAS – from the transportation engineering literature) to generate interregional coefficients.

This work has been extended in many directions: (a) to a supply-driven model, for example, to quantify effects of terrorist attacks on ports (import disruptions), (b) to a price-sensitive supply-side model, incorporating exogenous price elasticities of demand and (c) to a flexible model, in which input and output coefficients matrices are altered in an RAS procedure as a result of natural disaster or terrorist attack. Among the several applications, in addition, are assessments of the sectoral/spatial impact of an outbreak of mad cow disease, Mexico–US border closure and attacks on theme parks.

An Optimization Model for Interregional Flows In Canning and Wang (2005), the authors formulate a quadratic programming problem to estimate interregional, interindustry transaction flows in a national system of regions. They choose a mathematical programming approach because of the flexibility that such a format provides for incorporating constraints (adding-up constraints, upper and/or lower limits on values of individual variables, etc.). While the ultimate goal is to estimate the elements of a several-region interregional input–output (IRIO) model, practical considerations mandated that a simpler multiregional (MRIO) model be used. (These models are explored in Chapter 3.) Variables to be estimated are regional inputs (ignoring regional origin), $z_{ij}^{\cdot r}$, and interregional flows (ignoring sectoral destination), z_i^{rs}. The approach requires a national input–output table and regional data on gross outputs (x_i^r), value added (v_i^r), final demand (f_i^r), exports to foreign destinations (e_i^r) and imports from abroad (m_i^r).

Specifically, consistency conditions for variables z_i^{rs} and $z_{ij}^{\cdot r}$ in the MRIO model require:

1. For each commodity i and region r, total output is completely distributed to users (intermediate and final) in all regions plus overseas

$$\sum_{s=1}^{p} z_i^{rs} + e_i^r = x_i^r$$

2. For each i and r, the value of gross output is attributable to intermediate inputs (regardless of their origin) plus primary inputs (value added)

$$\sum_{j=1}^{n} z_{ji}^{\cdot r} + v_i^r = x_i^r$$

3. Total requirements (intermediate plus final) for i in r are completely met by shipments from all regions (including r) plus imports from overseas

$$\sum_{j=1}^{n} z_{ij}^{\cdot r} + f_i^r = \sum_{s=1}^{p} z_i^{sr} + m_i^r$$

4. Intermediate purchases of commodity i by sector j in region r, when summed over all regions, must equal the national (superscript N) transaction amount

$$\sum_{r=1}^{p} z_{ij}^{\cdot r} = z_{ij}^{N}$$

In addition, constraints from the national accounts specify that regional output, value added, final demand, foreign exports and imports, for each commodity i, when summed over all regions, are equal to their associated national totals. That is, $\sum_{r=1}^{p} x_i^r = x_i^N$, $\sum_{r=1}^{p} v_i^r = v_i^N$, $\sum_{r=1}^{p} f_i^r = f_i^N$, $\sum_{r=1}^{p} e_i^r = e_i^N$, and $\sum_{r=1}^{p} m_i^r = m_i^N$. These linear equations can be incorporated easily as constraints into a mathematical programming format.

Subject to these (or similar) constraints, the authors suggest an objective function in which deviation from prespecified "estimates" of the unknowns is minimized. In their formulation, this takes the form of a weighted quadratic function. There are many options for how this is specified, and the details are beyond the scope of this book.

The authors present one application to a 4-region, 10-sector data set.[17] The results for this one application indicated relative success with respect to estimates of the interregional flows (z_i^{rs}), with mean average percentage errors (MAPEs) in the 4–7 percent range, while MAPEs for the regional inputs ($z_{ij}^{\cdot r}$) were less impressive (in the 15–20 percent range). Notice that a two-region model (region r and the rest of the nation) could be cast in this format, taking advantage of the adding-up constraints above.

8.7 Hybrid Methods

In this section we summarize a few of the (many) approaches that have been used by researchers in many parts of the world to derive regional input–output data. This represents only a small sample of real-world studies, virtually all of which use a hybrid approach with a combination of "superior data" or partial surveys and RAS or other techniques. As will be seen, these methods often embed the (intra)regional table estimation problem in a larger several-region system. Because of their tendency to (at least originally) focus on a regional table, we include them here rather than below, in section 8.8, on estimating interregional flows. However, the division is rather arbitrary, since some of the approaches in the later section also generate estimates of intraregional data.

[17] The "regions" were large – Japan, the USA, the EU, and the rest of the world.

8.7.1 Generation of Regional Input–Output Tables (GRIT)

A great deal of work has been done by Jensen and West and their colleagues in Australia on procedures for deriving input–output tables for various regions of that country, starting with a national table, employing allocation and quotient methods and paying attention to "superior data" and expert opinion when and as available. They have named this the GRIT technique. (See, for example, Jensen, Mandeville and Karunaratne, 1979 or West, 1990.) It has a long history, beginning in the late 1970s (those results are now known as "GRIT I"). Modifications led to "GRIT II" in the 1980s and then a version for estimating two or more regional tables and merging them into an interregional table ("GRIT III").[18] It is generally described as consisting of five steps (see Hewings and Jensen, 1986, for example):

1. Identify and adjust a "parent" table. Generally this will be a national table from time $(t-1)$ for the country in which the region of interest is located. This may be a transactions table or a coefficients table. Assume that the table incorporates competitive imports, so that the coefficients are true national technical coefficients, $\mathbf{A}^{\cdot n}(t-1)$. This will generally need to be updated from time $(t-1)$ to time t using RAS or some alternative technique – $\mathbf{A}^{\cdot n}(t-1) \rightarrow \mathbf{A}^{\cdot n}(t)$.[19]
2. Use some allocation or quotient method to convert national to regional coefficients; $a_{ij}^{\cdot r}(t) = r_{ij}^{r} a_{ij}^{\cdot n}(t)$ and then adjust for regional imports (e.g., using regional purchase coefficients) to produce an initial estimate of intraregional input coefficients, $a_{ij}^{rr}(t) = \rho_i^r a_{ij}^{\cdot r}(t)$.
3. Insert superior data from surveys, expert opinion, etc.
4. Define the appropriate regional sectors, usually through (weighted) aggregation of the national sectors. Insert additional superior data again, after the aggregation, in those cases where such information is known only at this more aggregated level. This might be done especially for "critical" (e.g., "inverse-important") cells, however determined (see section 12.3.3). The results are a prototype regional transactions table, $\mathbf{Z}^{rr}(p) = [z(p)_{ij}^{rr}]$, with an associated coefficients matrix $\mathbf{A}^{rr}(p)$ and Leontief inverse, $\mathbf{L}^{rr}(p) = [\mathbf{I} - \mathbf{A}^{rr}(p)]^{-1}$.
5. Using superior data and opinion once again – for example, by comparing multipliers derived from $\mathbf{L}^{rr}(p)$ in step (4) with those for "similar" regions – derive final versions of $\mathbf{Z}^{rr}$, $\mathbf{A}^{rr}$, and $\mathbf{L}^{rr}$.

Over the recent past, increasing emphasis has been placed on obtaining superior data from the outset, including extensive searches of published data (public and private sources) and special requests to national, state and local government agencies, followed by surveys.

18 A description of much of this history can be found in West, Morison and Jensen (1982).
19 If the initial tables are *national* transactions (exports excluded) then the import element for each sector (column) must be allocated up that column to the individual entries.

Miller, Ronald E.; Blair, Peter D.. Input-Output Analysis : Foundations and Extensions.
Cambridge, , GBR: Cambridge University Press, 2009. p 374.
http://site.ebrary.com/lib/mitlibraries/Doc?id=10329730&ppg=408

Table 8.2 Components in the DEBRIOT Approach

Intra- and Interregional Transactions	To Region r	To Region s	Regional Sales to Domestic Markets
From Region r	$\mathbf{Z}^{rr}, \mathbf{F}^{rr}$	$\mathbf{Z}^{rs}, \mathbf{F}^{rs}$	$\mathbf{Z}^{rn}, \mathbf{F}^{rn}$
From Region s	$\mathbf{Z}^{sr}, \mathbf{F}^{sr}$	$\mathbf{Z}^{ss}, \mathbf{F}^{ss}$	$\mathbf{Z}^{sn}, \mathbf{F}^{sn}$
Regional Use of Domestic Products	$\mathbf{Z}^{nr}, \mathbf{F}^{nr}$	$\mathbf{Z}^{ns}, \mathbf{F}^{ns}$	

8.7.2 Double-Entry Bi-Regional Input–Output Tables (DEBRIOT)

Researchers in the Netherlands have developed an extensive set of regional (and interregional) input–output tables for that country. [See Oosterhaven, 1981, for work up until the 1980s, Boomsma and Oosterhaven, 1992, for a description of the DEBRIOT approach and Eding *et al.*, 1999, for the procedure when one starts with regional Make (supply) and Use tables.] Most of these are of the two-region sort – the region of interest (r) and the rest of the country (s). The primary object is to estimate an intraregional transactions matrix, $\mathbf{Z}^{rr}$ (the elements in the light gray area in Table 8.2). Toward that end, the procedure requires estimates of regional sales to domestic markets and regional use of domestic products, the elements in the dark gray areas. As a result of the two-region nature of the accounts, the approach also generates $\mathbf{Z}^{rs}, \mathbf{Z}^{sr}$, and $\mathbf{Z}^{ss}$ (the matrices in the medium gray areas).[20]

The approach is based on observation that firms in the Netherlands are generally better informed about the spatial destination of their sales than they are about the spatial origin of their purchases. Thus attention is directed not primarily to purchase data (as is the case with regional purchase coefficients) but to information on the sectoral and spatial destination of sales. Also, there is an almost total absence of quotient methods, and hence the inherent upward bias associated with the no cross-hauling feature of those methods may be mitigated.

These major components of DEBRIOT are:

1. $\mathbf{Z}^{nr} = [z_{ij}^{nr}]$, the regional *domestic use matrix* for region r. Here the superscript n indicates the nation, i.e., $r + s$.[21] So z_{ij}^{nr} is the use by sector j in region r of i goods produced domestically, in either r or s. Estimate the regional *technology* matrix (transactions) by applying national technology coefficients, (z_{ij}^{n}/x_j^{n}), assumed

[20] In all cases, $\mathbf{F}$ (a matrix) is used to allow for disaggregation of final demand, including possibly households distinguished by income brackets, etc. In the simplest of models, we would have $\mathbf{f}$ (a vector). In this brief summary we use $\mathbf{Z}$ (transactions) matrices. In a commodity-by-industry accounting setting, one would deal with $\mathbf{U}$ (Use) matrices.

[21] Recall that notation such as $\mathbf{Z}^{rs}$ describes transactions between sectors in two spatially distinct regions, r and s. Here $\mathbf{Z}^{nr}$ describes purchases by sectors in r from the national pool of domestic outputs, some of which come from sectors in r and some from sectors in s.

known, to regional total use, also known: $z_{ij}^{\cdot r} = (z_{ij}^{\cdot n}/x_j^n)x_j^r$.[22] Next, it is assumed that each $z_{ij}^{\cdot r}$ can be broken down into its domestic and foreign components: $z_{ij}^{\cdot r} = z_{ij}^{nr} + m_{ij}^r$. This may be done by using the national import coefficients, m_{ij}^n, to reduce $z_{ij}^{\cdot r}$ by the *national* proportion of imports of i to total use of i

$$z_{ij}^{nr} = z_{ij}^{\cdot r} - (m_{ij}^n / z_{ij}^{\cdot n}) z_{ij}^{\cdot r} = [1 - (m_{ij}^n / z_{ij}^{\cdot n})] z_{ij}^{\cdot r}$$

Construct $\mathbf{Z}^{ns} = \left[z_{ij}^{ns} \right]$ similarly from information on rest-of-nation output, x_j^s, and construct $\mathbf{F}^{nr}$ and $\mathbf{F}^{ns}$ similarly.

2. $\mathbf{Z}^{rn} = \left[z_{ij}^{rn} \right]$, the regional *domestic sales matrix* for region r. Survey to find an *overall regional domestic export coefficient* for sector i in region r, $t_i^{rs} = (z_{i\cdot}^{rs} + f_{i\cdot}^{rs})/(x_i^r - e_i^r)$. The denominator is total domestic sales of i made in r, the numerator is the total amount of i made in r that went to s, and so this ratio is the *proportion* of r's total domestic sales of i that went to s. Similarly, $(1 - t_i^{rs}) = t_i^{rr}$ is the *proportion* that remained in r.[23] Using t_i^{rs}, estimate *nonsurvey region r domestic sales coefficients* as a weighted average of the demand structure of the rest of the country and the region of interest:

$$s_{ij}^{rn} = t_i^{rs}[z_{ij}^{ns}/(z_{i\cdot}^{ns} + f_{i\cdot}^{ns})] + (1 - t_i^{rs})[z_{ij}^{nr}/(z_{i\cdot}^{nr} + f_{i\cdot}^{nr})]$$

The denominator in the first bracketed expression is the total amount of i from all domestic sources $(r + s)$ that is demanded in region s, and so the expression in brackets is the proportion of that total used by sector j in s. Multiplication by t_i^{rs} (the proportion of r's domestic sales of i that went to s) generates an estimate of the proportion of domestically supplied i from r used by j in s. The second bracketed term on the right represents the proportion of the total amount of i from all domestic sources used by sector j in r. Thus the sum on the right-hand side represents the proportion of domestically supplied i from r used by j in the nation. Then the regional sales to the domestic market are estimated as $z_{ij}^{rn} = s_{ij}^{rn}(x_i^r - e_i^r)$. Construct $\mathbf{Z}^{sn}, \mathbf{F}^{rn}$, and $\mathbf{F}^{sn}$ similarly.

3. Construction of $\mathbf{Z}^{rr}, \mathbf{Z}^{rs}$, and $\mathbf{Z}^{sr}$. Note, initially, that

$$z_{ij}^{rr}(\max) = \min(z_{ij}^{nr}, z_{ij}^{rn})$$

from which

$$z_{ij}^{rs}(\min) = z_{ij}^{rn} - z_{ij}^{rr}(\max)$$

and

$$z_{ij}^{sr}(\min) = z_{ij}^{nr} - z_{ij}^{rr}(\max)$$

[22] Boomsma and Oosterhaven use $z_{ij}^{\cdot r} = [z_{ij}^{\cdot n}/(x_j^n - v_j^n)](x_j^r - v_j^r)$ to account for Round's fabrication effect (see above), but that detail need not concern us at this point.

[23] These have been called *regional sales coefficients* (*RSC*), in contrast to *regional purchase coefficients* (*RPC*) that were discussed in Chapter 3 and earlier in this chapter.

Survey "important" cells (again, however defined) to find cell-specific domestic export coefficients t_{ij}^{rs}. Then $z_{ij}^{rs} = t_{ij}^{rs} z_{ij}^{rn}$, from which, by subtraction, $z_{ij}^{rr} = z_{ij}^{rn} - z_{ij}^{rs} = (1 - t_{ij}^{rs}) z_{ij}^{rn}$. For all other cells in $\mathbf{Z}^{rr}$, z_{ij}^{rr} (max) is decreased until it reaches a level that is consistent with the overall domestic export coefficient t_i^{rs}, from which z_{ij}^{rs} and z_{ij}^{sr} can then also be found.[24]

4. Finally, $\mathbf{Z}^{ss} = \mathbf{Z}^{nn} - \mathbf{Z}^{rr} - \mathbf{Z}^{rs} - \mathbf{Z}^{sr}$.

8.7.3 The Multiregional Input–Output Model for China, 2000 (CMRIO)

Early work on national input–output tables in China apparently began in the 1960s. Starting in 1987, the National Bureau of Statistics (NBS) produced survey-based tables every five years (1987, 1992, 1997, etc.), and regions (provinces) construct their own regional input–output tables (except Tibet and Hainan), with the same sector classifications and for the same years as the national tables. (See Chen, Guo and Yang, 2005. Also see Polenske and Chen, 1991, for a history of Chinese input–output work up to that time.)

There also was some early work on connected-regional models, with three regions and ten sectors. A much more ambitious multiregional model for China was produced for the year 2000 (CMRIO), with eight regions (provinces) and four levels of aggregation – three, eight, 17, and 30 sectors. [The main references are Institute of Developing Economies–Japan External Trade Organization (IDE-JETRO), 2003 and Okamoto and Ihara, 2005.[25] The IDE-JETRO publication contains results for three, eight, and 17 sectors; the 30-sector data are on an accompanying CD-ROM disc.] Details concerning the construction of this ambitious data set are contained in Okamoto and Zhang (2003), who note that regional economic disparity "… has become the main topic for Central government of China" (p. 9), and this underscored the need for a multiregional input–output approach. Similar observations are made in Okamoto and Ihara (p. 201)[26]:

> Recent studies on the regional development of China have shown that regional disparity has become a significant problem and this has led many policy makers and researchers to pay attention to the issue of how we might develop the underdeveloped regions of the nation. It should be noted, however, that most of the approaches to date have focused on the situations in specific regions, rather than considering interregional interdependency. Therefore, in order to add something substantial to these previous studies, we felt the need to consider the interregional feedback effects and/or spatial interactions quantitatively. This was the main reason why we compiled a full-scale interregional input-output model for China as a useful analytical tool for considering spatial economy.

24 Details abound, and can be found in Boomsma and Oosterhaven, 1992.

25 IDE in Tokyo, Japan, was founded in 1960 as an organization under the jurisdiction of the then Ministry of International Trade and Industry (MITI; now the Ministry of Economy, Trade and Industry) to act as a social science institute for basic and comprehensive research activities in the areas of economics, politics, and social issues in developing countries and regions. In July 1998 it merged with the Japan External Trade Organization (JETRO) and became IDE-JETRO. It is now a major source of input–output data assembly and analysis.

26 The authors use "interregional" in a general sense. The implementation is a hybrid approach but essentially in the "multiregional" style (estimation of interregional transactions z_i^{rs}, not z_{ij}^{rs}).

The compilation consisted of three broad phases of essentially two steps each:

1. Collection and estimation of exogenous data. Provincial input–output data were collected (these are unpublished data that cannot be accessed by foreigners), with attempts to check for consistency with national data. Estimates were required for provincial value added, final demand, and foreign trade. The final result of this phase is a collection of regional input coefficients for each region.
2. Estimation of interregional commodity flows. Survey data were collected from over 500 "important" enterprises. For other commodities, estimates were generated using a Leontief–Strout gravity model approach (section 8.6.1), complemented by superior data, where available. This phase generates sets of interregional trade coefficients.
3. Compilation of the multiregional model. Here the results of the two earlier phases were joined together and the (inevitable) discrepancies reconciled.

The various chapters in Okamoto and Ihara (2005) explore a number of applications of the CMRIO model with the goal of analyzing such important regional economic phenomena as interregional multipliers, feedbacks and spillovers and spatial linkages.

8.8 International Input–Output Models

8.8.1 Introduction

The notion of extending the several-*region* input–output model framework to several *countries* apparently first appeared in Wonnacott (1961), who created a connected Canada–USA two-country model. In what follows we explore several more elaborate applications of this idea – involving more than two countries – including examples for Asia, the European Community, and other many-country models. The model structures follow exactly the logical lines of the interregional or multiregional cases. In some instances, data collection is made easier because of the "national" nature of the "regions." For example, while "export" and "import" figures are often sketchy or nonexistent for regions, they are often available, in various forms, for a nation's external trade.[27]

8.8.2 Asian International Input–Output Tables

The idea of modeling the input–output connections among Asian nations became attractive to scholars in that area because of the emerging interdependence of many Asian economies. Initial work was carried out by researchers at the Institute of Developing Economies (IDE) in Japan. Their first attempt at an "international" input–output table began in 1965; it covered six "mega-regions" (North America, Europe, Oceania, Latin America, Asia, and Japan).[28] In various publications, these and subsequent tables have

[27] There can be many compatibility issues with regard to a country's export and import data – for example, distinguishing competitive vs. noncompetitive imports, valuation of imports at *ex customs* prices and exports at producers' prices.

[28] This can be viewed as an early example of a "global" or "world" model. See section 8.8.5, below.

Miller, Ronald E.; Blair, Peter D.. Input-Output Analysis : Foundations and Extensions.
Cambridge, , GBR: Cambridge University Press, 2009. p 378.
http://site.ebrary.com/lib/mitlibraries/Doc?id=10329730&ppg=412

also been labeled "multinational" and "multilateral." These are more appropriate labels, since the work builds on an MRIO (Chenery–Moses) framework.

A comprehensive history of the IDE work on international input–output tables can be found in Institute of Developing Economies (2006a), especially Part 1: "Compilation of the Asian international input–output table." (This material is also covered in the "Introduction" in Furukawa, 1986.) The historical overview encompasses three phases.

The first phase (1973–1977) launched comprehensive development of an international input–output structure for East and Southeast Asian countries – three national tables (Indonesia, Singapore, and Thailand) and three "bilateral" tables (Korea–Japan, USA–Japan, and Philippines–Japan) were produced.

The second phase (1978–1982) encompassed construction of a 1975 multilateral table among ASEAN (Association of Southeast Asian Nations) countries, Japan, Korea, and the USA. This included estimation of national tables for 1975 where necessary (and updates for Malaysia, Philippines, Singapore, and the USA and construction of bilateral tables for Indonesia–Japan, Thailand–Japan, and Korea–Japan). Finally, these were linked together as a single international (multilateral) table for 1975. This work was completed in 1983.

In the third phase (1988–present) an international table was created for 1985, now including China and Taiwan. Since then IDE has created multilateral tables every five years – thus far for 1990, 1995, and 2000 – with 10 countries and 7-, 24-, and 76-sector levels of aggregation.[29]

As might be imagined, the data compilation problems are enormous. For example, the 10 different national tables exhibit a number of differences. These tables must all be made "consistent" in order to be included (as on-diagonal blocks) in the overall multinational table.[30] In estimating the international transactions, export vectors and import matrices are created in a very detailed set of procedures (and then converted to producers' prices). Import statistics are relied on more heavily than export, because import data are more carefully collected for customs duties in each country. Details can be found, for example, in IDE-JETRO (2006a), Part 1, III "Linking of the tables."

This work provides an extremely rich data set for empirical studies that make use of analytical methods that depend on input–output data sets. Among these are linkage analysis (both sectoral and spatial) and other techniques designed to assess relative importance of sectors (or regions). These topics are covered in some detail in Chapter 12. Representative examples include Sano and Osada (1998) [sector linkages]; Meng *et al.* (2006) [linkages for 1985, 1990, 1995, and 2000 for sectors within each country and across countries] and Kuwamori and Meng (2006) [sectoral linkages over time within individual countries, evolution over time of total intermediate inputs (sectoral input

[29] The countries are: China, Indonesia, Japan, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, and the USA. The data appear in Institute of Developing Economies (2006b).

[30] From IDE-JETRO (2006a, p. 15): "… one of the most complicated, nerve-racking tasks of compilation is the adjustment of national tables to conform to a common format."

structures) and total final demands (sectoral demand structures), linkages between countries, the impact of Beijing Olympic Games-related investments on regional economic growth in China]. Using the 1990 and 2000 Asian input–output data sets, Kuwamori (2007) examines the relative importance of each of the 10 countries on each of the others, as well as specific industries in those countries, via the "hypothetical extraction" process (also Chapter 12). The emerging influence of the Chinese economy is made clear through comparison of some of the results from the 1990 and 2000 data.

8.8.3 "Hybrid" Many-Region Models for the EC

The formation of the European Community (EC) in 1971 [preceded by the European Economic Community (EEC) from 1958] generated an interest in and need for consistent economic data on each member country's economic activities, not only internal transactions but also intercountry connections. Van der Linden and Oosterhaven (1995) address the need for a consistent set of intra- and intercountry input–output tables for the EC in order to address a variety of important policy issues, such as interregional and intercountry income spillovers.

Presently Eurostat (the statistical office of the EC) produces consolidated tables for the EC as a whole, including what amounts to $\mathbf{Z}^{rr}$ and $\mathbf{x}^r$ for each of the member states.[31] Additional information, including $\mathbf{Z}^{\cdot r}$ (where the "." indicates shipments from all other EC countries) and other import data, are also available. From these, the authors create a kind of many-region (or many-nation) model for the EC that lies between the IRIO and MRIO styles.[32] The presence of $\mathbf{Z}^{rr}$ and $\mathbf{x}^r$ permits calculation of intracountry input coefficient matrices of the IRIO type, namely $\mathbf{A}^{rr} = \mathbf{Z}^{rr}(\hat{\mathbf{x}}^r)^{-1}$. From data on imports, the authors estimate $c_i^{sr} = m_i^{sr}/m_i^{\cdot r}$; these are used across rows of $\mathbf{Z}^{\cdot r}$ to approximate $\mathbf{Z}^{sr}(s \neq r)$ in standard MRIO fashion, namely, $\mathbf{Z}^{sr} = \hat{\mathbf{c}}^{sr}\mathbf{Z}^{\cdot r}$. There are problems associated with accounting for services and with the kinds of prices in which the data are available (e.g., producers' vs. CIF or ex-customs prices). Also, there are discrepancies with import and export data that are created by the use of the MRIO approach; for example, initial estimates of country r's total exports of commodity i to other EC countries generally differ from the figure found by summing imports of i from r to each of the countries. The authors use an RAS balancing approach to deal with these issues.

An illustration of the kinds of questions that can be addressed with these intercountry EC models is provided by Hoen (2002), who uses these EC tables as the starting point for his input–output analysis of the economic effects of European integration. For example, he examines various multipliers and spillovers, and he presents a decomposition of value-added growth, among others, all based on the input–output data. For these purposes, however, he requires a set of data in constant prices, not current (as are generated in the van der Linden and Oosterhaven work). To achieve this Hoen employs an RAS approach and compares his results with those from the usual "double deflation"

31 See Eurostat, 2002, for a thorough discussion. Some years do not include tables for all member states. See van der Linden and Oosterhaven, 1995, or Hoen, 2002, for details.
32 This work builds on Schilderinck, 1984, where the first attempt at a consistent set of connected-country tables for the EC was presented.

Table 8.3 Structure of the TIIO Model

	ASEAN5	C1	⋯	C7	J1	⋯	J8	EA	USA
ASEAN5									
C1									
⋮									
C7									
J1									
⋮									
J8									
EA									
USA									

procedure. In fact, he suggests that double deflation can be viewed as a special case of a more general RAS approach.

8.8.4 China–Japan "Transnational Interregional" Input–Output (TIIO) Model, 2000

This is another ambitious IDE-JETRO undertaking. It is a ten-sector model that combines a "multinational" character – China, Japan, ASEAN5 (Indonesia, Malaysia, the Philippines, Singapore, and Thailand), East Asia (Korea and Taiwan) and the USA – with *regional* disaggregations of China into seven regions and Japan into eight regions. Thus there are 18 geographic areas; some are true sub-national regions (the 15 in China and Japan), one is a nation (USA) and two are multinational areas (ASEAN5, East Asia). (Primary references are Inomata and Kuwamori, 2007, and Development Studies Center, IDE-JETRO, 2007.) This is known as the "Transnational Interregional Input–Output (TIIO)" model.

The tables are compiled from the 2000 Asian data (section 8.8.3) and the interregional tables for China (section 8.7.3) and Japan. As might be expected, there were many issues regarding data compatibility, and many assumptions were required to translate national trade data to the regional level (in the cases of China and Japan). The overall structure of this ambitious project is indicated in Table 8.3. Each cell contains a 10×10 transactions (or coefficients) matrix. We explore details of estimations in the lighter shaded area – namely Chinese exports to Japan at the regional level in both countries. Estimation of elements in the darker shaded area follows the same approach.

Chinese Exports to Japan for Intermediate Demand We use Japan (J) as an illustration of the external country – the lighter shaded portion of Table 8.3. Procedures for ASEAN5, East Asia, and the USA do not involve regional breakdowns for the receiving (importing) area. The object here is to include region and sector specificity for the Chinese origins and Japanese destinations of Chinese exports to Japan, as indicated in Table 8.4, where $\mathbf{Z}^{rs} = [z_{ij}^{rs}]$ for $i, j = 1, \ldots, 10$.

Miller, Ronald E.; Blair, Peter D.. Input-Output Analysis : Foundations and Extensions.
Cambridge, , GBR: Cambridge University Press, 2009. p 381.
http://site.ebrary.com/lib/mitlibraries/Doc?id=10329730&ppg=415

Table 8.4 China-to-Japan Intermediate Transactions in TIIO

		Japanese Region				
		J1	…	Js	…	J8
Chinese Region	C1	$\mathbf{Z}^{11}$	…	$\mathbf{Z}^{1s}$	…	$\mathbf{Z}^{18}$
	⋮	⋮		⋮		⋮
	Cr	$\mathbf{Z}^{r1}$	…	$\mathbf{Z}^{rs}$	…	$\mathbf{Z}^{r8}$
	⋮	⋮		⋮		⋮
	C7	$\mathbf{Z}^{71}$	…	$\mathbf{Z}^{7s}$	…	$\mathbf{Z}^{78}$

The following are known from trade data ($\bar{m}$ indicates Japanese import data, $\bar{e}$ indicates Chinese export data):

z_{ij}^{CJ} = total Chinese exports of good i to Japanese sector j (= total Japanese imports by sector j of good i from China),
$\bar{m}_{i\cdot}^{Cs}$ = Japanese region s imports of i from China,
$\bar{m}_{i\cdot}^{CJ} = \sum_{s=1}^{8} \bar{m}_{i\cdot}^{Cs}$ = total Japanese imports of i from China,
$[(\bar{m}_{i\cdot}^{Cs}/\bar{m}_{i\cdot}^{CJ}) \times 100]$ = percentage of Japanese imports of i from China that goes to region s in Japan (comparable to the $c_{i\cdot}^{rs}$ data in MRIO models),
$\bar{e}_{i\cdot}^{rJ}$ = Chinese region r exports of i to Japan,
$\bar{e}_{i\cdot}^{CJ} = \sum_{r=1}^{7} \bar{e}_{i\cdot}^{rJ}$ = total Chinese exports of i to Japan,
$[(\bar{e}_{i\cdot}^{rJ}/\bar{e}_{i\cdot}^{CJ}) \times 100]$ = percentage of Chinese exports of i to Japan that comes from region r in China.

Assumptions:

1. Each sector j in region s in Japan gets $[(\bar{m}_{i\cdot}^{Cs}/\bar{m}_{i\cdot}^{CJ}) \times 100]$ percent of its i from China. (This is the standard MRIO model assumption.) That is,

$$\tilde{z}_{ij}^{Cs} = (\bar{m}_{i\cdot}^{Cs}/\bar{m}_{i\cdot}^{CJ})z_{ij}^{CJ}$$

Suppose $[(\bar{m}_{i\cdot}^{Cs}/\bar{m}_{i\cdot}^{CJ}) \times 100] = 12$ (meaning that 12 percent of the input of i for *each* sector in region s in Japan comes from China); then if $z_{ij}^{CJ} = 2000$, $\tilde{z}_{ij}^{Cs} = 240$.

2. Each region r in China contributes $[(\bar{e}_{i\cdot}^{rJ}/\bar{e}_{i\cdot}^{CJ}) \times 100]$ percent of China's exports of i to Japan. Then

$$\tilde{z}_{ij}^{rs} = (\bar{e}_{i\cdot}^{rJ}/\bar{e}_{i\cdot}^{CJ})\tilde{z}_{ij}^{Cs} = (\bar{e}_{i\cdot}^{rJ}/\bar{e}_{i\cdot}^{CJ})(\bar{m}_{i\cdot}^{Cs}/\bar{m}_{i\cdot}^{CJ})z_{ij}^{CJ}$$

Suppose $[(\bar{e}_{i\cdot}^{rJ}/\bar{e}_{i\cdot}^{CJ}) \times 100] = 10$; this means that 10 percent of Chinese exports of i to Japan come from region r in China. Then $\tilde{z}_{ij}^{rs} = 24$.

The authors recognize that this is admittedly a strong assumption (Development Studies Center, 2007, p. 67):

In general, it seems unlikely to assume that the proportion of inputs of [sector 1] in region 1 of China to the inputs as a whole in the industry related to daily lives in Hokkaido [Japan region 1] is identical to the proportion of the inputs in the industry related to daily lives in the Kanto Region [Japan Region 8]. Even so, since there is no information available which proves that this is "not true", estimation has been made under the assumption [that the data on each Chinese region's input supply proportions] are applicable to all [eight Japanese regions].

This produces the estimate of one element, $\tilde{z}_{ij}^{rs}$, of the 100 in $\mathbf{Z}^{rs}$. Similar calculations are needed for each additional element in $\mathbf{Z}^{rs}$ and for each of the remaining 55 matrices (each 10×10) in Table 8.4.

Applications This data set has prompted a large number of studies of international linkages, including feedbacks and spillovers (Chapter 3), for individual countries as a whole (all industries) as well as for individual sectors. Some of these results appeared in Inomata and Sato (2007) and a large collection of such studies can be found in Inomata and Kuwamori (2007).[33]

8.8.5 Leontief's World Model

Another example illustrating expansion from a "multiregional" to "multinational" input–output perspective is to be found in Leontief's world model[34]. This huge project from the early 1970s was sponsored by the United Nations as part of its search for "… possible alternative policies to promote development while at the same time preserving and improving the environment" (United Nations, 1973, p. 2).

The final version consisted of 15 regions (four advanced industrial countries, four centrally planned economies and two groups of developing countries (three resource-rich and four resource-poor), each with 48 sectors, including eight exhaustible resources as well as eight types of major pollutants and five types of abatement activities (since the motivation was one of environmental impacts). Data were assembled for the base year of 1970, and projections were made to 1980, 1990, and 2000. National input–output tables formed the basis of the intraregional data sets; various accounting practices and sectoring schemes created many consistency issues.

For the interregional data, Leontief created "world trade pools" to model trading relationships for each traded good. For each good and each region there are two sets of parameters: import coefficients and export shares. For good i and region r, an element of the latter specifies the proportion of the total amount of world exports of good i that is provided by region r to the world pool of good i, $e_i^r = x_i^{r\cdot} / \sum_{q=1}^{p} x_i^{q\cdot}$. The import

33 A paper by Oosterhaven and Stelder (2007) contains an extensive and informative comparison of results from four "hybrid" models with the IDE-JETRO Asian 2000 table. The four alternative approaches reflect the differing kinds of national import and export data that may be available in real-world situations – such as with or without separate import matrices (in *ex customs* prices), with or without export matrices (in producers' prices), and using RAS procedures at various stages in the process.

34 This is outlined in Leontief, 1974 (his Nobel Memorial Lecture). The evolution of the model is presented in Fontana, 2004; see also Duchin, 2004, for more background.

shares indicate the volume of competitive imports as a fraction of domestic production of the same good, $m_i^r = x_i^{\cdot r}/x_i^r$. These parameters are estimated, based on observed data (the x's) and expert opinion.

> The world pool idea avoided the need for building an input–output international trade model, with country-to-country flows for each commodity ... [W]ith Leontief's idea of world pools ... nothing is required to be known about the bilateral relations between regions. (Fontana, 2004, p. 34.)

In effect, this approach carries the simplification of the IRIO model one step beyond the MRIO formulation: z_{ij}^{rs} (IRIO) $\rightarrow z_{i\cdot}^{rs}$ (MRIO) $\rightarrow z_{i\cdot}^{r\cdot}$ and $z_{i\cdot}^{\cdot s}$ (World Model).

Results from this project were published in Leontief, Carter and Petri (1977). Other applications include Leontief, Mariscal and Sohn, 1983b, Leontief *et al.*, 1983a and Leontief and Duchin, 1983. However, as Duchin (2004) noted, the model generated little in the way of long-term interest.

> Among economists, even those in the IO community have paid relatively little attention to the World Model ... [T]he descendant of Leontief's World Model was last used for research completed in the early 1990s (Duchin and Lange, 1994), and the team that did the analysis has dispersed (p. 59).

In Duchin and Lange (1994) the world model framework was employed to examine alternative environmental futures for the planet. It consisted of 16 world regions and about 50 sectors. A sense of the broad-brush approach necessary in such an ambitious world model is given in Appendix 8.1, where 189 countries are grouped into the 16 geographical classifications used in the model.[35]

Duchin (2005) presents a generalization of the World Model in a linear programming format that is designed to be particularly applicable for analyzing scenarios dealing with environmental impact and sustainable development. As Fontana (2004, p. 37) notes "The Leontief world model was a stepping stone for explorers of the long-term future of the world economy."

8.9 The Reconciliation Issue

In section 7.2 we noted that problems can arise in constructing survey-based interindustry transactions tables when the row total for a sector differs from the column total for that same sector. This happens also in hybrid approaches to both updating and regionalization. Since one common approach to reconciliation uses an RAS approach, this discussion was postponed until we had introduced the RAS technique in its more usual updating or regionalization role.

Some input–output tables (especially at the regional level) have been constructed exclusively on the basis of information on purchases by sectors in the economy. A sample of establishments in each sector are asked to identify the magnitudes of their inputs, by sector and by region – or at least whether the input came from inside the region in question or was imported from outside that region. This is sometimes known as the "purchases only" or "columns only" approach, since the transactions table (and

[35] The complete list of countries and their geographic assignments to world regions can be found in Appendix C, "World Model Geographic Classification," in Duchin and Lange (1994).

Miller, Ronald E.; Blair, Peter D.. Input-Output Analysis : Foundations and Extensions.
Cambridge, , GBR: Cambridge University Press, 2009. p 384.
http://site.ebrary.com/lib/mitlibraries/Doc?id=10329730&ppg=418

hence the direct-input coefficients matrix) is compiled column by column. It depends on information from establishments regarding the distribution of their costs. (This was used in constructing the 496-sector Philadelphia table for 1959; see Isard and Langford, 1971.) Similarly, a "sales only" or "rows only" procedure depends entirely upon information on the magnitudes of sales from a particular sector to all other regional sectors, and to final-demand purchasers. This relies on information from establishments regarding the distribution of their products. [For a study that used this approach, see Hansen and Tiebout, 1963, and recall that DEBRIOT (section 8.7.2) emphasizes sales over purchases information.]

Usually, there will be some (but not complete) information on purchases and some (but also not complete) information on sales – for example, from a questionnaire in which firms are asked for data on both sales and purchases. Thus, for many cells there may be two estimates of the z_{ij}^r transaction. If one has independent estimates of regional total gross outputs, x_j^r, from published sources, this of course means that there will be two estimates of the regional direct-input coefficient. The issue then is one of reconciling the two estimates. (Early examples of empirical studies using both row and column information include Bourque *et al.*, 1967; Beyers *et al.*, 1970; Bourque and Conway, 1977; Miernyk *et al.*, 1967 and Miernyk *et al.*, 1970.)

Often, the reconciliation is made entirely on the basis of the judgment of the researchers, reflecting their knowledge of the regional economy and comparisons with national coefficients; Bourque *et al.* (1967) provides one such example. Building on the general discussion in Miernyk *et al.* (1970), in which an attempt was made to estimate the relative accuracy (reliability) of various pieces of information, Jensen and McGaurr (1976) propose a two-stage procedure. Let the two transactions estimates for the i, jth cell be r_{ij} and c_{ij}, from the "rows-only" and "columns-only" information. On the basis of knowledge of sampling procedures and other features of the data and of probable sources of error, a pair of what Jensen and McGaurr termed reliability weights are chosen for the two estimates. Let k_{ij} denote this weight for the rows-only estimate ($k_{ij} \geq 0$), then $(1 - k_{ij})$ will be the weight for the columns-only estimate. Then, a first approximation to the reconciled transactions estimate for the i, jth cell is found as the simple weighted sum $z_{ij}^1 = k_{ij}r_{ij} + (1 - k_{ij})c_{ij}$. The superscript 1 represents the fact that this is a first estimate. For example, if one believed that a rows-only estimate r_{ij} was "almost" completely accurate, its k_{ij} might be set at 0.9; if, in the judgment of the researchers, the row and column estimates for a particular cell were equally likely to be correct, k_{ij} would be 0.5 for that cell, and so on.

In addition to the total output vector, $\mathbf{x}^r$, suppose that independent estimates have been made of the magnitudes of final-demand purchases from each sector, so the final-demand column vector is known, and also assume that there are estimates of all value-added payments by each sector (including imports), so the value-added row vector, $\mathbf{va}^r$, is also known.[36] Then the total value of interindustry transactions is given by $T^r = \mathbf{i}'(\mathbf{x}^r - \mathbf{f}^r) = \sum_i (x_i^r - f_i^r)$, or, equivalently, by $T^r = (\mathbf{x}^r - \mathbf{va}^r)\mathbf{i} = \sum_j (x_j^r - va_j^r)$. It is then

[36] Here we resort to using va_j^r for value added in sector j in region r because v_j^r will be needed for total intermediate inputs in the RAS balancing technique that follows.

necessary to check the total of the estimated transactions, $Z^1 = \sum_i \sum_j z_{ij}^1$, against this (independently estimated) total figure, T^r. If, as is very likely, these are not equal, each z_{ij}^1 is scaled upward or downward through multiplication by T^r/Z^1. This produces a second set of estimates of reconciled transactions, $z_{ij}^2 = z_{ij}^1[T^r/Z^1]$. These estimates are consistent in the aggregate, in that $\sum_i \sum_j z_{ij}^2 = T^r$. This concludes stage one.

While the transactions z_{ij}^2 have now been adjusted so that they sum to the proper aggregate flow, they must also be consistent with the *individual* row and column sums. This is where RAS comes in. Since x_i^r and f_i^r have been independently estimated, then total intermediate output for each sector, u_i^r, is found as $u_i^r = x_i^r - f_i^r$. Similarly, given estimates of va_j^r, then total intermediate input for each sector, v_j^r, is found as $v_j^r = x_j^r - va_j^r$. The issue then is whether $\sum_j z_{ij}^2 = u_i^r$, for each sector $(i = 1, \ldots, n)$ and also whether $\sum_i z_{ij}^2 = v_j^r$, for each sector $(j = 1, \ldots, n)$. In general, not all of these constraining equations will be met, and so the estimates in z_{ij}^2 must be further adjusted to conform to the marginal information for each row and each column. This is exactly the kind of problem for which the RAS technique is suited, and it is the procedure that is suggested by Jensen and McGaurr. This is stage two of the adjustment. The result will be a third and final set of transactions estimates z_{ij}^3. Given the estimates of x_i^r the direct input coefficients can then be estimated.[37]

This approach has been discussed because it represents one formalized way of attempting to incorporate subjective judgments (via the reliability weights) and also a certain amount of objective structure (via the RAS adjustments) in the reconciliation procedure. Many researchers have incorporated alternative approaches to reconciling conflicting estimates. An example can be found in step 3 of the DEBRIOT procedure (section 8.7.2), above, and there is considerably more detail in Boomsma and Oosterhaven (1992).

An entirely different approach was suggested by Gerking, in the context of a stochastic view of input–output models (Gerking, 1976a, b). He proposes that coefficients can be estimated and that the reconciliation problem can be addressed using regression techniques (Gerking, 1976c, 1979b). This generated a good deal of critical comment and response in the literature. (For example, Brown and Giarratani, 1979; Miernyk, 1976, 1979; Gerking, 1979a, c.) The reconciliation issue is far from settled; the range of possibilities from wholly subjective to entirely mathematical is very wide indeed.

8.10 Summary

In this chapter we have looked at some options that are available for estimating a table of regional input–output coefficients when a full matrix of regional transactions is not

[37] If independent estimates of f_j^r and va_j^r are not available, then one can employ the same procedure as outlined above on an expanded transactions table; this would include estimates from firms on not only their interindustry transactions but also on sales to final-demand sectors and purchases from value-added sectors. In this case the first reconciliation would scale all transactions so that their total was $\sum_j x_j^r (= \mathbf{i}'\mathbf{x})$, and the second reconciliation would compare row and column sums against each x_i^r and x_j^r. This is, in fact, the procedure used by Jensen and McGaurr (1976, 1977) in their discussion and in their empirical work.

available. In the regional case, location-quotient like procedures and regional purchase coefficient information take advantage of comparative economic data on the region vs. the nation of which it is a part. In addition, the RAS procedure is as applicable to the regionalization problem as it was to the updating problem of the last chapter. And, again, it is usual to find a combination of partial-survey information, expert opinion and RAS (or RAS-like) techniques blended into a hybrid approach that generates superior results. We also explored some real-world applications of these techniques in both sub- and super-national studies.

Appendix 8.1 Geographical Classifications in the World Input–Output Model

The 16 world regions covering 189 countries in the World Input–Output Model are (Duchin and Lange, 1994):

High-income North America (5)
Newly industrializing Latin America (5)
Low-income Latin America (40)
High-income Western Europe (23)
Medium-income Western Europe (8)
Eastern Europe (7)
Former Soviet Union
Centrally planned Asia (3)
Japan
Newly industrializing Asia (7)
Low-income Asia (16)
Major oil producers (15)
Northern Africa and other Middle East (16)
Sub-Saharan Africa (34)
Southern Africa (5)
Oceania (3)

Problems

8.1 The economy of the Land of Lilliput is described by the following input–output table:

	Interindustry Transactions		Total
	A	*B*	Outputs
A	1	6	20
B	4	2	15

Land of Brobdingnag is described by another input–output table:

	Interindustry Transactions		Total
	A	*B*	Outputs
A	7	4	35
B	1	5	15

Miller, Ronald E.; Blair, Peter D.. Input-Output Analysis : Foundations and Extensions.
Cambridge, , GBR: Cambridge University Press, 2009. p 387.
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The economy of the distant land of the Houyhnhnms is described by yet another input–output table:

	Interindustry Transactions		Total
	A	*B*	Outputs
A	20	30.67	100
B	2.86	38.33	15

a. Compute the vectors of value-added, intermediate inputs, final-demand, and intermediate outputs for each economy.

b. A Lilliputian economist is interested in examining the structure of the Brobdingnagian economy. Likewise, a Brobdingnagian economist is interested in examining the structure of the Lilliputian economy. However, each economist only has available to him the value-added, final-demand, and total-output vectors for the foreign economy. Each economist knows the RAS modification procedure and uses it with the technical coefficients matrix of his own economy serving as the base **A** matrix. Which of the two economists calculates a better estimate of the foreign economy's technical coefficients matrix in terms of mean absolute deviation (all elements of **A**)?

c. An economist in the distant land of the Houyhnhnms learned of the two other economies from a world traveler. He becomes interested in the economic structures of these foreign lands but is only able to obtain the final-demand, value-added, and total-output vectors for each economy from the world traveler. The economist uses RAS with his own country's **A** matrix as a base to estimate the interindustry structure of the two distant lands. Which economy does he estimate more accurately in terms of a mean absolute deviation? Do you notice anything peculiar about the comparative structures of the Lilliputian, Brobdingnagian, and Houyhnhnm economies?

d. The Land of Lilliput plans to build a new power plant which will require the following value of output (in millions of dollars) from each of the economy's industries (directly, so it can be thought of as a final demand presented to the Lilliputian economy) of $\mathbf{f} = [100 \quad 150]'$. How accurate, measured as an average mean absolute deviation, is the Houyhnhnms' estimate of the total industrial activity (output) in the Lilliputian economy required to construct this power plant?

8.2 Suppose the economies given in problem 8.1 are really three-sector economies where the economy of the Land of Lilliput is described by the following input–output table:

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	Interindustry Transactions			
	A	*B*	*C*	Total Outputs
A	1	6	6	20
B	4	2	1	15
C	4	1	1	12

The economy of the neighboring land of Brobdingnag is described by another input–output table:

	Interindustry Transactions			
	A	*B*	*C*	Total Outputs
A	7	4	8	35
B	1	5	1	15
C	6	2	7	30

The economy of the distant land of Houyhnhnms is described by yet another input–output table:

	Interindustry Transactions			
	A	*B*	*C*	Total Outputs
A	5.5	33	33	1,101
B	22	11	5.5	82.5
C	22	5.5	5.5	66

Solve parts a, b, and c of problem 8.1 for these new economies.

8.3 Consider the following input–output table for Region 1:

	A	*B*	Total Outputs
A	1	2	10
B	3	4	10

Miller, Ronald E.; Blair, Peter D.. Input-Output Analysis : Foundations and Extensions.
Cambridge, , GBR: Cambridge University Press, 2009. p 389.
http://site.ebrary.com/lib/mitlibraries/Doc?id=10329730&ppg=423

We are interested in determining the impact of a particular final demand in another region (Region 2). Suppose we have the following data concerning Region 2.

	Value Added	Final Demand	Total Outputs
A	10	11	15
B	13	12	20

Suppose that the cost of computing an RAS estimate of Region 2's input–output table using Region 1's **A** matrix as a base table is given by nc_1, where n is the number of RAS iterations. One iteration is defined by one row and one column adjustment, that is, $\mathbf{A}' = \mathbf{RAS}$ (a row adjustment alone as the last iteration would also be counted as an iteration). We ultimately wish to compute the impact of a new final demand in Region 2. This impact (the total outputs required to support the new final demand) can be computed exactly or by using the round-by-round approximation of the inverse. We know that: (1) The cost of computing the inverse exactly on a computer is c_1 and the cost of using this inverse in impact analysis is c_2 (let us assume that $c_2, = 10c_1$, that is, the cost of computing the inverse is ten times the cost of using it in impact analysis). (2) The cost of a round-by-round approximation of impact analysis is mc_1, where m is the order of the round-by-round approximation, that is, $\mathbf{f} + \mathbf{Af} + \mathbf{A}^2\mathbf{f} + \cdots + \mathbf{A}^m\mathbf{f}$.

a. Assuming that a fourth-order round-by-round approximation is sufficiently accurate ($m = 4$), which method of impact analysis should we use to minimize cost – (1) or (2)?
b. What is the total cost of performing impact analysis, including the cost of the RAS approximation (tolerance of 0.01) and of the impact analysis scheme you chose in a?
c. If the budget for the entire impact-analysis calculation is $7c_1$, what level of tolerance can you afford: 0.01, 0.001, 0.0001, 0.00001, or 0.000001?

8.4 Examine the behavior of the adjustment term that converts location-quotient approach *FLQ* to *FLQA*, $\lambda = \{\log_2[1 + (x^r/x^n)]\}^\delta$ for values of $x^r/x^n = .01, .1, .25, .5, .75$, and 1 cross tabulated with values of $\delta = 0, .1, .3, .5$, and 1.

8.5 The matrix of technical coefficients for a national economy, $\mathbf{A}^N$, and the vector of total outputs, $\mathbf{x}^N$, as well as the corresponding values for a target region, $\mathbf{A}^R$ and $\mathbf{x}^R$, are

$$\mathbf{A}^N = \begin{bmatrix} .1830 & .0668 & .0087 \\ .1377 & .3070 & .0707 \\ .1603 & .2409 & .2999 \end{bmatrix} \quad \mathbf{x}^N = \begin{bmatrix} 518,288.6 \\ 4,953,700.6 \\ 14,260,843.0 \end{bmatrix}$$

$$\mathbf{A}^R = \begin{bmatrix} .1092 & .0324 & .0036 \\ .0899 & .0849 & .0412 \\ .1603 & .1170 & .2349 \end{bmatrix} \quad \mathbf{x}^R = \begin{bmatrix} 8,262.7 \\ 95,450.8 \\ 170,690.3 \end{bmatrix}$$

Compute the matrix of simple location quotients (SLQ) and the estimate of the matrix of regional technical coefficients using the SLQ.

8.6 For the national and regional data specified in problem 8.5, compute the matrix of Cross-Industry Quotients (CLQ) and the estimate of the matrix of regional technical coefficients using the CLQ.

8.7 Consider once again the national and regional data specified in problem 8.5. Estimate the matrix of regional technical coefficients using the RAS technique.

8.8 Compare the estimated regional matrices of technical coefficients computed in problems 8.5, 8.6, and 8.7. In terms of mean absolute deviation from the actual regional technical coefficients, which technique provides the most accurate estimate?

8.9 Using the three-sector, three-region Chinese MRIO data for 2000 from Table 3.7, create estimates of the intraregional input coefficients and their associated Leontief inverses for regions 2 (South China) and 3 (Rest of China), using the same reduction techniques and measures of difference that appear in Table 8.1 for region 1 (North China).

8.10 The following are the 1997 matrix of technical coefficients and vector of total outputs for the State of Washington as well as the 2003 matrix of technical coefficients for the United States, where the sectors are defined as (1) agriculture, (2) mining, (3) construction, (4) manufacturing, (5) trade, transportation and utilities, (6) services, and (7) other:

$$\mathbf{A}^W = \begin{bmatrix} .1154 & .0012 & .0082 & .0353 & .0019 & .0033 & .0016 \\ .0008 & .0160 & .0057 & .0014 & .0022 & .0002 & .0001 \\ .0072 & .0084 & .0066 & .0043 & .0074 & .0196 & .0133 \\ .0868 & .0287 & .0958 & .0766 & .0289 & .0244 & .0205 \\ .0625 & .0278 & .0540 & .0525 & .0616 & .0317 & .0480 \\ .0964 & .1207 & .0704 & .0596 & .1637 & .1991 & .2224 \\ .0020 & .0031 & .0056 & .0019 & .0045 & .0051 & .0066 \end{bmatrix} \quad \mathbf{x}^W = \begin{bmatrix} 7{,}681.0 \\ 581.7 \\ 17{,}967.1 \\ 77{,}483.7 \\ 56{,}967.2 \\ 109{,}557.6 \\ 4{,}165.5 \end{bmatrix}$$

$$\mathbf{A}^{US} = \begin{bmatrix} .2225 & .0000 & .0012 & .0375 & .0001 & .0020 & .0010 \\ .0021 & .1360 & .0072 & .0453 & .0311 & .0003 & .0053 \\ .0034 & .0002 & .0012 & .0021 & .0035 & .0071 & .0214 \\ .1724 & .0945 & .2488 & .3204 & .0468 & .0572 & .1004 \\ .0853 & .0527 & .0912 & .0950 & .0643 & .0314 & .0526 \\ .0902 & .1676 & .1339 & .1261 & .1655 & .2725 & .1882 \\ .0101 & .0140 & .0103 & .0214 & .0206 & .0200 & .0247 \end{bmatrix}$$

Using the RAS technique, estimate the Washington State table using the US matrix of technical coefficients as a starting point. Compute the mean absolute deviation of the estimated state technical coefficients matrix from the actual state matrix.

8.11 Suppose in problem 8.10 that we do not know all of the technical coefficients for the Washington State economy, $\mathbf{A}^W$, but we do know several, namely a_{11}^W, a_{62}^W, and a_{65}^W. Using RAS as an estimating procedure, how do we incorporate knowing these coefficients only into the process of estimating the balance of the Washington State technical coefficients using $\mathbf{A}^{US}$ as the initial estimate using the total outputs and intermediate inputs and outputs that you found in problem 8.10? Compute a revised estimate of the Washington State economy. How does it compare with the original estimate you found in problem 8.10?

8.12 Suppose in problem 8.11 you are able to determine from exogenous sources some alternative technical coefficients, namely a_{67}^{W}, a_{42}^{W}, and a_{54}^{W}. Compute a revised estimate of the Washington State matrix of technical coefficients using these known coefficients. Compute another estimate using both these and the previously identified known coefficients (from problem 8.11). How does this yet again revised estimate of the Washington State matrix of technical coefficients compare with the estimates you found in problems 8.10 and 8.11?

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