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A method for constructing commodity by industry flow matrices

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Abstract This paper presents theory and methods used to construct an interregional commodity by industry flow matrix for the United States. The interregional flow matrix method involves the construction of single-state (and DC) social accounting matrices (SAMs) using data derived from IMPLAN. Once complete, the interregional flows connecting states are estimated using a method based on the commodity flow survey data published by the Bureau of Transportation Statistics. The estimated interregional SAM is then adjusted to insure the integrity of intra-regional and system-wide accounts. The procedures have been designed with ease of replicability as a goal so that updates and extensions of the database can be generated efficiently and at low cost as new data are released. The resulting US interregional framework describes flows within and among the 51 regions. The method is flexible and will provide a valuable database for a broad range of analyses on regions, interregional relationships, and policy.

1 Introduction

As an economy develops and evolves, the economic interactions among industries, governments, and households become more closely tied and complex. Trends in deregulation and structural change in market-based economic systems within an interregional domestic context have received far less attention than those effecting national and international relations. Recent studies, in both the US and Japan, have found that within-country interregional trade is growing more rapidly than intra-regional and international trade and that, overall, regions have become more closely tied together (for example, Hewings et al. 1998 and Hitomi et al. 2000). In fact, according to the commodity flow survey (CFS) of the Bureau of Transportation Statistics (BTS), US industries shipped approximately $7 trillion

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worth of goods in 1997 interregionally using the nation's highways, railroads, waterways, pipelines, and aviation systems (11 billion tons and 2.7 trillion ton-miles). This volume has increased by 18.8% (up to 14.5 and 9.9% for tons and ton-miles, respectively) since 1993; therefore, not only has the volume of interregional trade increased, but the trading patterns have also become more complex.

It is also critically important for regions to understand the nature of their economic interdependencies and to analyze the public policy implications arising therefrom. In particular, further investigating these economic relationships in detail, identifying which industries in one state have the strongest and the closest relationships with which industries in another can provide a better understanding of how policy changes in one region create impacts in other regions.

As social accounting matrices and methods find increasing interest and use, a wide body of literature has developed around them. Most SAMs are constructed for nations or individual regions and although work on interregional SAMs has been evolving over the last decade, very few attempts to generate these models for US regions have been reported in the literature, with a recent notable exception of Canning and Zhi (2005). This paper describes the methods used to construct an interregional commodity by industry flow matrix for the United States. It presents an export distribution estimation method and describes the steps necessary to generate the interregional trade flow portions of an ISAM, insuring the consistency of both the individual SAM accounts and the system as a whole. After problem and data definition, we examine generating single-region social accounting matrices, estimating interregional trade characteristics by commodity, apportioning aggregate interregional commodity flow estimates, and, finally, adjusting foreign trade to insure the integrity of the intra-regional and system-wide accounts.

2 Organization and data

The social accounting matrix (SAM) framework provides details of interactions among economic agents (industries, governments, and households). The SAM framework describing the full circular flow of income and establishing separate accounts for production, consumption, and transaction with other regions was originally pioneered by Stone (1961) and applied at the regional and interregional level by Pyatt and Round (1983), Round (1985), and Bell et al. (1982).

Traditional interest in SAMs stems from their application in a developing country context (Pyatt and Thorbecke 1976; Pyatt and Round 1983, for example) where income distribution and poverty issues are paramount. More recent empirical research in developed countries using this framework includes the construction of community-level social accounts (Cole 1993), the construction of SAMs for European nations (Round 1995), the analysis of interstate capital flows in the US (Kilkenny and Rose 1995), and the analysis of US rural–urban interdependencies (Kilkenny 1995).

At its most basic level, interregional trade has been dealt with in a relatively ad hoc way, relying primarily on sub-proportions derived from national tables. There has recently been renewed work in estimating these relationships more uniquely. These include Canning and Zhi (2005), who develop a formal model to estimate interregional inter-industry transaction flows in a national system of economic regions, and the methods of Lindahl et al. (2005) on estimating point-to-point trade within a state-based modeling system. In addition, Southworth (2002) and Southworth and Peterson (2000) develop notable work specifically estimating freight flow among origin–destination pairs. Notable as well is the work on rectangular IO of Eding et al. (1999), which builds upon Oosterhaven (1984) and Batten and Martellato (1985) who establish a simple hierarchical relationship among five models associated with interregional trade within an input–output system, including Isard, Chenery, and Leontief. They conclude that these models could be reduced to a statistical estimation problem dependent on the varying degree of interregional trade data available to the modelers.

The empirical application most similar to ours for US states was done during the 1970s, initiated at the Harvard Economic Research Project and developed by Polenske (1972). In the most detailed form, it was a 51-region multiregional input–output (MRIO) model for 1963 (50 states and Washington, DC) with 79 sectors in each region (for a review, see Polenske 1980 for a complete description of the model and its construction). Further work was performed by the staff at Jack Faucett Associates, who assembled the 1977 version of the US MRIO model for 51 regions and 120 industries (Faucett Associates 1983). These US MRIO models brought many new research opportunities for the detailed analysis of economic structure and policy analysis and were employed in numerous research projects in subsequent years. Recent applications of these models include the Miller and Shao (1990) comparison of 1963 and 1977 models to examine the sectoral and spatial aggregations, the US Army Corps of Engineers (1994) creation of their own Red River MRIO model based on the 1977 model to evaluate the Red River Water Project, and the examination of interregional trade in comparison to interregional migration in the US by Horiba (2000) using the 1977 model.

Our procedure produces a similar and current database for inter-industry activities among regions and also generates a more extensive and complete database for the US state economies. Moreover, the interregional SAM described in this paper generates fully specified interregional relationships, more comparable to the interregional input–output framework of Isard (1951), providing more detailed information regarding economic interactions across regions than Polenske's multiregional framework provided.

3 Single-region SAMs

A single-region IMPLAN generated SAM with imports treated separately (import ridden as opposed to import laden) generates data with a specific structure as presented in Table 1. The SAM data are reported by IMPLAN in this format to assist GAMS users in constructing single-region CGE models from the data. The structure and partitioning of these data, when properly assembled, yields a SAM in the format presented in Fig. 1. Industry sectors for our model were defined to correspond closely with the commodity codes used by the US Bureau of Transportation Statistics. The modeled framework encompasses 51 regions and 54 industry and commodity sectors along with four factors of production and 18 institutions. IMPLAN naming conventions are utilized throughout the paper for convenience. Thus, while the industry-make sub-table may be labeled 1×2, it is in reality a 54×54 table for each region. Similar statements could be made about any of the other partitions in Fig. 1.

Table 1 IMPLAN SAM partitions

2×1	Domestic use of commodities by industries
3×1	Factor incomes
7×1	Industry foreign import use
8×1	Industry domestic import use
1×2	Domestic industry make
4×2	Domestic institutional make
4×3	Factor distributions
5×3	Foreign factor imports
6×3	Domestic factor imports
2×4	Domestic institutional use
4×4	Inter-institutional transfers
7×4	Institutional foreign import use
8×4	Institutional domestic import use
1×7	Industry foreign export make
4×7	Institutional foreign export make
5×5	Foreign transshipments
1×8	Industry domestic export make
4×8	Institutional domestic export make

Note that while our method employs IMPLAN data, this is merely a convenience.[1] Indeed, as was noted previously, IMPLAN is itself engaged in devising a method to estimate interregional flows (Lindahl et al. 2005). Any balanced SAMs for regions exhausting the US could be used to estimate interregional trade flows with our methods without resorting to the use of IMPLAN whatsoever.

The general structure of the *interregional* SAM is shown in Fig. 2 for a three-region model, which generalizes straightforwardly to our 51-region case. By design, IMPLAN differentiates between foreign flow within a region and domestic flow and, as such, we can concentrate on only the domestic component of trade in partitions 8×1, 8×4, 1×8, and 4×8. The challenge in constructing an interregional SAM lies in the estimation of those values for the shaded and labeled partitions in the off-diagonal blocks of Fig. 2 and the necessary adjustments to other sectors to ensure a balanced table consistent with the accounting identities of the SAM. An additional portion of the adjustment lies in eliminating mutual inconsistencies within the IMPLAN trade flows generated by the RPCs not being jointly estimated for all the regions in question. The RPCs are estimated independently for each individual region and, therefore, suffer from aggregation inconsistencies when they are either combined to form larger regions or subdivided to form smaller regions. The methods used to overcome the mentioned estimation problems form the basis for the procedure described in the remainder of this paper.

[1] The authors have no formal relationship with IMPLAN. The approach we present here should be transferable to other data foundations that have corresponding informational content and data.

	1-Industry	2-Commodity	3-Factors	4-Institutions	5-Foreign Trade	6-Domestic Trade
1-Industry		1x2			1x7	1x8
2-Commodity	2x1			2x4		
3-Factors	3x1					
4-Institutions		4x2	4x3	4x4	4x5	4x8
5-Foreign Trade	7x1		5x3	7x4	5x5	
6-Domestic Trade	8x1		6x3	8x4		

Fig. 1 Single-region, import ridden SAM

4 Export distributions

The US Bureau of Transportation Statistics collects trade data through its commodity flow survey. Although these state-to-state commodity flow estimates are published and available from the BTS, their usefulness is limited for a number of reasons. Foremost among these reasons is that state-to-state origin–destination tables are dominated by disclosure codes or other annotations for almost all listed commodities. The most common of these codes indicates that the estimate is not published due to an unacceptably high statistical variability and the resulting lack of confidence in the estimate. A second problem for model construction is that the CFS data report shipment origin and destination rather than manufacturing origin. Hence, we develop an alternative approach effectively generalizing the distance–volume relationships embedded in the BTS data, smoothing out irregularities

3-Region SAM		Region1				Region2				Region3				ROW(f)	ROW(d)	
		Ind.	Com.	Fact.	Inst.	Ind.	Com.	Fact.	Inst.	Ind.	Com.	Fact.	Inst.	Ind.	Fact.	
Region1	Industry		1x2				1x8				1x8			1x7		TIO
	Commodity	2x1			2x4	8x1			8x4	8x1			8x4			TCD
	Factors	3x1														TFR
	Institutions		4x2	4x3	4x4		4x8				4x8			4x7		TIR
Region2	Industry		1x8				1x2				1x8			1x7		
	Commodity	8x1			8x4	2x1			2x4	8x1			8x4			
	Factors					3x1										
	Institutions		4x8				4x2	4x3	4x4		4x8			4x7		
Region3	Industry		1x8				1x8				1x2			1x7		
	Commodity	8x1			8x4	8x1			8x4	2x1			2x4			
	Factors									3x1						
	Institutions		4x8				4x8				4x2	4x3	4x4	4x7		
ROW(f)	Industry	7x1			7x4	7x1			7x4	7x1			7x4			
	Factors			5x3				5x3				5x3				
ROW(d)	Factors			6x3				6x3				6x3				
		TII	TCS	TFP	TIE											

Where the Column and Row Sums are as follows (for Region 1):

TII: Total Regional Industry Input (use)
TCS: Total Regional Commodity Supply (make)
TFP: Total Regional Factor Payments to Institutions
TIE: Total Regional Institutional Expenditures
TIO: Total Regional Industry Output
TCD: Total Regional Commodity Demand
TFR: Total Regional Factor Receipts from Industry
TIR: Total Regional Institutional Receipts

Fig. 2 General structure of the interregional SAM observed in the more specific origin–destination commodity-specific shipments data, and enabling application to regions whose boundaries do not coincide with states.

Estimates of intra-regional flows, total domestic imports, and total domestic exports are generated in the construction of the single-region SAMs. Because the SAMs are estimated sequentially rather than simultaneously, complete *mutual* consistency is unlikely. While we could modify all values in the IMPLAN-generated SAMs, we instead make the simplifying assumption that the intra-regional trade estimates from the IMPLAN-generated single-region SAMS are correct. The task, therefore, is to estimate only the interregional commodity flow distributions and to modify the trade portion of each regional SAM in such a way as to retain or restore internal and external consistency. Individual SAM identities must hold and, because the SAMs exhaust the entire US, the total amount imported by all regions from all other regions must also equal the total amount exported by all regions to all other regions. Domestic imports must equal domestic exports for all regions combined.

We, therefore, need an estimating equation that generates the distribution of known regional domestic exports (given by the single-region SAMs) from each region to each of the other domestic regions in the model. We assume that the *distributions of exports* from one region to all others are fixed, while *export levels* vary with regional production. Hence, our estimating equation need only be a function of transportation costs (as measured by interregional distances) and region-specific commodity demand. To this end, we have applied the following formulation.

For each commodity i, let the predicted value of the flow from region m to region n be computed as:

$$\hat{Y}_i^{mn} = \frac{\left(w_i^n\right)^{\varphi_i} \exp(-\delta_i d^{mn})}{\sum_n \left(w_i^n\right)^{\varphi_i} \exp(-\delta_i d^{mn})} y_i^{m\bullet} \tag{1}$$

where $\left(w_i^n\right)$ is a weight-reflecting region n 's demand for imports of commodity i, d_{mn} is the distance separating region m from region n, and

$$y_i^{m\bullet} = \sum_{n \neq m} y_i^{mn}$$

are total domestic exports of commodity i from region m.

Ideally, the y_i^{mn} are actual shipments derived from observed values published in the 1997 BTS commodity flow survey. The parameters δ_i and φ_i are elasticities on distance and commodity demand. Commodities with larger δ values are more sensitive to demand variations, while those with smaller values for φ are more sensitive to shipment distances.

In estimating the values of the elasticities for each commodity, δ_i and φ_i ideally would be selected to minimize the absolute difference between estimated and observed flows or min $Z = \left|\hat{y}_i^{mn} - y_i^{mn}\right|$. Because of the gaps in the BTS CFS data, we do not use observed interregional flows per se. However, we do make use of the

BTS commodity-specific summary data to generate an observed flow estimate. Each two-digit SCTG[2] code commodity has associated aggregate BTS data on distances shipped in the US.[3] These data report commodity value shipped by distance range (0–50, 50–99, 100–249 miles, etc.). The resulting estimated flows were then used to parameterize Eq. 1 via optimization.

Figure 3 serves to further illustrate the method employed. The locus of points corresponds to the cumulative shipment at any distance. The points x' and x'' in the diagram correspond to cumulative flows at distance d with a buffer width of s, seen as $d_{mn} + s$ and $d_{mn} - s$, respectively. Thus, calculating the difference between the two flows gives the total flow over the range $[d_{mn} + s,\ d_{mn} - s\ ]$. Such a distance range is an ideal representation for the purposes of this study as the shipment from one state to another cannot accurately be defined by a point-valued distance. The buffer s also provides a convenient mechanism by which we can adjust the regression-generated flows to better match the IMPLAN-generated regional import totals, which is the goal of the first-stage estimation.

For all but three commodities, the following Box–Cox regression specification was used to estimate the distance decay function for each commodity:

$$\frac{f_i^{\lambda_i}}{\lambda_i} = \beta_1 + \beta_r \frac{d_r^{\lambda_i}}{\lambda_i} \tag{2}$$

where f_i are the cumulative flows for commodity i, d_r are the distance range upper limits, λ_i is the Box–Cox transformation parameter, and β_r are commodity-specific distance coefficients. The results of specification tests for Eq. 2 may be seen in Table 2 below.

The results lead one to conclude that the Box–Cox specification (Eq. 2) yields an acceptable fit for all but the three highlighted sectors. For the 24 (electronic equipment), 27 (precision instruments), and 29 [waste sectors (SCTG 35, 38, and 41–43, respectively)], a double log regression specification was adopted (natural logs of flows and distance) to parameterize the distance decay function for these commodities.

$$\ln(f_i) = \beta_1 + \beta_r \ln(d_r) \tag{3}$$

The coefficient values derived from estimates of these functions are then used to generate synthetic "observed" flows corresponding to state centroid inter-regional distances:

$$\begin{aligned} F_i^{mn} = \Bigg[& \left(\hat{\beta}_1 + \hat{\beta}_2 \frac{(|d_{mn} - str_m| + \min(s, d_{mn} - .5))^{\lambda - 1}}{} \lambda \right)^{\frac{\lambda+1}{\lambda}} \\ & - \left(\hat{\beta}_1 + \hat{\beta}_2 \frac{(|d_{mn} - str_m| - \min(s, d_{mn} - .5))^{\lambda - 1}}{\lambda} \right)^{\frac{\lambda+1}{\lambda}} \Bigg] * X_r \end{aligned} \tag{4}$$

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[2] SCTG—Standard Classification of Transported Goods codes are used by the BTS.

[3] Where the SCTG sectors do not match the model sectors precisely data for industries with similar output characteristics are used.

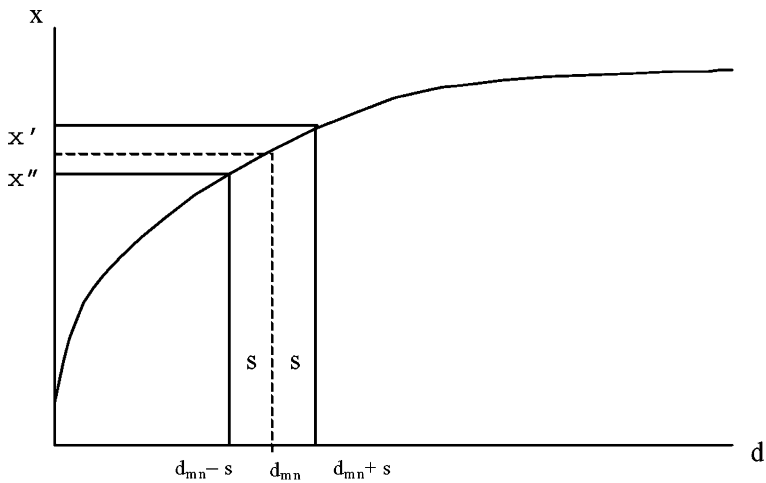

Fig. 3 Cumulative distance function

where F_i^{mn} is the regression-generated (synthetically observed) commodity flow from region m to region n, d_{mn} represents interregional distance, str_m is the distance from the population centroid to the region border, s is the size of buffer around interregional point-to-point distances, and X_r represents domestic export shares derived from the IMPLAN CGE file corresponding to the 1×8 block in Fig. 1.

As described above, generating the observed flows requires the specification of distance buffers around the interregional point-to-point distances. The width of these buffers, s, are constrained by two factors: The width must be less than the interregional distance d_{mn} for each commodity and must not exceed the centroid-to-edge distance of the regional polygons. Given the constraints, the buffers are determined by minimizing the sum of the absolute differences between the sums of the synthetically observed (regression-generated) region-specific imports and the IMPLAN-generated totals of region-specific domestic demand for imports, while accounting for each region's share of total system exports of the commodity.[4] Buffer width minimization is accomplished using the following equation:

$$\underset{s}{Min}\left|\sum_m F_i^{mn} - IM\right| \tag{5}$$

where $\sum_m F_i^{mn}$ is the regression-generated total import demand for region n and IM is the corresponding IMPLAN import demand.

[4] For non-goods commodity sectors (such as higher-level services), averages of the regression parameters from the goods sectors were used. This reflects the assumption that interregional trade in these sectors is related to information flows, which should be reflected by patterns of overall trade. Note that IMPLAN provides the estimate of total exports of these commodities, while our procedure estimates only the interregional distributions of the exports.

Table 2 Tests on Box–Cox distance equation

Sector	Box–Cox λ	Likelihood ratio statistic: χ^2 and *P*-value		
		H_0: λ = −1	H_0: λ =0	H_0: λ = 1
01: Farm products	−0.4395	31.39 (0.00)	30.38 (0.00)	47.66 (0.00)
02: Forest products	−1.4299	10.88 (0.001)	33.72 (0.00)	40.55 (0.00)
03: Metallic ores	−0.7421	15.24 (0.00)	35.63 (0.00)	47.55 (0.00)
04: Coal	−0.4717	16.23 (0.00)	16.26 (0.00)	30.74 (0.00)
05: Crude/NG/gas	−0.7248	20.97 (0.00)	41.54 (0.00)	53.61 (0.00)
06: Nonmetallic minerals	−0.4823	22.51 (0.00)	23.80 (0.00)	39.21 (0.00)
07: Food—meats	−0.3426	26.11 (0.00)	17.80 (0.00)	37.47 (0.00)
08: Food—ag products	−0.5641	27.04 (0.00)	34.14 (0.00)	48.31 (0.00)
09: Tobacco & alcohol	−0.2535	24.35 (0.00)	10.88 (0.001)	32.67 (0.00)
10: Textile mill prod	−0.3963	29.43 (0.00)	23.69 (0.00)	41.74 (0.00)
11: Lumber/wood prod	−0.6641	30.58 (0.00)	45.16 (0.00)	57.59 (0.00)
12: Furniture	−0.1950	21.52 (0.00)	4.84 (0.028)	25.78 (0.00)
13: Pulp/paper	−0.3224	17.76 (0.00)	8.96 (0.003)	26.72 (0.00)
14: Paper & paperboard	−0.4473	20.49 (0.00)	19.47 (0.00)	35.56 (0.00)
15: Printed matter	−0.2642	26.96 (0.00)	12.79 (0.00)	34.32 (0.00)
16: Chemicals	−0.1933	22.48 (0.00)	5.41 (0.020)	27.49 (0.00)
17: Pharm. & chemical	−0.3876	24.22 (0.00)	18.21 (0.00)	35.74 (0.00)
18: Petroleum prod	−0.4807	19.66 (0.00)	21.32 (0.00)	36.82 (0.00)
19: Rubber/plastic	−0.3076	20.77 (0.00)	10.38 (0.001)	29.26 (0.00)
20: Clay/stone prod	−0.5903	23.83 (0.00)	33.96 (0.00)	48.22 (0.00)
21: Primary metal	−0.5280	14.63 (0.00)	17.53 (0.00)	31.03 (0.00)
22: Fabricated metal	−0.3430	22.31 (0.00)	14.07 (0.00)	32.55 (0.00)
23: Machinery	−0.3016	23.28 (0.00)	11.92 (0.001)	31.65 (0.00)
24: Electronic/elec.	0.0471	34.51 (0.00)	**0.95 (0.329)**	30.71 (0.00)
25: Auto & truck	−0.3599	17.52 (0.00)	10.39 (0.001)	27.07 (0.00)
26: All other transport	0.4970	39.29 (0.00)	22.33 (0.00)	19.22 (0.00)
27: Instruments	0.0901	28.99 (0.00)	**1.60 (0.206)**	23.78 (0.00)
28: Misc. manuf.	−0.4106	34.40 (0.00)	29.83 (0.00)	47.94 (0.00)
29: Waste/other	−1.0236	**0.15 (0.699)**	33.72 (0.00)	41.54 (0.00)
Avg. value for sec. 30–54	−0.3005	29.36 (0.00)	17.50 (0.00)	38.45 (0.00)

With the first step complete, δ_i and φ_i can be calibrated by minimizing the squared percentage error between the logit-predicted and regression-generated flows:

$$\underset{\delta,\varphi}{Min} \sum_m \sum_n \left(\frac{\hat{Y}_i^{mn} - F_i^{mn}}{F_i^{mn}} \right)^2 \tag{6}$$

where $\hat{Y}_i^{mn}$ is the predicted flow of commodity i from region m to region n and F^{mn} is the regression-generated commodity flow from region m to region n.

Having calculated commodity-specific values for δ_i and φ_i, the aggregate commodity trade flow distributions in the interregional SAM can be derived by applying the generalized function of Eq. 1 to IMPLAN domestic export estimates from the single-region SAMs. The procedure described generates considerable variation in interaction parameters across commodities. Depending on the commodity, both regional demand and distance can be very important flow determinants or have virtually no effect on flow determination.

4.1 Sector-specific interregional commodity flows

The export distributions for each commodity are first used to apportion the IMPLAN-generated domestic export matrices to destination regions. This apportionment is applied equally to commodities exported by industries and by institutions. The export distributions are then unstandardized by IMPLAN export estimates and normalized by column sum. The result is a set of commodity-specific import distributions by region. These values correspond to the proportion of regional domestic imports that originate in each other region and are then used to apportion aggregate commodities imported by industries and institutions to regions of origin. Because it was derived from the actual export distributions, its use assures consistency between exports from region m to region n and imports by region n from region m (which appear in two separate partitions in the interregional SAM).

As it is unlikely that an ISAM resulting from this procedure would result in a balanced system, an additional adjustment procedure is implemented before the import and export apportionment to insure the integrity of both the individual SAMs and of the system as a whole.

4.2 The adjustment procedure

The adjustment is a bi-proportional reconciliation procedure. For each commodity, the sum of IMPLAN-generated foreign exports by region should equal the corresponding foreign exports from the national SAM. When this is not the case, total regional exports are increased or decreased in equal proportion with an offsetting adjustment to regional domestic imports. The matrix to be bi-proportionally adjusted in this case is a 51×2 matrix with regions as rows and regional domestic and regional foreign exports as columns. The first column margin is set equal to the original estimate of total regional exports less known total national exports, which is the second column margin. Row margins are set equal to total regional exports by region. The bi-proportional adjustment is then implemented until convergence is obtained. The results of this adjustment procedure ensure individual SAM and overall ISAM consistency. Use of the methods in practice on two differing regional data sets yielded approximately a 7% worst-case adjustment in domestic commodity estimates.

5 Summary and discussion

This paper has described an approach to the construction of an interregional SAM for the US, using IMPLAN data as a foundation and incorporating commodity flow data from the US Bureau of Transportation Statistics. The export distribution method provides a generalized function for each commodity and, in doing so, overcomes major obstacles in the use of the CFS data while still taking advantage of the information that is available. The method generates an interregional SAM that is consistent from an accounting perspective, both within each regional SAM and for the interregional modeling system as a whole.

Preliminary comparisons (Jackson et al. 2005) of our methods to others such as that of Liu and Vilain (2004) reveal that our method provides estimates that are approximately 30–50% better than those previously estimated, although the scope of comparison has been limited so far. A comparison between our method and that of Canning and Zhi (2005) is ongoing and the subject of future research papers.

Two areas also warrant additional attention and research. First, generalized export functions for non-commodity (e.g., service) sectors were estimated as a composite function of all flows. Although there is some theoretical justification for this approach, additional research is needed in this area to assess the viability of the embedded assumptions. Second, no attempt has been made in the approach presented by this paper to estimate interregional factor flows or inter-institutional transfers. Theory and methods underlying the estimation of these flows await further development.

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