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Interregional Impacts of Forest-Based Economic Activity

LAWRENCE TEETER
GREGORY S. ALWARD
WARREN A. FLICK

ABSTRACT. A view of forest-based economic activity is presented that highlights the interdependence among industries in separate producing regions. Interindustry transactions for the United States and four subregions (the Northeast, South, West, and Midwest states) were obtained from IMPLAN (IMpact analysis for PLANning), the USDA Forest Service's input-output modeling system. This information was combined with interregion product trade flow estimates obtained from a gravity model to yield an interregional input-output model of the United States emphasizing forest-based industries. The input-output model is used to determine the interregional output, employment, and income effects of final demand changes for products in particular regions. In general, the model reveals that forest-based industries are regionally interdependent, with the greatest spillover effects associated with forest-based industries in the Midwest and Northeast. FOR. SCI. 35(2):515–531.

ADDITIONAL KEY WORDS. Input-output analysis, interindustry analysis, regional economics, interregional trade flows.

PRODUCTION OF FOREST-BASED COMMODITIES in a state or region can be influenced by seemingly unrelated industries; for example, increased demand for food, chemicals, or steel will stimulate production in other industries, which in turn may demand more lumber or paper. Input-output (I-O) models reveal these interindustry effects and can therefore be used for a variety of purposes, including demonstrating the role forestry plays in regional economies (Troutman and Porterfield 1974, Porterfield et al. 1978, Flick et al. 1980, Troutman and Breshears 1981, Schooley and Jones 1983, Waghorne 1983, Jones and Zinn 1986). Regional models, however, only describe the transactions among regional (indigenous) industries and cannot be used to estimate demands placed on neighboring regions for inputs and sales.

Nevertheless, lumber produced in the West often finds its way to southern markets. Housing starts in the North may require wood inputs from the South or West. Interregional input-output models can account for such transregional relationships, showing how demand in one region influences production, employment, and income in other regions. Isard (1951), Leontief (1953), Chenery (1956), and Moses (1960) pioneered the theoretical development of interregional input-output. Wonnacott (1961), Davis (1968), and Polenske (1970a, 1980), among others, have provided useful applications of the theory to regional, national, and international problems.

Few studies have focused on the interdependence of regions of the total (U.S.) forest-based economy. Kaiser (1972) used an I-O model to describe

Lawrence Teeter and Warren A. Flick are Assistant Professor and Associate Professor, School of Forestry, Auburn University, Auburn, Alabama 36849. Gregory S. Alward is a Research Forester, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80526. Alabama Agricultural Experiment Station Journal Series No. 9-871404P. Manuscript received November 9, 1987.

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forest-based economic activity in multiple regions of the South, but did not include nonforest industries, and he did not compare the South's forest economy to that of other regions of the United States. Holley et al. (1975) acknowledged the interdependence of U.S. regions for fiber supplies and markets, but their goal was improved regional projections of timber inventory, growth, and cut rather than an I-O model. Neither of these studies sought to address the extent of interdependence among a broad spectrum of industries spread throughout the country.

Our objective is to provide a new view of the commercial forest economy that highlights the interrelatedness of forest-based industries in distinct regions. The approach is to build an interregional I-O model of the U.S. forest-based economy and show how it relates particular forestry sectors in each region to the economies of other regions and the nation. The paper has three parts. First, input-output modeling is described in general and the forest-based interregional model is presented. Following that, two sections describe some quantitative results and discuss the interregional multiplier effects of production and trade in forest-based products.

INTERREGIONAL MODELING

The distinctive feature of interregional models is that they treat apparently identical sectors located in different regions as distinguishably separate industries. The total output X of a particular sector i in a given region r can be represented in the following way:

$$x_i^r = \sum_{j=1}^{n} \sum_{s=1}^{z} x_{ij}^{rs} + \sum_{s=1}^{n} Y_i^{rs}$$
$$j = 1, \ldots, n$$
$$s = 1, \ldots, z$$

where X_{ij}^{rs} represents the output of industry i produced in region r and sold to industry j in region s, and the Y_i^{rs} represent sales of product i produced in region r to final consumers in region s. In each region, the output of industry i is equal to the sum of its sales to all industries and final consumers in all regions (Richardson 1972). An assumption of interregional models requires that trading coefficients (the proportion of sector i region j output sold to region s) remain relatively constant over time. Although somewhat weaker, this assumption is analogous to the expected behavior of the technical coefficients in any input-output model.

Determining the trading flows (X_{ij}^{rs} terms) is a key element in specifying this model. Several procedures have been devised for estimating these values since statistics describing the flows are not generally available (Polenske 1980). Two of the most widely known methods, the Chenery-Moses column coefficient method (Chenery 1953, Moses 1955) and linear programming transportation models, require base year estimates of trading activity among regions for each product. These data are not easily compiled for any industry, and in particular, the data are very poor for some forestry sectors (Polenske 1980, pp. 197–200). Also, cross-hauling, which is known to exist, is difficult to acknowledge using linear programming models. The Leontief-Strout (Leontief and Strout 1963) method adopted here does not require actual flows information and explicitly allows for cross-hauling. The method has been tested by Polenske (1970a, 1970b) and found to produce acceptable results. The following variables and equations are key to specifying the Leontief-Strout model:[1]

X^i_{go} = the production of commodity i in region g shipped to all (o) regions, $g = 1, \ldots, m$

X^i_{oh} = the consumption of commodity i in region h obtained from all (o) regions, $h = 1, \ldots, m$

X^i_{oo} = the aggregate domestic production/consumption of commodity i in all regions

Leontief and Strout refer to their approach as a "gravity potential" model in which the probability (potential) that a particular unit of commodity i in the national market is produced by region g is the ratio of regional to national production, X^i_{go}/X^i_{oo}. Similarly, the probability that a unit of i is consumed in region h is the ratio of regional to national consumption of i, X^i_{oh}/X^i_{oo}. If we assume that these probabilities are all that determine trade between regions, then the expectation P^i_{gh} that a unit of i is produced in g and shipped to h is:

$$P^i_{gh} = \frac{X^i_{go}}{X^i_{oo}} * \frac{X^i_{oh}}{X^i_{oo}} \qquad \text{for all } i, g, h \quad g \neq h$$

and the amount of i shipped from region g to region h is:

$$X^i_{gh} = X^i_{oo} * P^i_{gh} = \frac{X^i_{go}\, X^i_{oh}}{X^i_{oo}} \qquad \text{for all } i, g, h. \quad g \neq h$$

Other factors influencing trade enter the equation to yield the basic model:[2]

$$X^i_{gh} = \frac{X^i_{go} * X^i_{oh}}{X^i_{oo}} * Q^i_{gh} \qquad i = 1, \ldots, n \quad g,h = 1, \ldots, m \quad g \neq h$$

where $Q^i_{gh} = (C^i_g + K^i_h)\, d^i_{gh}\delta^i_{gh}$. The variable d^i_{gh} is a measure of the inverse of the transport cost of commodity i from region g to region h, δ^i_{gh} is a binary variable indicating whether or not a particular commodity is shipped between a pair of regions in a specific direction (from g to h), and C^i_g and K^i_h are parameters designed to characterize "the relative position of region g vis-a-vis all other regions as a supplier and of region h as a user of good i" (Leontief and Strout 1963). C and K values for each industry are determined as simultaneous solutions to a set of $2m-1$ equations, which include, as parameters, estimates of each region's production, consumption, and consumption of own production of good i. The method is detailed by those authors in their paper and reproduced in Appendix A.

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[1] Notation and much of this discussion of the gravity model follows Davis (1968). A completely specified model can be found in that publication and in its original form (Leontief and Strout 1963).

[2] Leontief and Strout (1963) describe four methods of implementing the gravity model: (1) the exact solution method, (2) the simple solution method, (3) a least squares procedure, and (4) the point estimate procedure. Bon (1984) has discussed the inadequacies of the point estimate procedure. This study used the exact solution method for estimating interregional product flows.

A Forest-Based Interregional I-O Model

The interregional modeling format selected for this study is a modified version of one suggested by Isard (1951). The modification that distinguishes this model from Isard's approach is that final demands are not disaggregated to identify the originating region of a particular product sold to final consumers. An accounting of interregional multiplier effects, however, is not dependent on disaggregating this vector, and so it was not included in this model's design.

Prior to constructing an interregional model, descriptions of the economic activity of each of the component regions must be obtained. IMPLAN (IMpact analysis for PLANning) an economic impact analysis system developed by the USDA Forest Service (Alward and Palmer 1983, Alward et al. 1985, Alward 1987), was used to construct a set of consistent regional I-O models as a foundation for the interregional modeling effort. In general, IMPLAN includes two parts: a descriptive component and an impact analysis component. The function of IMPLAN's descriptive component used in this study is to construct complete I-O accounts for regions of the United States. These accounts are quite detailed, using a classification of more than 500 industries and about 10 nonindustrial institutions. The I-O tables are not derived by directly measuring or surveying economic activity, but instead a variety of methods, collectively referred to as "nonsurvey" and "data reduction" techniques, are used to indirectly estimate the transactions utilizing an internal database of regional statistics. These regional statistics (for all U.S. states and counties) were drawn from a variety of published and generally available sources (such as economic censuses) and assembled using consistent I-O conventions (Alward and Lofting, in press).[3]

Consistency was considered important because a certain amount of art (professional, subjective opinion)—as well as a lot of money—is required to construct a survey based I-O model. It is therefore very difficult to compare survey models that are independently prepared. IMPLAN constructs each table in an identical manner so that problems related to incompatible definitions are avoided. The component states of the four regional models constructed are listed in Table 1. A national model was also constructed to provide control totals and information on foreign imports.

The industry detail provided by IMPLAN (over 500 industry/commodity groups) was significantly more than needed for this study. This number was reduced by aggregating industries according to their Standard Industrial Classifications (SIC codes) developed by the U.S. Department of Commerce. A 17-industry classification scheme (Table 2) was used to highlight the forest-based industries and show their general interactions with the rest of the economy. Six forest-based industries were identified: (1) Logging Camps and Logging Contractors, (2) Sawmills and Planing Mills, (3) Hardwood Dimension Lumber, (4) Plywood and Millwork, (5) Other Wood Products (including furniture), and (6) Paper and Allied Products. The component industries of each of these aggregated forest-based industries are detailed in Appendix B.

IMPLAN provides the information necessary to estimate most of the pa-

[3] While the database is internally consistent, the data are subject to the limitations of the original data sources. For example, to the extent that employment estimates are derived from data reported by the *County Business Patterns* (U.S. Dept. of Commerce 1983), they are subject to the limitations of that data: limited sampling (the first week of March) and only "covered" employment is reported. Similar restrictions apply to other data sources.

TABLE 1. Component states of the South, West, Northeast, and Midwest regions.

South	West	Northeast	Midwest
Alabama	Alaska	Connecticut	Illinois
Arkansas	Arizona	Delaware	Indiana
Florida	California	Maine	Iowa
Georgia	Colorado	Massachusetts	Kansas
Louisiana	Hawaii	Maryland	Kentucky
Mississippi	Idaho	New Jersey	Michigan
North Carolina	Montana	New Hampshire	Minnesota
Oklahoma	Nevada	Pennsylvania	Missouri
South Carolina	New Mexico	New York	Nebraska
Tennessee	Oregon	Rhode Island	North Dakota
Texas	Utah	West Virginia	Ohio
Virginia	Washington	Vermont	South Dakota
	Wyoming	Washington D.C.	Wisconsin

rameters required by the gravity model. Distance was used as a proxy for transport costs. For each region, a city was identified as the geographical center of consumption, and production activity and distances among regions were determined from these points. Centers of production and consumption for a region may not be the same, but no distinction was made for this model. The cities selected were Atlanta (South), Reno (West), New York (Northeast), and Chicago (Midwest). The equation system used to determine the summary parameters C and K (characterizing each region's position as a relative producer and consumer of particular goods) required estimates of regional production, regional consumption, and regional consumption of own production. Regional I-O accounts constructed with IMPLAN provided these estimates.

By using the gravity model, the domestic exports of each industry in each region (obtained from IMPLAN) were distributed to other regions. Table 3

TABLE 2. Industry groups and industry numbers identified for the interregional I-O model.

Industry number	Industry
1	Agricultural products
2	Mining
3	Construction
4	Food & kindred products
5	Fabrics, textiles & apparel
6	Logging camps & contractors
7	Sawmills & planing mills
8	Hardwood dimension lumber
9	Plywood & millwork
10	Other wood products
11	Paper and allied products
12	All other manufacturing
13	Transportation and communications
14	Wholesale and retail trade
15	Finance and real estate
16	Services
17	Government enterprises

TABLE 3. Interregional flows for the "Other Wood Products" industry $MM (1982).

	West	South	Northeast	Midwest
West	0	0	6	26
South	543	0	1047	969
Northeast	143	179	0	156
Midwest	9	0	0	0

provides an example flows matrix for the Other Wood Products industry. According to this flows matrix, cross-hauling is made explicit by this model. For example, the Northeast imports $6,000,000 worth of this industry's output from the West and 1.047 billion dollars worth of output from the South while exporting 143 million, 179 million, and 156 million dollars worth of output to the West, South, and Midwest, respectively.

The gravity model however, did not always produce a usable trade flow table. Often, the model produced negative trade estimates. This has been noted as a common complaint associated with the procedure (Polenske 1980). Also, the row sums (total domestic industry exports) and the column sums (domestic commodity imports) did not always correspond with totals estimates obtained from IMPLAN for each region.[4] To correct for either of these conditions, a two-step procedure was used: first, we assumed that negative flow estimates implied a zero level of trade in that product between the requisite regions, and second, the trade tables were balanced using RAS (Stone and Brown 1962, Bacharach 1970). RAS is not an acronym, but rather the order in which three matrices (labeled *R, A,* and *S* by Stone and Brown) are aligned in the algebraic solution to the biproportional (rows and columns) matrix adjustment problem.

The mechanics of RAS as it was applied in this study are straightforward. First, row sums of a trade matrix for an industry are compared to estimates of total domestic exports for each region. For example, if Table 3 represented an initial flows matrix, row sums are 32, 2559, 478, and 9 for the West, South, Northeast, and Midwest, respectively. If we have estimates of total domestic exports for each region (say 35, 2300, 500, and 12), then the flows estimates need to be adjusted to be consistent with the total estimates. By constructing ratios of the total estimates to the row sum for each region (35/32, 2300/2559, 500/478, and 12/9) and adjusting each entry in a row by its ratio, new row sums will equal the total estimates. The same operation is applied to the columns, so that column sums (domestic imports of a commodity to a particular region from several regions) equal the estimate of total domestic imports of the commodity for that region. After balancing the columns, row sums will no longer equal the total domestic exports estimates, but should be closer than they were prior to this first iteration. The adjustment procedure is repeated several times until the row and column sums converge to the imports and exports totals estimates.

Industry trade matrices (identifying destination industries in destination

[4] Readers need to distinguish between commodity imports and industry imports. Commodity imports represent the value of products of particular industries imported by a region, such as lumber imported by the Midwest. Industry imports represent the value of all commodities imported by a particular industry in a given region. For example, the paper and allied products sector in the South may import some pulp, chemicals, equipment, etc., and their collective value would represent industry imports for that sector.

regions) were constructed using the balanced flow tables. This involved a three-step procedure: (1) distribute foreign imports for the nation to the regions to identify domestic industry imports for each region, (2) distribute the domestic flows to each consuming industry in destination regions, (3) balance the set of trade matrices as a unit using RAS. The next two paragraphs outline these steps.

Total industry imports to a region include both foreign and domestic commodities, and IMPLAN does not distinguish their origin at the regional level. Since total foreign industry imports to the nation were known, this amount was distributed to each region according to weighting factors that reflected (1) each industry's propensity to import (total industry imports to a region relative to industry intermediate outlays) and (2) gross industry imports to the region. These foreign imports to each industry in each region were then subtracted from the industry imports total for a region leaving a residual that represented total domestic industry imports (all commodities) to an industry.

The flow of industry output from one region to another obtained from the gravity model was distributed to industries in a destination region according to the sales pattern established by the corresponding industry in the destination region. That is, each industry was expected to distribute its export to a destination region the same way that local industries distribute their products. This provided preliminary estimates of interregional interindustry trade. Final estimates were obtained by balancing the complete set of interregional trade tables using RAS and the domestic industry imports (determined above) and domestic exports as column and row control totals, respectively.

RESULTS

REGIONAL PRODUCTION

Table 4 indicates total industry output for the six forest-based industries in each region. Total output for these industries accounts for about 2.25% of the total output of all industries in the United States. It is evident from the table that concluding which region leads in forest-based industry production is a matter of definition. If only the Logging Camps and Contractors, Sawmills and Planing Mills, Hardwood Dimension Lumber, and Plywood and Millwork industries are considered (i.e., sectors 1–4), the West is the dominant producer. However, when Other Wood Products (particle board, pallets, etc., sector 5) are added to the measure, the South becomes the leading producer. Adding pulp, paper, and paperboard products alone (a portion of sector 6, Paper and Allied Products) does not affect how the re-

TABLE 4. Total industry output forest-based industries ($MM 1982).

		South	West	Northeast	Midwest
1	Logging camps & contractors	4879	5642	735	866
2	Sawmills & planing mills	3235	5336	680	667
3	Hardwood dimension lumber	558	136	130	211
4	Plywood & millwork	3689	4901	1552	3022
5	Other wood products	8006	3111	2760	4042
6	Paper & allied products	22796	9064	23201	24017
	Total Output	43163	28190	29058	32825

gions rank based on a measure considering only production of industries 1–5 (1st = South, 2nd = West, 3rd = Midwest, 4th = Northeast). However, the ranking changes dramatically when secondary paper products, e.g., bags, envelopes, paperboard containers, sanitary paper products, etc. (the remaining industries in sector 6) are added to the forest-based commodities list (1st = South, 2nd = Midwest, 3rd = Northeast, 4th = West).

INTERREGIONAL EFFECTS

The interregional effects of a change in regional production can be described using interregional multipliers. We estimated Type I interregional multipliers, which provide a relatively conservative measure of the economywide response of industries (except households) in all regions to final demand changes for regional industries. An interregional multiplier is calculated as a ratio of the total-to-direct effects of a final demand change (on output, income, or employment) just as regional multipliers are.[5] Interregional multipliers are generally larger than their regional counterparts because trade between regions is included in the total effects estimates rather than treated exogenously as imports.

Since a total effects estimate is a simple sum of the effects on each industry in each region, an interregional multiplier can be partitioned to show the proportion of the total effect that occurs in each region. The "interregional component" of a Type I output multiplier is the percentage of the direct-plus-indirect (total) output effect associated with a regional final demand change that occurs outside the producing region. Table 5 illustrates the relative magnitude of these effects for each industry in each producing region. Forest-based industries in the Midwest and Northeast have higher average interregional effects (16.36%, 15.73%) than other industries in those regions (9.53%, 9.99%). In the South and West, the average interregional effects for forest-based industries (8.99%, 10.07%) are much closer to the norm for nonforestry industries in those regions (7.99%, 10.62%).

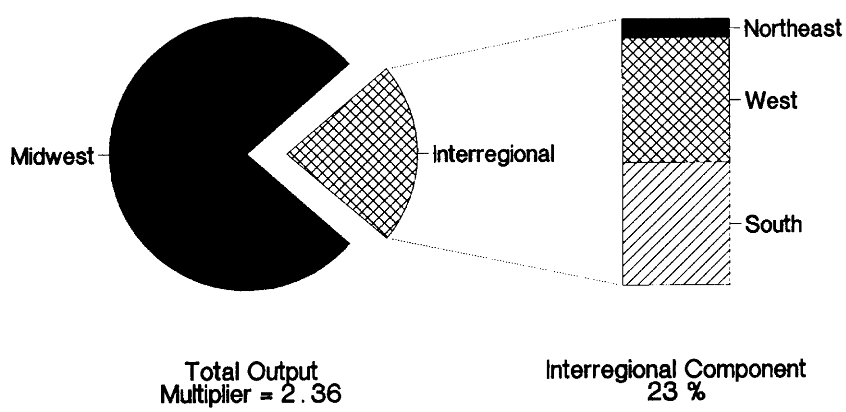

FIGURE 1. Twenty-three percent of the total output multiplier for the Midwest Sawmills and Planing Mills industry accrues to other regions: 45% of that amount is produced in the South; 45% is produced in the West; and 10% is produced in the Northeast.

[5] See Miller and Blair (1985) for a discussion of the procedures used to calculate Type I output, income, and employment multipliers.

TABLE 5. TYPE I interregional output multipliers, their regional components, and their interregional components expressed as percentages.[1]

Industrial sector	South			West	
	Total multiplier	Regional component	Interregional component	Total multiplier	Regional component
Agricultural products	2.38	2.11	11%	2.25	1.98
Mining	1.69	1.61	5%	1.67	1.56
Construction	2.19	1.95	11%	2.16	1.88
Food & kindred products	2.61	2.23	15%	2.56	2.13
Fabrics, textiles & apparel	2.66	2.51	6%	1.85	1.51
Logging camps & contractors	2.58	2.36	9%	2.45	2.18
Sawmills & planing mills	2.57	2.41	6%	2.50	2.32
Hardwood dimension lumber	2.34	2.11	10%	2.27	2.08
Millwork	2.45	2.20	10%	2.47	2.25
Other wood products	2.32	2.09	10%	2.29	2.01
Paper & allied products	2.50	2.29	8%	2.40	2.09
All other manufacturing	2.23	2.07	7%	2.17	1.97
Transportation and communications	2.02	1.87	7%	1.90	1.69
Wholesale and retail trade	1.56	1.48	5%	1.55	1.47
Finance and real estate	1.49	1.42	5%	1.46	1.39
Services	1.82	1.67	8%	1.82	1.65
Government enterprise	2.09	1.91	9%	2.02	1.80

[1] Interregional component = (total multiplier − regional component)/total multiplier.

Based on these results, we can conclude that expanding production in the forest economies of the South and/or West yields a lower level of benefits to other regions (in terms of induced economywide production in those regions) than similar expansions in the Northeast or Midwest. This implies that in the Northeast and Midwest, forest-based industries are more trade-oriented, because demand exceeds supply for internally produced inputs. Using the Sawmill and Planing Mills sector of the Midwest as an example, Figure 1 depicts how this percentage is distributed among supplying regions.

The inputs required from these regions are predominantly roundwood from the Logging Camps and Contractors sector and transportation services from the Transportation and Communications sector. Output multiplier feedback effects (additional intraregional effects resulting from indirect purchases of regional output from outside the region) were evaluated for this model and found, in general, to be relatively insignificant for all sectors. This was probably due to the low level of trading activity estimated by the supply-demand pool technique (used by IMPLAN version 1.1), although it generally agrees with results of other research (Miller and Blair 1985). The highest feedback effects did occur in forest-based industries (1,2,3) in the Midwest, however.

TABLE 5. Continued

West	Northeast			Midwest		
Interregional component	Total multiplier	Regional component	Interregional component	Total multiplier	Regional component	Interregional component
12%	2.24	1.87	17%	2.48	2.20	11%
7%	1.79	1.69	6%	1.80	1.69	6%
13%	2.10	1.92	9%	2.20	2.01	9%
17%	2.34	1.93	18%	2.79	2.49	11%
18%	2.41	1.98	18%	1.93	1.55	20%
11%	1.81	1.59	12%	2.38	1.97	17%
7%	2.13	1.61	24%	2.36	1.83	22%
8%	2.01	1.65	18%	2.08	1.72	17%
9%	2.10	1.82	13%	2.20	1.90	14%
12%	2.13	1.84	14%	2.20	1.89	14%
13%	2.25	1.96	13%	2.33	2.02	13%
9%	2.03	1.88	7%	2.23	2.04	9%
11%	1.79	1.59	11%	1.88	1.65	12%
5%	1.54	1.46	5%	1.56	1.47	6%
5%	1.54	1.46	5%	1.51	1.42	6%
9%	1.74	1.61	7%	1.86	1.72	8%
11%	1.80	1.65	8%	1.96	1.80	8%

Type I employment and income multipliers were determined for each region of the interregional model. Table 6 outlines interregional employment effects (the total number of jobs generated economywide for each new job created as the direct result of increasing forest-based industry final demand).[6] Both the Logging Camps and Contractors and the Paper and Allied Products sectors have relatively high employment multipliers for each region. Averaging about 3, these multipliers link two additional jobs in supplying industries economywide with each new job created in these regional industries by expanding final demand.

Table 7 depicts the economywide direct and indirect income effects of an increase in final demand for the forest-based industries in each region. Type I income multipliers are interpreted as the total direct-plus-indirect income

[6] A reviewer has noted that the Logging Camps and Logging Contractors employment multiplier for the Midwest seems high relative to the corresponding multiplier for the Northeast despite the fact that the production technology in each region is very similar. This is likely due to employee/dollar output ratio differences. The multipliers reported here reflect the data obtained from IMPLAN, which relies on secondary data sources to estimate employment. One possible reason for the employee/dollar output ratio differences may be that employment in that industry is not reported as completely in the Midwest as it is in the Northeast. When the Northeast's ratio is substituted in the calculation of the Midwest's employment multiplier, the result nearly equals the employment multiplier for the Northeast.

TABLE 6. Type I interregional employment multipliers (and how they rank among all 17 region industries).

	South	West	Northeast	Midwest
1 Logging camps & contractors	3.51 (3)	4.39 (1)	2.00 (8)	4.03 (2)
2 Sawmills & planing mills	1.91 (11)	2.34 (6)	1.67 (13)	1.68 (13)
3 Hardwood dimension lumber	1.59 (15)	1.45 (16)	1.47 (15)	1.49 (15)
4 Plywood & millwork	2.00 (10)	2.24 (8)	1.82 (11)	1.94 (9)
5 Other wood products	1.84 (12)	1.87 (11)	1.78 (12)	1.86 (10)
6 Paper & allied products	3.16 (4)	2.98 (3)	2.74 (2)	3.03 (4)

generated per dollar of direct income paid by the industry to meet expanded final demand. Table 8 indicates the percentage of the direct-plus-indirect income effects accruing outside the producing region. The magnitude of the interregional component of the forest-based industry income multipliers relative to nonforestry industries follows the pattern described above for the output multipliers. Forest-based industries in the Midwest and Northeast have higher average interregional income effects (15.4%, 13.6%) than other industries in those regions (9.7%, 8.7%). In the South and West, the average interregional income effects for forest-based industries (9.2%, 9.7%) are much closer to the average for nonforestry industries in those regions (8.9%, 10.5%).

DISCUSSION

The gravity model indicates that there are significant interregional spillover effects associated with the production of forest products in each of the four regions of the United States. This implies that forest-based industries are regionally interdependent; however, the degree of interdependence varies by region and industry. In general, production increases in the Northeast and the Midwest produce greater spillover benefits to other regions than similar increases in the South or West. The Sawmills and Planing Mills industry produces the greatest spillovers in the Midwest and Northeast while the Other Wood Products industry has the largest interregional impacts in the South and West.

Our conclusions about regional interdependence depend, of course, on our definitions of regions. If some states were removed from one region and added to another, our assessments of relative interdependence would likely change. Defining region boundaries is an aspect of regional analysis that requires thoughtful attention and depends considerably on the objectives of the analyst and the major economy of interest (in this case forest-based industries). The region definitions used in this study correspond closely to

TABLE 7. Type I interregional income multipliers (and how they rank among all 17 region industries).

	South	West	Northeast	Midwest
1 Logging camps & contractors	2.49 (6)	2.55 (4)	1.97 (8)	2.42 (4)
2 Sawmills & planing mills	2.16 (10)	2.20 (8)	1.93 (9)	2.07 (8)
3 Hardwood dimension lumber	1.99 (11)	1.83 (14)	1.81 (12)	1.83 (14)
4 Plywood & millwork	2.37 (7)	2.48 (15)	2.15 (6)	2.27 (6)
5 Other wood products	2.17 (9)	2.28 (6)	2.16 (5)	2.21 (7)
6 Paper & allied products	2.61 (5)	2.68 (3)	2.56 (3)	2.60 (3)

TABLE 8. Percentage of the direct plus indirect income effects accruing outside the producing region.

	South	West	Northeast	Midwest
1 Logging camps & contractors	10%	11%	11%	19%
2 Sawmills & planing mills	6%	7%	20%	20%
3 Hardwood dimension lumber	9%	7%	14%	14%
4 Plywood & millwork	11%	9%	12%	13%
5 Other wood products	10%	11%	12%	13%
6 Paper & allied products	9%	13%	13%	14%

definitions used in numerous federal studies (e.g., USDA Forest Service 1982, USDA Office of Budget and Program Analysis 1983). Alternative definitions may be more approriate to the needs of other analysts.

The primary purpose of this paper, however, was to provide a view of the forest economy that has previously been ignored. Analysts and/or planners charged with describing the effects of factor cost increases or the benefits of expanding production need to acknowledge that industries may depend on industries in other regions for inputs. Using Figure 1 as an example, the West and the South can expect to benefit considerably more than the Northeast from programs aimed at stimulating production in the Midwest Sawmills and Planing Mills industry. As a corollary, if the costs of suppliers to that industry increase, the effect will be greatest if the increase occurs in the South or West rather than the Northeast. Knowledge of the interregional component of industry interdependence will help industry and government leaders evaluate how demand level changes in particular regions impact the larger (multicounty, state, multistate, national) forest-based economy.

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APPENDIX A[7]

The basic Leontief-Strout (1963) gravity model is presented in the text as Equation (4) and is repeated here as the first equation of the appendix (the industry superscript i has been removed for convenience):

$$X_{gh} = \frac{X_{go}X_{oh}}{X_{oo}} Q_{gh} \qquad g,h = 1, \ldots, m \tag{A1}$$

where

$$Q_{gh} = (C_g + K_h)d_{gh}\,\delta_{gh} \tag{A2}$$

C_g and K_h are described in the text as parameters that characterize in a summary way the relative position of region g as a supplier and region h as a user of good i. They can be determined indirectly using IMPLAN estimates of regional production and consumption, and then balance relations that circumscribe internal trade in the national economy.

The supply of good i in region g is equal to the amount of good i shipped from g to all othe regions including g itself ($g = 1, \ldots, m$):

$$X_{go} = \sum_{h=1}^{m} X_{gh} \tag{A3}$$

Similarly, consumption of i in region h is equal to the amount of i shipped to h from all regions, including consumption of own production ($h = 1, \ldots, m$):

$$X_{oh} = \sum_{g=1}^{m} X_{gh} \tag{A4}$$

Substituting Equation (A1) into Equations (A3) and (A4) yields:

$$X_{go} = X_{go}\frac{\sum_{h=1}^{m} X_{oh}\,Q_{gh}}{X_{oo}} + X_{gg} \qquad \begin{matrix}(Q_{gg} = 0)\\ (g = 1, \ldots m)\end{matrix} \tag{A5}$$

$$X_{oh} = X_{oh}\frac{\sum_{g=1}^{m} X_{go}\,Q_{gh}}{X_{oo}} + X_{hh} \qquad \begin{matrix}(Q_{gg} = 0)\\ (h = 1, \ldots m)\end{matrix} \tag{A6}$$

Simplifying and substituting Equation (A2) into Equations (A5) and (A6) respectively, yields:

$$X_{go}\sum_{h=1}^{m} [X_{oh}(C_g + K_h)d_{gh}\delta_{gh}] = (X_{go} - X_{gg})X_{oo} \qquad \begin{matrix}(\delta_{gg} = 0)\\ (g = 1, \ldots, m)\end{matrix} \tag{A7}$$

[7] The discussion in this appendix draws heavily on Davis (1968) and Leontief and Strout (1963).

$$X_{oh}\sum_{g=1}^{m}[X_{go}(C_g + K_h)d_{gh}\delta_{gh}] = (X_{oh} - X_{hh})X_{oo} \qquad \begin{matrix}(\delta_{hh} = 0)\\ (h = 1, \ldots, m)\end{matrix} \tag{A8}$$

Together, Equations (A7) and (A8) form a set of $2m$ equations with $2m$ unknowns C_g and K_h. Since observable base-year values for production and consumption will satisfy the overall equality between the aggregates (aggregate production equals aggregate consumption and the sum of all trade flows, including intraregional shipments),

$$\sum_{g=1}^{m}\sum_{h=1}^{m} X_{gh} = \sum_{g=1}^{m} X_{go} = \sum_{h=1}^{m} X_{oh} = X_{oo} \tag{A9}$$

then one of the $2m$ Equations (A7) or (A8) is redundant and can be eliminated. In addition, if some set of C_g and K_h values satisfies the equation system, $C_g - c$ and $K_h + c$ (where c is an arbitrary constant) will also satisfy the system. This is to say that only $2m - 1$ and not $2m$ of these C and K parameters are needed to uniquely determine the magnitudes of all interregional flows. Therefore, not only is one of the $2m$ equations dropped, but one of the $2m$ unknowns must be arbitrarily fixed. The first equation ($h = 1$) is selected for elimination, and K_1 (for all i) is arbitrarily set equal to 0.

To ease computation, $X_{go}C_g$ and $X_{oh}K_h$ are treated as the unknowns rather than C_g and K_h and are respectively factored from Equations (A7) and (A8), and all observable values are expressed in terms of X_{oo} (effectively setting $X_{oo} = 1$):

$$X_{go}C_g\sum_{h=1}^{m}(X_{oh}d_{gh}\delta_{gh}) + X_{go}\sum_{h=1}^{m}K_hX_{oh}d_{gh}\delta_{gh} = X_{go} - X_{gg} \qquad (g,h = 1, \ldots m) \tag{A9}$$

$$X_{oh}K_h\sum_{g=1}^{m}(X_{go}d_{gh}\delta_{gh}) + X_{oh}\sum_{g=1}^{m}C_g\,X_{go}\,d_{gh}\,\delta_{gh} = X_{oh} - X_{hh} \qquad \begin{matrix}(g = 1, \ldots m)\\ (h = 2, \ldots m)\end{matrix} \tag{A10}$$

Dividing Equations (A9) and (A10) by X_{go} and X_{oh} respectively, yields:

$$X_{go}C_g\frac{\sum_{h=1}^{m}X_{oh}d_{gh}\delta_{gh}}{X_{go}} + \sum_{h=1}^{m}K_hX_{oh}d_{gh}\delta_{gh} = 1 - \frac{X_{gg}}{X_{go}} \qquad (g = 1, \ldots, m) \tag{A11}$$

$$X_{oh}K_h\frac{\sum_{g=1}^{m}X_{go}d_{gh}\delta_{gh}}{X_{oh}} + \sum_{h=2}^{m}C_gX_{go}d_{gh}\delta_{gh} = 1 - \frac{X_{hh}}{X_{oh}} \qquad (h = 2, \ldots, m) \tag{A12}$$

Equations (A11) and (A12) can be written in matrix form (in this case m equals four regions) and solved by inverting the square matrix on the left-hand side of (A13). The resulting C and K values can be inserted in Equation (A2) to determine interregional trade flows.

$$
\left[\begin{array}{ccc|cccc}
\sum_{g=1}^{4}\frac{X_{go}d_{g2}\delta_{g2}}{X_{o2}} & 0 & 0 & d_{12}\delta_{12} & 0 & d_{32}\delta_{32} & d_{42}\delta_{42} \\
0 & \sum_{g=1}^{4}\frac{X_{go}d_{g3}\delta_{g3}}{X_{o3}} & 0 & d_{13}\delta_{13} & d_{23}\delta_{23} & 0 & d_{43}\delta_{43} \\
0 & 0 & \sum_{g=1}^{4}\frac{X_{go}d_{g4}\delta_{g4}}{X_{o4}} & d_{14}\delta_{14} & d_{24}\delta_{24} & d_{34}\delta_{34} & 0 \\
\hline
d_{12}\delta_{12} & d_{13}\delta_{13} & d_{14}\delta_{14} & \sum_{h=1}^{4}\frac{X_{oh}d_{1h}\delta_{1h}}{X_{1o}} & 0 & 0 & 0 \\
0 & d_{23}\delta_{23} & d_{24}\delta_{24} & 0 & \sum_{h=1}^{4}\frac{X_{oh}d_{2h}\delta_{2h}}{X_{2o}} & 0 & 0 \\
d_{32}\delta_{32} & 0 & d_{34}\delta_{34} & 0 & 0 & \sum_{h=1}^{4}\frac{X_{oh}d_{3h}\delta_{3h}}{X_{3o}} & 0 \\
d_{42}\delta_{42} & d_{43}\delta_{43} & 0 & 0 & 0 & 0 & \sum_{h=1}^{4}\frac{X_{oh}d_{4h}\delta_{4h}}{X_{4o}}
\end{array}\right]
\left[\begin{array}{c}
x_{o2}K_2 \\ X_{o3}K_3 \\ X_{o4}K_{o4} \\ \\ X_{1o}C_1 \\ X_{2o}C_2 \\ X_{3o}C_3 \\ X_{4o}C_4
\end{array}\right]
=
\left[\begin{array}{c}
1 - \frac{X_{22}}{X_{o2}} \\ 1 - \frac{X_{33}}{X_{o3}} \\ 1 - \frac{X_{44}}{X_{o4}} \\ \\ 1 - \frac{X_{11}}{X_{1o}} \\ 1 - \frac{X_{22}}{X_{2o}} \\ 1 - \frac{X_{33}}{X_{3o}} \\ 1 - \frac{X_{44}}{X_{4o}}
\end{array}\right]
$$

APPENDIX B Standard Industrial Classificaton (SIC) Codes Included In Forestry Sector Definitions

	SECTOR description	SIC code
1	Logging Camps and Logging Contractors	2411
2	Sawmills and Planing Mills	2421
3	Hardwood Dimension Lumber	
	Hardwood dimension and flooring mills	2426
	Special product sawmills, n.e.c.[1]	2429
4	Plywood and Millwork	
	Millwork	2431
	Wood kitchen cabinets	2434
	Veneer and plywood	2435, 2436
	Structural wood members, n.e.c.[1]	2439
	Wood partitions and fixtures	2541
5	Other Wood Products	
	Prefabricated wood buildings	2452
	Wood preserving	2491
	Wood pallets and skids	2448
	Particleboard	2492
	Wood products, n.e.c.[1]	2499
	Wood containers	2441, 2449
	Wood household furniture	2511
	Wood tv and radio cabinets	2517
	Upholstered household furniture	2512
	Wood office furniture	2521
6	Paper and Allied Products	
	Pulp mills	261
	Paper mills, except building paper	262
	Paperboard mills	263
	Envelopes	2642
	Sanitary paper products	2647
	Building paper and board mills	266
	Paper coating and glazing	2641
	Bags, except textile	2643
	Die-cut paper and board	2645
	Pressed and molded pulp goods	2646
	Stationery products	2648
	Converted paper products, n.e.c.[1]	2649
	Paperboard containers and boxes	265

[1] n.e.c. = not elsewhere classified.