A Technique for Merging Areas in Timber Mart-South Data

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ABSTRACT: *For over20 yr, Timber-Mart-South (TMS) has been distributing prices of various woodproducts from southern forests. In the beginning of 1988, the reporting frequency changed from monthly to quarterly, a change readily addressed through a variety of established statistical techniques. A more significant statistical challenge is Timber Mart-South's change in 1992 from (typically) three reporting regions per state to two. We developed a conversion technique to address this change in reporting areas, permitting longitudinal analyses of the current two regionsperstate but extending back to the beginning of Timber Mart-South's reports in 1976. We report conversion factors for every state's regions, verify the statistical nature of all time series created using them, and report tests of seamlessness. We find that our technique enables the creation of new, seamless series for pine sawtimber stumpage and delivered sawlogs, and pine and hardwood pulpwood stumpage and delivered logs. In only 30 out of 126 cases were we able to identify remaining regime shifts in the time-series of quarterly prices that corresponded with the 1992 boundary reconfigurations. However, these statistically significant shifts may not be related to the boundary reconfgurations. South. J. Appl. For. 24(4):219-229.*

For over 20 yr, Timber Mart-South (Norris Foundation 1977-1999) has been reporting to subscribers prices of various wood products from southern forests. These long-term price series have been critical resources for research into optimal harvest behavior [e.g., Brazee and Mendelsohn (1988), Washburn and Binkley (1990, 1993), Haight and Holmes (1991), Thomson (1992), Hultkrantz (1993)], demand and supply equation estimates (e.g., Newman 1987) and general analyses of price and supply trends in the southern United States. Many of these analyses have relied on consistent temporal and spatial reporting units. The research mentioned has relied on the consistency of Timber Mart-South (TMS) data at least through 1987. Unfortunately, since 1987, these units have not been consistent. From 1976 (December) until 1988 (March), prices were reported monthly, but following the March 1988 report, the reporting frequency changed to quarterly. A quarterly time-series can be derived from a monthly time-series by either averaging the three months or by taking consistent (e.g., middle-month) samples from the monthly data. Indeed, many authors have already used such techniques to carry out their research with these data (Haight and Holmes 1991, Thomson 1992, Hultkrantz 1993, Washburn and Binkley 1993).

A more significant statistical challenge is Timber Mart-South's change in 1992 from (typically) three reporting regions per state to two. The goal of this article is to describe and statistically test the seamlessness of a conversion technique we developed to address this change in reporting areas. The resulting series permit longitudinal analyses of the current two regions per state, extending back to the beginning of Timber Mart-South's reports in 1976. This conversion is accomplished by weighting prices in the old regions by average annual removals from each county, yielding proxy prices that correspond to the new regions.

To evaluate the validity of this approach, we test these time series by (1) sampling the middle month of each region's pre-1988 proxy prices and taking the quarterly price for the 1988-1991 proxy series and appending them to the corresponding 1992-1998 actual quarterly series, creating quarterly series that run from 1977-1998; (2) conducting unit root tests of each 1977-1998 quarterly series to verify the need for differencing of the data; and (3) estimating intervention models of each of the differenced series, using a dummy variable corresponding to the 1992 regime shift. We analyzed the seamlessness of 6 product series for 21 TMS regions, including those that had reconfigured boundaries and those that did not. For brevity we'll refer to the TMS reporting regions as *Areas.*

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Methods

We begin our methods by explaining how region weights were calculated and applied, then explain the structure of the intervention models used to evaluate TMS Area weighting schemes. Middle-month sampling was used to generate the quarterly observations for the pre-1988 series.

Area Weighting

Early TMS reporting techniques were described in Gunter and Cubbage (1987). These authors explained that TMS prices have been reported as simple average sale prices per unit volume within an Area. Average prices are reported by contracted consultants to Timber Mart-South, Inc. For stumpage, reported prices are the observed average price of timber sales organized by the consultant. For delivered products, simple averages over all reporting mills are calculated. The published TMS "average" price for the Area for the period is the simple average of the reports within product categories for that period. Product categories analyzed here are southern pine (principally, ***Pinus taeda*** L., ***P. echinata*** Mill., ***P. elliottii*** Engelm., ***P. palustris*** Mill.) pulpwood stumpage and delivered logs, southern pine sawtimber stumpage and delivered logs, and mixed hardwood pulpwood stumpage and delivered logs.

TMS published maps of old and new TMS Areas, and these were used to identify Area boundaries. Old and new Area borders within each state, while described by TMS (Norris Foundation 1992) as "diffuse and gradual," typically follow state and county boundaries. We surmised, then, that county-level data on forest resources would provide a reasonable method for converting the old Area prices to new Area prices for 1976-1991.

Forest resources within each county were defined by product. Pine sawtimber and delivered sawlog prices were assumed to be most closely related to sawtimber resources, while pulpwood prices were assumed to be best related to poletimber resources. Similar reasoning led to resource definitions for hardwood products.

The USDA Forest Service's Forest Inventory and Analysis (FIA) recorded standing timber inventory, growth, and removals as part of its periodic surveys of forest resources. We chose county-level removals by species as the best weighting approach, since removals are priced by TMS, not inventory. This choice is similar to techniques outlined by Granskog and Crowther (1991) in creating weighted state- and southwide-average pulpwood price series.

Each TMS Area contains several counties and portions of counties. Equation (1) expresses the proportion, π, of the old TMS Area (i = 1,...,I) contained in the new Area (j = 1,2), as a function of the proportionp, of the removal volume q, found in the county k, for wood product r:

$$\pi_{ijr} = \sum_{k=1}^{K} p_{ijk} q_{kr} \qquad (1)$$

For example, in the counties assigned to Georgia new Area 1, 76.28% of pine sawtimber removals were attributed to counties previously assigned to old Area 1, 23.72% to counties assigned to old Area 2, and 0% to counties assigned to old Area 3. Hence, the weights for creating new Area 1 sawtimber and sawlog prices for Georgia are π_{11saw} = 0.7628, π_{21saw} = 0.2372, and π_{31saw} = 0. In our analysis, weights were calculated with Equation (1) for all southern states for which a consistent series of price data could be identified. Data on hardwood and softwood sawtimber and poletimber removals were obtained from the Forest Service's FIA database (USDA Forest Service 1997). Tables l-3 report the weights. (These are freely available in electronic form either directly from the authors or from the following Internet address: http://www.rtp.srs.fs.fed.us/econ/data/tmbrmart/index.htm)

Price series corresponding to the new TMS Area for product r were then generated from the old Areas with the following equation:

$$P_{jr,t} = \sum_{i=1}^{I} \pi_{ijr} P_{ir,t} \qquad (2)$$

where $P_{jr,t}$ is the price of product r in TMS new Area j in period t, and $P_{ir,t}$ is the price of product r in TMS old Area i in period t, and π_{ijr} is the weight used in converting old Area series to new Area series. Referring again to the Georgia new Area 1 example, if the old Area 1 price in January 1977 were \$63/mbf, old Area 2 were \$80, and old Area 3 were \$110, then the price corresponding to the new Area 1 in January of 1977 would have been (63 x 0.7628) + (80 x 0.2372) + (110 x 0) = \$67.03/mbf.

Figure 1 illustrates the effects of our weighting procedure. On the left side of the figure are plotted two old TMS Area series (Area 1, Area 2) for pine sawtimber stumpage in Georgia, from 1977-1991. On the right is the new TMS Area 1 price series for that same product, plotted from 1992-1998. The

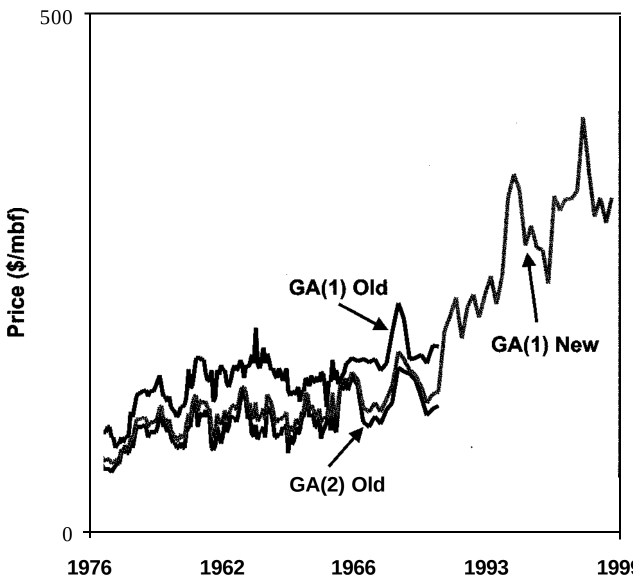

Figure 1. Georgia Timber Mart-South old Area 1, GA(1) Old, and 2, GA(2) Old, 1977-1991, and new Area 1, GA(1) New, quarterly pine sawtimber stumpage price series, 1992-1998. Price series for the 1977-1987 period were monthly. The GA(1) New series were constructed using the weights shown in Table 2 for 1977-1991 and are the actual Timber Mart-South new Area 1 series for 1992-1998.

Table 1. Timber Mart-South weighting schemes by new Area and old Area, using county-level pine poletimber removals volumes (mm ft^3) from FIA (1980s and 1990s surveys), applicable to pine pulpwood stumpage and delivered log prices.

State (survey year)	New area	Old area 1 weight	Old area 2 weight	Old area 3 weight	Total volume (mm ft^3)
Alabama (1990)	1	0.5083	0.4917	0.0000	57
	2	0.0171	0.4684	0.5145	47
Arkansas (1988)	1	0.7482	0.2518	0.0000	42
	2	0.0000	1.0000	0.0000	4
Florida (1987)	1	1.0000	0.0000	0.0000	117
	2	0.2804	0.0000	0.7196	72
Georgia (1989)	1	0.7622	0.2378	0.0000	31
	2	0.0000	0.5228	0.4772	59
Kentucky (1988)	1	0.5417	0.4583	0.0000	2
	2	na	na	na	0
Louisiana (1991)	1	0.9994	0.0000	0.0006	84
	2	0.0000	0.0000	1.0000	11
Mississippi (1987)	1	0.0000	0.6829	0.3171	25
	2	0.0000	0.0000	1.0000	31
North Carolina (1990)	1	0.5041	0.4959	0.0000	6
	2	0.0000	0.2830	0.7170	45
Oklahoma (1986)	1	0.9000	0.1000	0.0000	5
	2	na	na	na	0
South Carolina (1986)	1	1.0000	0.0000	0.0000	6
	2	0.0000	0.6600	0.3400	50
Tennessee (1989)	1	0.9286	0.0714	0.0000	6
	2	0.0000	0.4815	0.5185	3
Texas (1986)	1	1.0000	0.0000	0.0000	19
	2	0.0000	1.0000	0.0000	24
Virginia (1984)	1	1.0000	0.0000	0.0000	3
	2	0.0000	0.7456	0.2544	17

NOTE: na = insufficient data to calculate.

weights shown in our tables for Georgia Area 1 are concerned with constructing a 1977-1991 series corresponding to Georgia new Area 1. The constructed series for Area 1 is shown in the figure as a gray line.

TMS Areas changed only slightly in some states while others underwent substantial revision. One way to measure the degree of change is by measuring its relative diversity. For example, a new Area that is composed of equal parts of old Areas 1, 2, and 3 has experienced the most change in definition while one that is composed of 95% old Area 1 and 5% old Area 2 has changed little. A diversity index such as Shannon's diversity index can quantify the change. Area j's diversity index of reconfiguration for product r is therefore:

$$D_{jr} = -\sum_{i=1}^{I} \pi_{ijr} \log(\pi_{ijr}) \quad (3)$$

This diversity index is bounded by 0 and 0.477 for base-10 logarithms, where 0 indicates no reconfiguration, and 0.477 indicates creating one new Area from equal parts of three old Areas.

Intervention Modeling

To examine whether the price series generated by using our weighting procedure showed no residual effect of the procedure, we applied a statistical testing procedure called "intervention analysis." We generated price series using the weights shown in Tables 1-3, using removals data. Weights constructed using inventories of pine sawtimber and pine and hardwood poletimber were also examined (not shown), but we found few notable differences between removals-based and inventory-based series. For pulpwood prices, weights used in Equation (2) were those derived from poletimber removals (Table 1 for pine, Table 3 for mixed hardwood). For pine sawtimber prices, weights used in Equation (2) were those for pine sawtimber removals (Table 2). No hardwood sawtimber price series were examined because TMS has not had a consistent series of sufficient duration to make a useful evaluation.

Table 2. Timber Mart-South weighting schemes by new Area and old Area, using county-level pine sawtimber removals volumes (mm bf), from FIA (1980s and 1990s surveys), applicable to pine sawtimber stumpage and pine delivered sawlog prices.

State (survey year)	New area	Old area 1 weight	Old area 2 weight	Old area 3 weight	Total volume (mm bf)
Alabama (1990)	1	0.4905	0.5095	0.0000	633
	2	0.0188	0.4427	0.5385	851
Arkansas (1988)	1	0.8468	0.1524	0.0007	1,139
	2	0.0000	1.0000	0.0000	36
Florida (1987)	1	1.0000	0.0000	0.0000	625
	2	0.1100	0.0000	0.8900	481
Georgia (1989)	1	0.7628	0.2372	0.0000	370
	2	0.0000	0.5528	0.4472	843
Kentucky (1988)	1	0.5436	0.4564	0.0000	14
	2	0.0000	1.0000	0.0000	0
Louisiana (199 1)	1	0.9844	0.0147	0.0009	1,455
	2	0.0000	0.0000	1.0000	324
Mississippi (1987)	1	0.0013	0.4341	0.5646	390
	2	0.0000	0.0000	1.0000	732
North Carolina (1990)	1	0.7060	0.2940	0.0000	82
	2	0.0000	0.4684	0.5316	468
Oklahoma (1986)	1	0.8157	0.1843	0.0000	65
	2	0.0000	0.0000	1.0000	1
South Carolina (1986)	1	1.0000	0.0000	0.0000	32
	2	0.0000	0.4656	0.5344	629
Tennessee (1989)	1	0.8982	0.1018	0.0000	67
	2	0.0000	0.6502	0.3498	24
Texas (1986)	1	1.0000	0.0000	0.0000	238
	2	0.0000	1.0000	0.0000	815
Virginia (1984)	1	1.0000	0.0000	0.0000	27
	2	0.0000	0.3364	0.6636	153

The resulting data series covered the first quarter of 1977 to the last quarter of 1998. Prices were expressed in natural logarithms and were nominal (undeflated), to avoid problems encountered by filtering the data through a deflating mechanism (Schnute 1987). All quarterly price series were evaluated with augmented Dickey-Fuller (ADF) tests (Dickey and Fuller 1979) to determine whether series were integrated. ADF tests were performed for the entire series, a maximum of 88 observations/region/product (some regions had missing observations), and involved no dummies indicating either region shifts or frequency of price reporting.

ADF tests included an intercept and sufficient lagged-difference terms to ensure white-noise errors, and all showed that nonstationarity could not be rejected for any series. After first-differencing, then, all series were stationary using ADF tests, indicating that they could be effectively modeled as autoregressive-moving average (p, q), or ARMA (p, q), series. In the context of differenced price series, ARMA (p, q) series are those whose current price difference is a function of p past price differences and q past changes in price differences (see Hamilton 1994, p. 43-61).

Intervention models were used to test whether the change in region definitions were still detectable in the constructed price data, even after the weighting procedure was applied. The intervention models included a dummy variable with a value of 1 corresponding to the first quarter of 1992, 0 otherwise. The structure of this equation, suppressing region and product subscripts, was:

$$d(P_t) = a + \beta R_t + A(L)d(P_{t-1}) + B(L)\varepsilon_t \qquad (4)$$

where a is a constant; R_t is a dummy variable corresponding to the first quarter of 1992; ε measures the degree of price change for the first quarter of 1992, independent of other changes; $A(L)$ and $B(L)$ are polynomials in the lag operator; and the ε's are normally distributed random errors with $E(\varepsilon_t)=0$, $E(\varepsilon_t\ \varepsilon_t)= \sigma^2$ (for all t), and $E(\varepsilon_t\ \varepsilon_s) = 0$ ($t \neq s$). Also, $E(\varepsilon_t\ P_t) = 0$. The term βR_t is what is referred to as the "noise" in the model, deviations from the ARMA model that remain after all correlations with past changes in price and random errors are taken into accounted,

Table 3. Timber Mart-South weighting schemes by new Area and old Area, using county-level hardwood poletimber removals volumes (mm ft^3) from FIA (1980s and 1990s surveys), applicable to hardwood pulpwood stumpage and delivered log prices.

State (survey year)	New area	Old area 1 weight	Old area 2 weight	Old area 3 weight	Total volume (mm ft^3)
Alabama (1990)	1	0.5000	0.5000	0.0000	40
	2	0.0119	0.3943	0.5938	42
Arkansas (1988)	1	0.8422	0.1489	0.0089	45
	2	0.0000	0.9663	0.0337	9
Florida (1987)	1	1.0000	0.0000	0.0000	14
	2	0.3455	0.0000	0.6545	11
Georgia (1989)	1	0.8314	0.1686	0.0000	13
	2	0.0000	0.6831	0.3169	38
Kentucky (1988)	1	0.5702	0.4298	0.0000	12
	2	0.0000	0.2838	0.7162	7
Louisiana (1991)	1	0.8639	0.1208	0.0154	49
	2	0.0000	0.0000	1.0000	4
Mississippi (1987)	1	0.0568	0.5459	0.3974	23
	2	0.0000	0.0000	1.0000	20
North Carolina (1990)	1	0.8202	0.1798	0.0000	9
	2	0.0000	0.4845	0.5155	32
Oklahoma (1986)	1	0.8966	0.1034	0.0000	3
	2	0.0000	0.0909	0.9091	1
South Carolina (1986)	1	1.0000	0.0000	0.0000	3
	2	0.0000	0.3961	0.6039	21
Tennessee (1989)	1	0.7374	0.2626	0.0000	9
	2	0.0000	0.7789	0.2211	10
Texas (1986)	1	1.0000	0.0000	0.0000	8
	2	0.0000	1.0000	0.0000	12
Virginia (1984)	1	1.0000	0.0000	0.0000	11
	2	0.0000	0.6021	0.3979	19

Results

Intervention model estimates are reported in Tables 4-6 for stumpage prices and 7-9 for delivered log prices. Column 1 of each table shows the TMS Area identifier–the two-letter postal abbreviation plus the Area number (1 or 2). Column 2 in these tables contains indices of diversity of reconfiguration of new TMS Areas. Several TMS Areas appeared to have no changes in region definitions: FL1 (most cases), LAl, LA2, MS2, SCl, TXl, TX2, and VAl. By this measure, the Areas with the most radical changes in configuration were ALl, AL2, FL2, GA2, MS1, NC2, TN2, and VA2.

The third column of these tables reports augmented Dickey-Fuller tests of nonstationarity of the natural logarithms of undifferenced nominal price series over the entire period, 1977(I)-1998(IV). In only 1 series out of the 132 evaluated (Arkansas TMS Area 1 pine pulpwood stumpage) could a null hypothesis of nonstationarity be rejected, and in that case at only 10% significance. These results argued for differencing all series to obtain stationary series of changes in logarithmic prices.

Intervention equation estimates follow in the fourth through ninth columns. Not reported in these tables are the adjusted R^2s (all less than 0.30), or the Durbin-Watson test statistics of first-order serial correlation in the residuals of the equation estimates (all showing no significant residual autocorrelation). A Box-Cox approach to estimating the models was used (see Hamilton 1994, p. 109-l13), resulting usually in ARMA(l,0), ARMA(0,l), or ARMA(1,1) models. The validity of these models was evaluated by examining correlograms of residuals, to assure that the model residuals were independently and identically distributed with a common variance.

Seventeen of 63 stumpage price series and 13 of 63 delivered log price series registered region reconfiguration dummy coefficients significantly different from 0 at 10% significance. The frequency of statistical significance of that dummy coefficient was over twice the rate expected (13) given the 10% threshold.

Table 4. Results of nonstationarity tests and estimates of ARMA models with a region change dummy, weights based on removals, for southern pine pulpwood nominal, natural logarithmic stumpage prices, for 1977(I)-1998(IV), by new Timber Mart-South Area.

TMS area	Change diversity[a]	ADF test statistic[b]	ARMA equation estimate[c]					
			Intercept	Region dummy	AR(1)	MA(1)	AR(2)	AR(3)
AL1	0.30	-1.12	0.01**	0.01		-0.55 ***		
AL2	0.33	-1.14	0.01*	-0.06		-0.40 ***		
AR1	0.25	-2.75	0.01	-0.10		-0.31 ***		
FL1	0.00	-1.95	0.01	-0.01		-0.32 ***		
FL2	0.26	-1.93	0.01	-0.03	-0.27 **		-0.25 **	-0.38 ***
GA1	0.24	-1.34	0.01	0.40 ***		-0.40 ***		
GA2	0.30	-1.89	0.01	0.07	-0.20 *		-0.35 ***	
LA1	0.00	-1.55	0.02**	0.04		-0.46 ***		
LA2	0.00	-1.52	0.01	0.04	-0.22 **		-0.28 ***	
MS1	0.27	-0.13	0.02 **	0.28 ***		-0.31 ***		
MS2	0.00	-1.07	0.01**	0.23 *	0.44 ***	-0.84 ***		
NC1	0.30	-0.94	0.01*	-0.02	-0.25	-0.43 ***		
NC2	0.26	-0.67	0.01***	-0.10		-0.47 ***		
SC1	0.00	-0.76	0.01*	0.25 ***	-0.55 ***		-0.35 ***	-0.37 ***
SC2	0.28	-0.33	0.01	0.15	-0.28 ***		-0.33 ***	-0.45 ***
TN1	0.11	-0.51	0.02	-0.09	0.25 *		-0.35 **	
TN2	0.30	-1.21	0.01	0.18	-0.21			
TX1	0.00	-1.42	0.02	0.17		-0.42 ***		
TX2	0.00	-1.65	0.02 *	-0.12	-0.11		-0.19 *	-0.20 *
VA1	0.00	-0.17	0.02**	0.19 *	-0.50 ***		-0.35 ***	-0.23 *
VA2	0.25	-0.03	0.01***	0.05		-0.57 ***		

NOTE: Asterisks indicate that the estimated coefficient is statistically different from zero at 10% (*), 5% (**) or 1% (***) significance,

[a] Shannon's index of diversity of the mix of old TMS Areas.

[b] Augmented Dickey-Fuller tests of nonstationarity, with sufficient lagged-difference terms to attain white noise errors,

[c] Due to missing values and varying numbers of ARMA terms, usable observations ranged from 65 to 87.

For a subset of products and TMS Areas, prices in the first quarter of 1992 increased 20 to 40%. This was true irrespective of the amount of region configuration, and it was geographically centered on the Southern Appalachians. Of the 17 stumpage price series with significant region dummies, 7 had no TMS Area reconfiguration. The regions significantly affected for pine pulpwood stumpage were GA1 (northern Georgia), both Mississippi series, both South Carolina series, and VA1 (western Virginia). For pine sawtimber, the pattern was similar-both Georgia series, SC1 (western South Carolina), and VA1 (western Virginia).

Hardwood pulpwood stumpage did not follow the same pattern-price shifts were statistically different from zero in scattered locations and indicated both positive changes and negative changes in price corresponding to the time of area change.

Similar results are identifiable in delivered prices, with pine pulpwood and sawlog prices jumping upward in TMS Areas in and surrounding the Southern Appalachians. Uniformly, the amount of change was smaller than that exhibited by stumpage prices.

Why prices jumped a similar amount in the Southern Appalachian TMS Areas in the first quarter of 1992 might have been due to chance, a common force in the wider economy, or to simultaneous changes in sampling frequencies or intensities in these Areas at the same time as shifts. To examine the second possibility, we examined price data for southern pine lumber, housing starts, and gross domestic product. Incorporation of these data into

Table 5. Results of nonstationarity tests and estimates of ARMA models with a region change dummy, weights based on removals, for southern pine sawtimber nominal, natural logarithmic stumpage prices, for 1977(I)-1998(IV), by new Timber Mart-South Area.

TMS area	Change diversity[a]	ADF test statistic[b]	ARMA equation estimate[c]					
			Intercept	Region dummy	AR(1)	MA(1)	AR(2)	AR(3)
AL1	0.30	-0.81	0.01 **	0.20	0.57 ***	-0.89 ***		
AL2	0.33	**-0.80**	0.01***	0.21 *	0.75 ***	-0.98 ***		
AR1	0.19	-0.63	0.01	0.16	0.36 **	-0.13 ***		
FL1	0.00	-0.41	0.01	-0.02	0.02			
FL2	0.15	-1.56	0.01	0.08	-0.04			
GA1	0.24	-0.93	0.01 ***	0.41 ***	0.61 ***	-0.98 ***		
GA2	0.30	-0.55	0.01 ***	0.14 *	0.73 ***	-0.97 ***		
LA1	0.04	-0.97	0.01	0.10	0.38	-0.66 ***		
LA2	0.00	-0.71	0.01	0.09	0.53 **	-0.78 ***		
MS1	0.30	-0.70	0.01	0.03	0.48 **	-0.76 ***		
MS2	0.00	-0.96	0.01	0.08	-0.07		-0.29 ***	
NC1	0.26	-1.58	0.01	-0.17	-0.25 **		-0.42 ***	
NC2	0.30	0.60	0.01 ***	0.12	0.45 ***	-0.87 ***		
SC1	0.00	1.14	0.01 ***	0.53 ***	0.50 ***	-0.98 ***		
SC2	0.30	-0.85	0.01 ***	0.11	0.77 ***	-0.99 ***		
TN1	0.14	-1.47	0.01	0.20	-0.39 ***			
TN2	0.28	-0.85	0.01	0.14	-0.33 **		-0.25 **	
TX1	0.00	-1.14	0.01	0.08	0.43 ***	-0.68 ***		
TX2	0.00	-0.92	0.03	-0.06		0.17		
VA1	0.00	-0.67	0.01	0.30 *	-0.32 ***		-0.31 **	-0.38***
VA2	0.28	-1.06	0.01	-0.03	-0.18			

NOTE: Asterisks indicate that the estimated coefficient is statistically different from zero at 10% (*), 5% (**) or 1% (***) significance.
[a] Shannon's index of diversity of the mix of old TMS Areas.
[b] Augmented Dickey-Fuller tests of nonstationarity, with sufficient lagged-difference terms to attain white noise errors.
[c] Due to missing values and varying numbers of ARMA terms, usable observations ranged from 74 to 87.

the intervention equation estimates (not shown but available from the authors) resulted in a sometimes substantial reduction in standard errors of equation estimates and some partial, but not complete, explanation of the price jumps for the first quarter of 1992. Indeed, GDP in the United States increased by 8% (at an annual rate) from the fourth quarter of 1991 to the first quarter of 1992 (United States Department of Commerce 1999a), housing starts in the U.S. South increased by 14% over the previous quarter (United States Department of Commerce 1999b), and southern pine lumber prices increased by 8% between those two quarters (United States Department of Commerce 1999c).

Unfortunately, the Department of Commerce figures are applicable only at the regional or national level, while the observed price shifts happened at much finer geographical resolutions. Indeed, if the entire region were spatially integrated, then prices would move together region-wide and would be affected by the same market-level demand factors, but our results do not support this contention. If the jump in price is not a phenomenon of TMS sampling changes that began with the first quarter of 1992, then we must look to other factors.

Another way to uncover the effects of the region change for those with significant dummy coefficients would be to compare the corresponding TMS series with comparable

Table 6. Results of nonstationarity tests and estimates of ARMA models with a region change dummy, weights based on removals, for mixed hardwood pulpwood nominal, natural logarithmic stumpage prices, for 1977(I)-1998(IV), by new Timber Mart-South Area.

TMS area	Change diversity[a]	ADF test statistic[b]	ARMA equation estimate[c] Intercept	Region dummy	AR(1)	MA(1)	AR(2)	AR(3)
AL1	0.30	-0.23	0.02	0.02	-0.25 **			
AL2	0.32	-0.50	0.02	-0.20		-0.11		
AR1	0.20	-1.26	0.02	-0.12		-0.22 **		
FL1	0.00	-1.64	0.02 ***	0.05	0.57 ***	-0.97 ***		
FL2	0.28	-1.14	0.02	0.00	-0.28 **			
GA1	0.20	-0.95	0.01	0.21	0.01			
GA2	0.27	-1.02	0.02	-0.35 **		0.07		
LA1	0.19	-0.66	0.01	0.26	-0.33 ***		-0.17	-0.14
LA2	0.00	-0.59	0.01	0.34 **		-0.71***		
MS1	0.37	0.36	0.02 **	-0.15		-0.47 ***		
MS2	0.00	-0.66	0.02 ***	-0.09	0.32 **	-0.82 ***		
NC1	0.20	-0.61	0.02 ***	0.09	-0.38 *	-0.38 *	-0.25	
NC2	0.30	-0.69	0.01 ***	0.21	0.40 ***	-0.99 ***		
SC1	0.00	-0.32	0.02	0.25	0.41	-0.73		
SC2	0.29	0.02	0.02 **	0.32 **	0.39 **	-0.77 ***		
TN1	0.25	-0.66	0.02	0.01	-0.02			
TN2	0.23	0.23	-0.01	0.54 **	-0.30			
TX1	0.00	-1.65	0.01 ***	0.46 **	0.60 ***	-0.98 ***		
TX2	0.00	-1.73	0.02	0.00	-0.23 **			
VA1	0.00	0.06	0.01	-0.14	-0.19			
VA2	0.29	-1.12	0.01	-0.39 ***	-0.36 ***			

NOTE: Asterisks indicate that the estimated coefficient is statistically different from zero at 10% (*), 5% (**) or 1% (***) significance.
[a] Shannon's index of diversity of the mix of old TMS Areas.
[b] Augmented Dickey-Fuller tests of nonstationarity, with sufficient lagged-difference terms to attain white noise errors.
[c] Due to missing values and varying numbers of ARMA terms, usable observations ranged from 79 to 87.

non-TMS series or with price trends outside the region. Stumpage price data compiled by Haynes (1998, p. 30-68) show that large price increases in the first quarter of 1992 corresponded with similar price changes in the Pacific Northwest, probably resulting from a severe curtailment of timber harvests on national forests of that region. From the fourth quarter of 1991 to the first quarter of 1992, Douglas-fir *(Pseudotsuga menziesii* Franco) stumpage prices increased by 34% on eastside national forests of Oregon and Washington and 72% on westside national forests. Softwood timber harvests from those national forests dropped 4.4 bbf in 1990, 0.8 bbf in 1991, and 0.7 bbf in 1992. The delay in price rise until 1992 may have been due to low demand in 1991, only rising in 1992 when the national economy strengthened.

Data on Mississippi pine pulpwood prices, collected by the Mississippi State University Extension Service (Daniels 1992, 1993), show that Mississippi pine pulpwood price changes were large, just as the TMS series showed. The Extension Service's statewide average pine pulpwood stumpage price jumped in 1992 by 32% over the 199 1 level, while the price jump for a removals-weighted average of TMS Areas for that state was 27% over the same period. This argues that the significant dummy coefficients for these two series (MS1 and MS2 pine pulpwood stumpage) was not an artifact of our weighting scheme for that state.

Table 7. Results of nonstationarity tests and estimates of ARMA models with a region change dummy, weights based on removals, for southern pine pulpwood nominal, natural logarithmic delivered log prices, for 1977(I)-1998(IV), by new Timber Mart-South Area.

TMS area	Change diversity[a]	ADF test statistic[b]	ARMA equation estimate[c]					
			Intercept	Region dummy	AR(1)	MA(1)	AR(2)	AR(3)
AL1	0.30	-0.96	0.01 ***	0.00	0.48 ***	-0.85 ***		
AL2	0.33	-1.42	0.01 ***	-0.02	0.80 ***	-0.97 ***		
AR1	0.25	-1.70	0.01 *	-0.04		-0.53 ***		
FL1	0.00	-1.72	0.01 **	0.00	0.33	-0.67 ***		
FL2	0.26	-1.56	0.01 *	-0.02		-0.16		
GA1	0.24	-1.50	0.01	0.08 *			-0.39 ***d	
GA2	0.30	-1.81	0.01	0.10		-0.28 **		
LA1	0.00	-1.22	0.01 **	0.04	0.32 *	-0.73 ***		
LA2	0.00	-1.68	0.01	0.13		-0.57 ***		
MS1	0.27	-1.31	0.01	0.01	-0.15			
MS2	0.00	-1.74	0.01	0.01		-0.43 ***		
NC1	0.30	-1.77	0.01 **	-0.10 **		-0.44 ***		
NC2	0.26	-1.51	0.01 **	-0.02		-0.56 ***		
SC1	0.00	-1.27	0.00	0.14 **		-0.38 ***		
SC2	0.28	-1.65	0.01 ***	0.07	0.74 ***	-0.97 ***		
TN1	0.11	-0.65	0.01 **	-0.10 **	-0.35 ***			
TN2	0.30	-2.10	0.01	0.03		-0.36 ***		
TX1	0.00	-1.97	0.01 *	-0.06	0.12			
TX2	0.00	-2.24	0.01	-0.01	0.07			
VA1	0.00	0.21	0.01 ***	0.06	9.60 ***		-0.12	
VA2	0.25	-0.83	0.01 *	0.02	-0.54 ***		-0.19 *	

NOTE: Asterisks indicate that the estimated coefficient is statistically different from zero at 10% (*), 5% (**) or 1% (***) significance.
a Shannon's index of diversity of the mix of old TMS Areas.
b Augmented Dickey-Fuller tests of nonstationarity, with sufficient lagged-difference terms to attain white noise errors.
c Due to missing values and varying numbers of ARMA terms, usable observations ranged from 76 to 87.
d AR(5) parameter estimate.

Conclusions

Timber Mart-South data are an important statistical resource for economists and others interested in tracking timber prices over time. To make the whole length of series most useful, these series must be statistically consistent. We presented here a method to make the series statistically seamless. Our intervention model was able to detect for some of the reconstructed TMS Areas a degree of measurable and statistically significant residual price shock corresponding with the timing of the TMS region reconfiguration. However, after investigating secondary data sources and evaluating the potential effects of changes in the larger economy, we cannot conclude that the reconfiguration was the source of the statistically significant price change for these regions. Indeed, Mississippi Extension Service's price data showed a nearly identical price increase from 1991 to 1992 as that exhibited by the comparable Timber Mart-South series. Without comparison series from other states where a product price changed by a statistically significant margin, our results remain somewhat inconclusive.

Nonetheless, for 96 of the 126 series analyzed, we have confidence that the weighting scheme presented here produces seamless series, at least at the degree of statistical significance chosen (10%). Because the removal levels in Areas with significant dummies were small relative to those without significant dummies, these 96 seamless series account for prices representing the vast majority of the volume of southern timber. For the remaining 17 stumpage price series and 13 delivered log price series, we have somewhat

Table 8. Results of nonstationarity tests and estimates of ARMA models with a region change dummy, weights based on removals, for southern pine nominal, natural logarithmic delivered sawlog prices, for 1977(I)-1998(IV), by new Timber Mart-South Area.

TMS area	Change diversity[a]	ADF test statistic[b]	ARMA equation estimate[c]					
			Intercept	Region dummy	AR(1)	MA(1)	AR(2)	AR(3)
AL1	0.30	-0.11	0.01***	0.09	0.56 ***	-0.85 ***		
AL2	0.33	-0.98	0.01 ***	0.12	0.78 ***	-0.98 ***		
AR1	0.19	-1.13	0.01	0.10	0.66 ***	-0.86 ***		
FL1	0.00	-0.66	0.01***	0.05	0.76 ***	-0.98 ***		
FL2	0.15	-1.26	0.01	-0.05	-0.13			
GA1	0.24	-0.06	0.01**	0.19 ***	-0.34 ***			
GA2	0.30	-0.71	0.01***	0.11	0.54 ***	-0.83 ***		
LA1	0.04	-1.09	0.01	0.15	0.59 ***	-0.79 ***		
LA2	0.00	-0.95	0.01	0.10	0.67 ***	-0.84 ***		
MS1	0.30	-0.74	0.01*	-0.03	0.70 ***	-0.81 ***		
MS2	0.00	-1.42	0.01	-0.02	0.01			
NC1	0.26	-1.62	0.01 ***	0.01	0.48 ***	-0.97 ***		
NC2	0.30	0.21	0.01	0.25 **	0.40 **	-0.82 ***		
SC1	0.00	0.41	0.01***	0.37 ***	0.62 ***	-0.99 ***		
SC2	0.30	-0.81	0.01	-0.01	-0.17			
TN1	0.14	0.06	0.01***	0.16	0.49 ***	-0.90 ***		
TN2	0.28	0.03	0.01	0.06	-0.24 **			
TX1	0.00	-0.82	0.01	0.07	0.21	-0.40 **		
TX2	0.00	-0.89	0.01	0.08	0.20	-0.44 **		
VA1	0.00	0.89	0.02 **	0.08	-0.43 ***		-0.21*	-0.28 **
VA2	0.28	0.55	0.01 ***	-0.06		-0.59 ***		

NOTE: Asterisks indicate that the estimated coefficient is statistically different from zero at 10% (*), 5% (**) or 1% (***) significance.
[a] Shannon's index of diversity of the mix of old TMS Areas.
[b] Augmented Dickey-Fuller tests of nonstationarity, with sufficient lagged-difference terms to attain white noise errors.
[c] Due to missing values and varying numbers of ARMA terms, usable observations ranged from 79 to 87.

less confidence that they are seamless. Had we chosen a more stringent 5% statistical significance threshold, 8 more of the 126 series would have been deemed seamless.

Economists and others who are concerned about the integrity of data might avoid the questionable TMS series and confine inferential tests about market behavior to those series that were found to be seamless. Such a strategy would still permit testing on prices representing the vast majority of the timber and logs produced in the United States South.

Literature Cited

BRAZEE, R., AND R. MENDELSOHN. 1988. Timber harvesting with fluctuating prices. For. Sci. 34(2):359–372.

DANIELS, R. 1992. 1991 harvest of forest products. Mississippi Coop. Ext. Serv., For. Resour. (June), Mississippi State Univ. 8 p.

DANIELS, R. 1993. 1992 harvest of forest products. Mississippi Coop. Ext. Serv. For. Resour. (June), Mississippi State Univ. 9 p.

DICKEY, D.A., AND W.A. FULLER. 1979. Distribution of the estimators for autoregressive time series with a unit root. J. Am. Stat. Assoc. 74(366):427–431.

GRANSKOG, J.E., AND K.D. CROWTHER. 1991. Weighted South-wide average pulpwood prices. South. J. Appl. For. 15(2):100–102.

GUNTER, J., AND F. CUBBAGE. 1987. Dam collection for Timber Mart-South. For. Farm. 46(8): 17-18.

HAIGHT, R.G., AND T.P. HOLMES. 1991. Stochastic price models and optimal tree cutting: Results for loblolly pine. Natur. Resour. Mod. 5(4):423–443.

HAMILTON, J.D. 1994. Time series analysis. Princeton University Press, Princeton, NJ. 799 p.

HAYNES, R.W. 1998. Stumpage prices, volume sold, and volumes harvested from the national forests of the Pacific Northwest Region, 1984 to 1996. USDA For. Serv. Gen. Tech. Rep. PNW-GTR-423.91 p.

HULTKRANTZ, L. 1993. Informational efficiency of markets for stumpage: comment. Am. J. Agric. Econ. 75(1):234–238.

NEWMAN, D.H. 1987. An econometric analysis of the southern softwood stumpage market: 1950–1980. For. Sci. 33(4):932–945.

Table 9. Results of nonstationarity tests and estimates of ARMA models with a region change dummy, weights based on removals, for mixed hardwood pulpwood nominal, natural logarithmic delivered log prices, for 1977(1)-1998(IV), by new Timber Mart-South Area.

TMS area	Change diversity[a]	ADF test statistic[b]	ARMA equation estimate[c] Intercept	Region dummy	AR(1)	MA(1)	AR(2)	AR(3)
AL1	0.30	0.34	0.01	-0.03	0.01			
AL2	0.32	-0.44	0.01 ***	0.09		-0.77 ***		
AR1	0.20	-1.37	0.01	0.00		-0.46 ***		
FL1	0.00	-1.07	0.01	0.15 *	-0.14			
FL2	0.28	-0.03	0.01	0.11	-0.11		-0.04	-0.37 ***
GA1	0.20	-0.11	0.01	0.08	-0.25 **			
GA2	0.27	-1.68	0.01 ***	0.08	0.55 ***	-0.97 ***		
LA1	0.19	-1.60	0.01 ***	0.15 **	0.44 ***	-0.98 ***		
LA2	0.00	-0.73	0.01	0.08	-0.40 ***		-0.36 ***[d]	
MS1	0.37	-0.78	0.01 ***	0.16 ***	0.51 ***	-0.97 ***		
MS2	0.00	-1.01	0.01 **	0.00	-0.63 ***			
NC1	0.20	-0.89	0.01 ***	-0.10 ***	0.44 ***	-0.99 ***		
NC2	0.30	0.24	0.01 ***	0.06	0.53 ***	-0.98 ***		
SC1	0.00	0.23	0.01 ***	0.10 *	0.61 ***	-0.87 ***		
SC2	0.29	0.24	0.01 ***	0.08	0.43 ***	-0.84 ***		
TN1	0.25	-1.03	0.01 ***	-0.01	0.58 ***	-0.97 ***		
TN2	0.23	0.41	0.01 ***	0.03	0.37 **	-0.87 ***		
TX1	0.00	-1.74	0.01	-0.07	0.22 *			
TX2	0.00	-1.23	0.01	0.03	0.03		0.06	-0.42 ***
VA1	0.00	1.96	0.01 **	0.05	-0.60 ***			
VA2	0.29	-0.01	0.01 ***	0.20 ***	0.22 **	-0.99 ***		

NOTE: Asterisks indicate that the estimated coefficient is statistically different from zero at 10% (*), 5% (**) or 1% (***) significance.
[a] Shannon's index of diversity of the mix of old TMS Areas.
[b] Augmented Dickey-Fuller tests of nonstationarity, with sufficient lagged-difference terms to attain white noise errors.
[c] Due to missing values and varying numbers of ARMA terms, usable observations ranged from 71 to 87.
[d] Seasonal autoregressive parameter estimate (4th quarter).

NORRIS FOUNDATION. 1977-1999. Timber Mart-South. The Daniel B. Warnell School of For. Resour., Univ. of Georgia, Athens.

SCHNUTE, J. 1987. Data uncertainty, model ambiguity, and model identification. Natur. Resour. Mod. 2(2): 159-212.

THOMSON, T.A. 1992. Optimal forest rotation when stumpage prices follow a diffusion process. Land Econ. 68(3):329–342.

USDA FOREST SERVICE. 1997. Forest inventory and analysis data records. Forest Inventory and Analysis. <http://www.srsfia.usfs.msstate.edu / ewdata/ewrec.htm> (December 5, 1997)

UNITED STATES DEPARTMENT OF COMMERCE. 1999a. Gross domestic product. Bur. of Econ. Analysis. <http://www.bea.doc.gov/bea/dn1.htm>. (February 19, 1999)

UNITED STATES DEPARTMENT OF COMMERCE. 1999b. Housing starts. Bur. of the Census website. <http://www.census.gov/ftp/pub/const/www/c20index.html> (Feb. 19, 1999)

UNITED STATES DEPARTMENT OF COMMERCE. 1999c. Southern pine lumber price series. Bur. of Labor Stat. <http://146.142.4.24/cgi-bin/srgate> (February 19, 1999)

WASHBURN, C.L., AND C.S. BINKLEY. 1990. Informational efficiency of markets for stumpage. Am. J. Agric. Econ. 72(2):394–405.

WASHBURN, C.L., AND C.S. BINKLEY. 1993. Informational efficiency of markets for stumpage: reply. Am. J. Agric. Econ. 75(1):239–242.