Forest to Mill Timber Price Trends and Volatility for Mississippi Timber Products

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Abstract

We examined timber price trends along the Mississippi roundwood supply chain. Quarterly statewide data from Timber Mart-South for pine sawtimber, pine pulpwood, mixed hardwood sawtimber, and pulpwood were obtained covering 1992 to 2018. Prices for stumpage, delivered logs, and timber conversion—measured as the difference between delivered wood and stumpage—were analyzed across products for the 27-year series, as well as three equally spaced 9-year periods (Period 1, 1992 to 2000; Period 2, 2001 to 2009; Period 3, 2010 to 2018). Flat delivered wood prices, increased rates for timber conversion, and declining pine sawtimber and pulpwood stumpage prices were revealed over the long term. Hardwood product prices, however, increased across their supply chains. Prices have generally become less volatile, particularly from Period 2 to Period 3, indicating an increasing degree of price homogeneity within each product's market. The exception to this was pine sawtimber, suggesting resource, locational, and/or market differences may have emerged for this product. The hardwood price trends supported, as appropriate, considering silvicultural options to allow this resource's continued growth. Declining price expectations for pine products call into question any strictly financial rationale for extending rotation length.

The price of a timber product is a crucial statistic for timber management. When a decision to sell timber has been made, local timber price reports can be sought to calculate statistics and develop an expectation of what the current market may be willing to bear. After harvest, growth and yield and discounted cash flow analyses can be employed to set expectations for the next rotation. A business's pro forma statement would include some price measure, so potential costs and revenues could be benchmarked. Financial portfolio managers require timber price information to maximize shareholder investment in timber and timberland. Timber prices and their trends provide the information that clients can use to weigh alternatives, whether within forestry or between forestry and other opportunities (Wagner and Sendak 2005). Moving roundwood from forest to mill requires multiple exchanges, each at a different price level.

A large literature covers timber price trends from varying perspectives. Hunter (1982), Aruna et al. (2000), and Yin and Caulfield (2002) examined how delivered log prices fluctuated over the past decades in the southern wood basket of the United States. Another group of papers investigated timber harvest costs, like the examination of Cubbage et al (1988) into logging cost trends declining overall due to long-term advances in productivity. Sun and Zhang (2006) studied the timber harvest margin in southern states, which is the wood supply system's contribution to delivered log value. They found the real harvest margins from 1977 to 2001 for pine sawtimber, pine pulpwood, and hardwood sawtimber were declining in Mississippi, while hardwood pulpwood exhibited no trend. A 1.03 percent real growth rate of the logging contract rate was observed in Louisiana from 1992 to 2018 (McConnell 2020). Trucking was the largest cost component, and the rate of growth in trucking costs exceeded all other forest operation activities. Stumpage is theoretically the residual value of the final product(s)

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milled from standing timber (Hotvedt and Straka 1987), although timber stand and market characteristics at the time of a sale add layers of complexity to the concept. Klepacka et al. (2017) synthesized recent literature regarding stumpage price determinants and price trends.

Price levels alone do not provide information on the volatility of timber markets, which Hotvedt and Straka (1987) described as both cyclical and spatial. Price volatility also signals the presence of information asymmetry in the market, which can lead to inefficiencies in the marketplace and the transfer of social surplus from one or more groups (Munn and Palmquist 1997). Nagubadi and Munn (1998) reported declining price volatility occurred only in the South's pine pulpwood stumpage market, which suggested an increasing degree of price homogeneity for that product. Yin and Caulfield (2002) discussed price volatility in their study region. They found the large price appreciations of the 1990s were accompanied by increasing volatility. Pine prices were less volatile in the delivered log market than in the stumpage market. Linehan et al. (2003) found Pennsylvania's 1984 to 2000 stumpage price trends generally varied between 10 and 20 percent around the respective means. Ohio stumpage price volatility ranged from 10 to 15 percent over a 1960 to 2011 study period (Duval et al. 2014). This uncertainty complicates developing future price expectations (Dennis and Remington 1985).

Mississippi contains 19.8 million acres of forestland (Mississippi Forestry Commission 2018) and an industrially concentrated bioeconomy (Golden et al. 2015) that is becoming increasingly integrated into the greater state economy (Dahal et al. 2015). This underscores the importance of decision-making within a value chain reliant on a raw material that takes decades to mature. The goals of this study were to (1) report the long-run annual rates of price change across the Mississippi roundwood supply chain from 1992 to 2018 for pine sawtimber, pine pulpwood, mixed hardwood sawtimber, and hardwood pulpwood, (2) determine the price volatility occurring in Mississippi timber product roundwood supply chains, (3) report the short-run price changes and volatility that occurred within three 9-year periods for Mississippi's timber product markets, and (4) illustrate the influence timber price trends can have on the harvesting decision using an unthinned loblolly pine plantation as an example.

Methodology

Delivered log and stumpage prices for four types of timber products (i.e., pine sawtimber, pine pulpwood, mixed hardwood sawtimber, and hardwood pulpwood) were obtained from Timber Mart-South in 2019 (TMS; Norris Foundation 2019). The study covered from the first quarter of 1992 (1992Q1), when TMS transitioned from three reporting regions per state to two, to the fourth quarter of 2018 (2018Q4). Prices were quoted as dollars per green ton. The TMS series reports low-average prices, which represent the mean of the lower 50 percent of reported prices, and high-average prices that are the mean of the upper 50 percent of reported prices. Overall quarterly average price per product is the midpoint of these two means (Harris et al. 2003). General quarterly average prices for pine sawtimber and pulpwood are shown in Figure 1, and for mixed hardwood sawtimber and pulpwood are shown in Figure 2.

Timber conversion was assessed at the harvest margin, which was calculated by subtracting stumpage prices from delivered prices at each quarter. The harvest margin is a more comprehensive measure of timber conversion services that includes not only timber harvesting costs but also payments for trucking and wood dealer activities (Sun and Zhang 2006). The timber conversion rate covers services costs, allocations for risk and/or uncertainty as an opportunity cost of capital invested, and any profits obtained. We therefore adopted the term timber conversion to more comprehensively capture the payments made to these wood suppliers. Average quarterly timber conversion prices by product are highlighted in Figure 3. All prices were indexed to 2018 fourth quarter constant dollars per the WPU085 producer price index (PPI) for lumber and wood products: logs, bolts, timber, pulpwood, and wood chips (USDL Bureau of Labor Statistics 2020). We chose this index because it measures price changes across the roundwood supply chain specifically, but the PPI–all commodities and consumer price index are more general indexes that are often also used. Yin and Caulfield (2002) discuss various deflators and the effect that the choice of deflator can have on price trend results.

Average annual percentage rates of change for inflation-adjusted quarterly delivered log, conversion, and stumpage prices were computed using trend analysis

$$\ln(P_t) = \alpha_0 + \alpha_1 Q_t + v_t \tag{1}$$

$$v_t = -\varphi_1 v_{t-1} - \varphi_2 v_{t-2} - \varphi_3 v_{t-3} - \varphi_4 v_{t-4} - \varphi_5 v_{t-5} + \varepsilon_t \tag{2}$$

$$R = (e^{4\alpha_1} - 1) \times 100 \tag{3}$$

$$V = (e^{\sqrt{4s^2}} - 1) \times 100 \tag{4}$$

Logged price P, ln (P_t) (whether delivered log, conversion, or stumpage) at time t was the dependent variable; α_0 was the regression intercept; the slope parameter α_1 identified the continuous rate of change in price as a percentage; Q_t was a quarter, which was coded from $t = 1$ to $t = 108$ (Eq. 1). The residuals for these price series were not independent as required by Equation 1. Instead, they were autocorrelated, where the value of one residual typically is similar to proximate observations. Sendak (1991) suggested the generalized least squares approach described below when conducting trend analysis.

Equation 2 was the autoregressive model constructed to account for the autocorrelated error's predictor term v_t in Equation 1 (Linehan and Jacobson 2005). This included five initial lags of v_t for both autocorrelation and potential seasonal effects, autoregressive error model parameters φ_i, and the random error ε_t. Five lags were chosen specifically because the price data were quarterly; the SAS/STAT User's Guide (SAS Institute 2021) recommends specifying the number of lags to be a "value larger than the order of any potential seasonality, because seasonality produces autocorrelation at the seasonal lag." Maximum Likelihood stepwise autoregression was employed, and nonsignificant variables were eliminated in a backward process. Equations 1 and 2 were estimated simultaneously using SAS 9.4 (SAS Institute 2020), with a final error term in Equation 2 that was independent and normally distributed with mean zero and variance of σ^2 (Linehan and Jacobson 2005). Equation 3 specified the annual percentage rate of change, R, from the

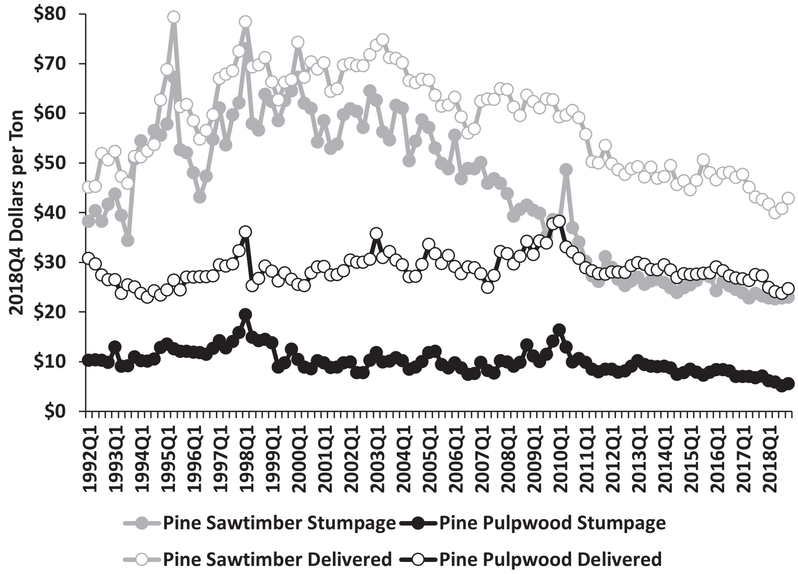

Figure 1.—Real quarterly stumpage and delivered prices ($ per ton) in Mississippi from 1992 to 2018 for pine sawtimber and pine pulpwood (Source: Norris Foundation 2019).

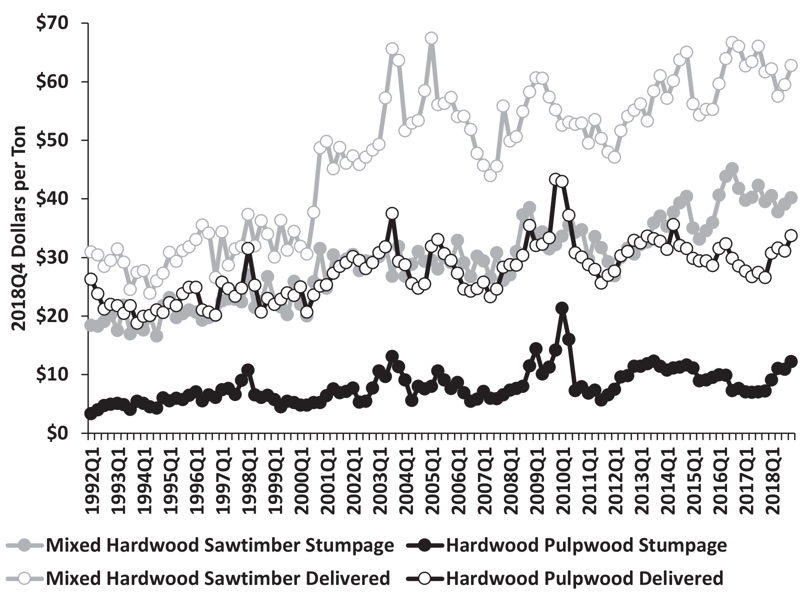

Figure 2.—Real quarterly stumpage and delivered prices ($ per ton) in Mississippi from 1992 to 2018 for mixed hardwood sawtimber and hardwood pulpwood (Source: Norris Foundation 2019).

continuous quarterly rate of price change. Equation 4 provided the annualized percentage volatility in prices, V, from the autoregression's mean square error, s^2 (Yin and Caulfield 2002; Linehan et al. 2003). Equations 3 and 4 were calculated using Microsoft Excel. Detailed results regarding Equations 1 and 2 can be found in the Appendix.

The delivered log, timber conversion, and stumpage price series were further analyzed in three equally spaced, 36-quarter (9-year) intervals. Equations 1, 2, and 3 were used as before but with Q_t instead spanning $t = 1$ to $t = 36$. Where autocorrelation was detected, five lags were again initiated and eliminated via backward stepwise autoregression as before. A limited number of these shorter price series possessed no autocorrelated effects. Ordinary least squares was applied in those cases. Statistical significance was tested at the level of alpha $= 0.05$[1].

Period 1 covered 1992Q1 to 2000Q4 and was a time of economic expansion in the United States following the 1990 to 1991 recession (Kliesen 2003). During this era, softwood timber harvest growth occurred in the South in response to harvest reductions in the Pacific Northwest (Haynes 2003), while the construction and remodeling industry's demand for appearance-grade hardwood lumber was strong (Duval

[1] Seasonal dummy variables were included in Equation 1 at an earlier stage of this research. Differences between seasons were not found to have been present ($P > 0.13$ in all cases). They were removed with the analyses rerun as presented here.

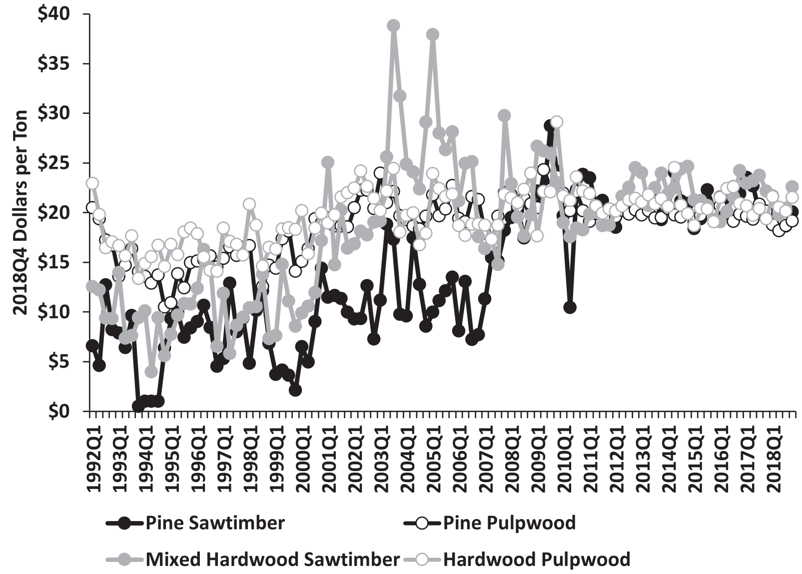

Figure 3.—Real quarterly timber conversion prices ($ per ton) in Mississippi from 1992 to 2018 for timber products. Subtracting the stumpage price from the delivered price provided the timber conversion price (Source: Norris Foundation 2019).

et al. 2014; Luppold et al. 2014). Period 2, which ran from 2001Q1 to 2009Q4, was comprised of two US recessions. The first was an 8-month shallow downturn that occurred in 2001 (Kliesen 2003). By 2005, softwood lumber production peaked (Parajuli et al. 2019), as did hardwood lumber consumption (Luppold et al. 2014). The 16-month global recession that was the subject of a *Forest Products Journal* special issue spanned December 2007 to March 2009. Period 3 from 2010Q1 to 2018Q4 was one recovery, the largest economic expansion in US history (Shiller 2020). Since the recession the southern pine lumber market has moved to favoring smaller sized pieces, such as 2 by 4s, which has subsequently led to seeking knowledge regarding the Chip-N-Saw timber market (e.g., Parajuli et al. 2019). Industrial products have overtaken other domestic uses to become the leading outlet for hardwood lumber (Luppold et al. 2014).

The implications of timber price changes were depicted through the financially optimum production of stumpage. Dennis and Remington (1985) illustrated how the discount rate's effect on forest management decision-making was either dampened or amplified by timber price changes. They broadened the land expectation value formula to incorporate the annual change in timber prices

$$PV_t' = \frac{(i-R)PV_t}{\left[1-e^{\left(-(i-R)t\right)}\right]} \equiv \frac{\ln\left(\frac{V_2}{V_1}\right)}{t_2-t_1} = \frac{i-R}{\left[1-e^{\left(-(i-R)t\right)}\right]} \quad (5)$$

where P was timber price; V_t' was the timber volume growth rate between two points in time; V_t was the timber volume at time t (volume was recorded in cubic feet outside bark and assessed in 5-year increments beginning at year 10). The real discount rate here was i (h in Dennis and Remington 1985), and R was the annual percentage rate of stumpage price change per Equation 3 above. The left-hand side of the identity symbol can be simplified to the right-hand side.

The influence of R on a 5 percent real discount rate was illustrated by timing the harvest of an unthinned loblolly pine plantation. Timber prices were considered to either be increasing at 2.0 percent per year, constant (no change), or decreasing at –2.0 percent per year. The Mississippi State University Cutover Loblolly Growth and Yield Model was used to evaluate a low-quality site (site index base age 25 of 50), a medium-quality site (site index base age 25 of 65), and a high-quality site (site index base age 25 of 80) planted with 545 seedlings per acre (Matney 1996). The analysis was streamlined across all scenarios to consider equal establishment costs, no intermediate treatments, and no landowner- or forest health-specific circumstances. The focus was only on determining the plantation's age at harvest using this financial maturity concept.

Results

Overall trends

The following observations, which should be considered merely descriptive, were drawn from the real price summary statistics (Table 1). We caution making comparisons across products due to their different markets and price levels. Over the entire 1992 to 2018 study period, pine sawtimber stumpage and sawlog prices have declined, while rates paid for conversion have increased. Pine sawtimber conversion price variation has temporally stabilized. The pine pulpwood stumpage price has steadily declined and has been more variable than its conversion and delivered prices. Mixed hardwood sawtimber stumpage and sawlog prices have increased over time. Stumpage prices for hardwood pulpwood have exhibited variability exceeding the conversion and delivered log price by a factor of two.

From 1992 to 2000, pine products averaged their highest prices. Each successive period saw average prices for these products decline. Timber conversion rates for sawtimber continually increased. Mills paid, and landowners received, higher prices for hardwood products across periods. Timber conversion coefficients of variation declined across periods for all timber products except for hardwood pulpwood.

Table 1.—Summary statistics of Mississippi timber prices (2018Q4 $ per ton).

Item	PST[a]			PPW[a]			HST[a]			HPW[a]		
	DEL	CVN	STG	DEL	CVN	STG	DEL	CVN	STG	DEL	CVN	STG
Real price, 1992 to 2018												
Mean	58.43	14.23	44.11	28.51	18.53	9.98	47.34	18.22	29.12	27.59	19.66	7.94
Beginning price	45.08	6.58	38.23	30.73	20.49	10.24	30.92	12.55	18.37	26.21	22.91	3.29
Ending price	42.81	20.04	22.96	24.65	19.15	5.50	62.68	22.57	40.11	33.66	21.49	12.17
Coefficient of variation	16.94	46.00	32.60	10.38	16.00	24.42	26.53	38.20	24.21	17.41	13.71	36.46
Real price, 1992 to 2000												
Mean	61.56	7.52	54.09	27.03	15.21	11.82	31.51	10.23	21.28	22.80	17.11	5.70
Beginning price	45.08	6.58	38.23	30.73	20.49	10.24	30.92	12.55	18.37	26.21	22.91	3.29
Ending price	68.86	14.36	54.18	29.03	18.93	10.10	48.62	17.17	31.45	25.10	19.91	5.19
Coefficient of variation	15.61	42.49	17.51	9.93	15.81	19.74	14.30	29.15	14.71	10.79	12.13	24.77
Real price, 2001 to 2009												
Mean	65.25	14.05	51.18	30.33	20.56	9.77	53.10	23.12	29.98	29.20	20.88	8.32
Beginning price	70.11	11.47	58.42	29.12	19.44	9.68	49.76	25.04	24.73	25.28	18.94	6.35
Ending price	62.65	24.11	38.55	37.69	23.58	14.11	55.16	23.00	32.16	43.25	29.08	14.17
Coefficient of variation	7.06	38.14	15.47	8.86	8.62	15.82	11.35	25.48	9.70	13.99	12.18	29.28
Real price, 2010 to 2018												
Mean	48.48	20.57	27.07	28.18	19.83	8.35	57.41	21.31	36.09	30.78	20.98	9.80
Beginning price	59.19	19.64	38.47	38.21	21.94	16.27	54.54	18.96	33.58	42.91	21.65	21.26
Ending price	42.81	20.04	22.96	24.65	19.15	5.50	62.68	22.57	40.11	33.66	21.49	12.17
Coefficient of variation	10.58	11.30	19.28	9.09	3.97	24.18	9.46	9.49	12.34	10.81	5.58	30.28

[a] PST = pine sawtimber; PPW = pine pulpwood; HST = mixed hardwood sawtimber; HPW = hardwood pulpwood; DEL = delivered log price; CVN = timber conversion price; STG = stumpage price.

Pine sawtimber

Pine sawtimber stumpage and sawlog prices began the series by increasing at rates of approximately 5 percent in Period 1; sawlog prices rose 4.96 percent ($P < 0.01$), and stumpage increased 5.21 percent ($P < 0.01$) (Table 2). The timber conversion rate during Period 1 did not significantly differ from zero, but the series was more volatile than prices at the mill or stump. Period 2 saw an annual product price decline of –5.18 percent for stumpage ($P < 0.01$), which largely negated Period 1's price appreciation. Sawlog prices fell –1.62 percent annually ($P = 0.02$), while prices paid for timber conversion increased 5.30 percent ($P = 0.01$). During Period 3, stumpage prices declined nearly 5 percent once more ($P < 0.01$). The sawlog price decline of Period 3 ($P < 0.01$) was more than double that of Period 2. Over the 27-year series, pine sawtimber stumpage prices were significantly declining (–2.82% per year, $P = 0.01$), while its timber conversion rate was annually increasing (3.22%, $P < 0.01$). Delivered log prices, while historically flat overall, have been more stable. Over the three periods, timber conversion prices have increasingly stabilized. Volatility fell by about half across all three series between Periods 1 and 2. In Period 3, though, stumpage prices became more volatile, as did delivered log prices.

Table 2.—Annual percentage rates of price change and percentage price volatility for Mississippi timber products. Bold denotes significantly positive values, and italics with an asterisk represents significantly negative* *values at alpha = 0.05.*

Item	PST[a]			PPW[a]			HST[a]			HPW[a]		
	DEL	CVN	STG	DEL	CVN	STG	DEL	CVN	STG	DEL	CVN	STG
Real price, 1992 to 2018												
% Price change	−0.64	**3.22**	*−2.82**	0.03	**0.72**	*−1.92**	**3.19**	**2.12**	**2.99**	**1.47**	**0.64**	**3.02**
% Volatility	12.12	**35.42**	*21.11**	14.03	**12.47**	*26.24**	**19.51**	**31.19**	**20.37**	**18.99**	**14.32**	**43.48**
Real price, 1992 to 2000												
% Price change	**4.96**	1.31	**5.21**	0.63	0.12	0.86	**3.19**	1.09	**3.78**	1.12	0.44	3.85
% Volatility	**16.97**	49.15	**24.65**	17.06	17.38	33.98	**24.21**	34.29	**19.88**	20.71	16.36	38.70
Real price, 2001 to 2009												
% Price change	*−1.62**	**5.30**	*−5.18**	1.49	0.71	2.15	1.26	0.47	**1.53**	3.03	0.18	4.75
% Volatility	*6.89**	**33.95**	*15.03**	15.09	11.14	25.68	17.61	35.09	**18.87**	21.29	17.77	51.49
Real price, 2010 to 2018												
% Price change	*−3.38**	0.33	*−4.99**	*−3.82**	*−0.45**	*−8.72**	**2.64**	1.13	**3.16**	−1.84	−0.36	−3.60
% Volatility	*8.49**	18.63	*17.19**	*8.03**	*4.84**	*20.68**	**10.69**	9.28	**14.07**	15.01	7.60	45.41

[a] PST = pine sawtimber; PPW = pine pulpwood; HST = mixed hardwood sawtimber; HPW = hardwood pulpwood; DEL = delivered log price; CVN = timber conversion price; STG = stumpage price.

Pine pulpwood

Pine pulpwood price changes were not different from zero during Periods 1 and 2. Significant price declines have occurred since 2009. Stumpage price decline exceeded –8 percent annually ($P < 0.01$), while the delivered wood price approached an annual fall of –4 percent ($P < 0.01$). Timber conversion prices also significantly fell ($P = 0.01$) but at an annual magnitude below product prices of –0.46 percent. The precipitous decline of pulpwood stumpage prices in Period 3 led to its overall 1992 to 2018 trend being significantly negative (–1.93%, $P < 0.01$). While pulpwood timber conversion prices were never significantly positive in any one period, over the long-term pine pulpwood conversion prices increased by 0.72 percent ($P = 0.01$). Pulpwood stumpage prices were more volatile, both within periods as well as overall. Prices stabilized across the pine pulpwood supply chain over the three study periods.

Mixed hardwood sawtimber

Mixed hardwood sawtimber experienced price appreciations exceeding 3 percent in both the sawlog and stumpage markets during Period 1 (both $P < 0.01$). While the log price trend flattened during Period 2, the price resumed moving upward during Period 3 ($P < 0.01$). The stumpage trend continued to appreciate over subsequent periods. In Period 2 stumpage prices increased another 1.53 percent ($P = 0.01$) followed by a subsequent 3.16 percent increase in Period 3 ($P < 0.01$). Stumpage prices overall increased by 2.99 percent annually ($P < 0.01$). While timber conversion prices did not differ from zero in any one period, hardwood suppliers over the 27-year series had seen price increases when the series was considered in total. This was driven by the price levels at the beginning of the series in 1992 and the ending price in 2018. Delivered log prices overall have increased as well ($P < 0.01$). Prices historically have been more volatile regarding timber conversion, as they have been for pine sawtimber. Delivered log and stumpage prices have consistently stabilized across periods. Timber conversion price volatility was similar in Periods 1 and 2, but it declined by about a factor of four in Period 3.

Hardwood pulpwood

Hardwood pulpwood prices, like pine pulpwood, were not exhibiting trends through Periods 1 and 2, but hardwood pulpwood prices also did not differ from zero in Period 3. When analyzed over the entire series, prices did increase. The stumpage price increase (3.02%, $P < 0.01$) was followed by the delivered log price trend (1.47%, $P < 0.01$), and then the timber conversion trend (0.64%, $P < 0.01$). Stumpage prices have been more volatile, with an error exceeding 40 percent over the series as a whole. Timber conversion and delivered log prices tended to fluctuate in a band of 15 to 20 percent.

Price trend influence on timber stand management

Timber harvest under the expectation of no future price changes would occur at age 17 on the high-quality site, age 20 on the medium-quality site, and age 23 on the low-quality site (Fig. 4). Declining timber prices intensified the 5 percent real discount rate's effect, which led to an earlier harvest. A –2 percent average annual price decrease revealed harvests would occur at ages 14, 17, and 20 for the high-, medium-, and low-quality sites, respectively. If timber prices had instead been increasing 2 percent per year on average, harvests could be delayed to approximately ages 19 (high), 23 (medium), and 27 (low).

Discussion

Some commonalities emerged from the annual changes in Mississippi timber products' prices over their full 27-year histories (Table 2). One was timber conversion rates paid to wood suppliers significantly increased across timber products. These rates were below 1 percent annually for hardwood and pine pulpwood but greater than 2 percent per year for sawtimber. Second was that stumpage prices were significantly changing. However, trends diverged depending on species. Standing timber prices for pine products were declining, while hardwood prices paid to landowners were increasing. Third was the consistent increase in prices for mixed hardwood sawtimber and pulpwood across the roundwood supply chain. Fourth, prices paid for timber conversion were more volatile in both the pine and mixed hardwood sawtimber markets; within the pulpwood markets, stumpage prices were more unstable.

Average log prices largely moved at slower rates than stumpage, except for mixed hardwood sawtimber. This was a generally expected result due to the wood supply system's functions as both a business network and concentration system that links thousands of landowners to hundreds of wood supply firms that haul to several dozen mills (Flick 1985). The supply chain in this sense becomes more structured and oriented, and product value tends to be better defined (Hotvedt and Straka 1987). Pine sawlog prices exhibited particularly less volatility than those for stumpage and conversion due to the construction sector's dominant position regarding softwood lumber demand (Haim et al. 2014). Mixed hardwood sawtimber volatility was somewhat more uniform across the wood supply chain owing to the hardwood industry's more fragmented structure (Luppold and Bumgardner 2008) and lack of cointegration in species pricing (Luppold and Prestemon 2003).

Southern pine sawtimber stumpage prices were at their series high during Period 1 of the 1990s. As timber demand shifted away from the Pacific Northwest and to the South (Haynes 2003), delivered log and stumpage prices moved upward in Mississippi. This was several years prior to the peak of the ''housing bubble'' (Byun 2010). Pine sawtimber prices fell during the brief 2001 recession, rebounded in 2002, but then began a long-term decline. By the end of the series, stumpage prices in 2018Q4 were 40 percent below where they started in 1992Q1. The global recession had a significant impact on the southern forest economy (Hodges et al. 2011). Southern pine sawmills electing to invest in advanced technologies could increase lumber recovery and more cost-effectively use smaller sized logs. Improved efficiencies lessened motivations to pay for larger logs where production processes do not dictate their need (Parajuli et al. 2019). The USDA Forest Service datasets collectively suggest the fewer, larger mills now residing in woodsheds are recovering more board feet from a lesser number of smaller sized trees (USDA Forest Service 2020a, 2020b).

Pine pulpwood has experienced a long-term price decline as well. Prices were higher during Period 1, when composite panel mills entered the South in the 1990s. A peak occurred in the late 1990s that mimicked the trend for pine sawtimber

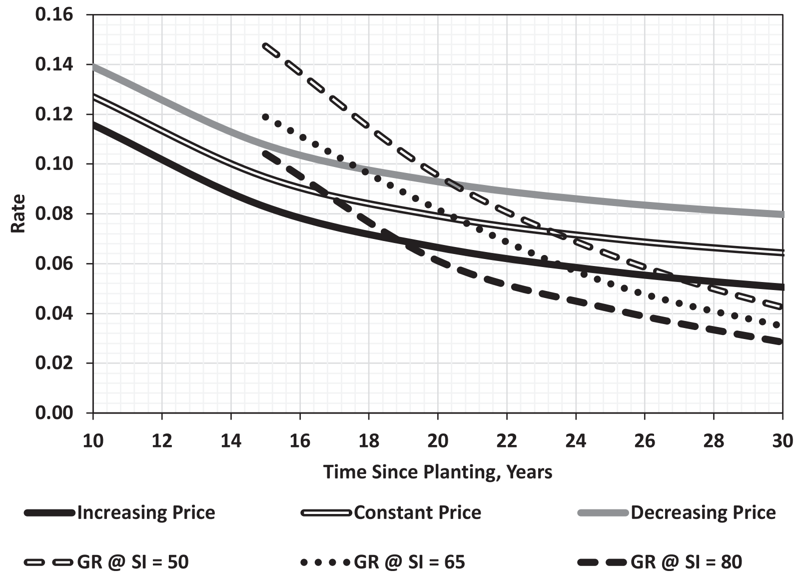

Figure 4.—Harvest decision timing for an unthinned loblolly pine plantation at a 5 percent real discount rate with timber prices either increasing at 2.0 percent per year, constant, or decreasing at –2.0 percent per year. The plantation scenarios involved planting 545 seedlings per acre on low-quality (site index base age 25 of 50), medium-quality (site index base age 25 of 65), and high-quality (site index base age 25 of 80) sites. GR = timber volume (ft^3) growth rate.

with shifting regional wood demands. However, production shifts in paper production away from North America also began during the 1990s (Ince 2002). Two pulp mills closed within Mississippi from 2000 to 2014, which reduced in-state daily pulping capacity by 1,675 tons (Johnson and Stapleton 2002; Bentley and Cooper 2015). Two additional pulp mill closures occurred outside Mississippi, but they drew significant wood volumes from the state. One was in Bastrop, Louisiana, and the other in Courtland, Alabama; combined pulping capacities exceeded 3,700 tons per day (Johnson and Stapleton 2002). Brandeis and Guo (2016) anticipated spillover effects into Mississippi from these closures that included losses of 570 jobs and $97.5 million in output. Composite panel production curtailments and mill closures occurred throughout the state during the recessionary period as well (e.g., Georgia-Pacific LLC 2012). Globally high energy prices and European Union policies favorable to renewable energy propelled wood pellet production and wood pellet mill construction projects across the South during Periods 2 and 3 (Velarde et al. 2013). However, wood pellet expansion to date in Mississippi has not balanced production losses in composite panel manufacturing (USDA Forest Service 2020a).

Hardwood stumpage prices were improving at rates approaching 3 percent annually. Sawmills during Period 1 capitalized on improving demand for mid-grade and lower grade lumber from secondary manufacturers and pallet producers that in turn made for competitive stumpage markets in the 1980s and 1990s (Luppold and Baumgras 1996). Where competition was fierce, stumpage prices often increased faster than lumber and log prices (Baumgras and Luppold 1993; Luppold and Baumgras 1996). Industrial consumption of hardwoods surpassed appearance-based consumption in 2007, and the increased demand following the 2007 to 2009 recession in this industrial segment improved the market for hardwood stumpage (Luppold and Bumgardner 2016). Landowners in the 1990s were likewise benefiting from improved technologies for hardwood pulpwood use (Nagubadi and Munn 1998). Hardwood pulpwood production peaked in the South in 1997, comprising 27 percent of the region's total pulpwood production (Gray et al. 2018). Mississippi's hardwood pulpwood statistics regularly place it among the leading producers in the South; competition for hardwood pulpwood has historically concentrated along the state's eastern border with Alabama (Gray et al. 2018). By Period 3, hardwood pulpwood prices were declining along with those of pine pulpwood, although not at rates considered statistically significant.

Prices paid to convert standing timber to industrial roundwood products have been increasing in Mississippi over the long term. The first 10 years of our study overlapped Sun and Zhang (2006), who found the timber conversion price trend in Mississippi from 1977 to 2001 was stable for hardwood pulpwood and declining for other timber products. Our findings for Period 1 from 1992 to 2000 were similar for hardwood pulpwood, but other products' trends were no longer decreasing. Logging costs began increasing in the mid-1990s (Stuart et al. 2003; Baker et al. 2014; McConnell 2020). Prior to that, costs had been in a long-term decline due to advances in technologies and shifts to mechanized longwood operations (Cubbage et al. 1988). While the average rates of price change were higher for pine conversion than their hardwood product counterparts, pine conversion price levels were lower at their respective averages than those for hardwood conversion (Table 1). Pine's greater uniformity can increase logger productivity and help control costs, while hardwoods' widely varying form and quality can slow harvest operations (Cubbage et al. 1989).

In general, timber price volatility levels were observed to have declined, particularly from Period 2 to Period 3. This could indicate the forest economic structure in Mississippi was evolving to one of increasing homogeneity within each product's market. The exception to this was pine sawtimber, suggesting market differences may have emerged for this product. Tanger and Parajuli (2018) concluded Chip-N-Saw, an intermediate-sized pine timber product, possessed a degree of substitution with pine sawtimber. Lagged sawtimber price generated a significantly positive effect on Chip-N-Saw demand. Thus, when sawtimber prices increase in one quarter, buyers to some degree move in the subsequent quarter to Chip-N-Saw purchases and away from sawtimber. The growing forest inventory of pine timber exceeding 9.0 inches diameter at breast height, which in 2019 was more than double the 1994 volume (USDA Forest Service 2020b), has offered mills greater flexibility in their log procurement strategies. This flexibility at the mill could consequently affect landowners depending on the characteristics of the timber they offer for sale. Future research will be required to test hypotheses of any time-dependent price variance.

The straightforward example of the unthinned loblolly pine plantation illustrated how the harvest date could be affected for several years due to price movement alone. Declining rates of timber price change must be overcome by robust stand growth if a harvest decision is to be delayed. Ensuring this growth requires silvicultural measures, such as more intensive site preparation methods, planting genetically improved seedlings, and controlling woody and weed competitors. Each activity comes with a cost that anticipated timber returns increasingly cannot support in the near term, i.e., one rotation. Over the long term, active management of low-quality sites becomes progressively more difficult to justify (Row and Teese 1980). Moreover, timberland on the whole could become viewed as an unattractive financial asset. This is because one approach to valuing timberland is substantiated on the present net worth of all future cash flows. Any anticipated changes therein impact the maximum an investor can pay for bare land at his/her desired rate of return (Bullard and Straka 2011). The price trend effect for hardwood stands would behave similarly (Dennis and Remington 1985). Mississippi's hardwood timber prices, therefore, offer opportunities for targeted silvicultural improvements that can improve tree quality of economically and ecologically valued species, such as oak, for local markets.

Conclusions

Trend analyses covering 1992 to 2018 in Mississippi concluded real prices paid for timber conversion (harvesting, trucking, brokering, etc.) have been significantly rising, as have prices paid across the roundwood supply chain for mixed hardwood sawtimber and pulpwood. Stumpage prices paid to landowners for pine products have been declining. Prices paid to move sawtimber from forest to market were more volatile across the supply chain, while stumpage prices were historically more unstable for pulpwood. Further study of the timber products' price series revealed pine sawtimber stumpage and sawlog prices were significantly increasing in the 1990s but have been declining since 2000. Mixed hardwood sawtimber was the lone timber product to bring higher prices to landowners across periods consistently. Price volatility declined across products from Period 2 to Period 3, with the exception of pine sawtimber. A model unthinned loblolly pine plantation illustrated how a declining price trend required harvest to occur at a younger stand age. Holistic consideration of timber price movement better informs both short-term (harvest timing) and long-term (land use and planning) management decisions that can lead to improved stand growth, yield, health, and investment return.

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Appendix. Equations 1 and 2 Results

Pine sawtimber, 1992 to 2018

Table A.1.—Stumpage.

Parameter	Estimate	t
Ordinary least squares[a]		
α_0	4.2167	97.89
α_1	−0.0090	−13.09
Generalized least squares[b]		
α_0	4.0567	21.76
α_1	−0.0071	−2.53
AR1	−0.9211	−24.94

[a] Durbin–Watson = 0.1894; total $R^2 = 0.6179$; MSE = 0.0494.
[b] Durbin–Watson = 2.1379; total $R^2 = 0.9297$; MSE = 0.0092.

Table A.2.—Timber Conversion.

Parameter	Estimate	t
Ordinary least squares[a]		
α_0	2.6871	77.85
α_1	0.0081	14.71
Generalized least squares[b]		
α_0	2.6949	44.26
α_1	0.0079	8.22
AR1	−0.5297	−6.39

[a] Durbin–Watson = 0.9321; total $R^2 = 0.6711$; MSE = 0.0317.
[b] Durbin–Watson = 1.9984; total $R^2 = 0.7640$; MSE = 0.0230.

Table A.3.—Delivered Log.

Parameter	Estimate	t
Ordinary least squares[a]		
α_0	4.2106	145.92
α_1	−0.0029	−6.29
Generalized least squares[b]		
α_0	4.0788	28.40
α_1	−0.0016	−0.74
AR1	−0.9408	−28.58

[a] Durbin–Watson = 0.1585; total $R^2 = 0.2715$; MSE = 0.0222.
[b] Durbin–Watson = 1.8938; total $R^2 = 0.8867$; MSE = 0.0035.

Pine pulpwood, 1992 to 2018

Table A.4.—Stumpage.

Parameter	Estimate	t
Ordinary least squares[a]		
α_0	2.5317	70.51
α_1	−0.0048	−8.31
Generalized least squares[b]		
α_0	2.520	28.37
α_1	−0.0049	−3.41
AR1	−0.8960	−9.86
AR2	0.4008	3.53
AR3	−0.4435	−4.81
AR5	0.1818	2.38

[a] Durbin–Watson = 0.5558; total $R^2 = 0.3947$; MSE = 0.0343.
[b] Durbin–Watson = 2.1327; total $R^2 = 0.7698$; MSE = 0.0136.

Table A.5.—Timber Conversion.

Parameter	Estimate	t
Ordinary least squares[a]		
α_0	3.2267	192.84
α_1	0.0022	8.17
Generalized least squares[b]		
α_0	3.2504	76.30
α_1	0.0018	2.67
AR1	−0.7499	−11.65

[a] Durbin–Watson = 0.5167; total $R^2 = 0.3861$; MSE = 0.0075.
[b] Durbin–Watson = 2.0950; total $R^2 = 0.7184$; MSE = 0.0035.

Table A.6.—Delivered Log.

Parameter	Estimate	t
Ordinary least squares[a]		
α_0	3.3189	170.51
α_1	0.0005	1.56
Generalized least squares[b]		
α_0	3.3396	65.80
α_1	0.0001	0.09
AR1	−0.7666	−12.04

[a] Durbin–Watson = 0.4741; total $R^2 = 0.225$; MSE = 0.0101.
[b] Durbin–Watson = 2.0389; total $R^2 = 0.5862$; MSE = 0.0043.

Mixed hardwood sawtimber, 1992 to 2018

Table A.7.—Stumpage.

Parameter	Estimate	t
Ordinary least squares[a]		
α_0	2.9399	149.32
α_1	0.0074	23.46
Generalized least squares[b]		
α_0	2.9395	97.20
α_1	0.0074	15.32
AR1	−0.4157	−4.69

[a] Durbin–Watson = 1.1605; total $R^2 = 0.8386$; MSE = 0.013.
[b] Durbin–Watson = 2.1267; total $R^2 = 0.8669$; MSE = 0.0086.

Table A.8.—Timber Conversion.

Parameter	Estimate	t
Ordinary least squares[a]		
α_0	2.9942	82.26
α_1	0.0058	9.93
Generalized least squares[b]		
α_0	3.0187	30.62
α_1	0.0053	3.41
AR1	−0.5704	−6.70
AR3	−0.1888	−2.19

[a] Durbin–Watson = 0.6364; total $R^2 = 0.4822$; MSE = 0.0353.
[b] Durbin–Watson = 2.1046; total $R^2 = 0.7348$; MSE = 0.0184.

Table A.9.—Delivered Log.

Parameter	Estimate	t
Ordinary least squares[a]		
α_0	3.3746	120.14
α_1	0.0081	18.17
Generalized least squares[b]		
α_0	3.3874	45.39
α_1	0.0079	6.72
AR1	−0.7868	−13.16

[a] Durbin–Watson = 0.4166; total $R^2 = 0.7570$; MSE = 0.0210.
[b] Durbin–Watson = 2.2068; total $R^2 = 0.9091$; MSE = 0.0079.

Hardwood pulpwood, 1992 to 2018

Table A.10.—Stumpage.

Parameter	Estimate	t
Ordinary least squares[a]		
α_0	1.6285	32.20
α_1	0.0070	8.74
Generalized least squares[b]		
α_0	1.6060	19.04
α_1	0.0074	5.54
AR1	−0.7419	−10.91
AR5	0.1580	2.32

[a] Durbin–Watson = 0.5706; total $R^2 = 0.4191$; MSE = 0.0681.
[b] Durbin–Watson = 1.8904; total $R^2 = 0.7274$; MSE = 0.0326.

Table A.11.—Timber Conversion.

Parameter	Estimate	t
Ordinary least squares[a]		
α_0	3.2929	226.20
α_1	0.0017	7.33
Generalized least squares[b]		
α_0	3.2999	136.48
α_1	0.0016	4.17
AR1	−0.4745	−5.54

[a] Durbin–Watson = 1.0411; total $R^2 = 0.3364$; MSE = 0.0056.
[b] Durbin–Watson = 2.0490; total $R^2 = 0.4782$; MSE = 0.0045.

Table A.12.—Delivered Log.

Parameter	Estimate	t
Ordinary least squares[a]		
α_0	3.0937	127.98
α_1	0.0038	9.96
Generalized least squares[b]		
α_0	3.1084	54.75
α_1	0.003641	4.07
AR1	−0.7198	−10.73

[a] Durbin–Watson = 0.5554; total $R^2 = 0.4835$; MSE = 0.0156.
[b] Durbin–Watson = 1.8497; total $R^2 = 0.7513$; MSE = 0.0076.