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Sawmill Willingness to Pay Price Premiums for Higher Quality Pine Sawtimber in the Southeastern United States

Arun Regmi [1,*], Donald L. Grebner [1], John L. Willis [2] and Robert K. Grala [1]

[1] Department of Forestry, Mississippi State University, Starkville, MS 39762, USA; don.grebner@msstate.edu (D.L.G.); r.grala@msstate.edu (R.K.G.)
[2] Southern Research Station, U.S. Department of Agriculture, Forest Service, Auburn, AL 36849, USA; john.willis@usda.gov
* Correspondence: arunregmiiof@gmail.com

Abstract: The southeastern United States is widely regarded as a leading region for intensively managed, short rotation pine forests. One drawback of this intensive approach is the production of more juvenile wood with lower quality properties that are less desirable for solid end uses. Improved construction sectors (e.g., housing) demand larger diameter sawtimbers. Delaying the final harvest allows for the production of larger diameter higher quality solid wood; however, this approach may incur additional costs to the landowner, which may disincentivize extending the rotation without additional monetary compensation. Sawmills are a primary consumer of pine sawtimber and exert a strong influence on stumpage prices. Therefore, understanding the importance of wood quality to sawmills is important for understanding price dynamics. To explore this aspect, we conducted a mail survey of softwood sawmills in the southeastern United States to determine willingness to pay price premiums for higher quality pine sawtimber. Most sawmills (57%) were willing to pay price premiums. The mean willingness to pay, estimated using a tobit regression, ranged from USD 4.22/ton to USD 12.98/ton. Sawlog size, procurement radius, sawlog grade, and the number of employees positively influenced sawmills' willingness to pay a price premium for higher quality sawtimber, while sawmills' processing capacity and the number of years in business had a negative impact. The results will be useful to landowners considering delaying the final harvest to grow large diameter sawtimber.

Keywords: price premium; sawmills; southern pine; tobit regression; willingness to pay

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1. Introduction

Over the past several decades, southeastern pine forests have experienced tremendous changes in ownership type and management practices [1]. Most forests in the region (86%) are privately owned and landowners seek to maximize productivity using improved genetics, chemical site preparation, and fertilization [1–3]. Improved genetics and silvicultural practices have reduced rotation lengths as trees reach harvestable size at younger ages (often 20–30 years); and improved the financial performance of pine plantations, making southeastern pine plantations one of the most efficient regions in the world for softwood production [1,2,4].

Although intensively managed pine plantations typically generate greater monetary returns than natural stands, intensive plantation silviculture can adversely affect the quality of solid wood [5,6]. Here, wood quality refers to wood properties, such as growth ring tightness, latewood: earlywood ratio, and wood density, that are sought in solid wood products. A major drawback of short rotation harvesting is the production of smaller-diameter sawlogs containing a higher proportion of juvenile wood—a core formed near pith consisting of wider growth rings and lower wood density [5–7]. Juvenile wood is generally considered undesirable for solid end uses because of inferior wood properties that are prerequisites for solid wood, such as low stiffness, strength, and stability [6–8].

Consequently, there is growing concern over declining wood quality in intensively managed plantations for solid wood end users [5,6,8–12].

Extending the final harvest age is one way to produce larger-diameter sawtimber (usually greater than 40 cm diameter) for solid wood products [5]. Delaying the harvest allows trees to add additional mature wood, thereby reducing the relative contribution of the juvenile core to the bole [6,11]. Biblis and Carino [11] found that loblolly pine trees harvested in older age (i.e., 50 years) met quality requirements for standard lumber compared to trees harvested at an earlier age. Butler et al. [13] also suggest that waiting to harvest mature trees can lead to the production of quality structural lumber in intensively managed forests.

While extending the rotation may be a biologically sound method for increasing wood quality, landowner willingness to delay final harvest will play a pivotal role in determining the supply of higher quality mature sawlogs in the southeastern United States [14]. Delaying the final harvest negatively affects the financial performance of the plantation due to the time value of money. As such, profit-seeking landowners may be hesitant to forego harvesting at a young age, unless they are compensated with an appropriate monetary incentive for extending the rotation. Regmi et al. [15] evaluated that landowners would require the minimum price premium ranging from USD 4.56/ton to USD 6.71/ton (on top of existing stumpage price) in even-aged management regimes to delay the final harvest by 10 years with further increases occurring at greater rotation extensions. Nevertheless, forest landowners represent only part of the timber supply chain. Thus, it is equally essential to understand the demand from the market (i.e., sawmills) for higher quality wood.

In the timber supply chain, sawmills are the primary consumer and processor of sawtimber, and manufacturer of lumber and structural panels. Almost 80% of softwood dimension lumber in the United States was consumed by the construction sector [16], whereas 69% of 2017 softwood lumber production was utilized in housing construction alone [17]. Therefore, demand for lumber in the southeastern United States is largely driven by the construction sector, such as the housing market, which has been gradually recovering from the Great Recession of 2007, resulting in increased demand for lumber and other solid wood building products [17,18]. Recently, the average sawtimber prices of southern yellow pine have reached the highest level in over a decade, signifying the strong lumber demand primarily for housing construction [19,20]. In last few years, sawmills expansion and new openings are increasing in the southeastern United States, potentially increasing the demand for sawtimber [21]. To meet the increasing market demands for solid end uses, sawmills require a significant amount of manufacturing raw material. Private forest landowners who own more than two thirds of forest land are the major source for supplying the raw material. Hence, sawmills might consider paying a price premium to source desired large sawlogs that can be used to meet the increasing demand for solid wood products. Further, sawmills in the U.S. are highly competitive and might consider manufacturing quality end products to remain in the market and maintain reputation [22]. Trees that are tall, straight, large in diameter, and with minimal stem defects are highly sought and can yield profitable high-grade lumber and fine veneer quality plywood. Therefore, sawmills might be willing to pay a premium to obtain high value, extended rotation sawtimber compared to lower quality wood from short rotation pine plantations.

There are several factors that can constrain a sawmill's ability to offer a price premium. For example, the technological aspects of sawmills, such as the characteristics of sawing machines and logs, production capacity, location of mills, and mill size [23–27]. Tree size (i.e., length and small-end diameter) are important sawlog specifications that might vary based on sawmill log processing capacity. Tree size often determines the product value, as taller and large diameter trees typically contain more usable volume and have higher lumber recovery rates resulting in higher prices [28–30]. Proximity to timberlands is another important factor for sawmills because it can substantially influence transportation costs [31]. Besides the technical aspects, customer demand, economic constraints, and availability of labor are other important factors that influence sawmill interest in higher quality sawlogs. Although some survey-based studies of sawmills have been conducted in the southeastern United States, all have focused on the willingness to utilize woody biomass for bioenergy production (e.g., [32,33]). To our knowledge, no research has evaluated the willingness of sawmills to pay (WTP) a higher price for higher quality pine sawtimber. To answer this question, we conducted a sawmill survey in 2018 across the southeastern United States. The objective of the study was to estimate sawmills' WTP price premiums for higher quality sawtimber grown to longer rotation ages and identify factors affecting sawmills' WTP. Our findings will help guide land management decisions and help foresters and landowners to market sawtimber.

2. Materials and Methods

2.1. Study Site

The study area included the 13 states in the southeastern United States: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia (Figure 1). A large portion of this region (31%) is covered by southern pine stands, which include loblolly (*Pinus taeda*), shortleaf (*Pinus echinata*), longleaf (*Pinus palustris*), and slash pine (*Pinus elliottii*), among which loblolly pine is the most commercially managed pine species [34]. Of the total forest area in this region, 20% are of plantations origin, which are mostly (86%) dominated by southern pine monocultures (i.e., loblolly-shortleaf pine—71%, and longleaf slash pine—15%). About 40% of total plantations are owned by non-industrial private forest (NIPF) landowners. The southeastern timberlands have made a significant contribution to the nation's economy. For example, this region alone supplies more than half (60%) of all timber in the United States [3]. The forestry-related business in the southeastern region is responsible for over 1.3 million jobs (45% of the nation total contribution) and approximately 55 billion in total payroll [22].

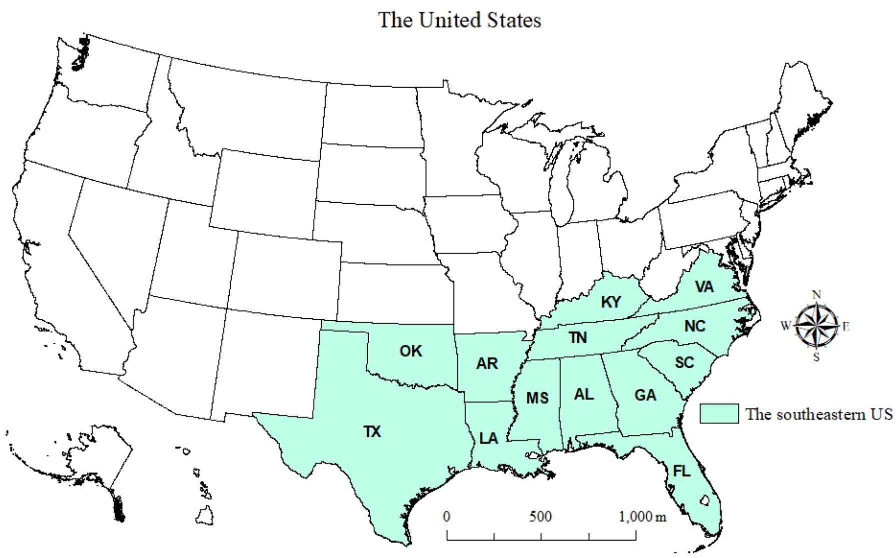

Figure 1. Location of the study area in the map of the United States.

2.2. Data Collection

In 2018, data were collected from a total of 517 softwood sawmills located throughout the study region using a mail survey. Since the study focused on southern pines, only softwood sawmills were included in the survey. Sawmill mailing addresses were obtained from the Primary Forest Product Locator website [35] operated by the Southern Group of State Foresters. The survey was developed using the modified Tailored Design Method [36]. A pilot testing of the survey instrument was conducted in person before sending it to the respondents. Five mailings were sent to sawmills: (1) a questionnaire including an introductory cover letter addressed to the sawmill owner, (2) a thank you/reminder postcard, and (3) three follow-up questionnaires including a cover letter.

The survey instrument consisted of two sections. The first section contained questions related to sawmill characteristics and production capacity. The second section focused on questions pertaining to sawmill preferences for raw timber material and their WTP a price premium for higher quality pine sawtimber. The respondents were asked to state their WTP amount above the five-year average market prices obtained from Timber Mart-South (2013–2018) for two different price scenarios: stumpage price (USD 24.72/ton) and delivered price (USD 42.57/ton). The stumpage price refers to the price paid for the standing trees on the stump, while the mill delivered price includes all of the logging processing and transportation costs and is paid at the mill. Under each price scenario, respondents were asked to report their WTP amount for three different log grades: Grade 1, Grade 2, and Grade 3. Sawlog grade definitions were adopted from the United States Forest Service (USFS) National Core Field Guide, Version 7.2_2015_Southern Pine Tree Grades [37]. Due to insufficient survey responses related to Grade 3, the final analysis included only Grades 1 and 2, resulting in a total of four models.

2.3. Non-Response Bias Test

A non-response bias test was conducted to detect a potential response bias by comparing responses obtained from the first and last 30 returned survey questionnaires using a two-sample paired *t*-test at the 5% level of significance. Responses obtained from the last 30 questionnaires served as a proxy for non-respondents. This is because sawmills responding later were assumed to have responded due to follow-up postcards and mailings and are more like non-respondents [38].

2.4. Econometric Model

This study is theoretically based on the theory of profit maximizing behavior of a firm, which assumes that profit maximization is the primary objective of a firm's operations [39]. A sawmill's WTP price premiums for higher quality sawtimber depends on its preferences for sawlog size, grade, and other inputs, such as labor, which maximize profit while increasing the production capacity of sawmills. A sawmill's WTP amount was used as a continuous dependent variable. WTP amounts are generally left-censored at zero bid amount as they cannot be reported in negative numbers. Sawmills that are not interested in paying premiums would most likely report zero bid values. The presence of a substantial number of zero values provides inconsistent parameter estimates in the ordinary least square regression model as it is biased towards zero values [40]. Hence, for censored data, a tobit model is preferred to OLS [40]. Unlike the OLS model where only observed variables are used, the tobit model assumes unobservable variables, also known as "latent variables", estimating the probability of zero bidders changing to positive bids based on a change in the independent variables [41]. In addition, the tobit model is fundamentally sound as it is based on the maximum likelihood estimation and uses all responses to analyze the impact of independent variables on the dependent variable [40].

This study used a single set of independent variables to model sawmills' WTP price premiums for two sawlog grades (Grade 1 and Grade 2). Following Anastasopoulos et al. [42], instead of running multiple tobit regressions for each sawlog grade, the multivariate tobit regression was used to jointly model WTP by a sawlog grade using a left-censored limit at zero. This is because the joint estimation accommodates the possible cross-equation error correlation [42,43].

The structural Equation of the left-censored multivariate tobit model (1) was written as:

$$WTP_i = \begin{cases} X_i\beta + \epsilon_i & if \quad X_i\beta + \epsilon_i > 0 \\ 0 & if \quad X_i\beta + \epsilon_i \le 0 \end{cases} \quad (1)$$
$$i = 1,\ 2,\ \ldots\ldots,\ N.$$

Expected Mean WTP was estimated using the following Equation (2) (adopted from [44]).

$$E[WTP_i] = X_i\beta\left[\Phi\left(\frac{X_i\beta}{\sigma}\right)\right] + \sigma\left[\phi\left(\frac{X_i\beta}{\sigma}\right)\right] \quad (2)$$

where *WTP* = a premium in USD a mill was willing to pay above the current market stumpage or delivered gate price for higher quality pine sawtimber, X = a vector of independent variables representing sawmills characteristics, N = number of observations, β = a vector of regression coefficients, ϵ_i = random error $\epsilon_i \sim N(0, \sigma^2)$, Φ = the cumulative normal distribution, and ϕ = the normal probability density function (McDonald and Moffitt, 1980).

The estimate of marginal effects was necessary to interpret the direct effect of changing one unit of the independent variable on the dependent variable (the mean WTP price premium). Marginal effects were calculated using the following Equation (3).

$$\frac{\partial E(WTP_i|x)}{\partial x_k} = \beta_k \Phi\left(\frac{X_i\beta}{\sigma}\right) P\ (WTP_i\ >\ 0) \quad (3)$$

The final empirical model for the *WTP* a price premium for higher quality pine sawtimber was specified with hypothesized explanatory variables as follows Equation (4):

$$WTP_{\ (Price\ Premium)} = f\ (\text{ENDDIA, LENGTH, MAXDIA, GRADE, DISTANCE, YEAR, CAPACITY, EMPLOYEE}) \quad (4)$$

The analysis was carried out in SAS version 9.4 statistical software package using the "PROC QLIM" procedure.

2.5. Variable Description

Sawmills are the primary buyers of pine sawtimber and consider a variety of factors when pricing stumpage and/or delivered high-quality sawtimber [23]. Due to the absence of previous studies in a similar context, all independent variables were self-identified and evaluated based on the impacts of independent variables on the overall model fit and possible wood characteristics that a sawmill considered while selecting quality products. The model included variables describing characteristics of sawmills and their preferences for higher quality pine sawtimber. Table 1 presents descriptive statistics and a description of the explanatory variables used in the study. Independent variables used in the final model included preferred minimum sawlog end-diameters over bark (ENDDIA), preferred sawlog length (LENGTH), maximum log diameter processed in the mill (MAXDIA), procurement distance (DISTANCE), preferred sawlog grade (GRADE), processing capacity of the mill (CAPACITY), years in business (YEAR), and the number of employees (EMPLOYEE).

Taller and large diameter trees typically hold more usable volume and have higher lumber recovery rates [28,29]. Hence, it was expected that quality-seeking sawmills would be willing to pay a premium price for longer (LENGTH) and larger small end-diameter (ENDDIA) sawlogs produced from mature stands. Respondents were asked to report numeric values for the log length. However, a substantial number of mills reported "tree length" as their preferred length without being more specific. Thus, LENGTH was binary coded as '1' if the preferred length was less than six (6) meters indicating a standard log length and '0' otherwise. Likewise, mills that do not possess the capacity to process large diameter logs (MAXDIA) were not expected to pay a premium. It is also possible that if fewer sawmills are capable of processing large logs, there will be less competition and mills would not be interested in paying price premiums as long as there is a sufficient supply of required raw material.

Table 1. Description of variables used in estimating sawmill willingness to pay (WTP) a price premium for higher quality pine sawtimber grown to an extended rotation across the southeastern United States based on a 2018 mail survey.

Variable	Description	N	Mean	St.d.
ENDDIA	Preferred minimum small-end diameter inside-bark (in cm)	105	22.78	7.87
LENGTH	The preferred log length in meter (data collected) Dummy: 1 if log length less than 6 m, 0 otherwise	105	8.65 0.47	5.14 0.50
MAXDIA	The maximum diameter of pine sawlogs processed (in cm)	101	73.64	26.04
GRADE	The most used pine log grade. Categorical (1 = low grade, 4 = high grade)	104	2.53	1.31
DISTANCE	Maximum procurement radius for pine sawlogs Categorical (1 = 0–40 km, 2 = 41–80 km, 3= 81–120 km, 4 = 121–160 km, and 5 = >160 km)	104	3.53	1.02
CAPACITY	Average annual output from a mill (million board feet) (log transformed)	98	70.92	99.05
YEAR	Years in a business (collected data) Dummy: 1 = less than 40 years old, 0 = otherwise	105	44.72 0.53	28.72 0.50
EMPLOYEE	No. of full-time employee work in a mill	103	72.39	63.16

Note: Dependent variable is WTP price premium for Grade 1 and Grade 2 pine sawlogs grown to an extended rotation age.

Since a log grade is a practical indicator of wood quality, sawmills were asked to indicate the mostly used log grade (GRADE). It was expected that sawmills using higher grade sawlogs would be more concerned about quality and more likely to offer a price premium for higher quality sawtimber. Thus, GRADE was expected to have a positive impact on WTP a price premium. The variable GRADE was measured as a categorical variable using four levels ranging from 1, indicating a no grade, to 4, indicating high grade.

Procurement distance (DISTANCE) is another important factor that reflects sawmill behavior while purchasing raw materials (Sorenson et al. 2015). This categorical variable was measured on a five-point scale: 1 = 0–40 km, 2 = 41–80 km, 3 = 81–120 km, 4 = 121–160 km, and 5 = >160 km. It was expected that sawmills preferred purchasing raw materials within the shortest hauling distance to their mill to reduce transportation costs and time [31]. Therefore, high-quality timber-seeking sawmills were expected to be able to offer a price premium if quality wood was available within relative proximity from their locations. The variable YEAR indicated the number of years a sawmill had been in business. We assumed that sawmills were likely to increase their production capacity by upgrading technology over time. However, it is possible that sawmills might not be upgraded despite operating for many years. Thus, the variable YEAR was expected to have a positive relationship with WTP a price premium. The variable YEAR was transformed into a binary (dummy) variable based on the median score, where values below the median score were assigned '1' (i.e., if sawmills were in business for less than 40 years), and '0' otherwise.

Two variables, CAPACITY and EMPLOYEE, evaluated the effect of sawmills' production capacity and the number of employees. In general, larger sawmills have a tendency to produce more output; thus, the average annual output is one of the best measures of mill capacity [26]. The CAPACITY variable was log-transformed because responses were right-skewed. Further, it was assumed that larger sawmills tend to have more employees and produce more output. Thus, these two variables were expected to have a positive association with WTP a price premium.

3. Results

3.1. Descriptive Statistics

A total of 175 questionnaires were returned of 517 mailed, of which 105 questionnaires were usable. There were problems with mill classification within the forest product industries database, which increased the number of unusable responses. For example, some sawmills were classified as hardwood and softwood sawtimber processing mills; however, they reported that they processed only hardwood. Many respondents reported that they were hardwood sawmills (47), whereas others reported they were not sawmills (10). The survey response rate was modified due to incorrect addresses (56), deceased owners (1), and mill closures (12). The overall adjusted response rate was 27%, which was comparable with recently conducted mill surveys across the southeastern United States (e.g., [31,33,45,46]. A non-response bias was not observed, indicating there was no statistical difference between early and late responses on key variables: ENDDIA ($p = 0.65$), LENGTH ($p = 0.31$), MAXDIA ($p = 0.59$), GRADE ($p = 0.89$), DISTANCE ($p = 0.56$), CAPACITY ($p = 0.93$), YEAR ($p = 0.20$), and EMPLOYEE ($p = 0.26$).

Most sawmills (96%) reported the maximum diameter (MAXDIA) they could process in their sawmills. About 17% of sawmills reported that they could not process sawlogs larger than 51 cm in diameter and 33% of sawmills reported the maximum processing sawlog diameter ranging from 51 to 74 cm. A relatively large percentage (50%) of sawmills reported that they could process larger sawlogs (>74 cm in diameter) with existing equipment. Sawmills reported that they could purchase pine sawlogs directly from multiple sources including loggers (71%), forest landowners (64%), wood dealers (63%), and other sources (2%), resulting in the total percentage greater than 100%.

3.2. Willingness to Pay a Price Premium for Higher Quality Pine Sawtimber

Nearly two-thirds of sawmills (64%) were interested in obtaining higher quality pine sawtimber. Most sawmills (57%) were willing to pay a price premium for wood grown on a longer rotation, 20% were not, while 23% were neutral (Figure 2). Most sawmills preferred sawlogs delivered to the mill rather than purchasing trees on the stump. Approximately 61% of sawmills paid both delivered and stumpage prices, 35% paid only delivered price, while only 4% paid a stumpage price.

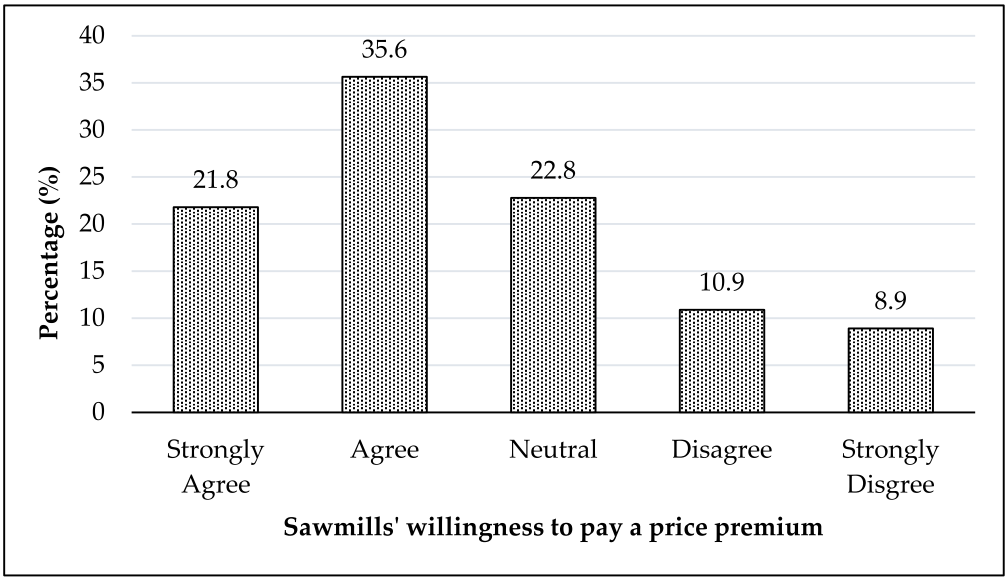

Figure 2. Sawmills’ willingness to pay price premiums for higher quality pine sawtimber grown on an extended rotation across the southeastern United States based on a 2018 mail survey.

Table 2 illustrates the frequency and percentage of responses for each sawlog grade under two different price scenarios. Sawmills were less likely to offer a price premium for Grade 3 sawlogs. Only 11% and 8% of mills reported their WTP price premiums for Grade 3 sawlogs above the current stumpage and delivered prices, respectively. About 62% and 68% of sawmills reported WTP price premiums for Grade 1 sawlogs above the stumpage and delivered price, respectively. Alternatively, nearly half of the sawmills reported price premiums for Grade 2 sawlogs for both price scenarios.

Table 2. Frequency and percentage of sawmills reporting their willingness to pay (WTP) a price premium for Grade 1 and Grade 2 sawlogs above the existing stumpage and delivered prices across the southeastern United States based on a 2018 mail survey.

Payment Amount (USD)	Stumpage Price				Delivered Price			
	Grade 1		Grade 2		Grade 1		Grade 2	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
USD 0	26	37.68	38	55.07	28	32.18	45	51.72
USD 1	1	1.45	5	7.25	2	2.30	9	10.34
USD 2.50	6	8.70	8	11.59	9	10.34	10	11.49
USD 5	10	14.49	10	14.49	8	9.20	10	11.49
USD 7.50	1	1.45	*	*	5	5.75	1	1.15
USD 10	7	10.14	2	2.90	11	12.64	5	5.75
USD 15	5	7.25	*	*	5	5.75	*	
USD 20	2	2.90	3	4.35	5	5.75	1	1.15
USD 30	5	7.25	2	2.90	2	2.30	*	*
USD 40	2	2.90	*	*	4	4.60	3	3.45
USD 50	3	4.35	1	1.45	4	4.60	2	2.30
USD 65	1	1.45	*	*	4	4.60	1	1.15
Total	**69**	**100**	**69**	**100**	**87**	**100**	**87**	**100**

* None of the respondents were willing to pay the given price premium amount.

3.3. Factors Influencing Willingness to Pay Price Premiums

Results from a tobit regression model for the stumpage price scenario (stumpage, hereafter) and delivered price scenario (delivered, hereafter) are presented in Tables 3 and 4, respectively. Likelihood ratio (LR) tests indicated that the explanatory variables were jointly significant (χ^2 = 54.47, $p < 0.001$) in the first, and (χ^2 = 54.95, $p < 0.001$) in the second scenario estimations.

Table 3. Results of a tobit regression model used to estimate a price premium for Grade 1 and Grade 2 sawlogs above the current stumpage price, grown to an extended rotation across the southeastern United States based on a 2018 mail survey.

Variables	Sawlog Category					
	Grade 1			Grade 2		
	Coeff.	Std. Err.	Marginal Effects	Coeff.	Std. Err.	Marginal Effects
INTERCEPT	−39.3 ***	12.538		−22.8 ***	9.636	
ENDDIA	1.104	1.240	0.599	−0.104	0.955	−0.043
LENGTH	1.716	4.934	0.931	2.663	3.791	1.094
MAXDIA	0.117	0.263	0.063	0.266	0.205	0.109
GRADE	7.291 ***	2.272	3.956	1.676	1.726	0.689
DISTANCE	6.945 **	2.943	3.768	4.081 *	2.267	1.676
CAPACITY	−7.107 ***	2.059	−3.856	−3.608 **	1.583	−1.482
YEAR	−5.560	4.593	−3.016	−5.789 *	3.518	−2.378
EMPLOYEE	0.139 ***	0.055	0.075	0.097 **	0.042	0.040
Sigma	16.165	1.879		11.994	1.534	
N	69			69		
Log Likelihood	−315.02					
LR Chi2	54.468 ***					

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4. Results of a tobit regression model used to estimate a price premium for Grade 1 and Grade 2 sawlogs above the current mill delivered price, grown to an extended rotation across the southeastern United States based on a 2018 mail survey.

Variable	Sawlog Category					
	Grade 1			Grade 2		
	Coeff.	Std. Err.	Marginal Effects	Coeff.	Std. Err.	Marginal Effects
INTERCEPT	−33.61 ***	12.005		−35.13 ***	11.744	
ENDDIA	1.974 *	1.155	1.176	1.995 *	1.086	0.837
LENGTH	0.610	4.757	0.363	0.529	4.536	0.222
MAXDIA	−0.025	0.259	−0.015	−0.132	0.250	−0.055
GRADE	6.022 ***	2.190	3.586	1.306	2.085	0.548
DISTANCE	5.239 *	2.921	3.120	5.957 **	2.773	2.501
CAPACITY	−5.285 ***	2.025	−3.147	−5.424 ***	1.895	−2.277
YEAR	−0.395	4.330	−0.235	-0.045	4.131	−0.019
EMPLOYEE	0.039	0.062	0.023	0.105 *	0.059	0.044
Sigma	18.072	1.728		16.367	1.722	
N	87			87		
Log Likelihood	−448.689					
LR Chi2	54.945 ***					

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In stumpage price models, three variables including DISTANCE ($p = 0.02$; $p = 0.07$), CAPACITY ($p = 0.001$, $p = 0.02$), and EMPLOYEE ($p = 0.01$; $p = 0.02$) were significant for both Grade 1 and Grade 2 sawlogs, whereas GRADE ($p = 0.001$) and YEAR ($p = 0.09$) were significant only in Grade 1 and Grade 2, respectively (Table 3). GRADE was positively significant, indicating that sawmills preferring higher grade sawlogs were more likely to offer a price premium for Grade 1 sawlogs; however, they were unwilling to pay a premium for Grade 2 sawlogs. GRADE had a relatively greater marginal effect than other variables: a one-unit increase in sawmill's reported preferred sawlogs grade increased the premium by USD 3.96/ton. DISTANCE was positively significant for both grades indicating that sawmills were more likely to offer a price premium as they sourced higher quality sawtimber from further away destinations. The value of marginal effect suggested that every 40 km increase in the reported procurement distance was associated with an extra USD 3.77/ton for Grade 1 and USD 1.68/ton for Grade 2 sawlogs, respectively.

The variable CAPACITY had a negative and significant impact on mean WTP, suggesting that sawmills with higher annual outputs were less likely to offer a price premium. Since CAPACITY was log-transformed, the interpretation for the marginal effect was different than for other variables: a one percent increase in annual output level was associated with a decrease in the WTP price premiums by USD 3.86/ton and USD 1.48/ton for Grade 1 and 2 sawlogs, respectively. Similarly, the variable YEAR was negatively significant for Grade 2 sawlogs; however, it was insignificant for Grade 1 sawlogs. The marginal effect suggests that sawmills that were in business for many years were likely to pay USD 2.39/ton more for Grade 2 sawlogs compared to newer sawmills. The variable EMPLOYEE had a positive and significant impact on mean WTP, suggesting that sawmills with more employees were more likely to offer greater price premiums. The marginal effect indicated that one additional employee was associated with the premium increase of USD 0.08/ton for Grade 1 and USD 0.04/ton for Grade 2 sawlogs, respectively. The impact of this variable was relatively smaller on mean WTP compared to other variables.

In the delivered price models, variables ENDDIA ($p = 0.09$; $p = 0.07$), DISTANCE (0.07; $p = 0.03$), and CAPACITY ($p = 0.01$; $p = 0.004$) were statistically significant for both grades, whereas GRADE ($p = 0.006$) and EMPLOYEE ($p = 0.08$) were significant only for Grade 1 and 2, respectively (Table 4). Unlike stumpage, ENDDIA had a positive and significant impact on the price premium for both grades, indicating that sawmills that preferred larger small-end log diameter were more likely to offer a premium for both Grade 1 and

Grade 2 sawlogs. The marginal estimates illustrated that a one-inch (2.54 cm) increase in end diameter was associated with a premium of USD 1.18/ton for Grade 1 and USD 0.84/ton for Grade 2 sawlogs, respectively. Similar to stumpage, GRADE had a positive and significant impact on price premium, suggesting that sawmills were more likely to offer a price premium for Grade 1 sawlogs than the Grade 2. GRADE had a relatively greater impact on mean WTP, such that a one grade increase in sawlog was associated with the premium increase of USD 3.59/ton.

Similar to the stumpage price models, sawmills were more likely to offer a price premium for both sawlog grades sourced from greater distances. The estimate of marginal effect for DISTANCE suggested that each 40 km increase in procurement radius related to the premium increase of USD 3.12/ton for Grade 1 sawlogs and USD 2.50/ton for Grade 2 sawlogs, respectively. Similarly, CAPACITY was negatively significant in both grade categories, indicating that sawmills that have a low annual output were more likely to pay a price premium than sawmills with a large annual output. The marginal effect showed that a one percent change in output level resulted in the premium decrease of USD 3.12/ton and USD 2.50/ton for Grade 1 and Grade 2 sawlogs, respectively. The variable EMPLOYEE was positively significant for Grade 2 sawtimber only, suggesting that sawmills with a larger number of employees were more likely to offer a price premium. The marginal effect suggested adding one more employee related to the premium increase of USD 0.11/ton for Grade 2 sawlogs.

Table 5 presents the mean price premium offered by sawmills for Grade 1 and Grade 2 sawlogs for stumpage and delivered prices. On average, sawmills who purchased pine sawlogs directly from forest landowners were willing to pay USD 10.59 per ton and USD 4.22 per ton for Grade 1 and Grade 2 pine sawlogs, respectively, above the existing stumpage price. Likewise, sawmills were willing to pay USD 12.98 per ton and USD 6.17 per ton for Grade 1 and Grade 2 sawlogs above the existing mill delivered gate prices. The price premium offered for Grade 1 sawlogs were 44% and 31% of current market stumpage and delivered prices, respectively, while for Grade 2 sawlogs it was 18% and 15% of the stumpage and delivered prices, respectively.

Table 5. Average and percentage price premiums offered for Grade 1 and Grade 2 pine sawlogs grown to an extended rotation age additional to the existing stumpage and delivered price across the southeastern United States based on a 2018 mail survey.

Product Prices *	Sawlog Category			
	Grade 1		Grade 2	
	Average Premium (USD/ton)	Premium Offered (%)	Average Premium (USD/ton)	Premium Offered (%)
Stumpage price	USD 10.59/ton	44.22%	USD 4.22/ton	17.62%
Delivered price	USD 12.98/ton	30.49%	USD 6.17/ton	14.49%

* Five-year average (2013–2018) stumpage and delivered price for pine sawtimber across the southeastern United States was USD 24.72/ton and USD 42.57/ton, respectively.

4. Discussion

This study provides evidence that some softwood sawmills across the southeastern United States preferred wood grown to an extended rotation and were willing to pay a price premium to obtain it. Our results provide baseline price premium estimates that will help land managers and landowners make more informed decisions on whether to extend pine plantation rotations to produce large diameter trees and whether they might reasonably expect a price premium to justify the final harvest delay. The study found several factors influencing sawmills' willingness to pay premiums for higher quality sawtimber. Of the eight variables used in the regression analysis, six variables: CAPACITY, EMPLOYEE, GRADE, ENDDIA, DISTANCE, and YEAR were found to be significant in at least one sawlog grade category in both stumpage and delivered price scenarios.

Assuming that more labor is required to produce more output, it was expected that CAPACITY and EMPLOYEE would be positively correlated with the WTP a price premium. Contrary to that expectation, the variable CAPACITY was negatively associated with mean WTP, indicating that sawmills having a higher production level were less likely to pay a price premium for higher quality pine sawtimber. One possible explanation could be that large sawmills diversify their product portfolio to limit their investment risks [26]. For example, large sawmills might not always rely on a single product type. They may diversify their raw timber material in a different product class (e.g., dimension lumber and value-added products) and create distribution networks accordingly [26,47]. Likewise, some large sawmill companies grow timber on company land or procure raw material from other sources (e.g., wood dealers) to purchase only when internal supply is low [48]. Alternatively, small sawmills generally do not own timberland and are more reliant on outside timber sources [49]. Thus, small sawmills are more reliant on landowners to provide sawtimber than are large sawmills [26]. In addition, reputation and provision of high-quality products and services are key factors differentiating many small sawmills from their competitors [47]. Small sawmills must provide a high-quality product and maintain their reputation to stay in business. This suggests that landowners tend to receive a premium price while dealing with small sawmills compared to larger sawmills.

As expected, EMPLOYEE was positively associated with the mean WTP, which suggests that sawmills with a larger number of employees are more likely to pay a price premium. The contradiction between CAPACITY and EMPLOYEE could be due to several factors. It is possible that the technological transformation led to recruiting a smaller number of well-trained employees in large sawmills. The southeastern United States consists of highly automated and capital-intensive large sawmills with a fast log processing ability that need fewer employees per unit of input [50]. On the other hand, many small sawmills cannot afford modern technology and depend on manual labor instead [51]. A large sawmill can produce the same product at a lower per unit cost compared to a small sawmill because of their advanced equipment [51]. Hence, number of employees is a potentially misleading indicator of sawtimber size. Future research should develop variables such as technology that can better assess a mill's size, production capacity, and age.

The variable GRADE was positively significant for the Grade 1 sawlogs in both stumpage and delivered price models, suggesting that sawmills processing Grade 1 sawlogs were more likely to offer a price premium for higher grade sawlogs. The possible reason for Grade 2 being insignificant in both scenarios could be the nature of the question and given WTP scenario. For example, quality concerned sawmills would be willing to pay a price premium for Grade 1 sawlogs compared to the sawlog grade they produce the most (i.e., Grade 2 or lower). This suggests that landowners who grow larger size and higher quality pine sawtimber with more Grade 1 logs are more likely to receive a price premium.

As expected, ENDDIA had a positive and significant impact on mean WTP in the delivered price model. This shows that sawmills consider log size (small-end diameter) while determining price premium when they purchase sawtimber delivered to the mill gate; however, they were indifferent about paying a premium based on end-diameter while purchasing sawtimber on stump. Sawmills often have their own set preferences/specifications for sawlog size. Thus, sawmills would rather consider paying a price premium for sawtimber meeting their specifications at the mill gate than paying a premium for stumpage to avoid the associated logistical costs (e.g., transportation costs and time) [31]. Furthermore, results showed that the majority of sawmills source sawlogs from logger/wood dealers. This shows that landowners might benefit more from selling sawtimber through third party arrangements (e.g., contractor, loggers, or dealers). This finding can be useful for landowners looking to negotiate with wood dealers, as sawmills showed more interest in paying a price premium for gate wood.

In both stumpage and delivered price models, the variable DISTANCE was positively significant indicating that sawmills were more likely to offer a premium for securing high-quality pine sawtimber from more distant sources, which was contrary to the expectation.

In general, mills incur more hauling costs as they travel further away and would be less likely to pay a premium. However, it is possible that due to the declines in wood quality and the shortage of high-quality sawlogs closer to the sawmill, they were willing to pay premiums to obtain desirable raw material to keep the mill running [52]. Sawmills prefer to be located in proximity to forests to reduce the transportation costs of raw materials resulting in agglomeration of sawmills [31]. Consistent with Anderson and Germain [52], we found that most sawmills (approximately 80%) procured their sawlogs supply from within 40–160 km of the mills. However, clustering of sawmills may lead to competition in the local markets and difficulty in obtaining desired quality sawtimber in local markets. Thus, sawmills might be willing to outbid other mills for high-quality sawtimber to meet their demand and contractual obligations if the overall costs adhere to the competitive local market sawtimber price. The unexpected effect of DISTANCE might also be due to the question format. For example, formatting the question with hauling distance as a continuous variable may do a better job of capturing the complete range of hauling distances than our current format.

The percentage of a price premium offered was higher for the stumpage price than for the delivered price even though the average price premium was higher for the delivered price scenario. This could be due to the price discrepancy between stumpage and delivered prices. For example, the stumpage price for pine sawtimber is typically lower than the mill delivered price; therefore, it is possible that sawmills offer a higher price when they purchased sawtimber directly from forest landowners because they can deliver logs themselves, which could be less than what they pay for mill gate wood. The average price premium offered by sawmills ranged from USD 4.22/ton to USD 12.98/ton depending on the type of price paid and sawlog grades. The price premium might encourage landowners to extend the financially optimal rotation age to grow higher quality sawtimber as long as the price premium offered could justify the cost associated with time to wait for harvesting higher quality sawtimber. Based on the findings of Regmi et al. [15], a price premium in this range would be sufficient to justify the financially optimal rotation extension by 10 years at an interest rate of 5% and 20 years at a 3% rate.

This study used the five year (2013–2018) average stumpage and mill delivered prices of southern pine sawtimber as a baseline price. The price information was derived from Timber Mart-South because of its wide acceptance. This price level might not be applicable to those sawmills who are already paying higher prices than what we provided as a baseline price. However, the results are still useful because sawmills will be informed about the trends in existing solid-wood markets and collective opinions of southern sawmills regarding higher quality pine sawtimber.

The timber supply chain in the southeastern U.S. mainly consists of landowners, logger, and sawmills. This research evaluated sawmills' interest in obtaining and paying a premium price for higher quality sawtimber grown on an extended rotation. While this study presented the demand side of higher quality sawlogs, it is equally important to understand the opinion of supply side. For example, the capacity of loggers and wood dealers to handle and process large-size sawlogs, landowner interest in extending rotation age, and landowner willingness to accept a price premium are important questions that will help determine the viability of producing higher quality sawtimber by extending rotation lengths. Future research can focus on these unanswered questions.

5. Conclusions

The study evaluated the willingness of sawmills to pay a price premium for higher quality sawtimber grown on longer rotations. Softwood sawmills in the southeastern United States showed considerable interest in obtaining high-quality pine sawtimber. Sawmills' mean willingness to pay price premiums ranged from USD 4.22/ton to USD 12.98/ton. This shows that forest landowners can potentially be compensated for growing higher quality pine sawtimber on longer rotation ages; however, the compensation amount relies on a variety of factors. Sawlog end-diameter, sawlogs grade, sawlogs procurement radius, and number of employees had a positive impact on mean WTP a price premium, whereas sawmill annual production capacity and years in business had a negative impact. Of the six variables, ENDDIA, GRADE, RADIUS, and CAPACITY had greater impacts on mean WTP than other variables. Sawmills that mostly used higher grade sawlogs were more supportive of paying a premium for quality sawtimber than other mills. This suggests that under the increasing pressure of intensive plantation management, landowners interested in growing pine trees for longer rotation age could be incentivized for extending the rotation length. These findings will be useful for forest landowners and land managers in making more informed management decisions pertaining to the delayed harvest to grow higher quality sawtimber. Results may benefit the sawmilling industry in understanding sawmill attitudes towards processing high-quality sawtimber on a regional scale. Furthermore, these findings will be useful for forest landowners who may find the intensive plantation management costs prohibitive since they can receive a premium price for their high-value trees.

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