Unit Costs and Trends within Louisiana's Logging Contract Rate

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Abstract

Quarterly unit costs for a hypothetical logging firm were determined from the logging contract rate for Louisiana spanning the years 1992 to 2018. Machine rate methods were employed to disaggregate the contract rate into five cost centers: felling, skidding, loading, trucking, and tertiary (e.g., trucks, bulldozer, chainsaw). Risk was explained by the quarterly interest rate on a 30-year mortgage, and income taxes were estimated as a fixed percentage of gross income. The real logging contract rate averaged US$19.08 per ton (2018 constant dollars), and it has risen at an annual rate of 1.03 percent above that of inflation for roundwood. Trucking was the firm's highest cost activity followed by skidding, loading, felling, and tertiary. Rates of cost change followed the order of tertiary, trucking, loading, felling, and skidding. The firm faced financial hardship sporadically from 1992 through 2001, but profits were consistently returned from the second quarter of 2000 through the fourth quarter of 2006 (2000Q2 through 2006Q4). Since then, company earnings have fluctuated between profit ($n = 25$ quarters) and loss ($n = 23$ quarters). Losses were consistently generated from 2010Q4 through 2013Q2, and all of 2014, as well as in the final three quarters of 2018. Simulation of the contract rate and firm unit costs as stochastic processes utilizing a uniform distribution indicated a 0.48 probability of at least breaking even, but that increased to 0.69 when employing a normal distribution.

A strong understanding of costs is critical to the success of any business. For businesses participating in the commercial logging industry, a firm's outlays center on extracting and delivering roundwood in a safe and timely manner. Logging costs can be quite variable due to many factors. These can include soils (wet/dry site), timber volume, timberland acreage, the company's equipment configuration, and distance to mill, among others. Thus, there is no one set unit cost across the industry.

Collecting financial data from the logging industry can be challenging (Luppold et al. 1998). Logger contract rates and unit costs are not widely published and must often be derived from multiple sources (Cubbage et al. 1988). One recent example of publishing logging rate data is the nonprofit price service Timber Mart-South, but those data are provided as regional averages for the US South. Private firms specializing in market analysis offer more localized logging cost data but at a potentially significant price. Commonly, a local estimate of the harvest margin is derived using published market reports by subtracting the delivered mill price of roundwood from the stumpage price paid to landowners (Sun and Zhang 2006). The harvest margin represents the logger's contract rate and includes logging costs, an allocation for risk and/or uncertainty as an opportunity cost of capital invested, and any profits obtained. In local areas where wood dealers are significant mill suppliers, a dealer commission is incorporated as well.

Machine rate calculations from engineering economics are one generally accepted way of understanding equipment costs (Werblow and Cubbage 1986), although Bilek (2008) provided discussion of their shortcomings. Fixed costs are those paid whether a machine is running or not. Such costs include the machine itself, interest, insurance, and taxes. They are therefore based on the full amount of scheduled work for the year. Operating, or variable, machine costs are dependent upon the actual work a machine performs in production. Fuel, lubricants, and maintenance and repair are common variable costs in machine rate accounting. Labor has generally been considered a variable cost, but Carter et al. (1994) did study of workers' earnings as a fixed cost.

Matthews (1942) demonstrated the use of machine rates in his seminal text on logging costs. Miyata (1980) updated the machine rate literature as harvesting technologies rapidly evolved to longwood and fully mechanized systems. Miyata and Steinhilb (1981) then compared three methods for calculating machine rates. Cubbage (1981) provided productivity and machine rate tables for harvesting southern pine. Brinker et al. (2002) provided machine rates for a variety of makes and models used in southern forest harvesting operations. Carter and Cubbage (1994) and Carter et al. (1994) used machine and productivity rates to derive unit costs of pulpwood operations, comparing

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productivity and cost changes between the years 1979 and 1987.

Modern computational power offers simulation as an efficient means to study interrelated variables whose outcomes result from random, or stochastic, processes, such as accounting for randomness between logging companies and annual harvests to determine carbon credit prices in the study by Rossi et al. (2017) of forest degradation in central Africa. The technique is colloquially termed ''Monte Carlo'' after the casino resort located in the European state of Monaco. In an industry in which raw material is grown over decades and processors are highly capitalized with inordinate degrees of uncertainty due to environmental, social, and economic factors, stochastic simulation can provide insight into the probability of occurrence resulting from deterministic models. Cassens et al. (1993) applied Monte Carlo simulation to lumber manufacturing processes to calculate final board dimensions. Elustondo and Avramidis (2005) compared a model of the lumber drying process driven by complete randomness to one based on numerical integration of frequency distributions.

This study's goal was to better understand logging rate trends and how firms have been subsequently influenced by them. First, the quarterly average logging contract rate for Louisiana firms was analyzed over a 27-year time period spanning from 1992 to 2018. The contract rate was next decomposed into its unit cost components along each step of the forest-to-market process using assumed machine and production rates for a hypothetical firm. Then, simulation was performed using two easily understood statistical distributions, the uniform and normal, to better understand the probability of occurrence associated with the contract rate as an assemblage of individual, random processes.

Methods

Quarterly timber price data for Louisiana from the first quarter of 1992 (1992Q1) to the fourth quarter of 2018 (2018Q4) were obtained from Timber Mart-South (Norris Foundation 2019). Stumpage and delivered prices were obtained for pine sawtimber, pine Chip-N-Saw, pine pulpwood, hardwood sawtimber, and hardwood pulpwood. The logging contract rate for each timber product was assumed to equal the difference between delivered price at the mill and the stumpage price paid to landowners (Sun and Zhang 2006). The contract rate was further assumed to be equal to the sum of logging costs, risk, taxes paid, and profits. The contract rate for each timber product (year by quarter) was weighted by that product's relative contribution to the *Louisiana Timber and Pulpwood Production* report published annually by the Louisiana Department of Agriculture and Forestry (LDAF), shown in Figure 1 (LDAF 2019a). Summing across all products provided a composite contract rate for each quarter over the time series. The rate was then indexed to the 1992Q1 value and compared with other economic indexes described in further detail below.

Fixed and variable machine costs were calculated for a hypothetical company using the equipment configuration presented in Table 1, with each machine operating at a 70 percent utilization rate. The logging operation produced a daily average of 15 loads, and each load was considered 27 tons. Equipment consisted of one 170-horsepower (hp) feller–buncher with a 21-inch-diameter capacity sawhead; two 160-hp grapple skidders; one 130-hp truck-mounted knuckleboom loader (the truck itself was a 300-hp 10-wheel truck running 10 h/wk to move the knuckleboom loader); one 165-hp knuckleboom trailer-mounted loader with pull-through delimber and slasher saw; five 500-hp 10-wheel logging truck-tractors with 8-wheel double-bunk set-out trailers; one transport flatbed trailer; one 80-hp dozer equipped with a 6-way blade; one 1-ton 6-wheel service-fuel truck; one 3/4-ton crew truck; and one 3-hp chainsaw with a 26-inch bar. Current equipment purchase costs were estimated from prices obtained from online searches (Forestry Equipment Guide 2019, Sandhills Global 2019) and conversations with forest industry managers. These were deflated to the proper year and quarter using the producer price index for machinery and equipment: agricultural machinery, WPU111 (US Department of Labor Bureau of Labor Statistics [USDL BLS] 2019a).

Machine rate calculations were applied to disaggregate the contract rate into unit cost components. Miyata's (1980) methods were followed, with the exception of labor costs, which are described later in further detail. Fixed costs were considered the sum of equipment depreciation plus interest, insurance, and taxes (IIT) over a 48-week year. Depreciation was calculated using the straight-line method:

$$D = \frac{P - S}{N} \tag{1}$$

where D was annual depreciation charge, P was the purchase cost, S was the salvage value, and N was the economic life, or tax life, for each piece of equipment. Depreciation for this study was from an accounting perspective of apportioning the depreciable fraction of equipment investment across its economic life for tax purposes, which is not necessarily equivalent to economic depreciation (Hansen and Lee 1991). The economic (tax) life is the period allowed for deducting depreciation from taxable income. An equipment's salvage value, which may also be known as resale or residual value, is the amount for which a used machine is sold.

Tax life of the chainsaw was 1 year and salvage value was 0 percent of the purchase price, while the tax life of all other equipment was 5 years (Bennett and Ward 2010). The salvage value for all other equipment was 20 percent, which approximated the average annual depreciation across all equipment categories from Cubbage et al. (1991). Because the salvage value is a future value, it was additionally discounted to a present value at the average annual inflation rate from index WPU111, 3.05 percent, for 5 years. The IIT collectively was 14 percent of the average annual investment (AVI) based on findings from *Route Chaser*, a tract-to-mill trucking cost calculator (Stuart and Grace 2004). Equation 2 defined AVI as

$$\mathrm{AVI} = \frac{(P - S)(N + 1)}{2N} + S \tag{2}$$

where AVI was the average annual investment, and P, S, and N were as defined above. Interest represented 6 percent of AVI, insurance equaled 4 percent of AVI, and taxes comprised 4 percent of AVI.

Variable costs were considered the sum of maintenance and repair, fuel usage, lubricant consumption, and labor. A 48-week work year was used to allocate weekly maintenance and repair as a percentage of straight-line depreciation, which varied by equipment (Table 2). Fuel costs for woods-run equipment were determined on an hourly basis

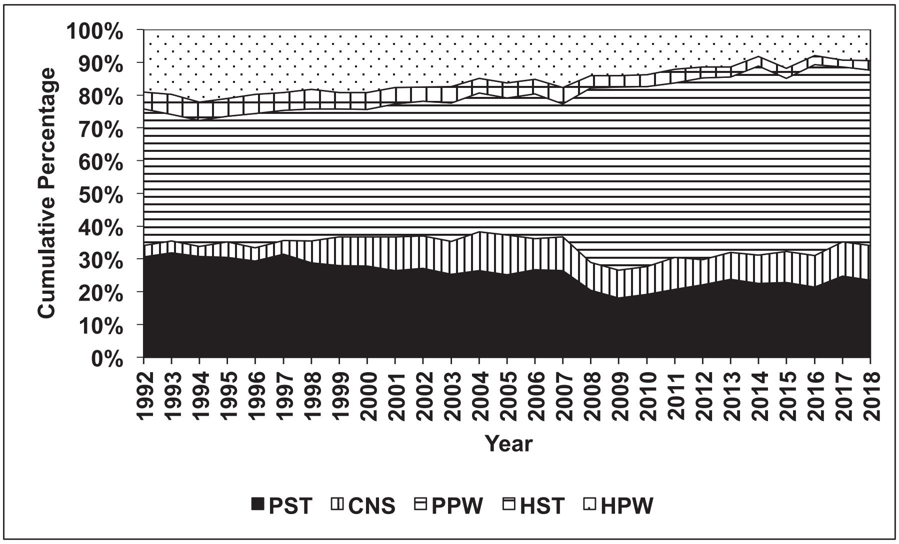

Figure 1.—Stacked percentage of state harvest by timber product in Louisiana, 1992 to 2018. PST = pine sawtimber; CNS = pine Chip-N-Saw; PPW = pine pulpwood; HST = hardwood sawtimber; HPW = hardwood pulpwood.

using Equation 3:

$$\mathrm{GPH} = \frac{F \times P \times HP \times nHP}{W} \tag{3}$$

where GPH was gallons of fuel consumed per hour, F was the pounds of fuel consumed per hp-hr (F equaled 0.40 lb for diesel and 0.46 lb for gasoline), P was the per gallon fuel price, HP was equipment horsepower, nHP represented the net horsepower used to that available (nHP across all equipment was assumed as 0.65), and W was the weight of 1 gallon of fuel (W was 7.08 lb for 1 gal of diesel and 6.01 lb for 1 gal of gasoline). Equation 3 and its constants were per Miyata (1980). Fuel usage was determined on the 70 percent utilization rate of a 40-hour work week, which equaled 28 hours.

Gulf coast fuel prices were obtained from the US Energy Information Administration (2019) and quarterly averages were calculated for a calendar year. The off-road diesel fuel price was assumed to be $0.50/gal less than the on-road diesel price (all costs are in US dollars). The diesel price series only covered the period beginning in 1994Q2. Earlier prices were calculated by deflating the 5-year average from 1994Q2 through 1999Q1 by the producer price index for fuels and related products and power: no. 2 diesel fuel, WPU05730302 (USDL BLS 2019a). The regular gasoline price series began in 1992Q2. The first 20 quarters were averaged and deflated to 1992Q1 per the producer price index for fuels and related products and power: petroleum products, refined, WPU057 (USDL BLS 2019a).

Fuel cost for the log trucks was based on mileage at 15 loads per day by average 100 miles round trip per load at 5 mi/gal (average haul distance was assumed as 50 mi one-way.) Average distance from the business office to the work site was 50 miles. Fuel cost for the service truck and crew truck was therefore based on mileage driving 100 mi/day round trip at 10 mi/gal. Gasoline cost was for the chainsaw only. Lubricant consumption was calculated as 35 percent of fuel costs across all pieces of equipment.

Table 1.—Equipment configuration for the benchmark Louisiana logging firm. The utilization rate was assumed to be 70 percent across all machines.

Machine	Quantity	Purchase price (US$)
Chainsaw	1	925
Feller–buncher	1	300,000
Skidder	2	570,000
Trailer-mounted loader with pull-through delimber and slasher saw	1	192,000
Knuckleboom loader	1	80,000
Knuckleboom loader truck	1	22,000
Log tractor trucks	5	525,000
Log tractor truck trailers	5	175,000
Flatbed transport trailer	1	30,000
Bulldozer	1	115,000
Service truck	1	55,000
Crew tuck	1	49,000
Total	21	2,113,925

Table 2.—Percentage of equipment straight-line depreciation used to determine weekly maintenance and repair costs by equipment piece for the benchmark Louisiana logging firm. Values were obtained from Brinker et al. (2002) where possible; otherwise, they were assumed rates for this study.

Machine	Straight-line depreciation (%)
Chainsaw	100
Feller–buncher	100
Skidder	90
Trailer-mounted loader with pull-through delimber and slasher saw	35
Knuckleboom loader	90
Knuckleboom loader truck	30
Log tractor truck	30
Log tractor truck trailer	30
Flatbed trailer	30
Bulldozer	50
Service truck	30
Crew truck	30

Employees included five logging truck drivers, two skidder operators, one feller–buncher operator, one loader operator, and one delimber–slasher operator. Each person was paid the labor rate for loggers obtained from the Occupational Employment Statistics (OES) for Louisiana (USDC BLS 2019b) and multiplied by a factor of 1.5 to account for worker compensation, fringe benefits, and other associated costs. Earnings were comprised of scheduled work at 40 h/wk for 48 weeks, with no overtime. Because the OES series dated to 1997, the 5-year average from 1997 to 2001 was deflated for each respective quarter from 1992 to 1996 per the index of aggregate weekly payrolls of production and nonsupervisory employees: Mining and Logging, CES1000000035 (USDL BLS 2019a).

Costs were aggregated into the following categories: felling, skidding, loading, trucking, and tertiary. Tertiary included the service and crew trucks, bulldozer, transport trailer, and chainsaw. Machine costs were then converted from fixed and variable bases to a production-based unit cost format in dollars per ton. From this point, the methodology diverges from Miyata (1980). Labor was not reported separately as a cost alongside other cost centers, such as skidding. Rather, each worker was allocated to their respective role in the functioning of the system. This was done because the machines require labor to perform their work.

Dollars per ton reflected 27 tons per load, 15 loads per day, 5 days/wk. A margin for risk and uncertainty was accounted for as equaling the interest rate on a 30-year mortgage (Federal Reserve Bank of St. Louis 2019). Risk in dollars therefore was considered the product of the weighted contract rate and the prevailing 30-year interest rate for each respective quarter. Income taxes were assumed to represent 3.21 percent of gross income, here the contract rate, per Perry and Nixon's (2002) figures for Louisiana in their study of farm taxes. Income taxes paid were assumed as zero in instances where total costs—the sum of tertiary, felling, skidding, loading, trucking, and risk—exceeded the contract rate itself prior to calculating tax cost. Tax-loss treatment was considered simply as lost (Bilek 2008). Quarterly profit was determined by subtraction of all cost factors from the contract rate. All cost, risk, tax, and profit results are reported and discussed in 2018 constant dollars per the producer price index for logs, bolts, timber, pulpwood, and wood chips, WPU0851 (USDL BLS 2019a).

Average annual percentage rates of change (APR) were computed for inflation-adjusted results using trend analysis per Duvall et al. (2014):

$$Y = \beta_0 + \beta_1 X + \varepsilon \tag{4}$$

$$APR = (e^{4\beta_1} - 1) \times 100\% \tag{5}$$

where $Y = \ln(C_t)$, with C_t being the activity cost at time t (yr/quarter); β_0 was the regression intercept; the slope parameter β_1 identified the continuous rate of change in activity cost as a percent; X was a year/quarter, which was coded from $n = 1$ to $n = 108$; and ε was the random error that followed a first-order autoregressive process due to residual autocorrelation (Eq. 4). Annualizing the continuous rate of change required multiplying it by 4, and the product served as the exponent to which the base of the natural logarithm, e, was raised. Subtracting one and multiplying by 100 percent provided the annual percentage rate of change, *APR*, in Equation 5. The findings for income taxes and net profit required adding a constant, which was arbitrarily chosen to equal 10, because zero or negative values were obtained for those measurements in some quarters.

Lastly, probabilities of profitability for a randomly selected quarter were assessed via a cumulative distribution function generated from 10,000 simulations in Microsoft Excel of the logging contract rate, activity costs, taxes, and risk. Profit was calculated by subtraction. All variables were simulated over their respective ranges using two common and easy-to-understand statistical distributions, the uniform and the normal. The uniform distribution is a special case of the beta distribution where the shape parameters α and β both equal 1. It is depicted by a histogram having class frequencies of similar levels. The normal distribution is defined by the shape parameters μ and σ. This is illustrated by a histogram having class frequencies that increase and then decrease in a symmetric fashion centered around the mean, which is equal to both the median and the mode, to form the classic bell-shaped curve.

Results

Results prior to inflation adjustment show the nominal Louisiana logging contract rate index trending slightly above the national producer price index and slightly below the indexes for equipment costs (a national-level index) and labor (a state-level index), where 1992Q1 = 100 percent (Fig. 2). While an expected finding, there were much greater relative changes occurring within the regional fuel cost index over the study period compared to those for labor and equipment. Adjusting for inflationary effects revealed the real contract rate in Louisiana had generally fluctuated within a band of $15 to $25 per ton (Fig. 3), ranging from $11.41/ton (1994Q2) to $24.00/ton (2005Q4) over the time series (Table 3). The overall average was $19.08/ton.

The real contract rate index trended above inflation overall with an APR of 1.03 percent (Fig. 4). Indexing firm-level total costs to the initial quarter of the time series revealed costs on the whole had outpaced inflation since 2000Q3 (Fig. 4). Trucking was the primary cost component over the time series (Table 3), which averaged $6.90/ton and increased at an annual rate of 1.63 percent. This was followed by costs associated with skidding, loading, felling, and then tertiary equipment, which were all increasing over time as well. The opportunity cost associated with risk averaged $1.12/ton and had been decreasing over time. Income-related taxes were estimated to consume an average $0.51/ton, with a trend not significantly different from zero. Quarterly profit averaged $1.67/ton over the time series (Table 3). However, the standard deviation related to these data was greater than the average, with profit ranging from –$2.46/ton (2008Q3) to $7.89/ton (1998Q2). Profit declined at an average annual rate of 0.52 percent over the 27-year study period.

Logging costs plus risk and taxes collectively fell sharply from 1992 through 1993 (Fig. 5). Beginning in 1994, costs steadily trended upward through 2005Q4. They fluctuated for some following quarters before consistently being at or above $20 from 2007Q4 through 2014Q4. A relatively moderate drop occurred over five quarters to $18.18/ton in 2016Q1. From 2017Q3, a subsequent measured rise occurred once again. Logging costs plus risk closed at $19.59/ton in 2018Q4; however, the contact rate for that quarter was only $19.27/ton.

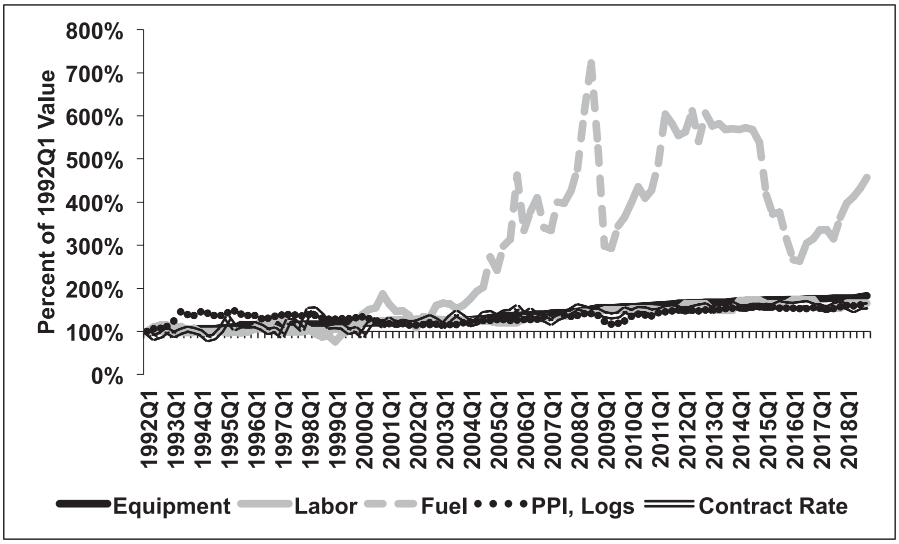

Figure 2.—Indexes representing trends for the nominal Louisiana logging contract rate alongside that of equipment, labor, fuel, and inflation from 1992 to 2018, where 1992Q1 = 100 percent. The equipment and inflation indexes are each at the national level, while fuel is regional for the Gulf Coast. The contract rate was a weighted average across the differences between delivered-to-mill price and stumpage price for pine sawtimber, pine Chip-N-Saw, pine pulpwood, hardwood sawtimber, and hardwood pulpwood. PPI = producer price index, Q = quarter.

A relative perspective was provided when costs, risk, and taxes were presented as percentages of the quarterly contract rate (Fig. 6). Where costs, risk, and taxes together summed to less than 100 percent, the company was assumed to have earned a profit. For quarters where the collective costs summed to greater than 100 percent, the company experienced a loss. Quarterly profit margin, or profit as a percentage of the contract rate each quarter, averaged 16 percent from 1992Q1 through 1998Q4, experiencing a negative value only in 1994Q2. From 1999Q1 to 2006Q4, the profit margin averaged 13 percent, with one quarterly loss in 2000Q1. The firm averaged a loss of –0.72 percent from 2007Q1 to 2014Q4. Moreover, from 2010Q4 to 2014Q4 the company experienced losses in 15 of 17 quarters. The company rebounded beginning in 2015, but its last profit was earned in 2018Q1.

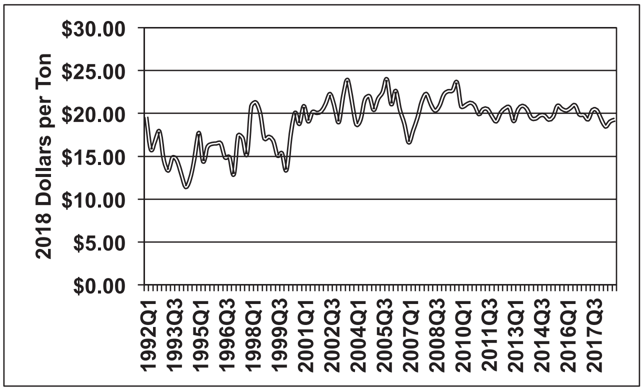

Figure 3.—Composite real logging contract rate, 2018 US dollars per ton, for Louisiana, 1992 to 2018. The contract rate was a weighted average across the differences between delivered-to-mill price and stumpage price for pine sawtimber, pine Chip-N-Saw, pine pulpwood, hardwood sawtimber, and hardwood pulpwood. Q = quarter.

Reading from the *x* axis at any selected point up to the cumulative distribution curve in Figures 7 and 8 and then over to the *y* axis will explain the probability of this firm earning a profit up to that dollar amount per ton for a randomly selected quarter over the time series. Further, subtracting one from that probability provides the complementary probability of the firm earning at least that dollar profit per ton. The probability of this firm losing money in a randomly selected quarter over the time series was 0.48 (P[x] $<$ \$0.00 = 0.48) when the processes' distributions were all considered uniform (Fig. 7). Conversely, its probability of at least breaking even was also 0.52 (P[x] $\geq$ \$0.00 = 0.52). The probability of quarterly profit lying between zero (breakeven) and up to \$1.67/ton, which was the average from Table 3, was 0.14 (\$0.00 $<$ P[x] $<$ \$1.67 = 0.14). The probability of attaining at least the average quarter's profit, therefore, was 0.38 (P[x] $\geq$ \$1.67 = 0.38).

The probability of the company losing money in a randomly selected quarter was 0.31 (P[x] $<$ \$0.00 = 0.31) when randomness followed a normal distribution (Fig. 8). Thus, the probability of at least breaking even when considering the contract rate, machine costs, risk, and taxes as normally distributed random processes was 0.69 (P[x] $\geq$ \$0.00 = 0.69). The probability of quarterly profit lying between zero (breakeven) and up to \$1.67/ton, which was the average from Table 3, was 0.20 (\$0.00 $<$ P[x] $<$ \$1.67 = 0.20). The probability of attaining at least the average quarter's profit, therefore, was 0.49 (P[x] $\geq$ \$1.57 = 0.49).

Discussion

The real Louisiana logging contract rate—considered in this study as the sum of costs, risk, taxes, and profit—was increasing at an annual rate of 1.03 percent throughout the study period and had trended above the average inflation rate since 2000 (Table 3; Fig. 4). In-woods and trucking costs have been increasing, and this affected profitability for the study firm. The most significant cost center for the logging industry is trucking (Shaffer and Stuart 1998,

Table 3.—Statistics of quarterly logging cost activities and average annual percentage of rate of change (APR) in logging cost activities for the benchmark Louisiana logging firm from the first quarter of 1992 through the fourth quarter of 2018.

Component of logging contract rate	2018 US$ per ton					
	Arithmetic average	SD	Min	Max	APR	APR *P* value
Total rate	19.08	2.71	11.41	24.00	1.03	0.0044
Trucking	6.90	1.54	4.25	9.96	1.63	0.0265
Skid	3.51	0.64	2.28	4.58	1.30	0.0314
Load	2.45	0.51	1.54	3.34	1.52	0.0264
Fell	1.87	0.34	1.22	2.44	1.30	0.0299
Risk/uncertainty	1.12	0.25	0.67	1.70	−2.12	0.0002
Tertiary	1.04	0.22	0.66	1.43	1.64	0.0090
Federal and state income taxes	0.51	0.24	0.00	0.77	−0.03	0.6589
Total costs	17.40	3.11	11.33	22.78	1.28	0.0329
Net profit	1.67	1.90	−2.46	7.89	−0.52	0.0080

Hamsley et al. 2007), and this study reflected that as well. Trucking costs in this study averaged 36.2 percent of the contract rate, and hauling costs were increasing faster than other related harvesting activities, with the exception of tertiary costs. The trucking costs determined in this study were similar (±5%) at points in time to other reported values (Hamsley et al. 2007, Reddish et al. 2011). A second cost center is skidding, where minimizing skidding distance works to control costs (Contreras et al. 2015); from the machine-cost perspective taken here, this study reflected that as well. The loader is commonly considered the logging firm's bottleneck that limits operational productivity, particularly when sorts move beyond simply pulpwood and sawtimber to include other products like Chip-N-Saw (Cass et al. 2009). These results suggested the loader to be one of the greater points of cost increase among in-woods activities.

Simulation was performed using the uniform and normal distributions to improve on a study limitation of holding some factors constant, such as production. This incorporated the randomness logging businesses must manage daily due to factors such as weather, quotas, equipment downtime, and labor availability, among others (Walter 1998). Despite the increasingly challenging economic environment over the study period (e.g., Pelkki 2012), simulation results over the entire study period suggested a probability of 0.48 (uniform distribution) and up to 0.69 (normal distribution) of at least breaking even in any one quarter (Figs. 7 and 8). The probability of the firm obtaining a profit level equal to or better than the overall average of $1.67/ton was 0.38 under conditions conforming to a uniform distribution, but this increased to 0.49 when a normal distribution was considered. However, the company's probability to survive would have potentially faced decreasing levels from 2007 onward (Fig. 6). The period from 2011 through 2014, in particular, would have been difficult for many companies to weather.

Greater economic forces could be impacting the trends seen here. One factor is mill consolidation. Since the 2007-to-2009 recession, mill consolidation has occurred across a number of forest industries in the US South (Hodges et al. 2011). Mill consolidation as a simple phenomenon, though, has been occurring for decades (Johnson et al. 2011). For example, substitution of oriented strand board for plywood over the past few decades concentrated demand for large

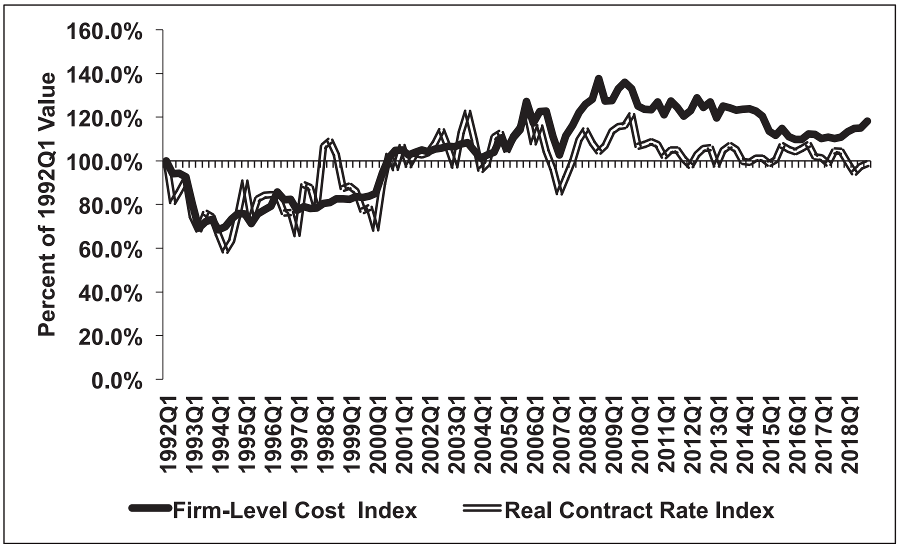

Figure 4.—Real logging cost index for the study firm and real logging contract rate index in Louisiana from 1992 to 2018, where 1992Q1 = 100 percent. The firm-level cost index was comprised of machine-related activities plus risk and associated income taxes. The contract rate was a weighted average across the differences between delivered to mill price and stumpage price for pine sawtimber, pine Chip-N-Saw, pine pulpwood, hardwood sawtimber, and hardwood pulpwood. Q = quarter.

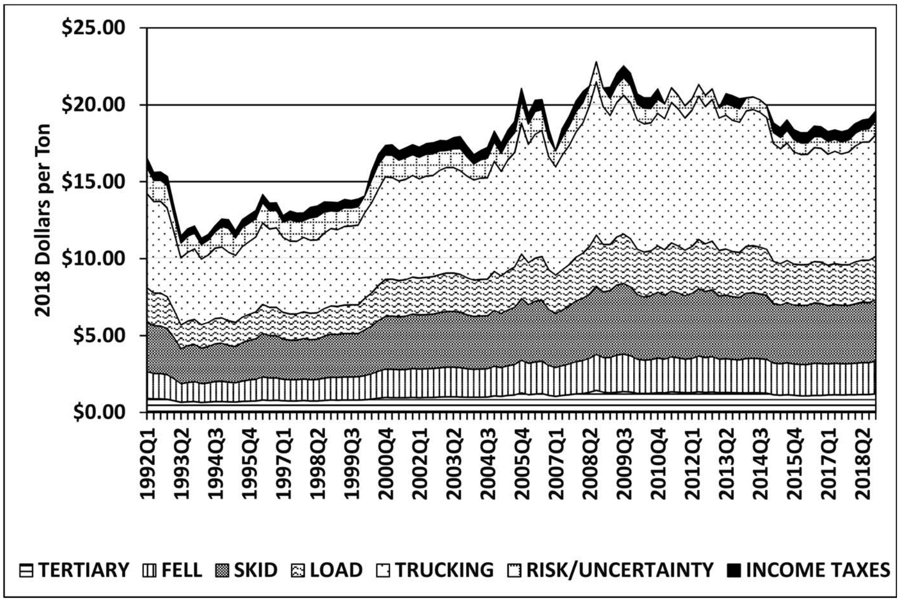

Figure 5.—Firm-level logging cost trend (2018 US dollars per ton) by cost activity in Louisiana from the first quarter of 1992 through the fourth quarter of 2018. Q = quarter.

sawtimber while expanding market opportunities for pulpwood (Wear et al. 2007). Even with the global recession, forest sector output and productivity in the US South progressed to increasingly higher levels with continued substitution of capital for labor (Dahal et al. 2015). By itself, consolidation perhaps offers an inadequate explanation.

Growing stock volume on the South's timberland increased 10 percent from 2007 to 2017, while harvests declined 13 percent (Oswalt et al. 2019). Data presented in Oswalt et al. (2019) also revealed that harvests, as a percentage of inventory, have steadily declined since 1997. Furthermore, planted acres have consistently exceeded 1.0 million acres since 1970 and 1.4 million acres since 1982. These findings imply timber oversupply, which has troubled timber market regions like Mississippi (Measells 2019). Many woodsheds are now occupied with only one or a couple of major participants. Log inventories can be tightly controlled through tightened product specifications (e.g., evolving preference to smaller-sized sawtimber [Parajuli et al. 2019]), delivery quotas, long-term fiber supply agreements, and exclusive contracts with wood dealers that eliminate gatewood deliveries.

The logging industry has for some time utilized multiproduct sorting to increase market outlets and revenues. A Louisiana contractor identified seven sorts conducted by his crew at a recent site visit in western Louisiana (anonymous, personal communication). Baumg-

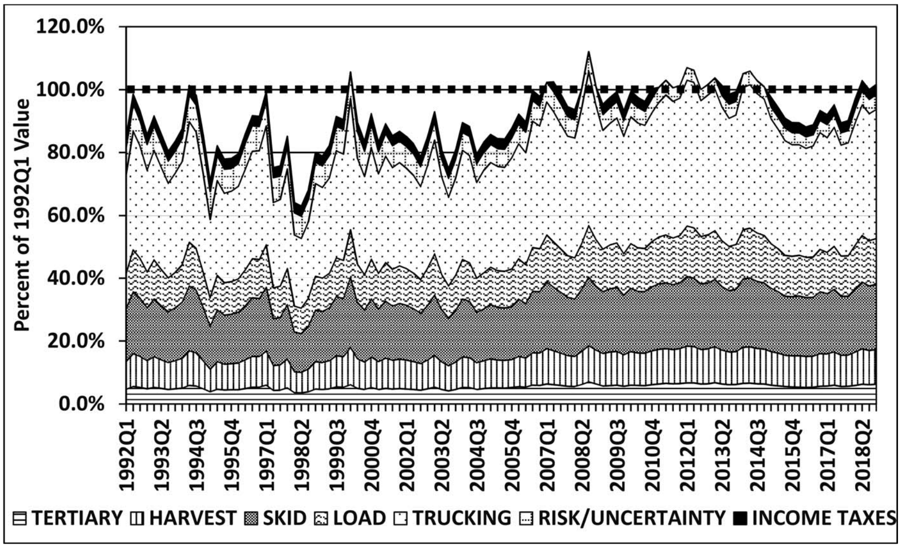

Figure 6.—Machine activity cost, risk, and income taxes as a percent of quarterly contract rate for a Louisiana logging firm from the first quarter of 1992 through the fourth quarter of 2018. Where costs and risk exceed the 100 percent line (denoted by linked squares) indicates the company generated negative profit that quarter. Q = quarter.

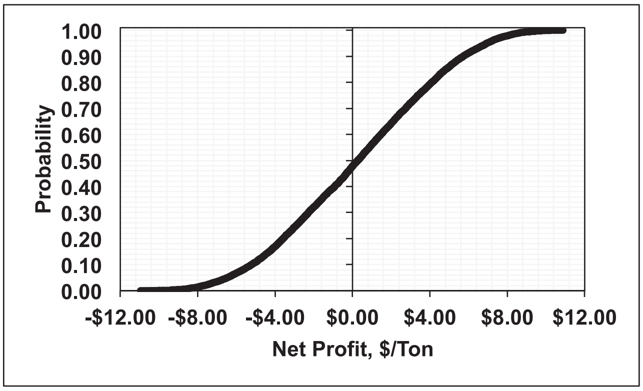

Figure 7.—Cumulative distribution function of profitability for a randomly selected quarter from 1992Q1 to 2018Q4 for a hypothetical Louisiana logging firm. This cumulative distribution function was generated from a uniform distribution.

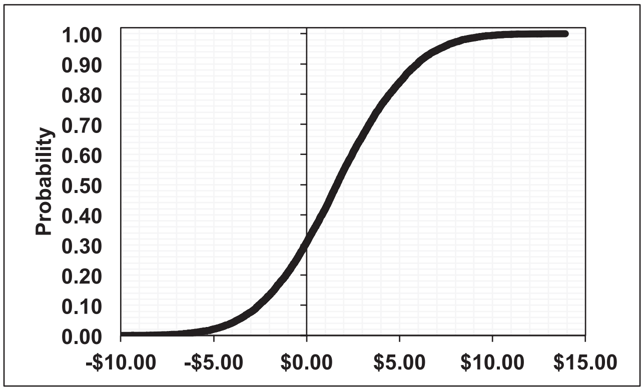

Figure 8.—Cumulative distribution function of profitability for a randomly selected quarter from 1992Q1 to 2018Q4 for a hypothetical Louisiana logging firm. This cumulative distribution function was generated from a normal distribution.

ras and LeDoux (1988) found multiproduct sorting for Appalachian hardwoods generated net gains of $200 to $400 per acre. Baumgras and LeDoux (1988) discussed the needs for multiproduct sorting to be successful: timber stand attributes—timber species, scale, and grade and product markets—log specifications (or appropriateness), and prices (or affordability), along with marketable volume to the market location (or availability). The more recent imposition of the limitations mentioned previously, such as quotas, exclusive agreements, etc., have placed an increased imperative on this procedure.

The finding that the contract rate trended at a pace exceeding the inflation rate (Fig. 4; Table 3) differed from earlier analyses by Cubbage et al. (1986, 1988). Those studies concluded the contract rate from the late 1960s through the mid-1980s was changing at rates less than the average inflation rate as well as two factors comprising logging costs, equipment and labor. The implication was that real logging costs had been declining. Their trends indicated the logging industry at the time was accepting a lower profit margin per unit, or had increased its productivity, or some combination of both. For example, one can have a lesser profit margin per ton but still increase revenues overall by producing a greater number of wood deliveries. They discussed the influence that replacing aging equipment or investing in newer technologies had on the industry overall.

Considered comprehensively, the previous era of innovation that maintained industry competitiveness by spreading fixed costs over increasing levels of production has perhaps evolved to one of declining rates of distribution associated with those costs. The rate of distribution would be hypothesized to have a negative sign alongside increasing haul distance, a positive sign due to increasing capacity utilization, and a positive sign as the proportion of pine harvested intensified (Walter 1998). As the distance traveled per haul increases, time per haul increases, and thus the production rate (loads per day or week) declines (Stuart 2003). Long-distance trucking is being compensated by many Louisiana mills as payments of mileage premiums for long hauls, regardless of timber product. Conrad (2018) stated some Georgia firms received increased trucking rates to offset other costs, but it was not specified whether this was an overall increase or specific to long hauls only.

Multiproduct sorting, while increasing economic returns per ton or per acre, could be generating an in-woods production bottleneck. Where hardwood markets exist for appearance-grade products, multiproduct sorting of natural and/or mixed stands can become complex. Increased hardwood harvesting decreases efficiency due to less stem uniformity as compared to pine. Higher-valued appearance-grade products require greater skill, care, and time for delimbing and bucking decisions (Walter 1998). Walter (1998) also mentioned the inventory and access implications of the more limited management of these sites. The recent trend of hardwood sawtimber's value outpacing that of pine sawtimber is providing greater justification for expending company resources on these tracts where available (LDAF 2019b).

Hodges et al. (2011) pointed to increasing rates of land conversion to pine plantation and harvest trends to intermediate thinnings in the South, and Figure 1 implies that as well in Louisiana (LDAF 2019a). The evolution of southern pine manufacturers from larger logs to smaller logs favors products such as oriented strand board and engineered composite joists and beams over plywood and solid-sawn lumber. Likewise, the increasing trend to Chip-N-Saw where a market exists, as it does in Louisiana, better meets sawmillers' demands to produce more desirable 2 by 4s and chips—for subsequent paper, particleboard, and fiberboard production—over 2 by 12s (Parajuli et al. 2019). This, too, creates complexity with regard to meeting mills' log specifications. Equipment furnished with newer technologies can better accommodate the wide between, but tight within, variations mill log specifications can exhibit.

Conrad et al. (2018) reported the number of Louisiana logging businesses fell by 38 percent from 1990 to 2016, while logging employment declined 18 percent. Consolidation in the logging sector, much like in manufacturing, has been occurring for decades. Logging costs had been rising even before the global recession (Stuart et al. 2008). Coupling those factors with the industry restructuring postrecession exacerbated the shortage of trucking capacity that still persists (Hodges et al. 2011, Conrad 2018). Compensation for long hauls aids the logger to a degree, but ultimately consumes more of the residual, the stumpage payment to landowners. LeBel (1996) concluded that studying the effect of either haul distance, capacity utilization, or pine harvest volume individually while holding the other two variables constant insufficiently illustrated the variables' impacts on logging production efficiency. Rather, the three interacted together as a "complexity factor." Walter (1998) found a greater level of influence was possessed by the haul-distance factor over the other two variables.

This leads one to question in the immediate term how long landowners can store their timber on the stump in the current decade of lower stumpage prices (LDAF 2019a). Historically, timber has possessed a low harvest penalty, meaning a delay in the harvest decision due to poor market opportunities allowed timber to continue to grow in both scale and grade until prices improved. But as the southern pine market has evolved to favor smaller-sized logs (Parajuli et al. 2019), and larger logs trend to lesser marketability, what will become of this timber in the coming years? Will hardwoods become more of a norm in Louisiana timber markets than an exception? Quality timber will always be prized in the market, but availability, affordability, and appropriateness will dictate the price received and value ultimately obtained.

This study focused on one hypothetical firm residing in Louisiana. Arriving at unit costs from machine rate analysis has limitations (Bilek 2008), but efforts were made to overcome multiple drawbacks. While simulation provided insight into any variation present within the contract rate, and the factors comprising it, it was specific only to this firm. McConnell (2013) found Ohio's logging industry was comprised of three distinct clusters, where cluster differences centered on equipment configuration, philosophy on equipment replacement, and haul distance for their product. Equipment configurations vary due to the niche a company seeks to fill in the marketplace, such as motor manual tree-length systems, versus highly mechanized full-tree systems, versus whole-tree chipping (Cubbage and Granskog 1982). Findings from equipment-replacement models have historically conflicted with field observations of business activities. Caulfield and Tufts (1989) suggested replacement of a grapple skidder after 2 years using risk-incorporated decision making; however, McConnell (2013) found Ohio loggers' equipment in many instances had long since "depreciated out." Georgia trucking firms interviewed by Conrad (2018) discussed the difficulties of maintaining profitability given average payload and number of loads delivered per day. Given these considerations, each could have figured prominently here had multiple firms been considered.

Conclusions

This study highlighted cost and profit trends for a hypothetical logging firm in Louisiana. From 1992Q1 to 2018Q4 the real logging contract rate averaged $19.08/ton. While risk (per the 30-yr interest rate) mitigated for the company over time, unit costs by machine activity center increased. Trucking costs were the highest cost center for the firm followed by skidding; higher rates of cost change were found for tertiary and trucking. These factors directly affected the firm's economic well-being. The company consistently generated quarterly profit from 1992Q1 through 2006Q4, excepting 1994Q2 and 2000Q1. Since 2007, volatile swings in profit/loss have occurred. Losses were produced in 15 of 16 quarters from 2010Q4 through 2014Q4. Likewise, losses have been experienced since 2018Q2.

Simulation provided additional depth by altering the firm's activities into a collective series of random processes described here by either a uniform or normal distribution. This facilitated determining the probability of an event's occurrence. The probability of the company at least breaking even in any one quarter when considering a uniform distribution was 0.48. When the processes were considered random normal, the probability of at least breaking even increased to 0.69. The probability of quarterly profit lying between zero (breakeven) and up to the average profit over the time series was either 0.14 or 0.20 depending upon whether the distribution considered was uniform or normal. The probability of quarterly profit being greater than or equal to the average profit over the time series was either 0.38 or 0.49 depending upon whether randomness followed uniformity or normality.

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