Logging productivity and production function in Alabama, 1995 to 2000

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Abstract

Logging costs are a large proportion of the wood material cost for forest industries. The efficiency and productivity of the logging industry are important factors in the competitiveness of the forest industry in the regional and international marketplace. This paper analyzes logging productivity in Alabama using data from a mail survey that was sent to firm owners, co-owners, or firm managers in 2000. The labor and machine cost productivities discussed were calculated by firm size, machine type, and products. The contribution and substitution between labor and machine cost were estimated using the ordinary least square econometric method.

With 22 million acres of forestland in Alabama (71% of the total area), forestry generates approximately $13 billion for Alabama each year and the forest industry employs about 10 percent of Alabama's total work force. Logging contractors' capital investment of $1.6 billion helps generate an annual income of $2.8 billion. The 5,000 loads of wood moved each day helps ensure there is a steady supply of wood for the 850 forestry companies (Alabama Forestry Association 2008). There is, however, little literature on the technical efficiency and logging productivity in Alabama.

Timber harvesting systems in the Southeastern United States have changed over the past 50 years from being labor-intensive to almost totally mechanized operations (Hines et al. 1981). Timber harvesting costs have remained of continued interest to loggers (Carter et al. 1994). Mississippi State University has produced a logging cost index for several years. The impact of technical change on the forest products sector has received enormous attention by economists over the past three decades. The earliest studies were primarily based on a simple measure of output and only capital and labor were considered as productive factors. Then flexible function forms with more complex representations of the production technology were applied. Examples include considering raw materials (Stier and Bengston 1992) and constant elasticity of substitution production function with two factors of labor and capital (Monroney 1968; Greber and White 1982; Stier 1982, 1983). Those studies found that technical change would promote production using capital to substitute labor.

Using Maximum Likelihood Estimation techniques for non-homothetic translog cost functions with two variable inputs, labor and capital, Smith and Munn (1998) found that substitution possibilities of these two basic inputs were limited. Other studies used the translog functional form (Stier 1980, Cain and Paterson 1981, Jorgersen and Mumeni 1981, Sherif 1983, Rao and Preston 1984, De Borger and Buongiorno 1985, Martinello 1985). Merrifield and Singleton (1986), Meil et al. (1988), and Bernstein (1989) combined short-run cost minimizing and profit maximization behaviors with the dynamics of firm adjustment over time. For technical efficiency valuation, Carter et al. (1994) and Carter and Cubbage (1995) claimed that average harvesting costs of the U.S. pulpwood harvesting industry had declined significantly during the period of 1979 to 1987 with production shifts from shortwood to mechanized longwood harvesting systems since the latter systems are more efficient.

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Acknowledging the importance of capital and labor as two basic factors in the efficiency of the harvesting sector, LeBel and Stuart (1998) pointed out that a better understanding of capacity utilization, contractor's zeal, procurement organization's philosophy, and government regulation would be important for improving the efficiency and performance of individual contractors and the wood supply system. After reviewing the literature on productivity and efficiency studies of the Canadian wood industry, Salehirad and Sowlati (2006) also suggested that further research in this area should incorporate factors and aspects specific to the wood industry including desirable and undesirable outputs of the production process into the models.

The objectives of this study were to test the effects of firm scale, machine age, and products on productivity of logging firms in Alabama, and the substitution elasticity between labor and machine cost in the production function. This study will contribute to the existing literature regarding the effect of firm size, machine age, and products on harvesting productivity. The results will provide useful information to loggers about the status of logging firms at the state level and future consideration of updating equipment and adjusting firm scale and labor forces.

Data

A survey was conducted in December 2000 with 200 questionnaires mailed to Professional Logging Manager (PLM) trained Alabama loggers. The initial mailing was followed with a postcard on December 22, 2000. The loggers selected were firm owners, co-owners, or corporate officers who had completed PLM training. Names were selected from that list of just over 900 loggers. Twenty loggers were randomly chosen from each of the 10 Alabama Loggers Council Districts. If more than one person from the same address was selected, only the first person's name (alphabetically) was included. It is possible that surveys were sent to co-owners or corporate officers at the same firm. Excluding multiple names from the same firm would have been problematic because in some cases a firm name was not included in the database and similar firm names may or may not have been the same firm.

The questions addressed in the survey included the length of business operation, the type of contractors, the labor forces and employment benefits provided, the primary forms of delivery (tree-length, log length, or shortwood), the primary products, the status of equipment, and the history of the operation, especially the changes in expenses and production from 1995 to 2000. Eighty-two responses were received out of the 193 surveys sent to valid addresses. Of those respondents, 67 were currently in the logging or log hauling business. An additional six had left the logging business in the last 3.5 years, and five out of those six left in the past 2 years. Half of the respondents' firms were started before 1983, with an average year of 1981. The primary work of most of the firms was cut and haul contractors on company- or dealer-owned stumpage (34%), followed by cut and haul contractors on company lands (31%), and owners of their own stumpage (25%). Several firms reported working in more than one category. Those firms moved wood primarily in tree-length form (94%) followed by log length (15%). Several reported multiple forms of delivery.

Methodology

To test the potential variations among firm groups in terms of firm size, machine age, and products, non-parametric statistical tests of Kruskal-Wallis, median one-way analysis, Van der Waerden one-way analysis, and Savage one-way analysis were used since they do not require normality in data distribution. Firms employing less than six laborers were categorized as small, more than eight laborers were large, between six and eight were medium. For grouping by machine age, a firm was categorized as 'new' if more than 30 percent of its machines were less than 1 year old, 'normal' if less than 30 percent of its machines were new but more than 50 percent of its machines were less than 6 years old, and 'old' if it utilized mostly old machines with less than 50 percent of its machines less than 6 years old. For product grouping, the first group consisted of firms that had harvested hardwood sawtimber; the second group consisted of firms that harvested pulpwood without pine sawtimber; and the third group consisted of firms that harvested pine sawtimber.

To estimate the substitution coefficients between capital and labor, a linear regression was conducted for a production function of Alabamian logging firms. Based on the Cobb-Douglas function and a simplification in interpretation of substitution coefficients of labor and machine costs through substitution elasticity measure, empirical models of Alabamian logging production were regressed using the following form:

$$\mathrm{Ln(Loads)} = a_0 + a_1\mathrm{Ln}(L_i) + a_2\mathrm{Ln}(K_i) + \varepsilon_i \qquad [1]$$

where:

i = logging firm,
Loads = production (the number of truck loads harvested per week),
L = laborers (the number of employees multiplied by the working days per week), and
K = machine cost (depreciated cost of machines used by the firms).

The summation of a_1 and a_2 measured return to scale or the function coefficient (Beattie and Taylor 1985). Restriction of $a_1 + a_2 = 1$ was applied to separate models (named with affix b in the model name) to test whether Alabama logging production has constant return to scale following the assumption of the Cobb-Douglas function. Two versions of the function were regressed with two kinds of machine cost, with and without trucks. In this study, machine expenses are depreciated using the Modified Asset Cost Recovery System (MACRS) method and a salvage value of 20 percent of the purchase price.

From the coefficients of labor days and machine cost in regressed models, elasticity of substitution between labor and machine cost was also calculated. Elasticity of substitution measures the percentage change in factor proportions due to a change in the marginal rate of technical substitution. In other words, for the production function, Y = f (K,L), the elasticity of substitution between capital and labor is given by:

$$\begin{aligned}\sigma &= \mathrm{dln}\,(L/K)/\mathrm{dln}\,(f_K/f_L) \\ &= [d(L/K)/d(f_K/f_L)] * [f_K/f_L)/(L/K)]\end{aligned} \qquad [2]$$

In production functions with firm groups of size, machine age, and products, the effects of the variables on production of logging firms in Alabama in 2000 were examined. The model specification test with SPEC option in SAS programming confirmed homoskedasticity of all of the models regressed. From the logarithm form of production functions regressed, the substitution elasticity between labor and machine cost was calculated by the ratio a_2/a_1. The long run elasticities of production in respect to labor and machine cost were also calculated from respective short-run elasticities estimated from the production function.

Results

Productivity among different groups

Table 1 shows the changes in production of firms in 1995, 1997, and 2000 as well as labor and capital productivity in 2000. Labor productivity and capital productivity were simply measured by the number of truck loads per labor unit, and per thousand dollar of machine cost, respectively.

Table 2 presents the results of the non-parametric tests among firm sizes. It is not surprising that additional employees would produce more loads per week, but no significant difference between firm sizes was found in either labor or machine cost productivity.

Table 3 shows productivity among machine groups. Very much as expected, the firms using new machines are likely to have higher weekly production, and higher labor productivity. No significant difference in machine cost productivity, however, was found among different machine groups. Only Savage one-way analysis found a difference in machine (without truck) cost efficiency at a 90 percent significance level.

Table 4 shows productivity by different products. The results from the non-parametric tests generally do not indicate a significant difference in production in 1995 and 1997 between the firms. A difference was found at the 90 percent significance level in 2000. The firms harvesting hardwood sawtimber had lower production relative to others. A significant difference in labor and machine cost productivity could not be found.

Table 1. — Production and productivity of logging firms in Alabama.

	Unit	N	Mean	SD[a]	Min	Max
Production in 2000	load/week	60	37.77	24.89	5	110
Production in 1997	load/week	59	43.37	29.42	7	138
Production in 1995	load/week	56	40.34	28.21	5	150
Labor productivity in 2000	weekly load/employment	60	6.02	2.69	0.95	15.83
Capital productivity in 2000	weekly load/$1,000	60	0.15	0.08	0.03	0.65

[a] SD = standard deviation.

Table 2. — Production and productivity by different logging firm sizes in Alabama.[a]

		Production (load/week)			Productivity in 2000		
Firm size	N	1995	1997	2000	Labor	Machine (with truck)	Machine (without truck)
Small (1 to 5)	33	25.60 (17.37)	26.13 (15.02)	24.71 (14.70)	6.1691 (2.5636)	0.1462 (0.0548)	0.1647 (0.0682)
Medium (6 to 8)	12	55.17 (34.30)	60.08 (25.80)	44.33 (21.97)	6.6925 (3.6030)	0.1903 (0.1480)	0.2419 (0.1667)
Large (> 8)	15	59.21 (24.71)	66.80 (32.50)	61.23 (26.63)	5.1350 (1.8726)	0.1362 (0.0577)	0.1689 (0.0682)
Kruskal Wallis test	χ^2	21.16	24.89	23.53	4.50	2.00	4.50
	p-value	< 0.0001	< 0.0000	< 0.0001	0.1055	0.3684	0.1055
Savage one-way analysis	χ^2	16.18	20.86	22.24	4.20	1.19	4.20
	p-value	0.00	< 0.0001	< 0.0001	0.1222	0.5517	0.1222

[a] Values in parentheses are standard deviations of the means.

Table 3. — Production and productivity by machine of logging firms in Alabama.[a]

		Production (load/week)			Productivity in 2000		
Machine group	N	1995	1997	2000	Labor	Machine (with truck)	Machine (without truck)
New (≥ 30 % in 0 to 1 year old)	18	51.17 (24.46)	56.14 (26.66)	57.08 (25.37)	7.8170 (3.5393)	0.1363 (0.0301)	0.1608 (0.0390)
Normal (< 30% new, > 50% in lifetime)	30	43.13 (30.29)	45.27 (30.53)	34.95 (20.53)	5.2154 (1.8820)	0.1704 (0.1073)	0.2073 (0.1257)
Old (≤ 50% in lifetime)	12	15.77 (8.93)	17.32 (7.68)	15.83 (7.78)	5.3125 (1.3781)	0.1321 (0.0584)	0.1464 (0.0660)
Kruskal-Wallis test	χ^2	17.06	18.39	24.65	8.88	2.31	3.79
	p-value	0.0002	0.0001	< 0.0001	0.0118	0.3146	0.1502
Savage one-way analysis	χ^2	9.58	9.86	17.67	12.64	3.99	5.81
	p-value	0.0083	0.0072	0.0001	0.0018	0.1361	0.0549

[a] Values in parentheses are standard deviations of the means.

Production function

Based on Equation [**1**], production functions were regressed to examine the effects of labor-day (L) and machine cost (K) on weekly logging production in Alabama. Considering that trucks are not a limiting factor of the logging industry because logging firms can rent trucks for transportation, two kinds of machine cost are considered: including truck value (K1) and excluding truck value (K2). Ordered categorical variables of firm size (1, 2, and 3 for small, medium, and large firms, respectively) and machines (1, 2, and 3 for new, normal, and old machine groups, respectively) are included in the function as controlling variables. Dummy variable for firm groups with different products are also included to explore possible effects of different harvested products.

Table 5 presents the regression results for logging production in Alabama. All of the estimated equations are relevant with sign-expected and significant coefficients of labor and machine cost, either with or without trucks. The results do not indicate that firm size in Alabama has a significant effect on its production. In the model with machine cost excluding trucks, the significant coefficient of machine group suggests that the firms with older machines achieved lower production than the firms using newer machines, but statistically it was not highly significant. The insignificant coefficients of product group 2 and product group 3 show that the difference in products does not have a significant effect on production.

The coefficients of machine costs and labor days both are regressed to be consistent with diminishing marginal returns to factor usage as they both are positive and less than 1. The summation of both, without the unitary restriction, is also less than 1. The Alabama logging industry has been shown to have decreasing returns to scale in 2000, which means it was less efficient for larger firms. With restriction of the unitary summation, labor appears to give more contribution to the Alabama logging production in 2000 because its coefficients are higher than 0.5 while the coefficients of machine costs are less than 0.5 in both equations with or without trucks (**Table 5**). The t-test, however, fails to reject that the coefficients in all of the production functions in 2000 are different than 0.5. The assumption of a constant return to scale in the Alabama logging industry thus cannot be rejected when the statistical test fails to reject the unitary function coefficients. With the test, labor and machine costs are likely to give equal influence on the firms' production as their coefficients are estimated around 0.5. When either weekly labor days or machine expenses increase by 10 percent, given other variables, the weekly loads increased by 5 percent. The results also show that the substitution elasticity between labor days and machine cost is unitary. That means when the

Table 4. — Production and productivity by different products of logging firms in Alabama.[a]

Product group	N	Production (load/week) 1995	1997	2000	Productivity in 2000: Labor	Machine (with truck)	Machine (without truck)
I (hardwood sawtimber)	11	36.35 (32.07)	35.50 (33.01)	25.32 (16.50)	4.8851 (1.9848)	0.1863 (0.1739)	0.2185 (0.2010)
II (pulp without pine sawtimber)	19	46.11 (25.10)	46.68 (31.83)	44.95 (22.92)	6.5948 (2.1818)	0.1454 (0.0377)	0.1677 (0.0502)
III (pine sawtimber)	30	38.05 (24.52)	43.90 (27.11)	37.78 (27.35)	6.0627 (3.0768)	0.1446 (0.0465)	0.1761 (0.0604)
Kruskal-Wallis test	χ^2	3.37	2.48	5.32	3.77	0.00	0.33
	p-value	0.1853	0.2893	0.07	0.1515	0.9997	0.8484
Van der Waerden one-way analysis	χ^2	2.94	2.37	5.27	3.90	0.01	0.25
	p-value	0.2304	0.3055	0.0719	0.1425	0.9952	0.884

[a] Values in parentheses are standard deviations of the means.

Table 5. — Production function of the logging firms in Alabama (dependent variable: production (load/week) in 2000 in logarithms).[a]

	Model 1a Estimate	Model 1a t value	Model 1b Estimate	Model 1b t value	Model 2a Estimate	Model 2a t value	Model 2b Estimate	Model 2b t value
Intercept	**−3.42148**	−2.31	**−3.97471**	−4.18	**−3.2276**	−2.02	**−3.70157**	−3.83
Firm size	−0.06528	−0.63	−0.10486	−1.61	−0.04817	−0.45	−0.07842	−1.15
Machine group	−0.15943	−1.65	−0.13355	−1.66	−0.15973	−1.58	***−0.13819***	−1.68
Product group 2	0.19105	1.22	0.18066	1.17	0.18435	1.14	0.17424	1.1
Product group 3	0.10207	0.72	0.09771	0.69	0.12534	0.86	0.12256	0.85
Ln (L)	**0.45317**	3.06	**0.50748**	5.21	**0.49208**	3.26	**0.53424**	5.38
Ln (K1)	**0.45999**	3.88	**0.49252**	5.05	–	–	–	–
Ln (K2)	–	–	–	–	**0.43676**	3.45	**0.46576**	4.69
Restricts	–	–	−0.416	0.6269	–	–	−0.31078	0.7103
Adjusted R^2	0.6935	–	0.6979	–	0.6786	–	0.6837	–
Substitution elasticity L/K	1.01505	–	0.970521	–	0.887579	–	0.871818	–
Function coefficient	0.91	–	1	–	0.93	–	1	–

[a] The values in **bold** refer to statistical significance at a 99% level.

machine cost increases by 1 percent, the working labor days decrease by 1 percent in 2000 production.

Conclusion

Methodologically Kruskal Wallis test and Savage one-way analysis were applied because they are more appropriate for the data of non-normal distribution. In this study production function, products, firm size, and machine age were controlled. The results from this study indicated that firm size, machine age, and product in general do not influence labor and capital productivity with statistical significance. Even though large firms have more total production, both labor and machine cost productivity seems the same among the various firm sizes. The joint production function, however, showed decreasing return of scale in Alabama. This means that a 1 percent increase in labor and machine value will bring in less than 1 percent of increase in production, implying that it is not worth increasing the logging firms on average. The firms harvesting hardwood sawtimber appear to have achieved a lower production in the year 2000 relative to others but the statistical tests failed to find a significant difference in labor and machine productivities among the firms with different products. Coefficients estimated in production functions permit us to derive unitary substitution elasticity between labor and machine cost, indicating labor-day and machine cost give equal influence to production of loggers in Alabama. Considering the limitation of data collection, interpretation of these results should be cautious. In addition, only labor and machine costs were considered. Other aspects of costs, firms organization, skills of loggers, amount of training, and contracting are important in logging costs and should be given attention.

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