LABOR PRODUCTIVITY IN SAWMILLS OF THE EASTERN AND SOUTHEASTERN UNITED STATES

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ABSTRACT

A survey of sawmills in the eastern and southeastern regions of the United States was conducted. Responding mills produced an average of 12,661 MBf in calendar year 1984 and 76 percent reported annual sales of less than $10 million. The majority of sawmills utilized circular saw headrigs and the most common type of computer controlled/assisted equipment was a log carriage. Softwood sawmills were found to have significantly higher labor productivity than hardwood sawmills. Regression analysis indicated that labor productivity economies of scale exist within the softwood segment of the industry. Labor productivity increased with mill size but at a decreasing rate. No strong evidence of labor productivity economies of scale in the hardwood industry segment was found.

Keywords: Productivity, sawmills, production.

INTRODUCTION

The lumber industry has changed significantly in recent times. Between 1977 and 1982, for example, the number of sawmills and planing mills (Standard Industrial Classification 2421) in the U.S. decreased by 1,228 establishments or approximately 16% (USDC-BOC 1985). During the same period, the industry experienced a 25% (43,300 employee) drop in employment (USDC-BOC 1985). In spite of these decreases, excess production capacity has been a problem and has contributed to relatively low lumber prices (Tetrick 1985).

A portion of these reductions is, undoubtedly, due to the failure of marginal mills. Another portion, however, may reflect planned moves by firms in the industry to improve the productivity of their operations through automation and the adoption of new processing technologies. This trend toward increased substitution of capital (equipment) for labor, in order to enhance labor productivity, has been suggested by several authors (Greber and White 1982; Kaiser and Guttenberg 1970; Kaiser 1974; Moslemi 1986). The results of improved labor pro-

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ductivity can be seen in the production figures. United States softwood lumber production in 1984 was equivalent to 1977 production at approximately 31 billion board feet (Anonymous 1986). Employment in softwood sawmills, however, was 25% lower in 1984 when compared to 1977 (Bayless 1986).

Investments in new technologies that increase productivity may be essential for the survival of many firms (Tillman 1985). However, high capital requirements may limit the adoption of these technologies, especially by smaller sawmills. Recent poor market conditions have depleted retained earnings and outside sources of funding may be difficult for these firms to obtain (Bayless 1986). In addition, productivity improving technologies may be available only on a scale inappropriate for smaller firms (Buse and Bromley 1975).

Because of the apparent changes in labor productivity in recent times and the potential barriers to increased labor productivity facing smaller sawmills, the research presented in this paper was undertaken. This paper represents a portion of a larger study which also investigated capital budgeting methods and equipment needs within the industry (Bush et al. 1987; Bush and Sinclair 1987).

The goal of this portion of the study was to provide quantitative information concerning sawmill labor productivity in the eastern and southeastern United States. Overall productivity levels were investigated, as were labor productivity differences associated with product type, equipment ownership, and mill size.

DATA COLLECTION

Sample frame

The study encompassed the majority of the eastern hardwood and southern pine regions and included mills in 25 states (Fig. 1). Within this study area, all 1,560 sawmills listed in the *Directory of the Forest Products Industry* (Miller Freeman 1982)[2] were included in data collection procedures.

Survey methods

Primary data were collected using mail survey techniques. The questionnaire used in the survey was first pretested and then mailed to all sawmills in the sample during October 1985. Follow-up mailings were used at approximately two-week intervals in order to enhance survey response.

Usable questionnaires were returned by 491 sawmills prior to the initiation of data analysis. The overall response rate (adjusted for undeliverable questionnaires as described by Dillman 1978) was 37%. This rate is comparable to the response rates experienced in similar mail survey based studies of forest products firms (Bowyer et al. 1986; Govett and Sinclair 1984; Sinclair and Govett 1983) and was sufficient to provide statistically significant results.

As is typical of anonymous surveys, response bias was a question and could not be addressed directly (i.e., by contacting non-respondents) since the identity of non-responding sawmills was unknown. However, date-of-response dependent trends within the data could be investigated. Trends in answers over time could indicate that early respondents differed systematically from late respondents and

[2] The 1982 *Directory of the Forest Products Industry* was the most recent edition available at the time the survey was conducted.

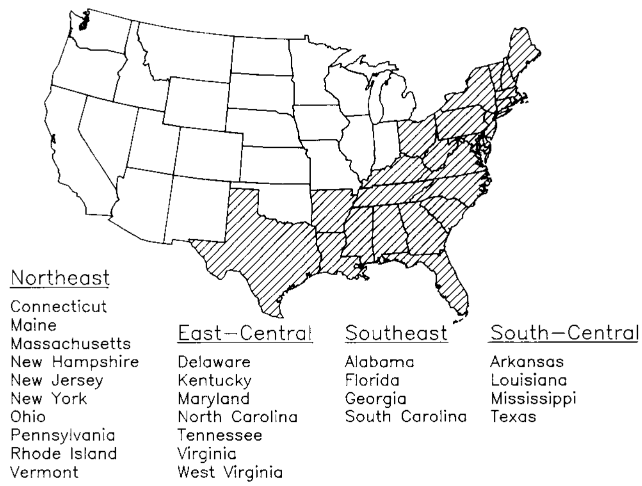

FIG. 1. Study area and state grouping used in analyses.

the groups should be analyzed separately. Such trends, if extrapolated, would also suggest that non-respondents differed from respondents.

A non-parametric technique, the Chi-square test, was used to test for date-of-response dependent relationships.[3] The results indicated that there was no systematic variation in sawmill size, location, or type over time. Consequently, responses were not separated by date-of-response in further analyses and the hypothesis of insignificant response bias was retained.

RESPONDENTS

Survey response was well distributed geographically. Usable questionnaires were returned by sawmills in every state within the study area with the exception of Delaware. To facilitate analyses, responses were grouped into four geographic regions; Northeast, East-Central, Southeast, and South-Central (Fig. 1).

The questionnaire was directed toward upper-management personnel to help ensure that accurate data were provided. In general, this effort was successful. Respondents included company presidents (28%), managers (25%), vice-presidents (14%), and owners (16%).

Responding sawmills reported production levels that averaged to 12,661 MBf (median of 5,000 MBf) in calendar year 1984. The majority (55%) of the sawmills reported annual sales of $1 to $9.9 million. Twenty-one percent reported annual sales of less than $1 million, and 24% reported annual sales of $10 million or more.

[3] The Chi-square test of independence (Norusis 1983) was used to test the null hypothesis that month of response and sawmill size (based on annual sales), sawmill location (by region), or sawmill type (softwood, mixed, or hardwood) were independent. A separate test was conducted for each characteristic and the decision rule used was to reject the null hypothesis if the level of significance (P) was less than 0.05. In no case could the null hypothesis be rejected. As reported in this paper, P-values represent the probability of obtaining the observed results assuming the null hypothesis is true. Unless otherwise noted, all statistical tests rejected the null hypothesis if $P < 0.05$.

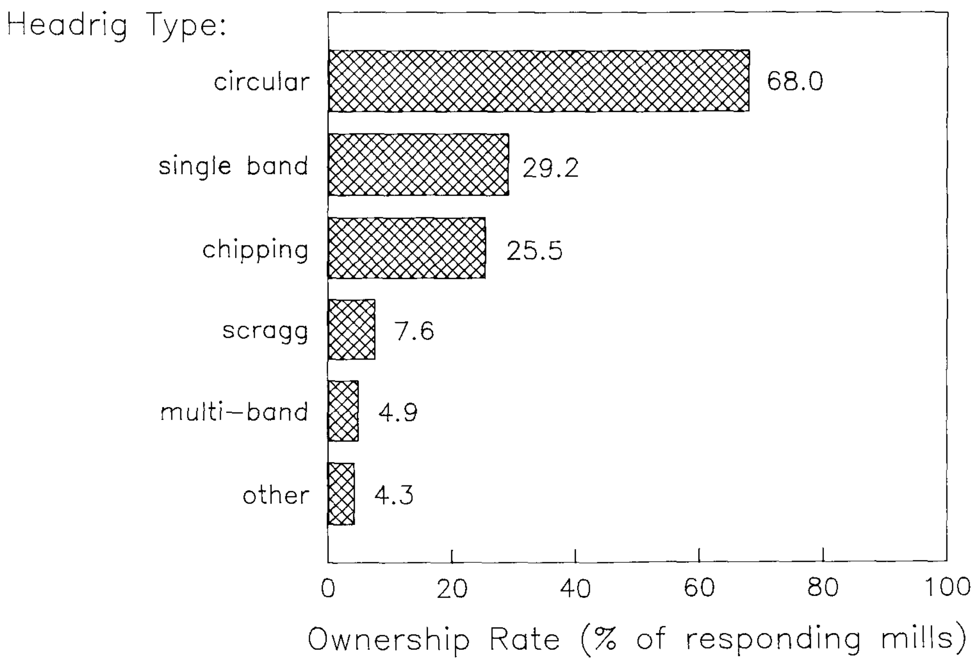

FIG. 2. Overall ownership rates of selected headrig types.

Production equipment

A variety of headrig types were owned by the responding sawmills (Fig. 2). Overall, circular saw headrigs were most common. This trend was especially evident in the less than $1 million annual sales category, where circular saw headrigs were owned by 88% of the sawmills. In contrast, multiple-band and single-band saw headrigs were most often owned by sawmills with annual sales of $10 million or more and were uncommon among smaller mills. Many sawmills reported owning more than one type of headrig, as indicated by Fig. 2.

The application of computers and microprocessors to the process of lumber manufacturing can result in increases in efficiency and productivity (Williston 1985; Haygreen and Bowyer 1982). However, computer controlled/assisted equipment has not been widely adopted by sawmills in this study, only 94 of the 491 responding sawmills reported owning such equipment. Within this group the most commonly owned types of computer controlled/assisted equipment were log carriages (19% of respondents), lumber sorters (12%), trimmers (11%), log decks (6%), and resaws (3%). As with the more sophisticated types of headrigs, computer controlled/assisted equipment was most often owned by mills in the larger annual sales categories.

Product mix

Information concerning the mix of products produced was provided by 479 of the 491 responding sawmills. Firms producing only softwood lumber products numbered 127 or 27% of the 479 mills. A total of 136 hardwood sawmills was identified (28%) and all but three of these mills produced 100% hardwood lumber products. The remaining three mills produced small amounts (less than 10% of total board feet production) of softwood products.

Approximately 45% of the sawmills (216 firms) produced both hardwood and softwood products. Production mixes ranged up to 90% hardwood products, with a median mix of 75% hardwood, 25% softwood. In addition, 96 of these mixed product sawmills were integrated into the production of pallets or bins.

RESULTS

Labor productivity

Labor productivity, as used in this study, is defined as annual production per production employee (MBf/production employee/year). In order to maintain relevance to the lumber industry and to reduce the number of confounding factors, sawmills that also produced pallets or bins were excluded from all analyses of productivity. In addition, only production employee numbers were used in calculating labor productivity. While certain types of non-production employees may influence productivity, other types, such as sales staff, may have little influence. In order to avoid this potentially confounding factor, labor productivity was calculated using only production worker numbers.

The exclusion of sawmills that produced pallets or bins left 395 firms in the sample. These sawmills produced an average of 14,364 MBf (median of 6,000 MBf) in calendar year 1984. Employment averaged 65 full-time production employees per mill. Labor productivity was computed for each sawmill and the average of these individual productivity levels was 295 MBf/production employee/year (median of 212 MBf/production employee/year).

Influence of product mix on labor productivity

As described previously in this paper, sawmills were categorized as hardwood, softwood, or mixed product. These three categories were compared on the basis of labor productivity, and softwood mills were found to have the highest mean and median productivity (Table 1). In addition, variability within the categories was found to be high.

The significance of apparent labor productivity differences was tested using the Kruskal-Wallis one-way analysis of variance.[4] The results of the test indicated that significant differences did exist and these differences were further examined using a Kruskal-Wallis based multiple comparison technique (Gibbons 1976). Softwood sawmills were found to differ from both hardwood and mixed product mills in terms of labor productivity. However, hardwood and mixed product mills were not found to differ. This result could be due, in part, to a more homogeneous raw material and limited product mix typical of softwood mills. The finding also reinforced the belief that differences between softwood and hardwood sawmills were of most interest, and subsequent analyses concentrated on comparing these types of mills.

[4] The non-parametric Kruskal-Wallis one-way analysis of variance was used to test the hypothesis that the three samples (hardwood, softwood, and mixed product sawmills) were from populations having identical labor productivity distributions. This hypothesis was rejected ($P < 0.01$, Chi-square = 32.78). Additional information concerning this test is provided by Norusis (1983) and Watson and McGaw (1980).

TABLE 1. *Sawmill labor productivity by type.*

Sawmill[1] type	Responses[2]		Production employees	Production (MBf/yr)	Productivity (MBf/emp./yr)[3]
Hardwood	136	Mean	45.1	6,129.5	297.9
		Median	23.5	3,971.0	175.0
		Std. Dev.	69.2	6,878.2	1,043.9
Softwood	127	Mean	96.6	27,604.2	321.8
		Median	65.0	15,000.0	244.7
		Std. Dev.	126.2	31,210.6	287.0
Mixed product	73	Mean	40.4	5,849.3	244.0
		Median	19.0	3,500.0	200.0
		Std. Dev.	85.8	7,812.3	231.8

[1] All softwood mills produced softwood lumber products exclusively. All but three of the hardwood mills produced only hardwood products and the remaining three produced less than 10 percent non-hardwood products. Mixed Product mills produce both hardwood and softwood products: neither one making up 90 percent or more of the total.

[2] Does not include sawmills that also produce pallets and/or bins or 59 mills that provided incomplete information.

[3] Mean and median productivity figures are based on individual sawmill productivity levels. Overall productivity levels (total production divided by total number of production employees) were as follows: Hardwood sawmills, 135.9 MBf/emp./year; Softwood sawmills, 285.8 MBf/emp./year; Mixed Product sawmills, 144.8 MBf/emp./year.

Influence of location on labor productivity

Labor productivity was computed for both hardwood and softwood sawmills in each of the four study regions. Mean and median values varied and Kruskal-Wallis one-way analyses of variance were used to determine the significance of labor productivity differences between regions. The results of the tests indicated that, for both categories of mills, the regions did not differ significantly in terms of labor productivity ($P = 0.17$ and 0.25 for hardwood and softwood mills, respectively).[5]

Influence of production equipment on labor productivity

As stated previously, the majority (68%) of the sawmills in this study utilized circular saw headrigs. A majority (57%) of the mills also utilized more than one type of headrig. Labor productivity differences based on headrig type were examined in two ways; first, by comparing mills that owned circular saw headrigs (regardless of other types of headrigs they might own) to mills that did not own circular saw headrigs and, second, by investigating labor productivity differences between mills owning only one type of headrig.

The labor productivity of hardwood sawmills that owned circular saw headrigs was compared to the productivity of hardwood mills that did not own this type of headrig using the Mann-Whitney test.[6] The results indicated no significant differences in labor productivity.

Only two types of headrigs, circular saw and single-band saw, were the sole type owned by a sufficient number of hardwood mills to warrant comparison. Sawmills owning only one of these two types of headrigs were compared on the

[5] See Note 2.

[6] The Mann-Whitney test is similar to the Kruskal-Wallis one-way analysis of variance but more appropriate for the two sample case (Gibbons 1976). The hypothesis that the two samples (circular saw owners and non-owners) were from populations having identical labor productivity distributions was retained ($P = 0.74$).

basis of labor productivity, again using the Mann-Whitney test. No significant difference between the two groups was found ($P = 0.41$).

Unlike hardwood sawmills, a Mann-Whitney test indicated that softwood sawmills owning circular saw headrigs did differ from softwood mills not owning circular saw headrigs ($P = 0.02$). Mills owning circular saw headrigs exhibited generally lower labor productivity.

Labor productivity in softwood sawmills owning only one of three types of headrigs (circular saw, single-band saw, or chipping) was compared using the Kruskal-Wallis one-way analysis of variance. No significant difference between the groups could be shown ($P = 0.06$). However, because of the low P-value, a multiple comparison using a $P < 0.10$ decision rule was computed. At this level, sawmills owning only chipping headrigs and those owning only circular headrigs could be shown to differ. Sawmills owning chipping headrigs had mean and median labor productivity of 577.5 and 392.2 MBf/production employee/year, respectively. The mean and median productivity for circular saw owners was 209.9 and 204.2 MBf/production employee/year, respectively.

It was hypothesized that sawmills owning certain types of computer controlled/assisted equipment would be more productive than mills owning non-computerized versions. The data for hardwood sawmills, however, did not support this hypothesis. Separate Mann-Whitney tests were conducted for several types of equipment (log carriages, resaws, lumber sorters, log decks, and trimmers), and no significant differences in labor productivity could be found between firms owning computerized and non-computerized versions.

In softwood sawmills, the results were mixed. Softwood sawmills owning computer controlled/assisted resaws, log decks, or trimmers could not be shown to differ, in terms of productivity, from those mills owning non-computerized versions of the equipment. However, sawmills owning computer controlled/assisted log carriages or lumber sorters exhibited significantly higher levels of productivity than sawmills owning non-computerized versions.

Economies of scale

Internal (within the firm) economies of scale result from technical efficiencies in the production process. These efficiencies originate, primarily, from the division and specialization of labor and the indivisibility of inputs (Buse and Bromley 1975). This study considered only the labor portion of internal scale economies.

The possibility of labor productivity economies of scale was investigated using regression analysis techniques. Because of the differences previously shown between hardwood and softwood sawmills, separate regressions were developed for each mill type. Annual production in board feet was used as a measure of mill size and as the independent variable. Annual production per production employee was used as a measure of labor cost and as the dependent variable. This resulted in an arrangement similar to that commonly used to illustrate economies of scale with two exceptions; only the labor portion of the cost per unit of output was represented (excluding raw material, equipment, land and other non-labor costs) and high values of labor productivity represented low rather than high cost per unit.

Plots of the data for softwood sawmills suggested that a relationship between mill size and labor productivity existed and was of the general power function form:

$$Y = \alpha X \beta \tag{1}$$

where:

Y = Labor productivity in board feet/production employee/year
X = Annual production in board feet

In addition to being suggested by the data plots, this model is appealing on theoretical grounds. Returns to increasing scale are usually thought to be large at small relative scales but decrease as the scale of an operation is increased (Buse and Bromley 1975). The power function form has this characteristic. Numerous other models were fitted to the data, but none were found that provided a better fit based on the percentage of variation in labor productivity explained by mill size.

The linearized form of the power function model was used to estimate the values of α and β for softwood sawmills. The regression resulted in the equation:

$$\log Y = 1.15 + 0.59 \log X \tag{2}$$

$$(R^2 = 0.61;\ F \text{ for regression} = 187.65;\ df = 1{,}120;\ P < 0.01)$$

where X and Y were as described above. The original model was then estimated as:

$$Y = 14.13X^{0.59} \tag{3}$$

Assumptions concerning the nature of the regression residual values were checked and found to be tenable.

While confounding factors clearly exist, this result suggests that there are economies of scale associated with labor productivity in the softwood segment of the industry. Also suggested is that, over the range of mill sizes studied (up to approximately 70,000 MBf/year), labor productivity increases with scale (economies rather than diseconomies) but the increment in productivity per unit increase in scale decreases with increasing mill size. The relationship is illustrated in Fig. 3.

No strong evidence could be found for economies of scale associated with labor productivity in hardwood sawmills. Data plots did not suggest a significant relationship and, while regressions using the linearized power function model were statistically significant, very little of the variation in labor productivity could be explained by mill size.

SUMMARY AND DISCUSSION

The sawmill industry in the eastern and southeastern United States is dominated (numerically) by relatively small mills utilizing circular saw headrigs and non-computer controlled/assisted production equipment. In hardwood sawmills, this apparent lack of modernization may not be significantly affecting labor productivity since ownership of computer controlled/assisted equipment or more sophisticated types of headrigs was not found to be associated with higher levels of labor productivity. However, it should be noted that this finding does not preclude

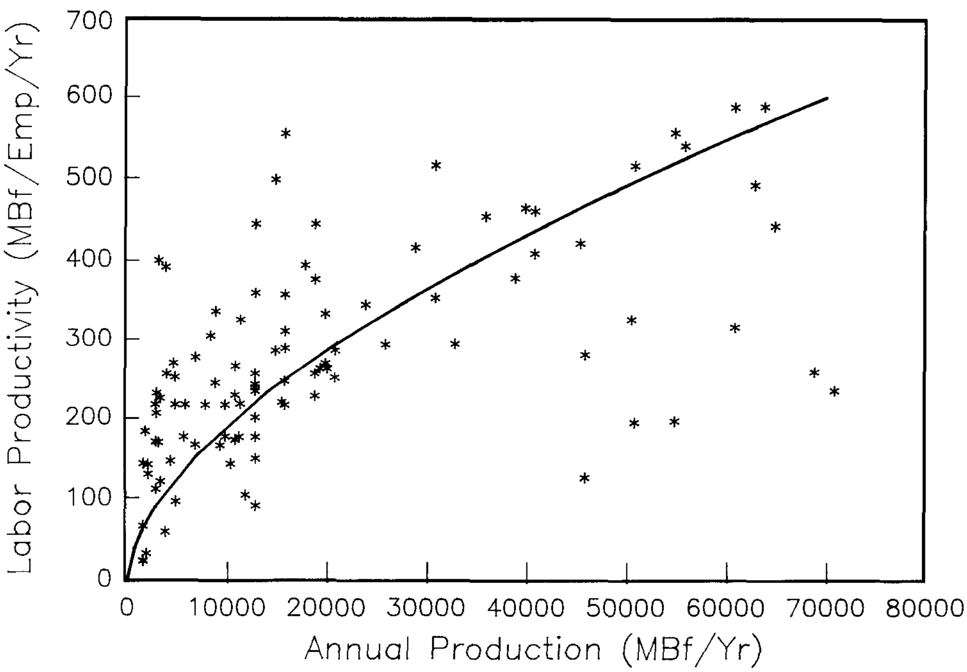

FIG. 3. Observed softwood sawmill labor productivity and regression line: $Y = 14.13X^{0.59}$.

the existence of benefits not directly related to productivity such as enhanced product quality.

In softwood sawmills, where certain types of equipment were found to be associated with higher levels of labor productivity, modernization through the acquisition of these equipment types may enhance the firm's competitiveness. Such modernization may be hampered by a lack of retained earnings or suitable outside sources of capital to finance investments (Bayless 1986; Bush et al. 1987).

Labor productivity in hardwood sawmills was not found to be strongly associated with mill scale. Labor productivity in softwood sawmills, however, was found to be positively associated with mill scale. It is hypothesized that this hardwood/softwood difference may be the result of a wider variation in product types and, subsequently, labor requirements in the hardwood segment. The latter finding implies that economies of scale in labor productivity exist in the softwood segment of the industry and has implications to the business strategies followed by smaller softwood mills.

Since the second major type of production efficiency, indivisibility of inputs, tends to favor large mills, it can be theorized that overall internal economies of scale also exist in the softwood industry segment. Unless counteracting external (outside of the firm) economies exist, this implies that small mills face an inherent cost disadvantage when compared to large mills. Consequently, small softwood sawmills may find business strategies based on low cost production of commodity products difficult to maintain during periods of weak demand. It is likely that this effect has contributed to the reduction in the number of mills previously noted in this paper. Small softwood mills might find strategies involving the production of less price sensitive specialty products or strategies that focus on a particular market segment to be more profitable.

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