Productivity, Cost, and Technical Efficiency Evaluation of Southeastern U.S. Logging Contractors

by

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Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Forestry

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May 19, 1998

Blacksburg, Virginia

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(ABSTRACT)

A group of 35 loggers located across the southeastern United States provided 192 logger years of productivity and cost information. Information, including logger demographics, business, and operational data, was also collected through an interview process with the participants.

Indicators of the overall economic health of the southeastern U.S. logging industry was determined by measuring technical efficiency, and by analyzing the demographic, organizational, business, productivity and cost information with a variety of quality control tools. Data Envelopment Analysis, a non-parametric statistical tool, was used to measure the technical efficiency associated with each logger year.

Demographic information, including age, experience, and education, appeared to have only minimal impacts on contractor efficiency, indicating that business, operational, and environmental factors have greater influence on efficiency.

Groups of observations with low proportions of total cost relating to equipment and consumables tended to have the highest median efficiency scores. Observations with lower median efficiency tended to have higher proportions of their costs associated with

equipment and/or consumables. These trends indicate that efficiency, or operating in the area of least costs, is not necessarily in the best interest of the logging contractors or the wood supply system as a whole. These contractors are not in the process of building equity, which is important in order to maintain a productive supplier force.

There was an upward trend in yearly production and costs during the period. Production and cost levels generally increased from 1990 through 1995, before dropping off in 1996.

Yearly efficiency was cyclical, but appeared to be in a general state of decline for the period. The Wilcoxon signed rank test ruled that 1996 was statistically lower than the previous 6 years at the 90% confidence level. The efficiency decline was due in part to the inability of productivity increases to keep pace with inflation throughout the 1990's, influence of fixed costs, and the period of pulp an paper market oversupply in the mid 1990's.

The relationship between efficiency and profitability was examined using marginal cost and revenue analysis. Profits were not collected as part of this study, therefore an arbitrary rate of $12 per ton was assumed. These analyses served to point out the approximate scale size associated with maximum efficiency and revenue. Efficiency is an important prerequisite of profitability, but when green tons of wood is considered the output of the process, the point of maximum efficiency is not always where efficiency is maximized.

Acknowledgements

I am very appreciative of everyone who provided guidance and support for this project. My advisory committee was extremely helpful and understanding. I would like to send special thanks to Drs. Bill Stuart and Kostas Triantis. Their guidance was crucial to the completion of the project. I would also like to thank Dr. Luc LeBel whose examples and patient instruction helped me in every step of the process.

I would like to send thanks to the Industrial Forestry Research Cooperative at Virginia Tech for their support. The support of Westvaco, Inland Container, Union Camp, Bowater and International Paper is especially appreciated.

I would also like to thank each logging contractor and their families for their hospitality, their time, and energy. They provided the backbone for this project, which I will always be grateful for.

Last of all I want thank my family for their love and support, which gave me the needed endurance to reach my goal of obtaining a master’s degree.

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Chapter 1 INTRODUCTION

1.1 Background Information

Independent logging contractors provide an important service for the forest industry and society. They are highly capitalized business professionals who perform the activities that manifest the forestry profession to the public (Stuart, Lebel, Walter, and Grace 1996). Their actions benefit society and the forest industry by providing the raw material used to make forest products so necessary to modern society, by providing jobs to communities, by realizing financial return on timber investments, by accomplishing silvicultural objectives resulting in more productive forestland, and by salvaging damaged timber (Walbridge and Shaffer 1990).

Independent logging contractors operate in a challenging business environment. They are affected by increasing equipment prices, increasing fuel prices, extremely high workers' compensation insurance rates, the need to pay competitive wages, and the need to hire and keep quality employees (Keesee 1997). In the past, these challenges have been met by gains in productivity. The majority of the technology that generated these past gains in productivity is two or three decades old. Therefore, it can not be expected for logging contractors to maintain those efficiency gains forever (Stuart, Lebel, Walter, and Grace 1996). This inability to remain efficient could cause the southeastern U.S. logging force to be surpassed by competitors in other parts of the world, jeopardizing the economic and social benefits they provide.

Due to the complex operating conditions, adverse forces encountered by logging contractors and the importance of the service they provide, it is critical to monitor their performance. This measure of performance can then be used assess the economic health of logging contractors, and the industry as a whole. Knowledge of the economic health of loggers will in turn help point out areas of potential improvement in the wood supply system, in logging business management, and in the legal and regulatory environment. Improvements must be constantly made to ensure that the U.S. forest industry will remain competitive in an increasingly global environment.

1.2 Definition of Performance

A basic definition of performance is needed before proceeding. Performance, as defined by Webster's Ninth New Collegiate Dictionary, is the act of completing, or accomplishing a task. While this definition is adequate, performance can be defined further by dividing it into different levels, depending on how fast, effectively, or thoroughly the task is completed. Level of performance is very important to the management personnel of any organization, including independent logging firms. If a firm is not improving its level of performance, it will likely be surpassed by competition, or may be on its way out of business. Management must clearly understand the definition of performance in the process, and how to measure it, to improve the performance of the activity (Triantis 1990).

Technical efficiency was the primary criterion used to measure performance in this study. Technical efficiency measures how effectively the inputs of the forest harvesting process are transformed into outputs. This translates into a measure that can be used by management to identify factors and conditions positively or negatively affecting performance.

Technical efficiency is an effective criterion to measure performance, but business profitability must also be considered. It is important for logging contractors to operate as efficiently as possible, while still focusing on the ultimate goal of any business, profitability. Efficiency and profitability are not necessarily synonymous, when green tons of wood produced is considered the output of the process. Distinction between the two terms is important. Therefore, both criteria will be considered in measuring the performance of the participating contractors.

1.3 Forces Affecting the Performance of Logging Contractors

This study will also focus on the five forces, identified by Stuart and Grace (1997), which affect the efficiency of the wood supply system, by introducing variability. The five forces include technical, organizational, natural, administrative, and regulatory forces.

1.3.1 Technical Forces

These forces refer to the individual machine productivity, reliability, and interaction with the stand being harvested (Stuart and Grace 1997). A variety of factors at the stand level influence an individual machine's performance, including tree size, terrain, tree species, and soil types. All of these factors can be combated to some degree through machine selection, mobility, training, and flexibility.

1.3.2 Organizational Forces

Organizational forces are managerial issues, which refer to business management skills and philosophies of a contractor, the business's role in the wood supply system, and the abilities and initiative of the work force (Stuart and Grace 1997). An example of this factor is how the contractor manages the trucking side of his business, whether he does his own hauling, contracts all, or a portion of the hauling out. Other examples include the type of service provided by the logger, which could include clear-cutting, whole-tree chipping, or thinning. Equipment strategy used by loggers is also an example. Many loggers prefer to operate older, less reliable equipment to avoid debt, but in doing so productivity may be sacrificed. These organizational forces have the potential to affecting the efficiency of the business by impacting productivity and allocation of costs within the business.

1.3.3 Natural Forces

Natural forces are the result of the interaction of weather events and the stand or specific region of operation (Stuart and Grace 1997). Examples include extreme heat, cold, precipitation, spring break-up or mud season. These forces vary somewhat depending on the region of operation. In the north country spring breakup or mud season is a major factor. It is fairly predictable in both time and severity. Trucking and logging both are severely slowed, or shut down as a result. In the South, natural forces are not nearly as predictable in timing or severity. Winter rains may shut down operations down for several days or a week, by affecting forest roads and the in-woods operations. The topography and soil types of the tract being harvested play a role in the severity of the impact. There is often enough time between these storms for the soil to dry and normal operations to resume, but the time required can depend on temperature, wind, and cloud cover. Natural forces can be combated somewhat through machine selection, mobility, training and flexibility as well.

LeBel (1993), which studied capacity utilization for 22 independent logging contractors in the South, found that the most frequent causes of lost production were adverse weather, quotas, and moving. Of these three, LeBel cited rain as having the greatest impact on loggers. Above-average rainfall was experienced during the study, but stricter environmental restrictions were expected to have increased the effect of rain, by shutting the operations down sooner and longer, thus, possibly increasing the effect of natural forces on logging contractor efficiency.

1.3.4 Administrative Forces

Administrative forces refer to operational issues imposed by the wood supply system that affect production (Stuart and Grace 1997). Examples include species-product class specifications; mill inventory management through production quota, and design flaws at the mill wood yard. Other examples include the amount of in-woods processing required, and inadequate procurement force planning, which includes tract scheduling and assignment of tracts.

Other administrative forces are associated with Best Management Practices and water quality issues. The notoriety of this type of action has increased since the inception of the American Forest and Paper Association's (AF&PA), Sustainable Forestry Initiative (SFI)™.

The main objective of the Sustainable Forestry Initiative is to promote new standards of performance regarding the use of forest resources in the United States. Through SFI™ AF&PA members are trying to meet the present demand of forest resources without endangering the resources for future generations. This will be accomplished by applying guidelines that combine reforestation, managing, and harvesting trees, while conserving the soil, air and water quality (AF&PA 1995).

There are costs involved in being a player in SFI™, some of which are passed on to logging contractors. SFI™ puts added pressure on mill wood procurement representatives to avoid situations that could violate the principles. This caution results in increased costs. These costs include reduction in stumpage recovered due to streamside management zones, extra effort required in closing logging jobs, time lost to attend training sessions, and possible reduction in the number of working days

1.3.5 Regulatory Forces

Regulatory forces stem from government policies at all levels. Examples include wage and hour laws, OSHA regulations, highway regulations, DOT inspections (Stuart and Grace 1997). These laws ensure safe and proper treatment of the public but at times can have unintended effects on small businesses. Examples include losing loads because of DOT inspections, when haul distances are increased due to road or bridge weight limits, when slow unloading results in exceeding a driver's legal operating hours, or increased costs because of additional safety equipment.

1.4 Study Objectives

This research is focused on independent mechanized logging contractors operating in the southeastern United States and will apply the approaches and tools developed in each of the previous logging contractor production and cost studies performed at Virginia Tech.

Additional productivity and cost data, provided by participating contractors, covering the time period of 1995 and 1996 were added to the existing data set to further assess productivity, cost, technical efficiency, and profitability trends of the timber harvesting industry in the region. Demographic data complimenting the information collected in Loving (1991) were also collected to track changes for the period and to aid in determining sources of contractor efficiency. The objectives of the study are as follows:

1. To describe and document changes over time of the demographic and operational characteristics of logging contractors included in the study.

2. To describe and quantify the components and trends associated with logging contractor productivity and costs, to understand the logging process and the operating environment it is part of.

3. To document the performance of southeastern United States logging contractors for the time period of 1988 through 1996, by analyzing productivity[1] and cost[2] data, technical efficiency measurements, and profitability measurements.

4 To explore the influences of technical, organizational, natural, administrative, and regulatory forces on southeastern U.S. logging contractors.

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[1] Productivity is the output of the technical efficiency measurements, which represents green tons of wood delivered to market during a certain time period.

[2] Costs associated with the equipment, consumable supplies, labor, combined with contract trucking are the inputs of the technical efficiency measurements.

Chapter 2 LITERATURE REVIEW

2.1 Measurement of Performance in Harvesting Operations

Much of the work done to date to measure performance in forestry operations has included engineering techniques focusing on individual machines, or processes within a specific harvesting operation or system. Common measures include production per man-day, machine availability, machine utilization, or machine production per hour. These methods were developed to make evaluations on individual machine performance in specific applications, and often contain broad assumptions (Stuart, LeBel, Grace and Shannon 1997). These assumptions may not be appropriate to the modern industry because of changing business conditions and technology. The studies that focus on individual machines, may not be applicable to other harvesting applications, and do not indicate whether the results can be obtained on a broad scale (Cubbage 1988).

Another popular measure of performance has been the total cost per unit measure. These measures use cost information obtained by accounting methods. Broad assumptions are therefore not needed due the detail of the data. Analyses using these data are not perfect, an example being the total cost measure. Since an overall cost per unit in a specific time period is obtained, it is difficult to make conclusions when comparing loggers operating within the same system type or region, due to lack of detail. Therefore, these measures are incomplete measures at best, because only one level of factors is observed (LeBel 1996).

There are, however, alternative methods of measuring performance that provide for more insight into technical and economic performance, within and across harvesting or wood supply systems. Technical efficiency measures can accomplish this, when coupled with personal knowledge of the logging contractor’s operations. These methods can be used not only to examine performance on a total cost basis but can be broken down into individual cost components.

This is necessary due to the diversity of business types and the legal environment of the timber harvesting industry. Logging businesses range from simple sole proprietorships to organizations containing several corporations. The different business structures result from tax issues, liability concerns, estate planning, equity formation, and insurance issues. Even with this complexity, certain elements remain constant; equipment depreciation schedules are dictated by the tax code, law and competition determine labor fringe benefits, and income taxes must be paid. These factors provide common ground for analysis of loggers with diverse legal and business characteristics.

There have been a few applications of efficiency analysis in forestry-related fields. These include Martin and Page (1983), Kao and Yang (1991), Carter and Cubbage (1995), and LeBel (1996). Only the latter two applications focused on southern U.S. timber harvesting. Martin and Page (1983) focused on production forestry in Ghana, and Kao and Yang (1991) analyzed Taiwan forest management. Carter and Cubbage (1995) and LeBel (1996) both focused on efficiency measurement of southern U.S. logging contractors.

Carter and Cubbage (1995) used econometric stochastic frontier estimation to measure efficiency of southern U.S. pulpwood firms between 1979 and 1987. The results stated that the overall efficiency for the firms was consistently around 60 percent. Efficiency differences among the firms studied were attributed to age and experience, technology used, and the scale of production. Basic differences between the Carter and Cubbage study and this study make comparison difficult. Carter and Cubbage (1995) was based on aggregate data, rather than individual firm observations, which is the primary difference between the two studies.

LeBel (1996) performed a similar independent logging contractor performance and efficiency study as the one being discussed in this study. Additional discussion of LeBel (1996) is warranted at this time.

2.2 Results from Similar Independent Logging Contractor Efficiency Studies

LeBel (1996) performed a similar independent logging contractor performance and efficiency study using the same analysis techniques, procedures, and types of data. The study included production and cost data covering the period from 1988 to 1994, from 23 Southeastern U.S. loggers. The data were then used to determine how efficiently the process inputs of equipment, consumables, and labor were transformed into outputs, green tons of wood delivered to market.

LeBel noted that the logging contractors included in the study were, for the most part, efficient during the period studied. Some of the loggers were consistently more efficient than others. There were cyclical trends where the loggers went through periods of efficiency, followed by periods of inefficiency. Several loggers were able to avoid this cycle thus remaining efficient throughout the period studied.

The inefficient periods were in part attributed to low production capacity utilization and inefficiencies relating to scale size. LeBel noted that efficient loggers on average utilized 85 percent of their production capacity, while less efficient loggers on average utilized 83 percent of their production capacity. LeBel also noted that approximately one-fourth of the observed inefficiencies were related to the scale size of the operations. The most efficient scale size was noted to be between 60,000 and 80,000 tons of wood produced per year.

LeBel also examined the relationship between profitability and technical efficiency by using observations provided by efficient contractors. The observations located at the most efficient operation size, referred to as the most productive scale size (MPSS), had the lowest average costs in this case. It was noted that observations with production at a higher level than the most efficient operation size had higher average costs, but that total profits continued to accrue until the point where marginal costs equaled marginal revenues. LeBel also stated that contractors producing at a level lower than where scale efficiency was maximized could decrease their average cost per ton and increase their profits by increasing their level of production. Therefore, to maximize profits a logger must produce at a level were marginal revenues equal marginal costs, which results in higher average costs than the point where the most efficient operation size is located. Even though profitability is the ultimate goal of any business and is directly related to the logging rate, performance measured by efficiency is very important. Efficiency is a prerequisite of profitability. Also, a procurement organization can not be expected to pay for the inefficiency of its logging contractors, unless it is the source of the inefficiencies. The discussion will now shift to the description of terms and analyses, which were used.

2.3 Technical Efficiency Measures

Farrell (1957) stated that efficiency was a measure that has both practical and theoretical importance (Ali and Seiford 1993). As an example, the measurement of efficiency can be used to test certain experimental hypotheses, and also to aid in economic planning to improve the productivity of a firm (Ali and Seiford 1993). Efficiency, which is often referred to as technical efficiency, can be defined using the following equation, when the unit observed consists of one input and one output (Boussofiane 1991).

Equation: 1.1.

$$TE = \frac{\text{Outputs}}{\text{Inputs}}$$

The inputs are any expense associated with delivering wood fiber to the wood-consuming mill. The output of the process is green tons of wood fiber, delivered to the mill. Technical efficiency can be measured in one of two ways, either by output maximization or input minimization (Lovell 1993). Output maximization involves maximizing output while keeping inputs constant. On the other hand, input minimization refers to producing at a constant level of output while using the lowest level of inputs possible. This study will measure efficiency in terms of input minimization.

A standard representing the highest achievable level of technical efficiency must be determined to measure empirical efficiency of a process or observations (Carter and Cubbage 1995). Technical efficiency can be measured using three methods: ratio analysis, parametric frontier functions, and non-parametric methods (LeBel 1996). Ratio analysis is a simple method in measuring how efficiently inputs are converted into outputs. Ratio analysis becomes difficult to use when more than one input, or output is included in the analysis.

2.3.1 Parametric Methods for Measuring Technical Efficiency

The parametric method uses a well-behaved neoclassical production function to measure predicted performance (Triantis 1990). Multiple regression analysis is used to obtain the shape and location of the production function or isoquant. The production function forms the basis for a description of input/output relationships of a firm (Ali and Seiford 1993). The corrected ordinary least squares approach is then used to move the production function to envelop all the data points by adding the maximum positive residual to it (Triantis 1996). Thanassoulis and Dunstan (1994) stated that the resulting standard of performance is based on the average relationships and could be influenced by outliers (LeBel 1996). Complicated computations must be performed to analyze multiple output situations as well (Koa and Yang 1991).

2.3.2 Non-Parametric Methods for Measuring Technical Efficiency

Non-parametric methods measure efficiency relative to all observations in a data set, and require no functional form assumptions (Seiford and Thrall 1990). Non-parametric approaches are based on frontiers instead of central tendencies. These methods can thus discover relationships, which could be missed by other methods (Seiford and Thrall 1990). Non-parametric methods can also be used to include multiple inputs and outputs in efficiency analysis. Non-parametric analyses will be used to obtain the technical efficiency scores for each observation, and will be discussed in more detail at this time.

2.4 Data Envelopment Analysis

Data Envelopment Analysis (DEA) was the non-parametric method used to measure efficiency in this study. A more comprehensive explanation of DEA as it applies to research in the timber harvesting industry is contained in LeBel (1996).

Data Envelopment Analysis (DEA) is a non-parametric, linear programming approach to measuring relative technical efficiency, which provides a way of finding efficiency standards from observed data (Ali and Seiford 1993). DEA extends the single input-output technical efficiency measure developed by Farrell (1957), to include multiple inputs and outputs (Charnes, et al. 1994). The observations analyzed through DEA can represent input-output combinations from a single firm or several firms, as long as the processes use similar technology and perform similar tasks (LeBel 1996).

The relative technical efficiency of process observations is found by comparing each observation against some standard of efficiency. This standard of efficiency, referred to as the production frontier, or the empirical production function, is made up of the most efficient observations. The production frontier therefore, forms the basis for study of input-output relationships within a process (Ali and Seiford 1993).

DEA uses the best practice approach to form the production frontier, by using linear programming methods. A line is formed, which connects the most efficient observations, or Decision Making Units (DMU's) in a data set. This line forms a shell, which covers or envelops the observations in the data set (LeBel 1998). The efficiency of individual observations is then determined by measuring their distance from the best practice frontier.

All DMU's must lie on or below the production frontier (Seiford and Thrall 1990). Therefore, it is important that the observations included in the data set are error free, especially ones located on or near the frontier. An error or bias in measurement in one or more of these DMU's, could result in the production frontier being shifted away from the other observations. If a DMU on the production frontier were erroneous or biased, the efficiency scores of the DMU's underneath the production frontier would be artificially low. DEA computes the technical efficiency of a DMU, which can be found using the following basic formula in equation 2.1.

Equation: 2.1. Charnes Cooper and Rhodes DEA Model (CCR)

$$TE = \frac{\text{Weighted sum of outputs}}{\text{Weighted sum of inputs}}$$

The input and output weights are defined separately for each DMU. These weights are defined in order to maximize the efficiency of the DMU in question, while not causing any other efficiency score to be above one (Charnes et al. 1978). This equation has specific characteristics for each model used in the analysis. Detailed formulations for each model used in the study can be found in LeBel (1996).

2.4.1 Radial and Non-Radial Measures

The DEA efficiency scores were calculated for each observation in the data set with Mathematica® for Windows® computer software, using models included in LeBel (1996). Five separate models were used to obtain the efficiency scores. The models will be used to compute both radial and non-radial measures of technical efficiency.

Radial measures of technical efficiency equiproportionally reduce the inputs of the process while still allowing for the same output to be produced (Parlikar 1996). If the inputs of an observation can be reduced, it is not deemed efficient, and therefore is assigned a technical efficiency score less than 1. If equiproportional reduction is not possible, the observation is deemed efficient, and therefore has an efficiency score of 1. Radial measures were used to obtain overall technical efficiency scores for each observation.

Non-radial measures project each input of an observation individually onto the production frontier, also referred to as the efficient subset. The inputs are therefore scaled individually by different proportions (Parlikar 1996). Non-radial measures were used to obtain partial efficiency scores, which provide efficiency scores for each input separately.

The models, which will be used to obtain radial measures of Technical Efficiency, include the Charnes, Cooper, and Rhodes model (CCR), and the Banker, Charnes and Cooper model (BCC). The non-radial measures of technical efficiency will be obtained by using the Asymmetric-Färe (AF) and the Färe-Lovell (FL) models.

2.4.2 The CCR Model

Two types of envelopment surfaces can be used by DEA constant returns to scale or variable returns to scale envelopment surfaces. The choice of the type of envelopment surface used depends on economic and other assumptions associated with the data set being studied (Ali and Seiford 1993). The CCR model calculates technical efficiency assuming constant returns to scale. This measure is referred to as aggregate efficiency because it considers not only the combination of inputs and outputs in the observation but also scale efficiency. The production frontier is a straight line that runs through the most efficient or productive scale size (LeBel 1996). This is important, because only observations operating in the area of the most productive scale size are considered efficient by this model (LeBel 1996).

2.4.3 The BCC Model

The BCC model calculates technical efficiency assuming variable returns to scale. This is also referred to as “pure efficiency” because it does not include scale efficiency. This model forms a best practice frontier, which is a curved line running through the most efficient observations in the data set (LeBel 1998). Therefore, an observation does not have to be at the most productive scale size to be labeled efficient by this model. The scale efficiency (SE) can be calculated by taking the ratio of the CCR model and the BCC model. When a DMU has a SE value not equal to 1 there are scale inefficiencies (LeBel 1996).

Returns to scale refers to the change in production level resulting from each additional unit of input. When a process is experiencing constant returns to scale, each additional unit of input produces the same level of output as the previous unit. On the other hand, when a process is experiencing variable returns to scale, each additional unit of input adds more or less output than the previous unit. Therefore, the process is either experiencing increasing or decreasing returns to scale. With increasing returns to scale, each additional unit of input produces more output than the previous unit. In decreasing returns to scale, each additional unit of input produces less input than the last.

2.4.4 The Non-Radial Efficiency Models

Non-radial technical efficiency measures can be used to obtain different efficiency scores for each input factor separately. Since radial measures were used only to give an overall technical efficiency measure, they can only be used to determine the most and least efficient observations. Non-radial models were used to calculate partial efficiency scores, which indicate how efficiently each input factor is utilized. Partial efficiency scores are extremely helpful in determining sources of inefficiencies.

Two non-radial models were used - the Färe Lovell model and the Asymmetric Färe (AF) model. The difference between the models involves how the peers for the efficiency measurements are selected. In this context the word “peers” refers to the observations on the production frontier, which form the efficiency standard used to compare the other observations. The FL model only compares observations with peers located on the efficient sub-set of the frontier. Ferrier and Eeckaut (1994) stated that the AF model in effect calculates the efficiency measure for each input while holding the others constant (LeBel 1996).

2.4.5 Input Excesses and Output Slacks

The presence of output slacks or input excesses determines if an observation on the production frontier is, in reality, efficient. Output slacks or input excesses occur when excessive amounts of inputs are used to produce a certain level of output (Triantis 1997). These observations are located on the flat portion of a production frontier.

A two-stage model must be used to avoid deeming observations with output slacks or input excesses efficient (Ali and Seiford 1993). Up to this point, only single-stage models have been discussed, which only accurately identify efficiency ratios and not whether slacks or excesses are present (Ali and Seiford 1993). The first stage in a two-stage model calculates the efficiency score of an observation, while the second stage determines if input slacks or output excesses are present (LeBel 1996).

2.5 Summary

It is important to continually monitor the performance of independent logging contractors in the southeastern U.S. Much of the previous work involving measuring the performance of independent logging contractors has either focused on individual operations, machines within a specific harvesting system, or on total cost per unit measures. These measures do not include the breadth or detail needed to adequately assess the performance and economic health of loggers. This information will enable recommendations to be made, which will ensure that the southeastern U.S. logging industry remains globally competitive in the future.

Technical efficiency is a performance measurement tool, which can be used to make those types of recommendations. Data envelopment analysis (DEA) is a widely used non-parametric mathematical programming technique, which was used to calculate relative technical efficiency, and to form a standard of comparison to achieve the goals of this study.

Chapter 3 METHODOLOGY

3.1 The IFO Production and Cost Study

Research involving logging contractor cost and production data has been an ongoing effort at Virginia Tech. Several researchers have contributed to the formation of the existing data set including Walter 1997, LeBel 1996, LeBel 1993, and Loving 1991. The data set has been updated to include 1995 and 1996 cost and production data for all participating contractors. The project consists of data from 35 logging contractors and 192 logger years of data. Data from 7 contractors goes back as far as 1988, but the number of years of data from each contractor depends on the year that they joined the project and the availability of historical data.

Logging contractors included in this study meet the following criteria: they are good loggers in the eyes of the industry and the public, are willing to participate in the study, and have adequate records to provide the needed information. Participating loggers were recommended by American Pulpwood Association member companies, or by peers within logging associations, in regards to the previous criteria. The contractors were then contacted to personally to see if they would agree to be involved.

3.2 The Data Set

3.2.1 Data Collection

The data collection process for this project included performing interviews with each contractor and collecting of the production and cost information. The interviews were conducted on the contractors logging job, shop, or office, and were completed in 1 to 3 sessions, lasting approximately 4-8 hours per contractor. Eighty-five additional contractor years of production and cost data were collected. Data for 14 contractors who participated in previous projects at Virginia Tech provided 1995 and 1996 information. Nine contractors, participating for the first time in the study, contributed production and cost data ranging from 1990 to 1996. Thirty-five contractors provided interview information, which was updated through the end of 1997. Thirteen of these contractors were included in the study for the first time, and the remaining 22 contractors participated in one or more of the previous studies.

Information obtained from the interviews included the following: demographics, organizational structure, number and location of markets, makes and models of equipment, insurance information, crew structure, and employee benefits. The interview process also served to determine possible inefficient periods and the causes of the inefficient periods to assess the sustainability of the current logging force and to categorize the loggers for further analysis. The information obtained during the interviews was based on a form adapted from Walter (1997) (Appendix A).

The production data, the output used in this study, was obtained directly from the participating loggers or from the forest product companies they supply. The production information represents the green tons of wood delivered to market during a particular period. The goal was to obtain weekly production for each contractor from 1990-1996 to help determine the sources of variation in production levels. Weekly production was not available for all of the contractors. In those cases, monthly, quarterly, or yearly production information was obtained depending on availability. Most of the data provided were in tons, but some were converted from cords or MBF to tons using local conversion factors.

The input for this study was the cost in dollars associated with getting the wood from the stump to the market. The objective was to collect quarterly cost information for each contractor. Yearly cost data were obtained from contractors who could not provide quarterly data. The information was obtained in several forms including, tax returns, reports from the contractor’s accountants, or directly from the contractor’s books. The majority of the cost information from the contractors was yearly information. Enough contractors provided quarterly information to form a substantial sub-sample to be used in the analysis. The cost information was consolidated into 6 categories, which are listed in Table 3.1.

Table 3.1. Six Cost Categories Used.

1. Equipment
    - A. Note payments or Depreciation
    - B. Taxes (Highway use, property tax)
    - C. Interest
2. Labor
    - A. Payroll (wages and salaries)
    - B. Payroll taxes (FUTA, FICA, Medicare)
    - C. Workers Compensation Insurance
    - D. Employee Benefits
3. Consumables
    - A. Tires
    - B. Fuel
    - C. Oil and Lubricants
    - D. Parts and Maintenance
    - E. Truck and Equipment washing
    - F. Expensed tools (chain saws)
    - G. Gravel
    - H. Mats
    - I. Wrecker Service
4. Administrative Overhead
    - A. Secretary Wages
    - B. Bookkeeping or Accounting fees
    - C. Office expenses
    - D. Licenses
    - E. Fines
    - F. Legal and Professional Dues
    - G. Travel Expenses
    - H. Phone and CB Radio Expenses
    - I. Medical Expenses
5. Insurance
    - A. General Liability
    - B. Equipment (Fire/Theft/Vandalism)
    - C. Umbrella Policy
6. Contracted Services
    - A. Contract Trucking (Any trucking performed by trucks not owned by the logging company. The independent contractor or a third party can own the separate trucking company).

3.2.2 Valuation of Equipment

It should be noted that the equipment category includes note payments (payment to principal) or depreciation expense in addition to taxes, licenses, and interest. Depreciation was used for all but two loggers for whom it was not available. Depreciation was used because it was more accessible than note payments.

Depreciation is easily obtained from tax forms or financial statements. Payment to principal, on the other hand, must be obtained directly from a logger's books, which would have proved to be more intrusive, challenging, and time-consuming. It is recognized that using depreciation strays from the desired cash flow analysis, primarily due to the time periods associated with each. Using depreciation is still an effective way of accounting for equipment costs.

The Modified Accelerated Capital Recovery System (MACRS) is popular among loggers. This method of calculating depreciation allows the majority of the value of a piece of equipment to be deducted in the first 3 years of ownership. Straight-line depreciation deducts the same value each year except for the first and last years. MACRS more closely mirrors the popular 3 or 4 year note than straight-line depreciation because the value of the equipment is depreciated more quickly. An example is included in Tables 3.2 and 3.3.

Table 3.2. MACRS and Straight-Line Depreciation Rates for Five-Year Property with a Half- Year Convention.

Year of Operation	MACRS	Straight-Line
1	20%	10%
2	32%	20%
3	19.2%	20%
4	11.52%	20%
5	11.52%	20%
6	5.76%	10%

Table 3.3. Note Payments and Depreciation Schedule Relating to a $50,000 Machine.

Year of Operation	Note Payments	MACRS	Straight-line	Interest	MACRS + Interest	Straight-line + Interest
1	$19,850	$10,000	$5,000	$3,000	$13,000	$8,000
2	$19,850	$16,000	$10,000	$3,180	$19,180	$13,180
3	$19,850	$9,600	$10,000	$3,370.80	$12,970.80	$13,370.80
4		$5,750	$10,000		$5,750	$10,000
5		$5,750	$10,000		$5,750	$10,000
6		$2,880	$5,000		$2,880	$5,000

The difference between note payments, MACRS, and straight-depreciation is shown in table 3.3. Note payments were calculated for a $50,000 machine with a 6 percent annual percentage rate loan for three years. Three-year loans are commonly used in harvesting because of the relatively short equipment life and depreciation schedules. MACRS and straight-line depreciation for 5-year property with half-year conventions were also calculated for the $50,000 machine. The same compound interest was applied to the depreciation schedules to better show the difference between using depreciation and note payments to estimate equipment expense.

MACRS + interest underestimates cash flows to note payments in the first year, closely approximates the value of note payments in the second year, and underestimates cash flows in the third. The first, second, and third years have differences of 34.5, 3.4, and 34.7 percent, respectively. Straight-line depreciation has discrepancies of 59.7, 33.6, and 32.6 percent, respectively, for the three-year loan.

In some cases, the differences associated with note payments and depreciation are not as extreme as indicated in the previous example. When contractors spread equipment purchases out over consecutive years, depreciation from previously paid off machines acts to moderate the differences between the two methods. In many cases, due to necessity or opportunity, loggers are not able to renew equipment on a regular schedule, causing differences in note payments and depreciation to more closely follow the example in Table 3.2. Therefore, these fundamental differences should be kept in mind when analyzing the equipment valuation data.

3.2.3 Inflation

Inflation was not accounted for in the data set. The objective of this study to track changes in technical efficiency, an indicator of the volume of wood produced from each dollar spent. The data needed to accomplish this task are the actual volume of wood produced and the actual cost associated with production. Inflation is a force that affects this efficiency. Correcting for it early in the analysis would have masked its effect.

3.2.4 Owners' Salaries

Owners' salaries varied in the amount and method of payment, which would have complicated the analysis. This information was also unavailable in many cases due to privacy reasons. To keep each logger on equal footing, an arbitrary $30,000 per year value was assigned to each logger. This value is believed to be justifiable because a salary of at least this much would be needed to hire a supervisor to assume the same responsibilities.

3.3 The Production Function

A production function forms the basis for a description of the input-output relationships of a firm (Ali and Seiford 1993). A production function is therefore, a mathematical relationship, which explains how quantities of inputs are transformed into the outputs of a process, and is the first step to determine the sources of efficiency and inefficiency (Triantis 1997).

Equation. 3.1. Production function for southeastern U.S. forest harvesting firms.
$q = f(\text{Capital, Consumables, Labor,})$
(q represents tons of wood produced)

3.3.1 The Big Three

The three largest cost categories, equipment, consumables, and labor, along with contract trucking were the inputs for this study. These categories represent the expenses, which are directly related to the production of the outputs of the process. The other expenses associated with the harvesting process, insurance and administrative overhead, are definitely important to the business, but they are not directly related to the production of wood fiber. Therefore, they will be omitted from the efficiency analysis, and discussed further in Chapter 6.

3.3.2 Contract Trucking

Equipment, consumables, and labor combined with contract trucking, account for over 90 percent of the total cost associated with operating a logging business. The participating loggers used 4 trucking strategies. Some elected to do all of their own trucking. Others sub-contracted all of the hauling to separate trucking companies. Some loggers had their logging and trucking organized in separate businesses, for legal and tax reasons. The others used a combination of contract trucking and contractor-owned trucks.

Contract trucking expense was included in the analysis because it is directly related to production. This posed a technical problem. Contract trucking could not be included as a fourth input category due to the nature of DEA's weighting procedure. DEA assigns weights to put each observation in the "most favorable light" possible (LeBel 1996). Furthermore, higher weights would be assigned to observations, which had no or extremely low values for contract trucking. These observations could be deemed more efficient than they actually were. It was determined that the best alternative was to consolidate contract trucking into equipment, labor, and consumables to avoid these problems.

In many cases, only a total cost figure for trucking was available. A method to determine the input mix associated with contract trucking was formulated. Contract trucking was equally divided and distributed among equipment, consumables, and labor. Each of these 3 categories was assumed to include 30 percent of the contract trucking. The remaining 10 percent were left to account for insurance and administrative overheads. Data was obtained from two trucking businesses to verify this assumption. Six years of trucking data were available for logger 804 and one year for logger 901 (Figures 3.1 and 3.2). Both contractors examined were organized in separate logging and trucking businesses.

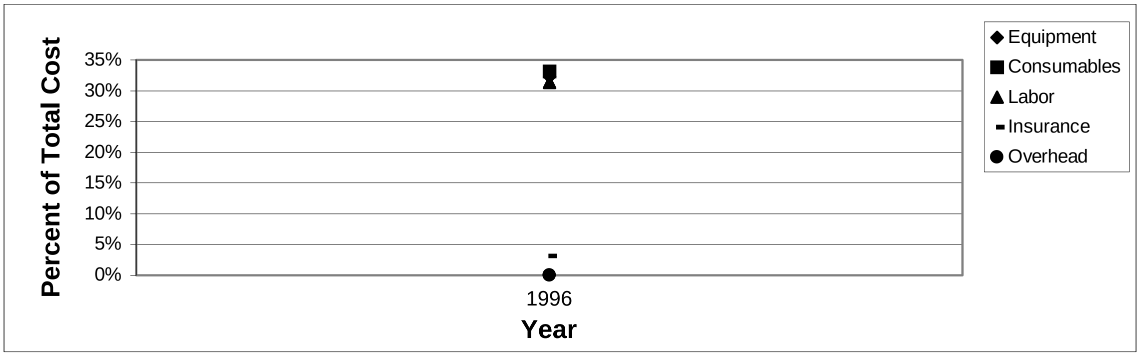


Figure 3.1. Percentage of Total Cost Associated with Each Cost Component in 1996 for Logger 901 Trucking.

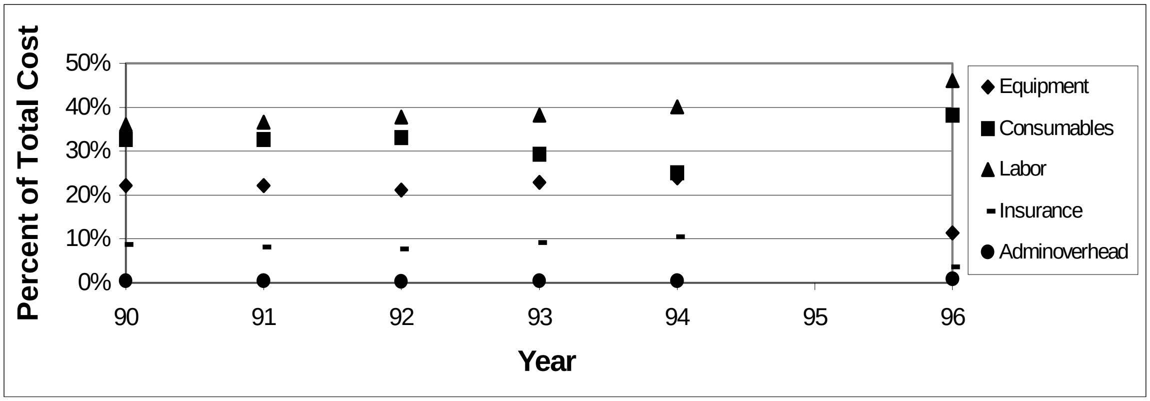


Figure 3.2. Percentage of Total Cost Associated with Each Cost Component in 1990-1994,
and 1996 for Logger 804 Trucking.

Trucking data obtained from logger 901 strongly supports the assumption. Equipment, consumables, and labor all accounted for between 30 and 35 percent of the trucking expense. Insurance and administrative overhead accounted for a lower percentage than expected. The first year that logger 901 organized trucking and logging into separate businesses was 1996. Therefore, it is possible that some overhead and insurance expenses overlap in the early stages of development.

The trucking costs provided by logger 804 were more dispersed than logger 901’s. Logger 804 chose to spend more on labor and less on in-woods equipment. This same strategy was apparent in the trucking operation. The percentage of trucking cost associated with the three categories ranged between 20 and 40 percent for the most part.

The last year is somewhat of an outlier because larger percentages of the total costs were associated with labor and consumables. The majority of the trucks used by logger 804 were purchased in the late 1980's and early 1990's, which accounts for the lower value associated with equipment. This is believed to be a short-lived trend. When reinvestment occurs there should be less of a difference between the cost components. Insurance and administrative overhead accounts for approximately 10 percent of the total costs as expected.

Due to the number of observations in the data set and the varying business strategies used by each contractor, a conservative estimate of the input mix was needed. As seen in Figures 3.1 and 3.2, by assigning 30 percent of the total cost to each of the big three cost categories, a reasonable estimate was obtained, which will accomplish the objectives.

3.4 Demographics, Business, and Operations Analysis

3.4.1 Description

The demographic, business, and operation analysis data were collected through the interview process. The majority of this information was compiled for a year-ending status report, which was sent to all participating loggers. The information was explored graphically and with descriptive statistics. As in Loving (1991), *post hoc* evaluations of certain relationships were explored graphically, including the relationship between contractor age, experience, education, and also the relationship between production and the number of workers involved.

3.4.2 Evolution

Evolution of contractor demographic, business, and operational characteristics from 1990 to 1997 was also explored. This was accomplished by focusing on the number of employees associated with each operation, fringe benefits provided, business organization, and the age distributions of the equipment, for a sample of 10 contractors who provided data in 1990 and in 1997. The 1990 data were collected by Loving (1991), and the 1997 data were collected through this study. The two groups were compared using graphical methods and with Mann-Whitney non-parametric tests.

3.5 Productivity Analysis

Weekly, quarterly, and yearly productivity information was collected, representing green tons of wood delivered to market during those time periods. Productivity variability, quarterly and yearly productivity trends, and productivity capacity utilization were analyzed.

3.5.1 Productivity Variability

Productivity variability was analyzed using weekly production information provided by 20 contractors. The contractors included in the study were categorized into three operating strategies, including upward elastic, downward elastic, or inelastic. The contractors were classified into the three groups depending on the elasticity built into their operations, which is an indicator of their ability to increase or decrease production according to forces effecting productivity. The contractors were classified using box plots of 1995 and 1996 data, coefficients of variation, average productivity compared to the maximum production level, and the average compared to the production level of the 25th percentile. Productivity data for one contractor in each of the 3 groups were analyzed using descriptive statistics and with graphical methods to describe the characteristics associated with each productivity strategy.

3.5.2 Productivity Trends

Quarterly productivity trends were analyzed using data from 15 contractors who provided complete quarterly production information from 1990 to 1996. The distributions of the quarterly productivity data were compared using two sample Kolmogorov-Smirnov tests, and cumulative relative frequency or ogive charts. Paired differences for each quarter were also analyzed using Wilcoxon signed rank tests. The cumulative relative frequencies or ogives were calculated by first dividing production data for each quarter into 60 equal classes. The relative frequency for each class were then calculated and summed algebraically.

Yearly productivity trends were explored using data from 20 contractors who provided complete yearly production information from 1990 to 1996. The data was analyzed using Wilcoxon signed rank tests, descriptive statistics, and graphical methods.

3.5.3 Capacity Utilization

Production capacity utilization, the ratio of actual production, to the maximum production level achievable during normal operating conditions, was analyzed using data from 21 contractors who provided at least some weekly productivity data between 1990 and 1996. Capacity utilization was calculated by taking the ratio of the median weekly production, to the 75th percentile value for each year of available production data. These data were then summarized using descriptive statistics. Capacity utilization trends were explored by using data from a sample of 16 contractors who provided complete weekly production data from 1990 to 1996. Wilcoxon signed rank tests, descriptive statistics, and graphical methods were used to analyze these trends.

3.6 Cost Analysis

The cost, in dollars, associated with delivering the green tons of wood to market is considered the input of the forest harvesting process in this study. Quarterly or yearly cost information was collected. The information was obtained in several forms, including tax returns, reports from the contractor’s accountants, or directly from the contractor’s books. The cost information was consolidated into six categories, which are listed in Table 3.1. Various analyses were performed to discuss characteristics of the 6 cost components, to explore quarterly and yearly cost trends, and also to explore the relationship of logging costs to production.

3.6.1 Cost Components

The characteristics of the 6 cost components were explored by using data from 31 contractors who provided at least one year of cost data between 1990 and 1996. The proportion of total yearly costs associated with the cost components was calculated for each observation. Descriptive statistics and graphical methods were then used to describe the cost components and the tradeoffs associated with them.

3.6.2 Cost Trends

Trends in quarterly and yearly costs were used to indicate changes in the business environment. Six contractors provided complete quarterly cost information for the period. Wilcoxon signed rank tests, descriptive statistics, and graphical methods were used to explore the quarterly cost information.

Yearly cost trends were explored using data from 15 contractors who provided complete yearly cost information for the period. Wilcoxon signed rank tests, descriptive statistics, and graphical methods were also used to explore the yearly cost information.

3.6.3 Relationship of Productivity and Costs

The relationship between the productivity and cost information was explored on a quarterly and yearly basis as a lead-in to the technical efficiency analyses. This was achieved by developing regression lines from quarterly and yearly production and cost data representing the years 1990 through 1996.

3.7 Technical Efficiency Analysis

Technical efficiency, an indicator of the green tons of wood produced per dollar of expenditure, was used to measure the performance of participating contractors. This measure was used to explore the influence of technical, organizational, natural, administrative, and regulatory forces on contractor performance. Quarterly and yearly trends and the relationship between efficiency and profitability were also explored.

3.7.1 Data Envelopment Analysis

Data Envelopment Analysis (DEA) was used to assign technical efficiency scores to each yearly or quarterly production and cost observation. Several DEA models were used. The dual and primal formulations of the CCR and BCC models were used to obtain overall efficiency scores for the observations. The presence of input excesses and slacks were determined with the use of a two-stage model. Partial efficiency scores were also obtained for each observation using the non-radial Asymmetric-Färe (AF) and the Färe-Lovell (FL) models

The BCC model was the preferred over the CCR model in this study because it is recognized that external factors such as tract size, species mix, and trucking distance do not allow operations to achieve the most efficient scale size. The BCC frontier defines the achievable efficiency for observations relative to operations for the same or similar scale sizes. As in LeBel (1996), the AF model was preferred over the FL model, because the straight line, one-dimensional nature of the AF model eased interpretation.

3.7.2 DEA Results

The results from these models were presented using descriptive statistics and graphical methods. These scores were also divided into three efficiency groups which include efficient (0.9 - 1.0), partially efficient (0.8 - 0.9), and least efficient (0.8> efficiency score). This sub-division, which follows the example of LeBel (1996), was performed to make the first separation to form a basis for comparison. The separations are felt to be justified due to the variability and changes that occur within the wood supply system. Observations located within the range specified for the efficient group all operate reasonably close enough to the production frontier to be considered efficient. The partially efficient group is outside the range where they could be considered completely efficient, but within reach. Those observations in the least efficient category would require more drastic changes in their working environment or operation to be included in the efficient group.

3.7.3 Demographics and Business Operation

The influence of the 5 forces affecting efficiency was assessed in part by dividing the efficiency results into several groups according to demographic and business organizational groups discussed in Chapter 4. The sample size for the groups analyzed varied at times; occasionally only one contractor's made up a group, therefore, the results should be analyzed with caution. It was difficult to isolate and to quantify the influence of any one force affecting efficiency, therefore, only suggestions were made.

The suggestions were made based on analyses performed using Pearson product moment correlation coefficients, Mann-Whitney tests, descriptive statistics, and graphical tools. The Mann-Whitney test is a non-parametric procedure, which is a two sample rank test. Ties, which refer to data in the two samples with the same value, were somewhat of an issue with these data, since several observations in each sample are likely to have efficiency scores of 1. Minitab, the statistical package used, accounts for this by assigning the average rank to each tied observation and by adjusting the resulting significance levels accordingly.

3.7.3.1 Age, Experience, and Education

The influence of contractor age was explored by dividing the observations into 5-year age classes, depending on contractor age for each observation. Contractors who have participated in the study since its start therefore were spread across 2 or more age classes. The influence of contractor experience was explored by dividing the observations into 5-year experience classes. As before, observations for some firms were spread across several experience classes. The influence of level of education on efficiency was explored by dividing the observations by years of education for each contractor.

3.7.3.2 Region and State of Operation

Efficiency scores were divided into the three physiographic regions represented by the contractors: the coastal plain, mountain, and piedmont. The influence of region of operation was explored further by dividing the observations into the 7 states represented: Alabama, Florida, Georgia, North Carolina, South Carolina, Tennessee, and Virginia.

3.7.3.3 Business Organization

The influence of business organization on efficiency was analyzed by dividing the observations according to the 4 business organization types used by contractors in this study. The business organization types represented were subchapter S corporations, full C corporations, sole proprietorships, and general partnerships.

3.7.4 Operational Characteristics and Strategies

The influence of the 5 forces affecting efficiency were also assessed by focusing on operational characteristics and strategies used by contractors. The available efficiency observations were divided into groups according to operational characteristics and strategies introduced in Chapters 4 – 6. Pearson correlation coefficients, Mann-Whitney tests, descriptive statistics, and graphical methods were used.

3.7.4.1 Species Harvested and Stumpage Acquisition

Information regarding the percentage of pine and hardwood harvested was obtained from production data, and contractor estimates. The influence of species type harvested on technical efficiency was explored by dividing the observations into 10-percent classes, depending on the proportion of pine harvested.

The southeastern U.S. wood supply system has three primary sources of raw material: stumpage owned by wood-consuming mills (either from fee lands or company owned timber deeds), stumpage purchased by wood dealers or brokerage firms, and stumpage purchased by logging contractors. The relationship between stumpage acquisition and efficiency was explored by dividing the efficiency observations into 5-percent classes, depending on the proportion of company or wood-dealer-owned stumpage harvested.

3.7.4.2 Production Capacity Utilization

Production capacity utilization, as defined in Section 3.5.3, is the ratio of actual production to the maximum production level achievable during normal operating conditions. It was calculated taking the ratio of the median to the value of the 75th percentile, using weekly production information provided by 21 contractors.
The relationship between capacity utilization and technical efficiency was explored by grouping the technical efficiency scores into 5 percent capacity utilization classes.

3.7.4.3 Operation Size

LeBel (1996) stated that deviation from the most productive size is a major cause of inefficiency for southern logging contractors. This was verified by dividing the operations into 40,000-ton production classes and analyzing the resulting CCR technical efficiency scores (Figure 7.16). The CCR model was used instead of the BCC model because it takes scale inefficiencies into account by comparing all observations to the most productive scale size.

3.7.4.4 Productivity Operating Strategies

Three categories were used to classify operational strategies relating to productivity. These categories included upwardly elastic, downwardly elastic, and inelastic. Downward elasticity requires foregoing technology to reduce time-based costs. Upward elasticity requires maintaining extra resources for use when the opportunity arises. Inelastic refers to operations, which maintain a fairly consistent level of production and manage the operation around that level of output. Twenty contractors, classified in section 5.1, were used to explore the relationship between operating strategy and efficiency.

3.7.4.5 Cost Component Tradeoffs

Contractors often use different combinations of the six cost components discussed previously. The effect of cost allocations among equipment, consumables, and labor on technical efficiency was analyzed. Contract trucking expenses were divided evenly among the three components to ensure that all costs associated with the logging process were included.

The proportion of the three cost components associated with each observation was found, ranked, and divided into four groups. The first group, referred to as low 1, includes observations in the first quartile. The second group, referred to as low 2, includes observations in the second quartile. The third group, referred to as high 1, includes observations in the third quartile. The last group, referred to as high 2, includes observations in the fourth quartile. Differences associated with these groups were explored using Pearson correlation coefficients, descriptive statistics, Mann-Whitney tests, and graphical methods.

The most efficient input combination was also explored. The observations, along with the proportion of total cost associated with each component, were sorted according efficiency scores, and then divided into the efficient, partially efficient and least efficient categories used previously. This information was then used to determine the strategies associated with each efficiency group. Mann-Whitney tests and descriptive statistics were used to explore these differences.

3.7.4.6 Trucking Strategies

Three trucking strategies were used by the contractors, including those who did all trucking in-house, those who contracted a portion of their trucking, and those who contracted all of their trucking out. The observations were divided into two groups, depending on whether the observations included contract trucking. Separate DEA analyses were done on both groups, using variable returns to scale (VRS) models from the OnFront™ software package. Separate analyses were performed because the contract trucking included an extra input category, for the trucking expense. The locations of the production frontiers were compared using Mann-Whitney tests performed on production and cost observations located on both frontiers.

3.7.5 Technical Efficiency Trends

Yearly and quarterly efficiency trends from 1990 to 1996 were explored to track contractor performance and to integrate cost and productivity trend analyses conducted in Chapters 5 and 6.

Quarterly efficiency data were divided into two groups. The first group included 6 contractors who provided complete productivity and cost data from 1990 through 1996. The second group included 15 contractors who provided at least two years of data for the period. Both groups showed the same general efficiency trends. The first group formed the basis for tracking efficiency of contractors across the entire period by using Wilcoxon signed rank tests, descriptive statistics, and graphical methods.

Yearly data were divided into 2 groups similar to the quarterly data. The first group included 15 contractors who provided complete productivity and cost data for 1990 through 1996. The second group included 32 contractors who provided at least two years of data for the period. Results from the first group tended to be more conservative, but both groups showed the same general efficiency trends. The first group was used to track efficiency across the entire period by using Wilcoxon signed rank tests, descriptive statistics, and graphical methods.

3.7.6 Efficiency and Profitability

The association of efficiency and profitability, introduced in Chapter 1, was explored further using marginal cost and revenue methods. Revenues were not collected as part of this study, so an arbitrary fixed unit price of $12/ton was used to represent revenues.

Marginal and average cost curves were found using similar methods as those discussed in LeBel (1996). Least-squares regression procedures were used to develop quadratic equations that expressed total costs as a function of yearly production for observations located in the efficient, partially efficient, and least efficient groups. The residuals associated with these regression lines were analyzed, and it was determined that a non-constant variance problem was present. Weighted least squares, using 1 over the square root of production (x) as the weight, was used to remedy the non-constant variance problem. Marginal cost and average cost curves were then developed from the resulting regression equations. The resulting cost curves were analyzed using graphical methods.

3.8 Summary

A data set including 35 loggers who contributed 192 logger years of productivity and cost information was compiled. Logger demographics, business, and operational data were also collected through an interview process with the participants.

The data collected as part of the study were used to measure the technical efficiency of the participating loggers, which provided indicators of the overall economic health of the southeastern U.S. logging industry. A variety of quality-control tools were used to analyze the demographic, organizational, business, productivity and cost information. The non-parametric tool, Data Envelopment Analysis, was also used to measure the technical efficiency associated with each logger year. Technical efficiency was the primary criterion, along with profitability considerations, used to evaluate the performance and overall economic health of the participating loggers.

Chapter 4 DEMOGRAPHICS, BUSINESS, AND TECHNOLOGY

This chapter contains descriptions of, and insights into, the evolution of the demographic, business, and operational characteristics of the contractors included in the study. This information will be used to identify specific contractor characteristics and operational and business strategies that could affect the overall performance of the participating contractors.

Thirty-three of the 35 contractors provided at least some productivity and cost information from 1988 through 1996. The loggers not providing production and cost data were included in this analysis to give a better representation of the most efficient and professional loggers. Only one contractor, who provided productivity and cost information early in the study, was not included in the interview process. Three firms included have more than one owner. Each owner playing a role in management was included in the analysis in this section.

4.1 Logger Demographic Information

4.1.1 Age, Experience, and Education

Contractors included in the study are white males between the ages of 31 to 65, with a median age of 47 years. The majority of the contractors were middle-aged; the middle 50 percent of the contractors (referred to as the inter-quartile range) were between 41 and 53 years old (Figure 4.1). This age distribution likely may be attributable to the selection criteria used for the study (Section 3.1).

The experience level of the contractors was measured by the length of time they had owned the business (Figure 4.2). The developmental years, either spent working up through a family business or for another contractor, were not included. The experience level ranged from 3 to 38 years, with the median being 19 years. The inter-quartile range was between 10 and 24 years of experience.

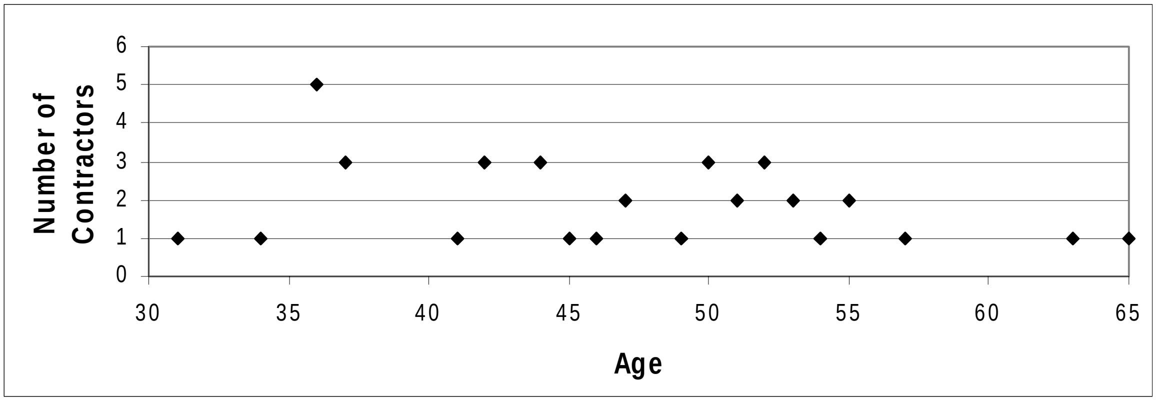


Figure 4.1 Age Distribution of Participating Contractors.

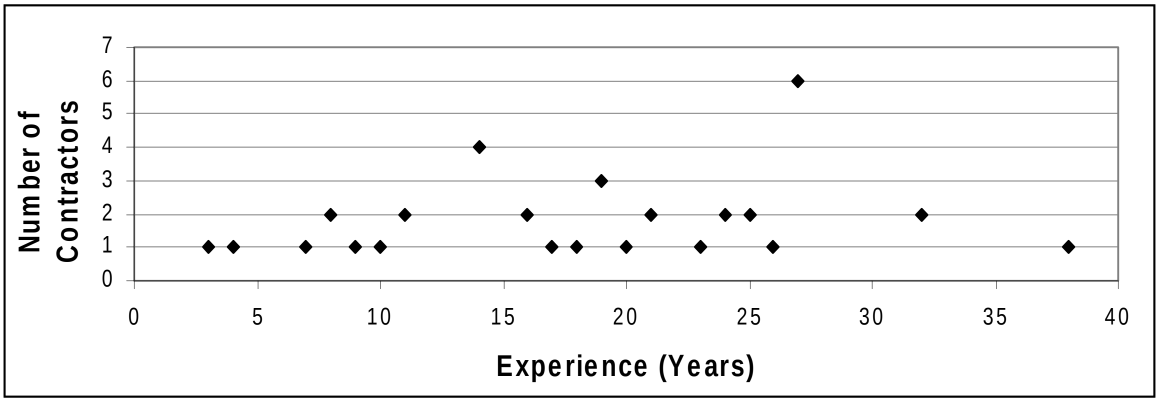


Figure 4.2. Experience Level of Participating Contractors.

All of the contractors at least had some high school education (Figure 4.3). Thirty three of the 35 contractors had graduated from high school, and of these contractors had at least one year of college. Three attended college but did not receive a degree. Two contractors earned two-year associate's degrees in forestry and agriculture, respectively. Six contractors earned bachelor's degrees in business, forestry, or geology.

There is a weak relationship between age, experience, and education of the contractors. Older, more experienced contractors had slightly less education than younger and less experienced contractors (Figures 4.4 and 4.5). The two contractors not receiving high school diplomas were over 50. Thirty-three percent of contractors above 50 years old had college education, and 35 percent of the contractors below 50 had college education.

All of the contractors with associate degrees and 60 percent of those with bachelor's degrees were less than 50 years old.

Factors other than age influence the level of education among logging contractors. There is a relatively small difference in the education levels of the contractors. A high school education appears to be the lower education threshold for a modern contractor. Also, the profession has not been particularly successful at attracting college graduates, possibly due to challenging environmental and business conditions associated with logging.

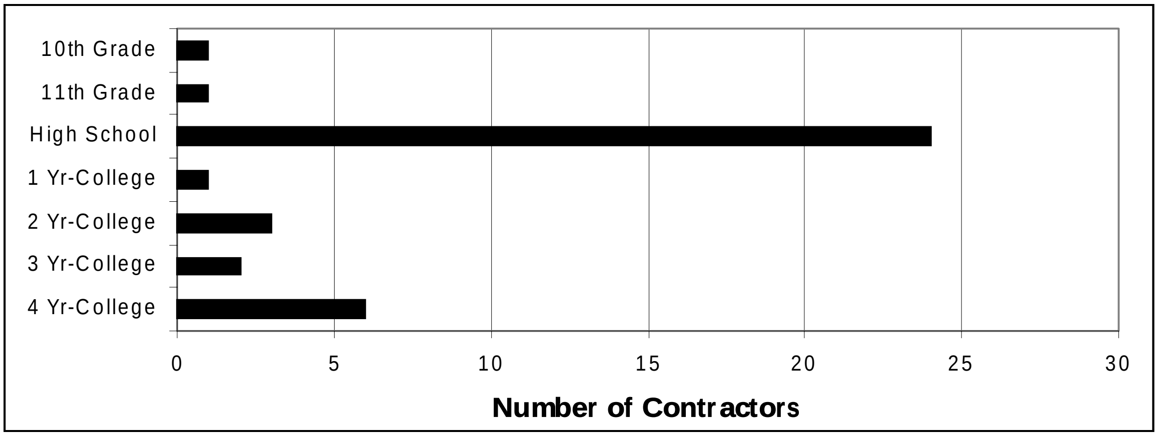


Figure 4.3. Education Level Obtained by Each Contractor.

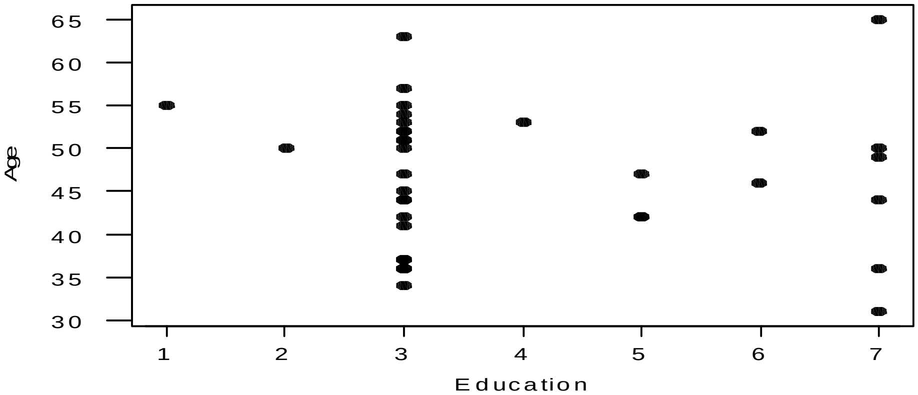


Figure 4.4. Contractor Education vs. Age.

1 = 10th grade 3 = high school 5 = 2 yr. of college 7 = 4 yr. of college

2 = 11th grade 4 = 1 yr. of college 6 = 3 yr. of college

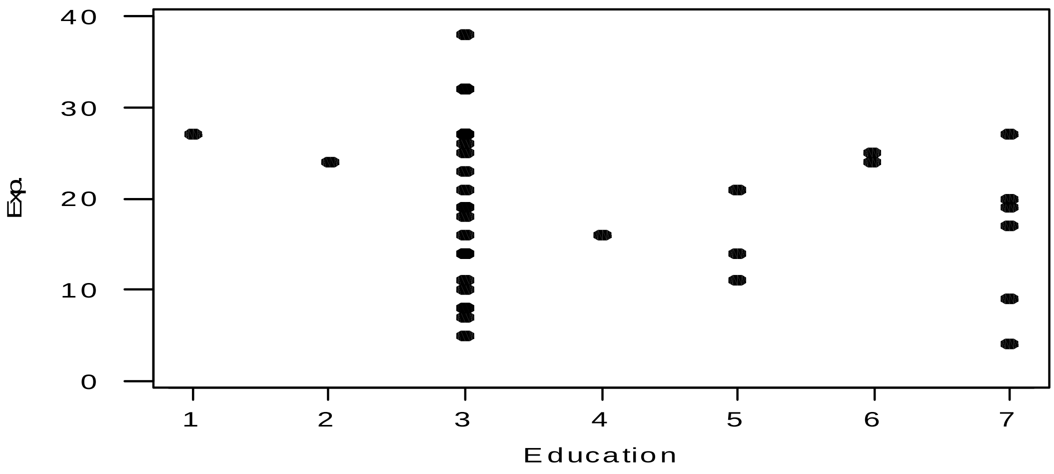


Figure 4.5. Contractor Education vs. Experience.
1 = 10th grade 3 = high school 5 = 2 yr. of college 7 = 4 yr. of college
2 = 11th grade 4 = 1 yr. of college 6 = 3 yr. of college

4.1.2 State and Region of Operation

Contractors included operate in 3 principal physiographic regions across 7 states (Figures 4.6 and 4.7). The broad area covered gives good representation of job types and situations encountered by logging contractors across the region. Most of the participating contractors were from Georgia (32%), followed by South Carolina (17%), Virginia (17%), North Carolina (14%), Alabama (12%), Florida (5%), and Tennessee (3%). The two contractors who provided interview information, but not productivity and cost information, were located in Florida and Georgia.

Participating contractors were classified into the coastal plain, piedmont, and mountain physiographic regions, based on their mailing address and a physiographic region map developed through the 1979 American Pulpwood Association - Southern Pulpwood Producers Survey. The majority of the loggers were located in the coastal plain region (49%), followed by the piedmont (37%), and the mountains with (14%) (Figure 4.7).

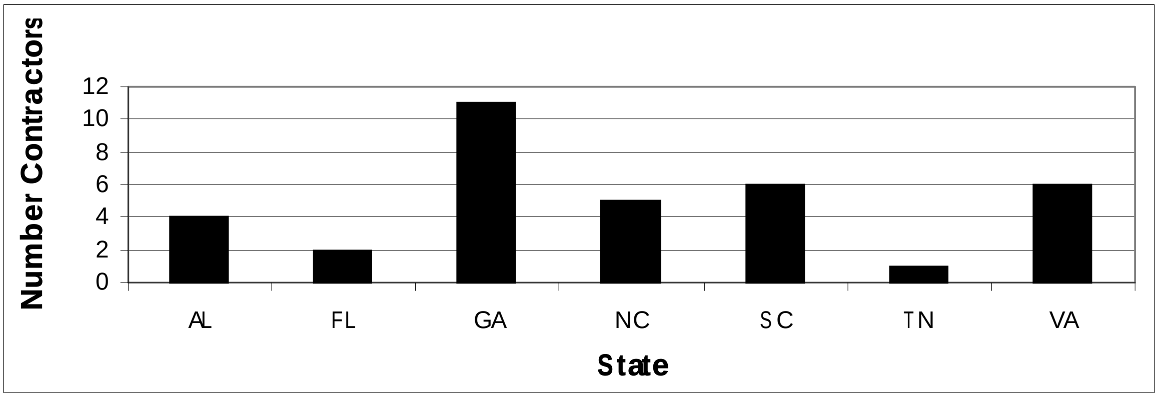


Figure 4.6 State of Operation for Participating Contractors.

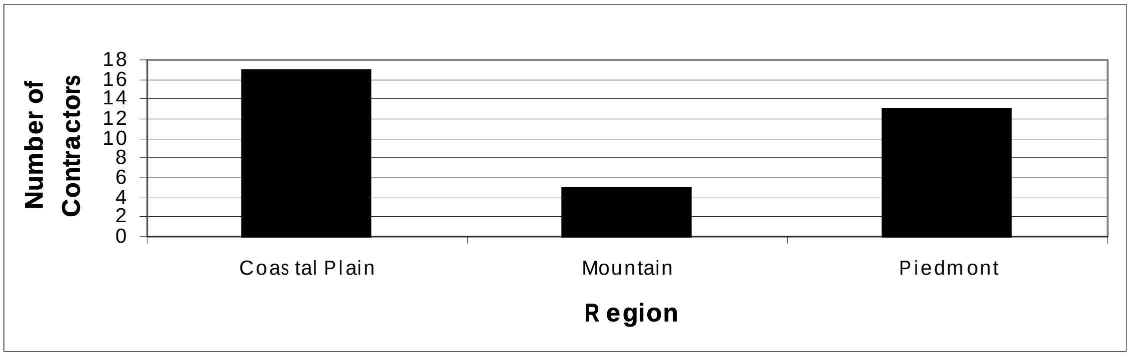


Figure 4.7 Region of Operation for Participating Contractors.

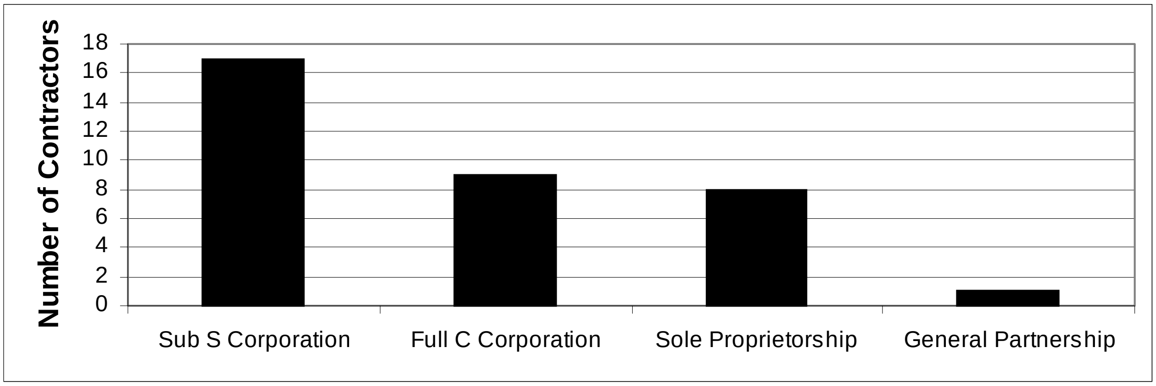
4.2 Business and Operation Characteristics

4.2.1 Business Organization

Four forms of business organization were found (Figure 4.8). Most of the contractors used S corporations (46%), followed by full C corporations (28%), sole proprietorships (23%), and general partnerships (3%).

Incorporation provides legal, tax, and insurance advantages. The legal advantages include personal liability reduction, primarily from truck accidents, and eased ownership transfer. The insurance advantages stem from the fact that the owner is an employee of the corporation and thus can be covered under its workers' compensation insurance. Tax advantages associated with incorporation include lease backs, income splitting, and minimizing the effect of the alternate minimum tax. At least one of the loggers using sole proprietorships or general partnerships was considering incorporation in the near future.

While incorporation has its advantages, it is not the most favorable business organization for all companies. Those who were not incorporated were trying to avoid the potential for increased paper work, added expense, or had not sought legal council on the matter.



4.8. Business Organization Types Used by Participating Contractors (Not including Contractor-Owned Trucking Companies).

4.2.2 Trucking Strategies and Business Organization

Trucking strategies can also be used to gain legal and insurance advantages. Some contractors either separated the trucking side of the business into another corporation or they used the services of trucking company owned by another party. Others preferred to keep things simpler by organizing the logging and trucking into one business.

By separating logging and trucking, contractors not only limit personal liability, but also limit the liability of the logging company from lawsuits resulting from trucking accidents and vice versa. This separation also has the advantage of lower workers' compensation insurance rates available to trucking companies.

The majority of the participating contractors (60%) had logging and trucking combined into one business. The remaining contractors either had logging and trucking organized in separate companies (26%) or they contracted all of their trucking (14%) (Figure 4.9).

Most of the contractors who had logging and trucking combined into one business were organized as sub S corporations (42%), followed by full C corporations (35%), sole proprietorships (14%), and a general partnership (Figure 4.10). Contractors who used the logging-only trucking strategy accounted for 2 full C corporations, 2 sole proprietorships, and a sub S Corporation.

Contractors who had separate logging and trucking companies utilized a combination of three business styles which included subchapter S corporations, full C corporations, and sole proprietorships (Figure 4.11). Three of these contractors used subchapter S corporations for both their logging and trucking businesses. Two contractors had their logging businesses organized as full C corporations and used sub S corporations for their trucking businesses. Two contractors also had both logging and trucking businesses organized as full C corporations. The remaining 2 contractors had their businesses organized as sole proprietorships.

Figure 4.9 Number of Contractors Utilizing Each of the Trucking Strategies.

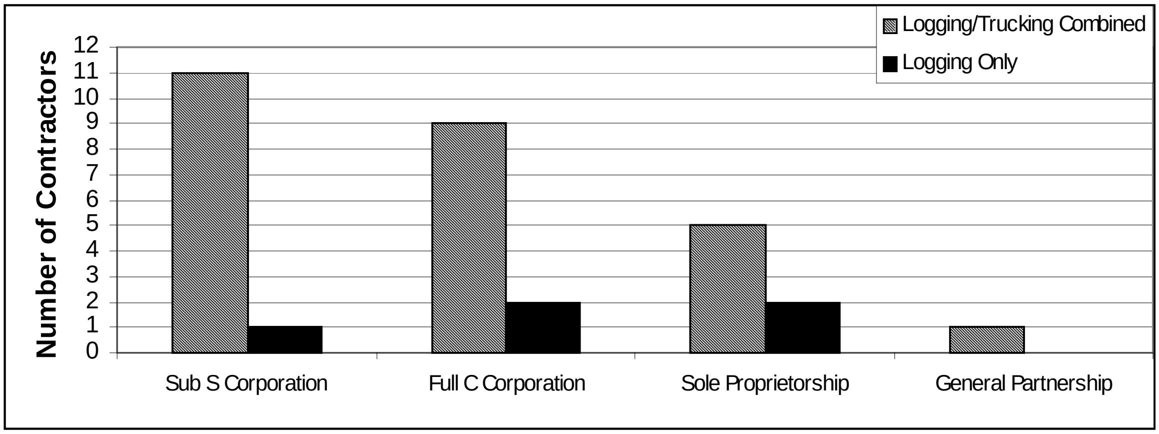


Figure 4.10. Business Organization for Contractors Using Logging and Trucking Combined in a Single Business and those Contracting All Trucking Out.

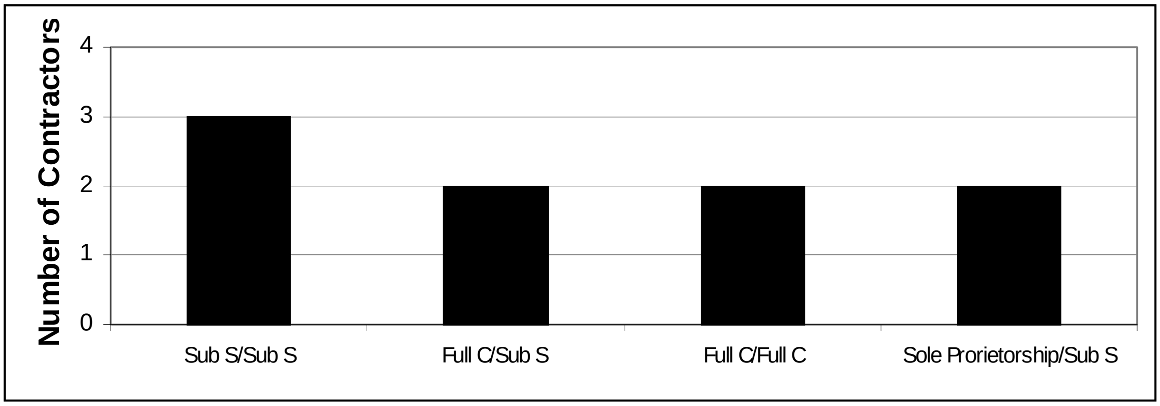


Figure 4.11. Business Organization for Contractors who have Separate Logging and Trucking Companies.

4.2.3 Stumpage Acquisition

The southeastern U.S. wood supply system has three primary sources of raw material including stumpage owned by wood-consuming mills (either from fee lands or company-owned timber deeds), stumpage purchased by wood dealers or brokerage firms, and stumpage purchased by the logging contractors.

The majority of the wood harvested by participating loggers was either provided by the wood-consuming companies or by wood dealers (Figure 4.12). A much smaller portion of the wood harvested was either owned or purchased by the contractors.

Wood-consuming companies and wood dealers furnished at least 75 percent of the stumpage harvested for 94 percent of the participating contractors. The remaining 6 percent represent 1 contractor. This contractor harvested a combination of stumpage furnished by the companies, wood dealers, and by his procurement forester. This contractor's total production was made up of 60 percent of stumpage purchased by his own procurement forester, and the remaining 40 percent was provided by several companies and wood dealers.

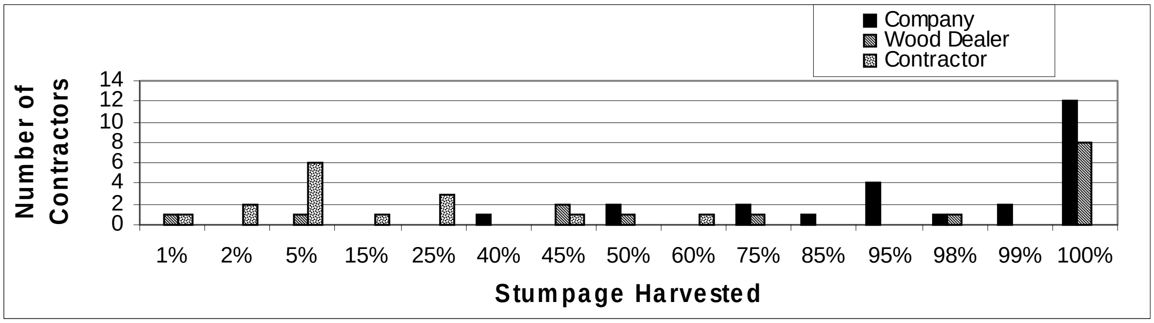


Figure 4.12 Sources of Stumpage Harvested by Participating Logging Contractors.

4.3 Labor

4.3.1 Number of Workers

The number of employees was a function of the type of harvest, region of operation, technology, production goals, and the number of support employees, which include bookkeepers, mechanics, and secretaries. The primary difference in technology was associated with delimbing and bucking. Many of the participating contractors used pull-through delimbers and slasher saws mounted on the knuckle boom loaders, which eliminates or reduces the need to have sawyers to perform these duties, resulting in fewer workers per crew.

The number of employees varied with operation size and production level (Figure 4.13). To achieve higher production, contractors often used more equipment and often used sawyers to perform delimbing and bucking, resulting in more men per crew.

A total of 312 workers were associated with the participating contractors, which included woods employees, truck drivers, contract truck drivers, and support employees (Figure 4.14). It was recognized that contract truckers are not the contractor’s employees, and their number often fluctuates with market conditions. An accurate estimate of the number of contract truckers was included because they are directly related to production.

The median number of workers was 12 and ranged from 5 to 46 (Figure 4.13). The interquartile range spread from 10 to 18 workers. These contractors had between 5 and 10 in-woods employees and 2 to 7 truck drivers, with medians of 7 and 4, respectively.

The 8 firms located within the first quartile (the bottom 25%) were geared toward lower production with 3 to 5 woods workers and 2 to 3 truckers. Of these firms 5 were family operations consisting of fathers, brothers, sons, and in-laws. Six of these contractors harvested plantation pine on company land, 2 specialized in plantation thinning. The remaining 2 contractors primarily clear-cut tracts purchased on the outside market.

All of the 8 contractors within the fourth quartile (the highest 25%) were geared toward high production with 8 to 26 woods employees, and 5 to 14 truck drivers. The median number of workers was 13 and 10 respectively. Five of these operations were multiple crew operations. These contractors clear-cut either company tracts, or tracts purchased on the outside market.

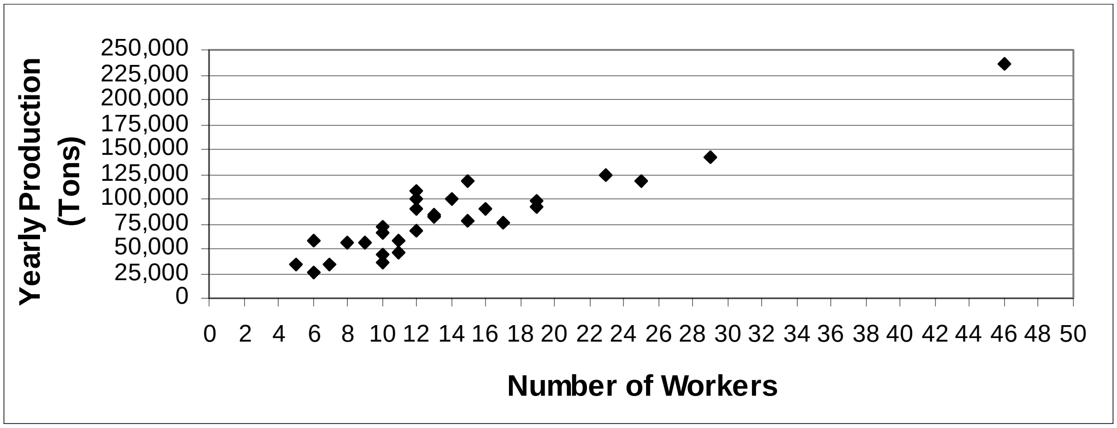


Figure 4.13. Relationship Between Production and Total Number of Workers for a Sample of Contractors (1996 Production Information).

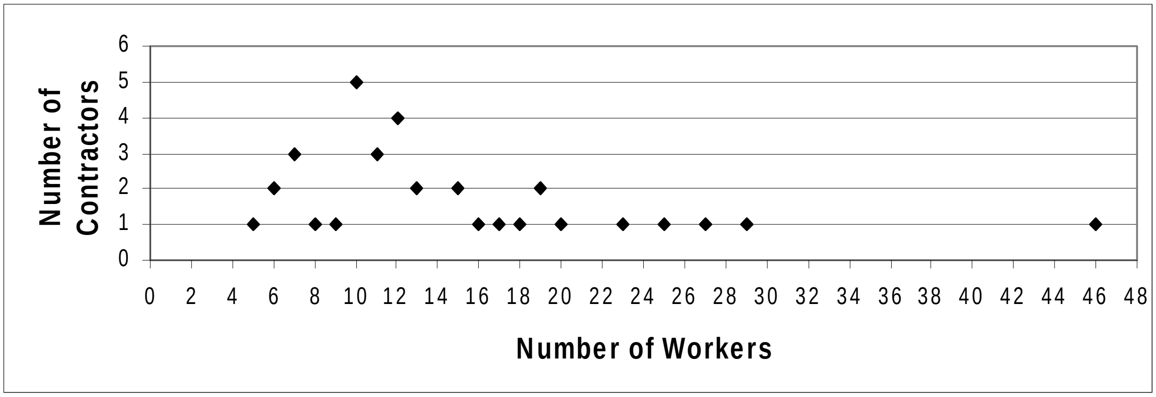


Figure 4.14. Total Number of Workers Associated with the Participating Contractors.

4.3.2 Crew Structure

The contractors had different philosophies regarding crew structure and size. Some contractors preferred multiple crew operations to take advantage of the possibility for increased production and flexibility. Other contractors preferred a single crew for better control over the operation, to make it as efficient as possible.

Twenty-nine of the 33 contractors ran one crew, 4 contractors operated 2 crews, 1 contractor operated 3 crews, and 1 contractor operated 4 crews (Figure 4.15). Three of the contractors downsized their operations from two to one crew during the course of the study. The three operations operated in different physiographic regions, but cited similar reasons for downsizing. These contractors determined they could be more efficient by consolidating their crews, avoiding the problems stemming from managing twice the labor and equipment, often with the crews working at great distances from one another.

Two contractors upgraded their operations during the study. One contractor increased in size from two crews to four, and the other grew from one to two crews. Both of these operations had a good group of employees, which facilitated expansion. Both were from the same area, which experienced industry expansion during the study. They were therefore, able to obtain contracts with more than one company, ensuring a supply of stumpage for each crew.

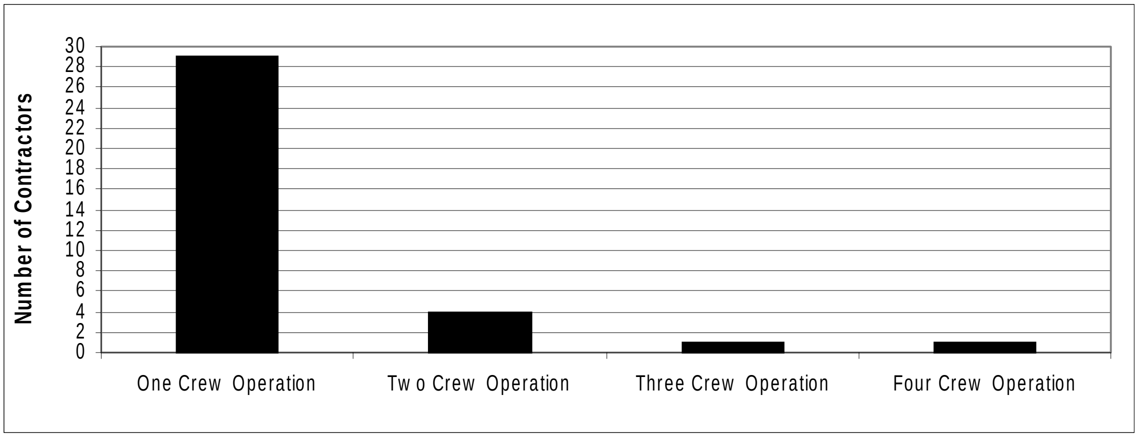


Figure 4.15. Number of Crews Employed by Participating Contractors

4.3.3 Crew Size

The number of workers per crew associated with in the woods and trucking operations will be discussed in this section. In multiple crew situations trucking was not separated along the same lines as the in-woods crews, only a total number of company employed, or contract truck drivers were collected. The trucking operations will therefore be considered as a single crew separate from the in-woods operations.

4.3.3.1 In-Woods Operations

In-woods crew size ranged from 3 to 11 men, with a median of 6 (Figure 4.16). The inter-quartile range was spanned 4 to 8 men per crew. A typical crew consisted of 1 loader operator, 1 to 3 skidder operators, 0 to 2 sawyers, 1 feller-buncher operator, and sometimes a supervising foreman.

The contractors within the first quartile (the bottom 25%) all had 3 employees per crew. All but one of these crews either thinned or clear-cut plantation pine. The remaining contractor harvested a combination of naturally regenerated stands, and plantation pine. Each of these contractors used pull-through type delimbers, eliminating the need for sawyers. These operations consisted of a loader operator, skidder operator, and feller-buncher operator. No sawyers were employed, and supervisors acted as machine operators.

The contractors within the fourth quartile (the upper 25%) had between 9 and 11 men per crew, with a median of 10. These loggers were geared toward higher production. These operations consisted of 1 to 2 loader operators, 2 to 3 skidder operators, 1 to 2 feller-buncher operators, 2 to 3 sawyers, and each had a supervising foreman.

4.3.3.2 Trucking Operations

The contractors used from 1 to 14 truckers, with a median of 4 (Figure 4.17). The inter-quartile range included contractors who used 3 to 6 trucks. Contracting firms who were within the inter-quartile range, had between 3 and 11 woods employees with a median of six. Estimated haul distances associated with these contractors ranged between 35 and 75 miles, with the median distance being 60 miles.

The contractors located in the first quartile, all used 2 trucks. The estimated haul distances for these loggers ranged between 30 and 85 miles, with the median distance of 45 miles. These operations had between 3 and 7 woods employees, with a median of 4.

Contractors, who were in fourth quartile, used between 7 and 14 truck drivers, with a median of 10. These contractors also employed 7 to 26 woods employees, with a median of 14 men. The estimated haul distance for these contractors ranged between 25 and 100 miles, with the median distance being 50 miles.

Haul distance, unloading time at the mill, and production level are all factors which influenced the number of trucks needed. Figure 4.18 shows the relationship between production and the number of logger employed truckers and contract truckers, for a sample of contractors during 1996. The number of truckers tends to increase with production, but the other factors such as haul distance and turn-around time have an effect.

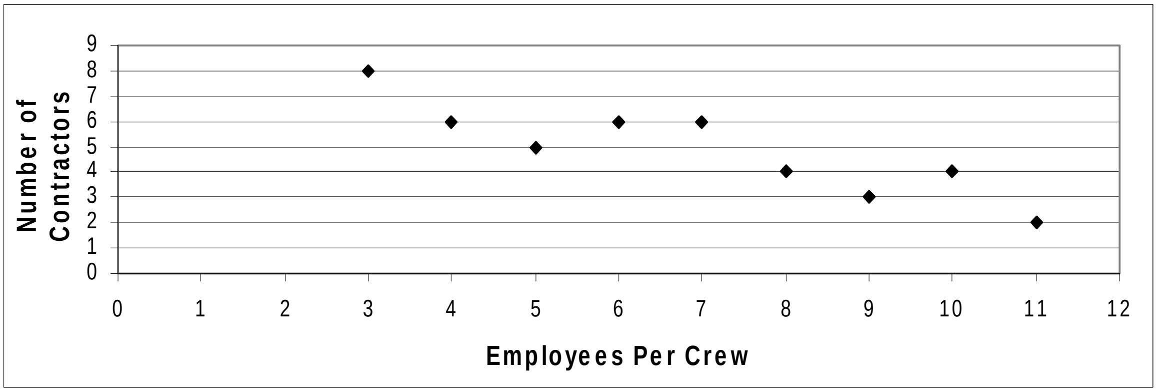


Figure 4.16. Number of Employees Associated with In-Woods Operations.

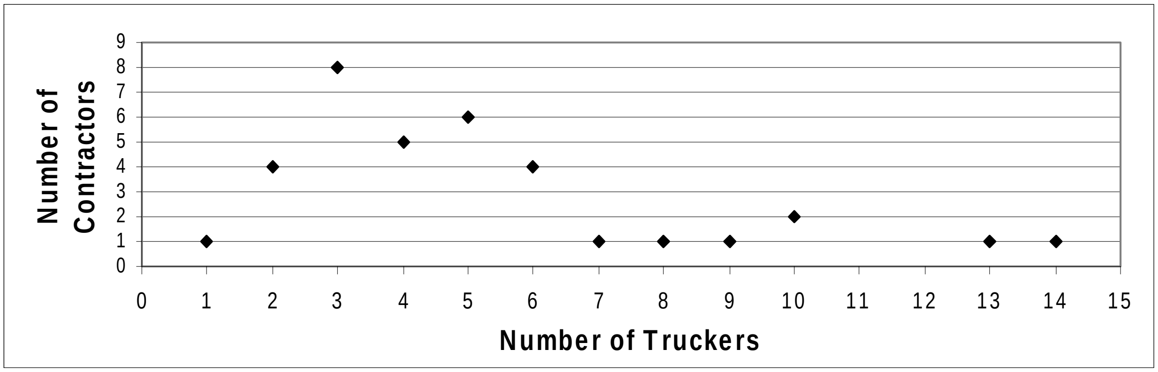


Figure 4.17. Number of Workers Associated with Trucking Operations.

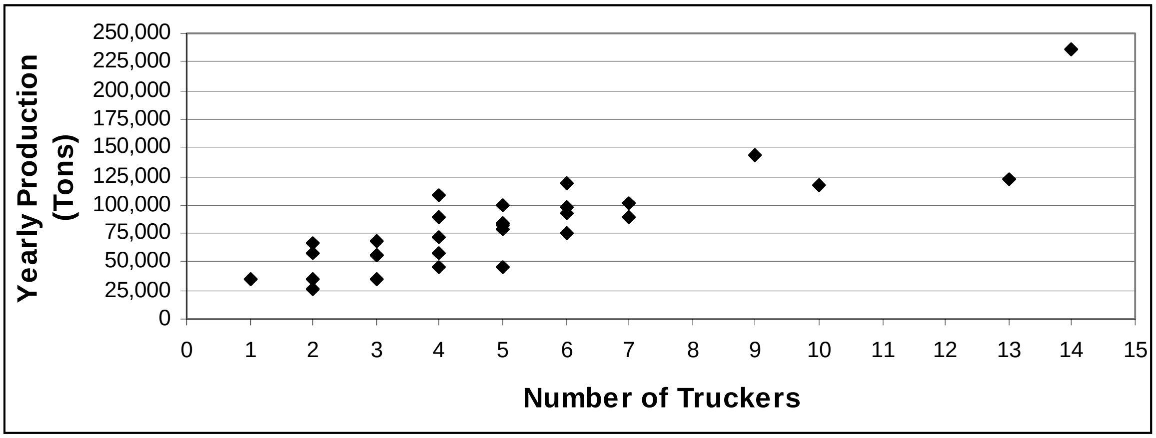


Figure 4.18. Relationship Between Production and Number of Truckers for Contractors (1996 Production Information).

4.3.4 Family Members

Over half of the contractors (54%) had family members associated with the in-woods or trucking operations (Figure 4.19). Family members included fathers, sons, brothers, and in-laws. Family participation ranged from 0 to 75 percent. The inter-quartile range spanned from 0 and 25 percent, with a median of 5 percent. Contractors with the highest percentage of family members tended to have smaller operations, with a range of 6 to 10 employees, with a median of 7.

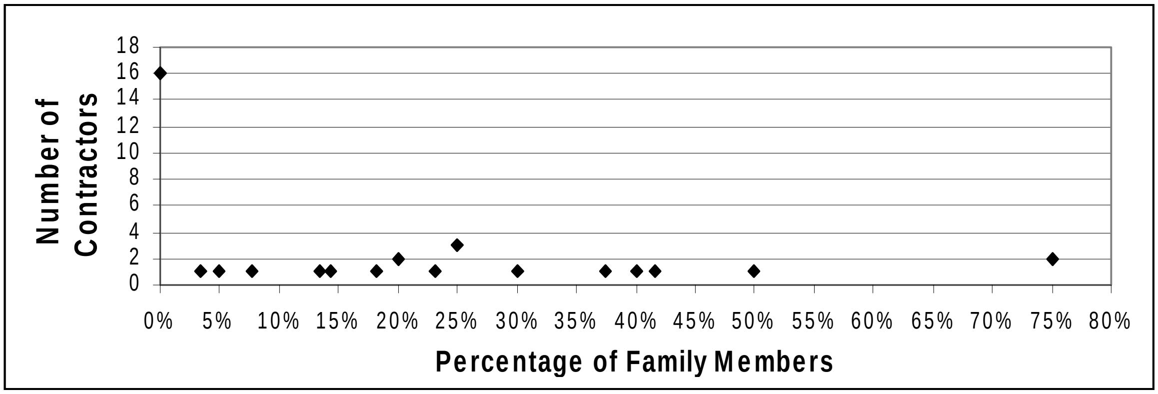


Figure 4.19. Percentage of Family Members Associated with the In-Woods and the Trucking Operations for Each Contractor.

4.3.5 Methods of Payment

A variety compensation methods were used. The most common included payment by the hour, on production basis, by the day, or by salary (Figure 4.20). The majority of participating contractors (77%) either paid employees by the hour or on a production basis. Twenty percent of the contractors paid employees by the day, the remaining contractor, used salaries.

Some contractors had alternative methods of payment for key employees. Seven of the contractors had key employees on salary, which in turn helped ensure their services for the future. One contractor paid truck drivers and woods workers on a difference basis. He paid his truck drivers by the mile while paying in-woods workers by production.

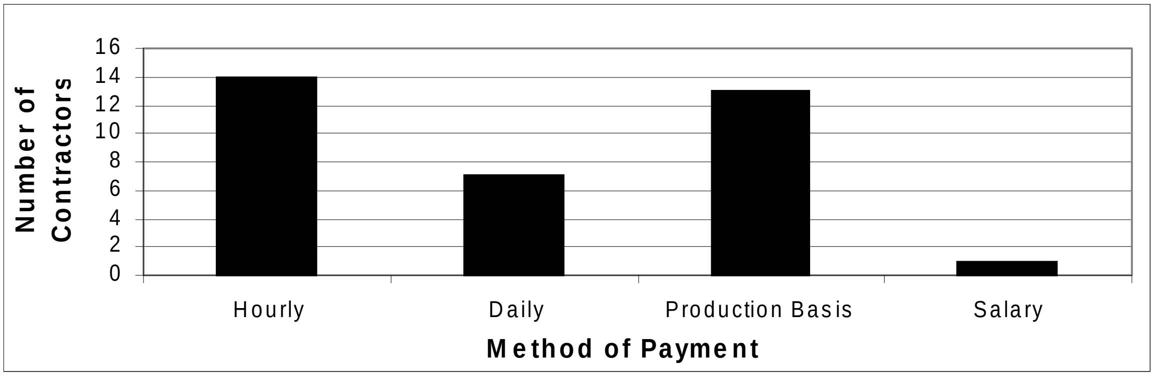


Figure 4.20. Payment Methods Used to by Participating Contractors.

4.3.6 Fringe Benefits

All contractors offered some type of employee benefits package to attract and keep qualified productive employees. Seven common employee benefits and the proportion of contractors who offered them are as follows: transportation to and from the logging site (77%), Christmas bonuses (74%), paid vacations (63%), employee financing or loans (54%), health insurance (34%), and retirement plans (8%) (Figure 4.21).

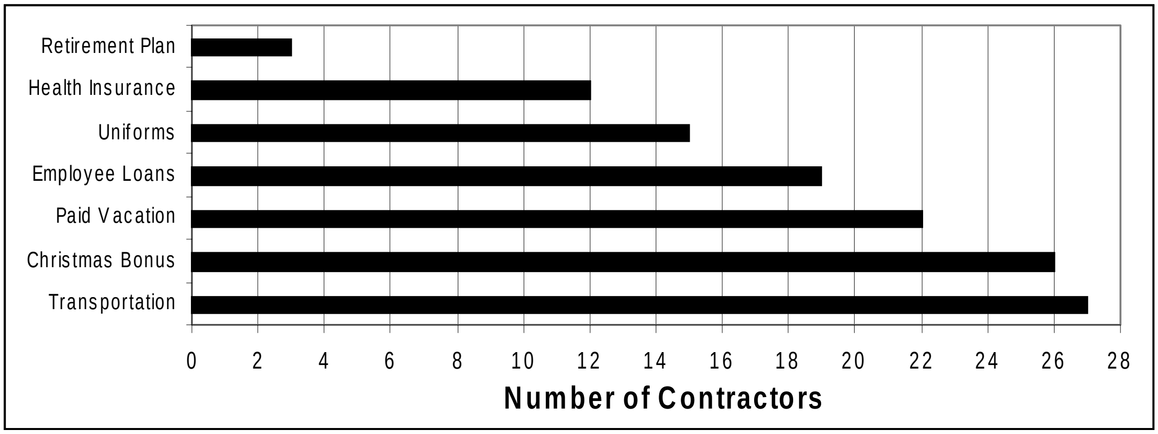


Figure 4.21. Employee Benefits Provided by Participating Contractors.

4.4 Process and Technology

4.4.1 Processes Employed

The contractors used similar operations and technology. The major technology difference was related to delimbing. The operations and technology used can be combined to form 3 different systems (Figure 4.22).

In system 1, the trees are felled and skidded to an intermediate landing away from the loader, where the limbs are removed. The trees are then skidded to the primary landing, where the trees are bucked and sorted, according to the species and product specifications, and then loaded onto tractor-trailers for delivery to market. All contractors using this system primarily hauled tree length material, except for some markets, such as hardwood sawmills, which required the trees to be bucked into specific lengths.

In System 2, the trees are felled, and skidded to a location near or on the primary landing where the limbs are removed. The trees are then bucked, and sorted depending on market specifications. Trees are then loaded and delivered to market.

Two participating contractors operating in extremely wet areas in the lower coastal plain used system 3. This system, referred to as shovel logging, allows tracts located in swampy areas to be harvested in an environmentally sound manner, while increasing the number of workable days in extremely wet conditions. The trees are felled in rows with feller-bunchers with high flotation excavator bases. The trees are laid trunk to crown along the length of the row; either with the feller-buncher, or with a knuckle boom loader on an excavator base. The skidders then pick this mat up working from the rear of the tract to the landing. The skidders never actually touch the ground in this system, reducing rutting, and increasing workable days. The trees are then bucked and sorted according to market specification, and loaded on tractor-trailers for delivery to market.

System 1 Fell ➡ Skid ➡ Delimb ➡ Skid ➡ Buck, Sort, Load ➡ Truck
System 2 Fell ➡ Skid ➡ Delimb ➡ Buck, Sort, Load ➡ Truck
System 3 Fell ➡ Shovel ➡ Skid ➡ Delimb ➡ Buck, Sort, Load ➡ Truck

Figure 4.22. Harvesting Systems Used by the Contractors.

4.4.2 Technology

4.4.2.1 Felling

Felling was accomplished entirely by mechanical means, using feller-bunchers equipped with either saw heads or shear heads. Seventy four percent of the contractors used saw-heads, while 26 percent used shear heads. The majority of contractors used feller-bunchers with rubber tire bases (89%). The remaining 11 percent used excavator-based machines to increase flotation, and reduce ground disturbance on extremely wet tracts.

The feller-bunchers ranged in model year from 1987 to 1997, with a median of 1995 (Figure 4.23). The inter-quartile range is between 1993 and 1996. The population is negatively skewed, evidenced by the fact that the median is located close to the 75th percentile. One-quarter of all the feller-bunchers were purchased in 1995, replacing machines manufactured in the late 1980’s and early 1990’s. Several contractors replaced equipment in 1996 and 1997, but at a lesser rate than in 1995. The reasons for this large reinvestment are largely unclear at this point, but could have been spurred by favorable economic conditions, mill expansion, or by necessity. The lower levels of reinvestment in felling equipment in 1996 and 1997 indicate that for loggers to continue to operate relatively new and productive equipment another large reinvestment should be expected in 1998 or 1999.

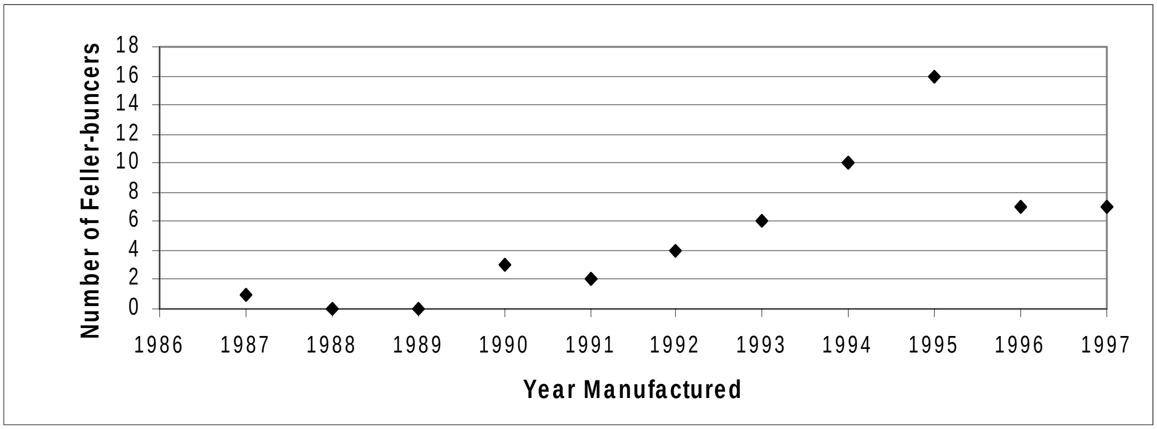


Figure 4.23. Age Distribution for Feller-Bunchers.

4.4.2.2 Skidding

All skidding was done with grapple skidders. The contractors used from 1 to 4 machines per crew. The year of manufacture ranged from 1986 to 1997 (Figure 4.24). The inter-quartile range of the ages of skidders was between 1993 and 1996, and the median year of manufacture was 1994.

Figure 4.24 indicates that large-scale replacement of skidders manufactured in the late 1980’s and early 1990’s occurred between 1993 and 1995. Reinvestment slacked off somewhat in 1996, but the level in 1997 was closer to that of 1994 and 1995. Another large-scale investment should be expected between 1998 and 2000 to replace the remaining skidders manufactured in the late 1980’s and early 1990’s.

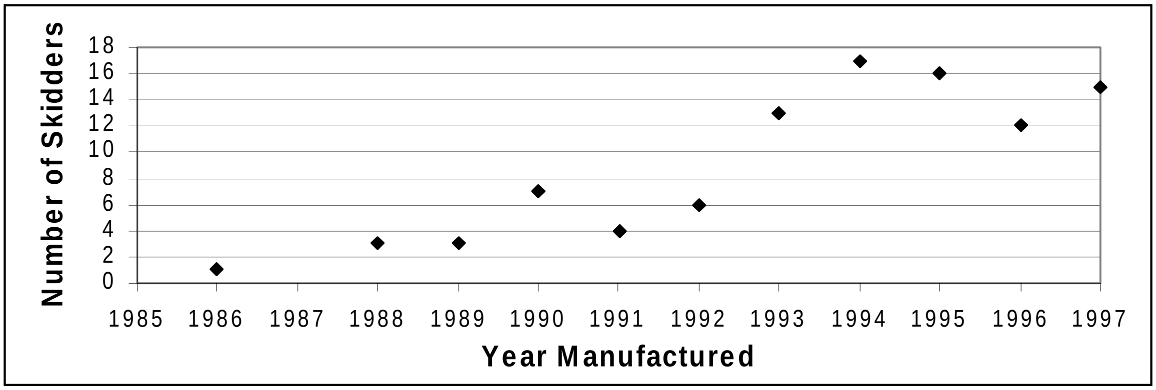


Figure 4.24. Age Distribution of Skidders.

4.4.2.3 Loading

The contractors used 1-2 knuckle boom loaders per crew. The years of manufacture ranged from 1989 to 1997, with a median of 1994 (Figure 4.25). The inter-quartile range of loggers was located between 1992 and 1996.

Figure 4.25 indicates that the age distribution associated with loaders was less negatively skewed than for mobile equipment. This implies that the loggers are able to operate loaders longer than skidders and feller-bunchers. Reinvestment had been fairly constant between 1993 through 1996, but 1997 marked a fairly significant drop off. The reasons behind this could be because loader reinvestment can be delayed longer than for other types of equipment because fewer are required per crew. Another large reinvestment should also be expected between 1998 and 2000.

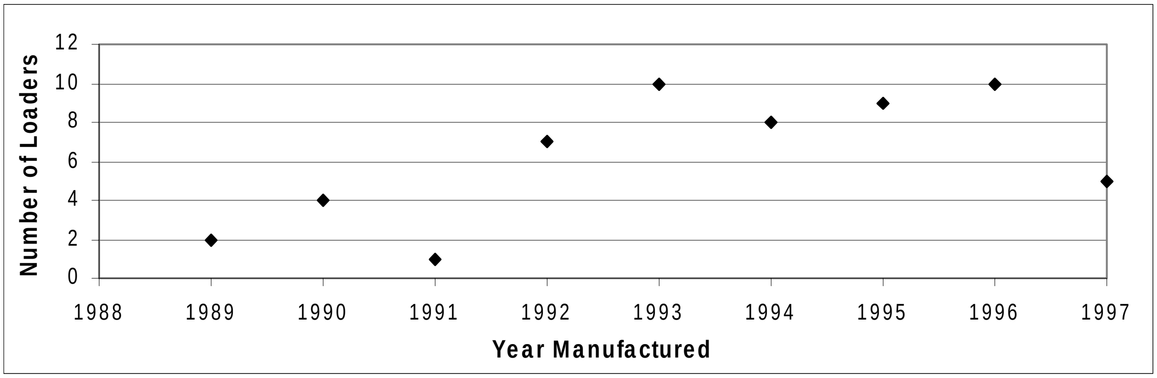


Figure 4.25. Age Distribution of Knuckle Boom Loaders.

4.4.2.4 Delimbing, Topping, and Bucking

Equipment used to delimb, top, and buck by the contractors depends on the size and species of timber being harvested. Many contractors who worked primarily with pine pulpwood chose to use gate delimbers, often in combination with sawyers or pull-through type delimbing machines. Contractors who harvested a large percentage of hardwood or large timber often relied on sawyers. Slasher saws often were used to buck hardwood or large timber. Slashers were also used to buck pulpwood into 5-foot lengths if markets required. These saws are equipped either with a bar and chain mechanism or a circular saw blade approximately 60 inches in diameter.

Many of the contractors used mechanical means to delimb, top, and buck trees where timber type and conditions permitted. Forty-nine percent of the contractors used pull-through type delimbers. Three of these loggers had multiple crew operations with 1 crew dedicated to harvesting pine pulpwood. Forty percent of the contractors used slasher saws to buck timber into logs or short-wood. The remaining 11 percent of the contractors removed limbs using a combination of gate delimbers and sawyers.

4.4.2.5 Trucking

All contractors hauled with tractor-trailer combinations. Trucks have a much longer life than other equipment used in logging. The trucks ranged in year of manufacture from 1980 to 1987 (Figure 4.26). The inter-quartile range was between 1988 and 1995, with a median located in 1992.

The truck age distribution resembled the distribution described in Loving (1991), with basically two populations represented. The first population included older model trucks ranging in age from 1980 to 1990. Repair and maintenance likely replaces equipment payments in this population. The next population included trucks ranging in model year from 1991 to 1997.

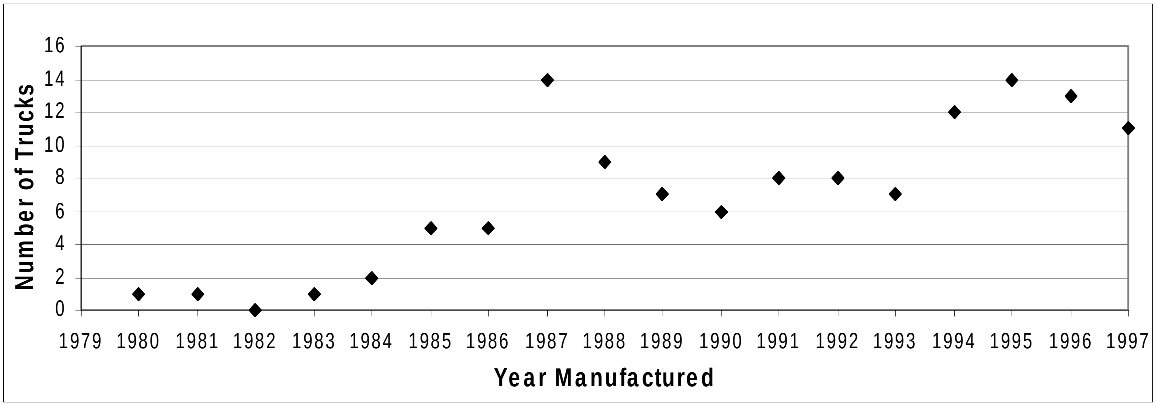


Figure 4.26. Age Distribution of Trucks Owned by the Contractors.

The age distribution of the trailers was more difficult to obtain than for the other equipment. Trailers last even longer than trucks. Therefore, contractors were often unable to determine the year of manufacture for each trailer. Figure 4.27 is a result of a sample of the trailers encountered. The year of manufacture ranged from 1972 to 1997, with a median of 1990. The inter-quartile range spanned from 1986 to 1994.

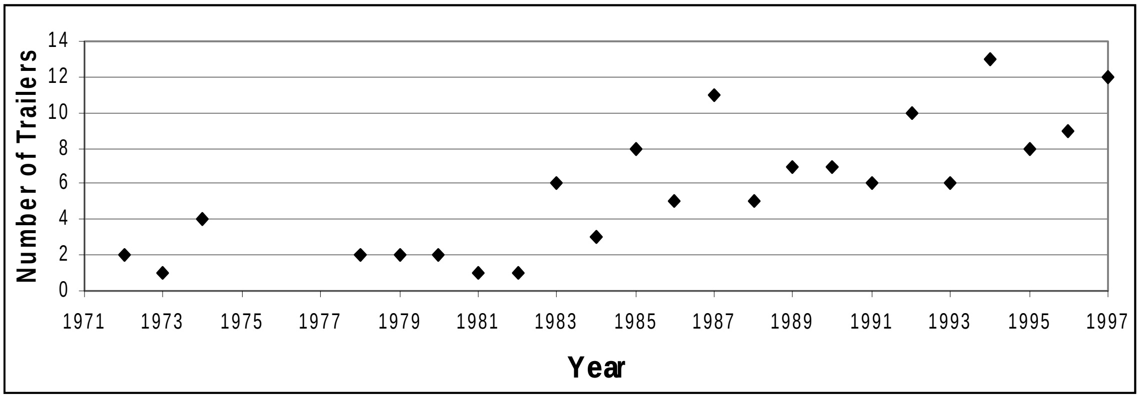


Figure 4.27. Age Distribution for a Sample of the Trailers Used by the Contractors.

4.5 Contractor Evolution

This section will examine the extent to which labor, business organization, and operation characteristics of the contractors have changed in the time period ranging from 1990 to 1997. This will be accomplished by focusing on the number of employees associated with each operation, fringe benefits provided, business organization, and the age distributions of the equipment used for a sample of 10 contractors who provided data in 1990 and in 1997. The 1990 data were collected by Loving (1991), and the 1997 data were collected through this study.

The Mann-Whitney rank sum test was used to determine if the sample of 10 contractors was representative of the entire population of 35 contractors (Table 4.1). The resulting p-values indicate that the samples representing the equipment age distributions and the number of employees of the contractors do not form different populations. Therefore, the samples are adequate representations of the operational and labor data from the entire population.

Table 4.1. Mann-Whitney Rank Sum Test Results Comparing the Operational and Employee Information from the Sample and the Remaining Contractors.

Sample vs. Remaining Contractors	P-Value
Feller-Buncher Age Distribution	0.9479
Skidder Age Distribution	0.7899
Loader Age Distribution	0.5857
Truck Age Distribution	0.9612
Total Number of Employees	0.2278
Number of In-Woods Employees	0.1172
Number of Truck Drivers	0.9112

4.5.1 Labor Evolution

4.5.1.1 Method of Payment and Fringe Benefits

There is very little difference in the methods of payment used in 1990 and 1997 (Figure 4.28). Some changes did take place though. One contractor switched from payment on production to payment by salary. Another contractor switched from paying by the day to paying by the hour in 1997. One contractor paid employees by the hour and production in 1990 and was paying exclusively by production in 1997. One contractor, who paid solely by salary in 1990, was paying new employees by the hour and more experienced employees by salary in 1997.

There were only a few changes in the employee benefits offered by the 10 contractors (Figure 4.29). Some contractors added and some reduced the number of benefits offered, but overall the total number of benefits offered stayed the same from 1990 to 1997. Two more contractors offered production bonuses in 1997 than in 1990. One fewer contractor offered Christmas bonuses in 1997. Two fewer contractors offered health insurance in 1997. One more contractor offered paid vacations and employee loans, respectively. One fewer contractor offered transportation to and from the job site in 1997, and the same number of contractors provided uniforms.

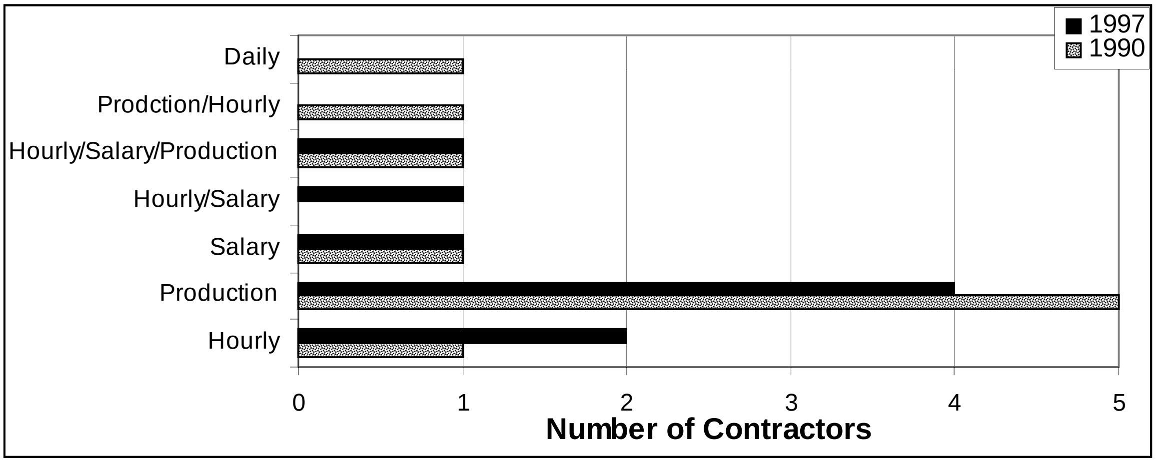


Figure 4.28. Method Payment in 1990 and 1997 for the 10 Contractor Sample.

Figure 4.29. Fringe Benefits Provided in 1990 and 1997 by the 10-Contractor Sample.

4.5.1.2 Number of Employees

The 10 contractors employed 82 people in both 1990 and 1997. Even though the total number of contractors remained the same, the mix within the businesses changed. There was a slight shift of workers from the in-woods operations to the trucking operations. The number of in-woods workers fell from 60 in 1990 to 56 in 1997. The number of truck drivers employed increased from 20 in 1990 to 25 in 1997. The number of sawyers used to perform delimbing duties dropped from 17 in 1990 to 9 in 1997. Also, one fewer contractor employed a mechanic in 1997. It should be noted that bookkeepers and secretaries were not included in this analysis.

The Mann-Whitney rank sum test was performed on each set of observations to determine if any were statistically different. As the results in Table 4.2 reveal, there is little or no evidence suggesting that the number of workers associated with each operation has changed between 1990 and 1997.

Table 4.2. Mann-Whitney Rank Sum Test Results Comparing Employee Information from the Sample and the Remaining Contractors.

Employee Responsibility	P-Values
Total Number of Employees	0.5967
Truck Drivers	0.5623
In-Woods Employees	0.8760
Sawyers	0.4324

4.5.2 Operations Evolution

The operations evolution of the sample of 10 contractors was judged by shifts associated with business organization, stumpage acquisition, and age distributions of the equipment used.

4.5.2.1 Business Organization and Stumpage Acquisition

There was very little business organization change between 1990 and 1997 for the sample of 10 contractors. One contractor separated his trucking into a separate corporation, and two contractors switched from sole proprietorships to sub chapter S corporations. These changes resulted in 50 percent of the contractors organized as sole proprietorships, 40 percent organized as sub chapter S corporations, and 10 percent organized as full C corporations.

As discussed in section 4.2.3, the stumpage harvested by participating contractors comes from forest products companies, wood dealers, and the contractors themselves. Estimates from the sample of 10 contractors were used to determine if the proportion of contractor-owned stumpage increased from 1990 to 1997 (Figure 4.30). The contractors appeared to be harvesting more of their own stumpage in 1997. The median was 3 percent in 1990 and 3.5 percent in 1997. The 1990 inter-quartile range was between 0 percent and 6 percent in 1990 and between 2 percent and 11 percent in 1997. Even though this shift occurred, results from the Mann-Whitney rank sum test indicate no significant difference between the two samples at the 95 percent confidence level (Table 4.3).

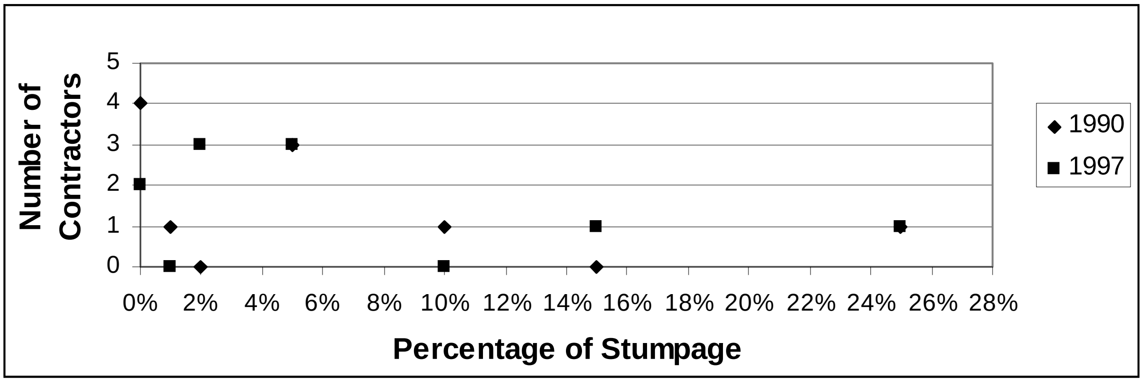


Figure 4.30. Proportion of the Total Production Made up of Contractor Owned Stumpage.

4.5.2.2 Equipment Age Distributions

The median age of the feller-bunchers operated in 1990 was 2.5 years compared to 2 years in 1997. The most noticeable difference between the two populations was the inter-quartile ranges, which in 1990 was between 1.25 and 5 years, and between 1.75 and 3.75 years in 1997. The inter-quartile range tightened in 1997, which is shown graphically with the boxplot included in Figure 4.31.

Boxplots show the location of the median, 25th percentile, the 75th percentile, and also the location of observations outside the inter-quartile range. The bottom of the box included in Figure 4.31, represents the location of the 25th percentile. The top of the box represents the location of the 75th percentile. The line drawn inside the box represents the median. The lines above and below the box extend to the largest and smallest observations, considered adjacent to the inter-quartile range. These adjacent observations are located within the upper or lower limits, defined as plus or minus 1.5 times the inter-quartile range. The asterisks represent outliers, which lie outside the upper or lower limits.

Figure 4.31 indicates that the contractors operated slightly newer equipment in 1997, even though the results from the Mann-Whitney rank sum test at the 95 percent confidence interval indicated no significant difference (Table 4.3). This difference could indicate that the contractors are now better equipped to operate in wet conditions, or it could be attributed to the fact that the 1990 survey was conducted during the first part of the year, and the 1997 survey was conducted at the beginning of 1998.

The median age of the skidders operated in 1990 was 4 years and 3 years in 1997. The inter-quartile range in 1990 was between 1.5 and 6 years, and 1 and 5.5 years in 1997 (Figure 4.32). This also indicates that the contractors operated slightly newer equipment in 1997 than in 1990, even though again the Mann-Whitney test indicated no significant difference at the 95 percent confidence level. As with the feller-bunchers, the difference could indicate that the contractors are now better equipped to operate in wet conditions, or it could be attributed to the time of year the surveys were conducted.

Analysis of the knuckle-boom loaders used in 1990 and 1997 reveals a large difference. The median age of loaders in 1990 was 5.5 years in 1990 and 2 years in 1997. The inter-quartile range in 1990 was between 3 and 12 years and between 1 and 5 years in 1997 (Figure 4.33). The results from the Mann-Whitney test indicated that the two samples are significantly different at the 95 percent confidence level (Table 4.3). This could indicate that loggers are operating newer, more powerful loaders to complement the increase in loader-mounted delimbing equipment.

The median age of the trucks used by the contractors in 1990 was 10 years and 5 years in 1997. The inter-quartile range for trucks operated in 1990 were between 6 and 12 and between 2 and 9 years in 1997 (Figure 4.34). The results from the Mann-Whitney test again indicate a significant difference between the trucks operated in 1990 and those in 1997 at the 95 percent confidence level. The decrease in truck age could be due to increased highway regulations to ensure truck safety. This may also be due to the fact that contractors seem to be realizing that the trucking side of the business is the most visible part of the business, and they are taking greater pride by using newer well maintained equipment.

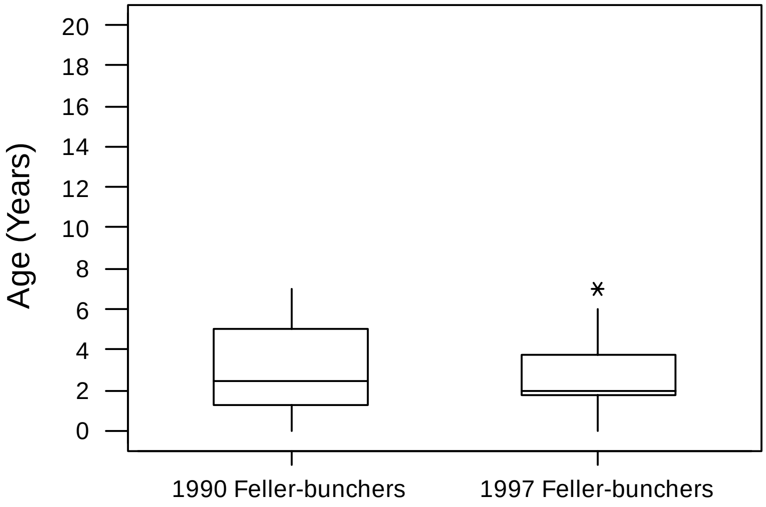


Figure 4.31. Boxplots of the Age Distributions of Feller-Bunchers in 1990 and 1997

Figure 4.32. Boxplots of the Age Distributions of Skidders Used by the Sample of 10 Contractors in 1990 and 1997.

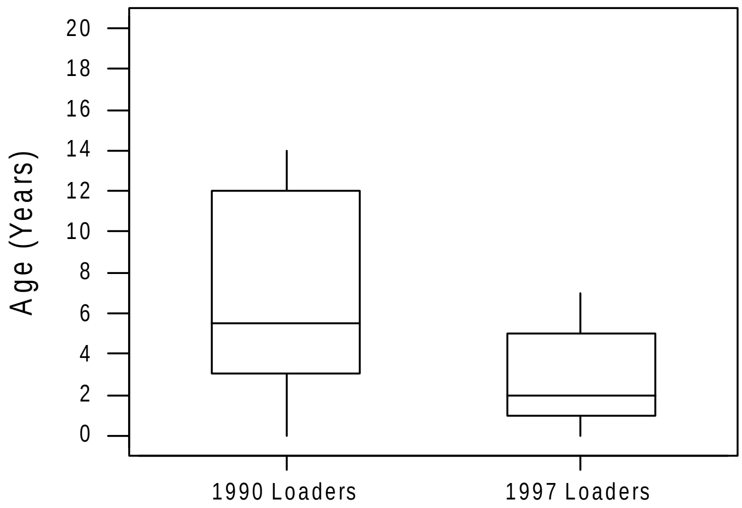


Figure 4.33. Boxplots of the Age Distributions of Knuckle-Boom Loaders Used by the Sample of 10 Contractors in 1990 and 1997.

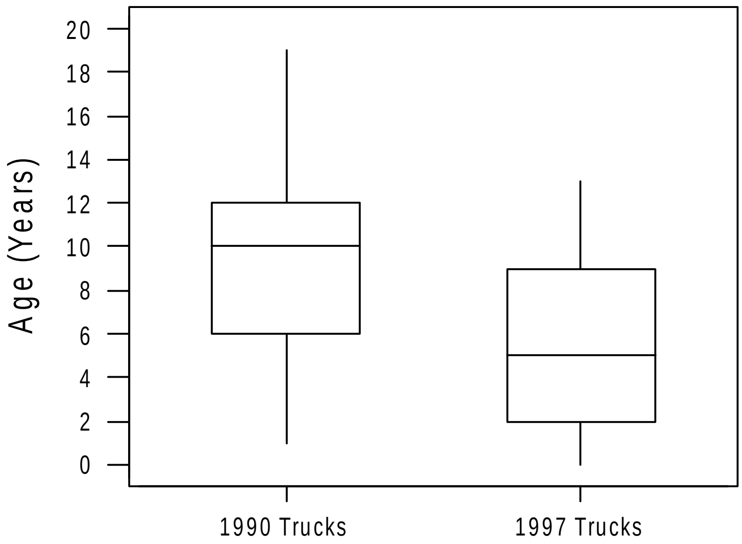


Figure 4.34. Boxplots of the Age Distributions of Trucks used by the Sample of 10 Contractors in 1990 and 1997.

Table 4.3. Mann-Whitney Rank Test Results Comparing Operation Information from the Sample and the Remaining Contractors.

Operational Characteristics	P-Value
Stumpage	0.5107
Feller-Bunchers	0.8432
Skidders	0.3980
Loaders	0.0427
Trucks	0.0023

4.6 Summary

This chapter includes analysis of the demographic, business, and operational characteristics of the 35 logging contractors, representing 7 southeastern U.S. states. The ages of the contractors ranged from 31 to 65 years, with a median of 47. The inter-quartile range was between 41 and 53 years. The contractors had 3 to 38 years of experience, with a median of 19 years. The inter-quartile range was between 10 and 24 years of experience.

All contractors had at least some high school education, with only 2 not graduating. Twelve contractors received at least some college education, 2 of whom received associate’s college degrees, and 6 received bachelor’s degrees. There was weak evidence that older contractors were less educated, since the only contractors not receiving high school diplomas were over 50 years old. Also, all contractors receiving associate’s degrees and 66 percent of the contractors receiving bachelor’s degrees were under 50 years old. Most contractors received little, if any, education after high school graduation. This points out that high school education is necessary in running a business today and that the profession has not been successful in attracting individuals with higher education possibly due to the challenging business and environmental conditions encountered in logging.

The most popular business organization style was the subchapter S corporation, used by 46 percent of the contractors, followed by full C corporations (28%), sole proprietorships (23%), and general partnerships (3%). The contractors used three separate trucking strategies. Sixty percent had logging and trucking combined into one business, 26 percent had logging and trucking organized in separate companies, and 14 percent contracted all trucking out. Either wood consuming companies or wood dealers supplied 75 percent or more of the total production for 94 percent of the participating contractors.

The number of workers associated with each operation depended on the type of harvest, region of operation, technology used, production goals, and the number of support employees utilized. The number of workers ranged from 5 to 46, with the median being 12. The majority of contractors (82 %) operated 1-crew operations. Three crews downsized from 2 to 1 crews during the study, and 2 added crews. Three to 11 workers were associated with each in-woods crew, with a median of 6. The inter-quartile range included 4-8 men per crew. The number of truck drivers ranged from 1 to 14 with a median of 4. The inter-quartile range included contractors with 3 to 6 trucks. The number of truckers associated with each crew is felt to be related to haul distance, turn-around time, and production level.

Over half of the contractors (54%) had family members associated with the operations. The proportion of family members per operation ranged from 0 to 75 percent, with a median of 5 percent. The inter-quartile range included firms with between 0 and 25 percent.

The methods used to compensate employees included production basis, hourly, salary, or by the number of days per pay period. The majority of the contractors (77%) paid by the hour, or by production, followed by daily (20%), and salary (3%). The 7 most common fringe benefits offered by contractors include transportation to and from the logging site (77%), Christmas Bonuses (74%), paid vacations (63%), employee financing (54%), health insurance (34%), and retirement plans (8%).

All contractors used similar operations and technology to complete the harvesting process. The operations and technology were combined to create three separate harvesting systems, which varied depending on methods used to delimb, and tract conditions encountered.

The evolution of contractor labor, business, organization, and operation characteristics were tracked by analyzing data provided by a set of contractors in 1990 and 1997. Mann-Whitney tests were used to test population differences.

There were no significant changes in payment method, the number of employees, business organization, or stumpage acquisition. There were significant differences associated with the age distributions of some of the equipment. Contractors tended to operate newer equipment in 1997 than in 1990. There were significant differences in the age distributions of the loaders and trucks. The purchase of new loaders could be because contractors are buying newer more powerful loaders to complement loader-mounted delimbing equipment. The newer trucks could reflect increased highway safety regulation and enforcement, or because the contractors are taking greater pride in the trucking side of the business.

The discussion in this chapter identified several contractor characteristics, operating strategies, business strategies, and other issues, which could potentially affect contractor performance. These topics which primarily include age, education, region of operation, business organization, trucking strategies, size of operation, and equipment spread management, will be used, along with other issues, to analyze contractor efficiency in Chapter 7.

Chapter 5 PRODUCTIVITY ANALYSIS

Productivity was measured by the green tons of wood delivered to market in a week, month, or year. This measure was chosen because it is closely related to cash flows and reflects the interaction between contractor performance and mill inventories (Stuart and Grace 1998). The factors affecting the productivity of logging contractors must be understood before starting the efficiency analysis. The purpose of this chapter is to provide background for the contractor efficiency discussion by exploring productivity variability, quarterly and yearly productivity trends, and productivity capacity utilization.

5.1 Productivity Variation

Productivity variation has a definite effect on contractor performance (efficiency). Many fixed costs, such as administrative overhead expenses, equipment payments, and labor expenses, accumulate even when nothing is delivered to the mill. When production is lost it can never truly be regained. Longer hours must be worked, which increases variable costs by putting additional stress on employees and equipment. Efficiency is likely to suffer when a contractor's production fluctuates from high to low levels.

Stuart and Grace (1997) identified 5 forces, technical, organizational, natural, administrative, and regulatory, which influence productivity variation (Section 1.3). The effects of these forces cause many contractors to build in a certain amount of elasticity into their operations. Elasticity as it relates to the logging industry refers to the ability of contractors to increase, or decrease production according to the effects of the forces affecting productivity (Loving 1991). The contractors included in the study were categorized into three operating strategies, upward elastic, downward elastic, or inelastic.

Downward elasticity requires foregoing technology to reduce time-based or fixed costs. Upward elasticity requires maintaining extra resources for use when the opportunity arises. Inelastic refers to operations, which maintain a fairly consistent level of production and manage the operation around that level of output.

Weekly productivity information was available from 20 contractors that could be used in the variation analysis. The contractors were divided into the 3 groups, by using box plots of 1995 and 1996 data, coefficients of variation, average productivity compared to the maximum production level, and the average compared to the production level of the 25th percentile. Data for the individual years were included to ensure that there were no technological changes in the contractors' systems. Twelve of the contractors fit the criteria of upwardly elastic, 5 were classed as inelastic contractors, and 3 were downwardly elastic. The contractors are separated into the 3 groups by the boxplots in Figure 5.1. A description of boxplots is included in section 4.5.2.2. Going from left to right, contractors 002-901 were inelastic, contractors 102-701 were downwardly elastic, and contractors 904-805 were upwardly elastic.

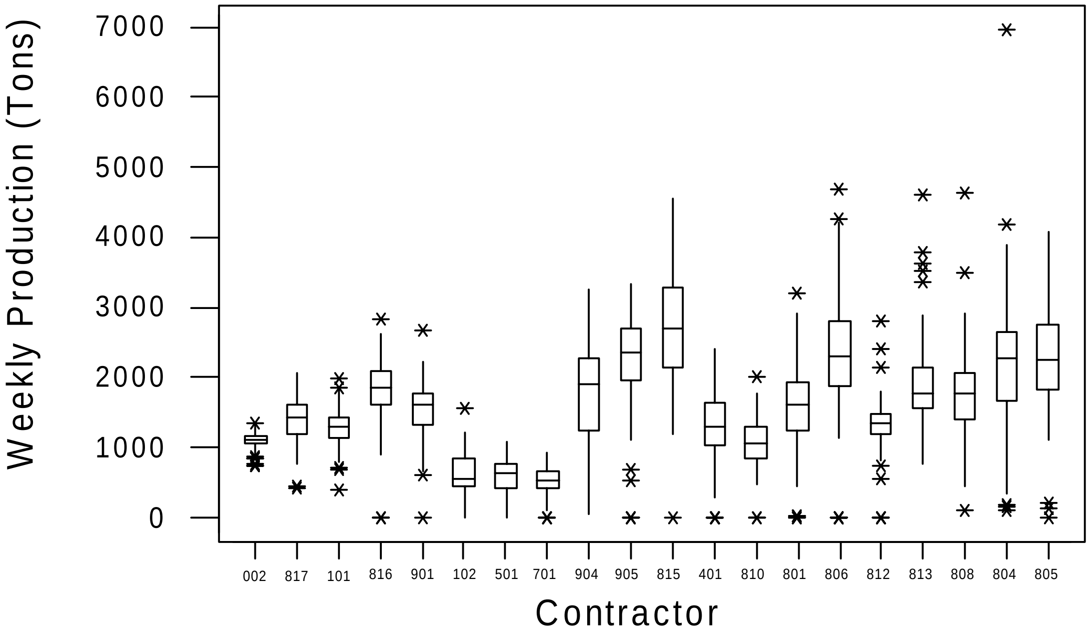


Figure 5.1. Boxplots for the 20 Contractors Providing 1995-1996 Weekly Productivity Information.

5.1.1 Upwardly Elastic Operation Strategy

The contractors in the upwardly elastic operating strategy were well equipped and geared toward moderate to high production. They produced between 54,832 and 232,609 tons during 1995 and 1996. The periods of highest production ranged from 150 to 320 percent of the average, and the 25th percentile was located between 12 and 24 percent of the average. Coefficients of variation, the standard deviation divided by the mean, ranged from 30 to 43 percent, due to the fact that contractors included tended to have production patterns with alternating periods of low and high production. This pattern symbolized the ability of the contractors to recoup some losses by increasing production when conditions permitted.

Figures 5.3 and 5.4 are a run chart and a cumulative sum chart (cusum) of 1995-1996 production for contractor 810, which is an example of an upward elastic operating strategy. The run chart tracks the weekly production, Monday through Saturday. The cumulative sum (cusum) chart represents the contractor’s position relative to the average weekly production, referred to as the wood balance. Cusums are generated in two steps. First, the average weekly production is subtracted from each week’s production. The difference for each week is then added algebraically week by week, giving the contractor’s status relative to his goal, or average production, on a weekly basis.

Average production for 1995 and 1996 was 1,064 tons per week for contractor 810. The inter-quartile range was between 858 and 1,310 tons per week, and the median production was 1,053 tons per week.

Production was slightly below average during January of 1995, with production steadily increasing until the first of February (Figure 5.2). February was marked by moderate swings from low to high production caused by winter weather. The contractor then exercised his upward elasticity ability in early April, taking advantage of favorable operating conditions to increase production to more than 180 percent of the 1995 and 1996 average. Production then took a down turn for the next two weeks, before returning to the routine of weeks of low production followed by weeks of increased production. This pattern was interrupted with two weeks of no production in July and September. The low to high pattern continued through the end of the year, but the lows and highs became more pronounced, possibly due to the relaxing of production quotas by the wood-consuming mill, the onset of winter weather, or the Christmas holidays. The low to high pattern may indicate that he continued to log during periods of low production, but was unable to deliver the output. In-woods inventories likely were built which were trucked and delivered the next week.

The next year began much as 1995 did, with low production followed by several weeks of higher production. The low to high pattern then set in, with the contractor using his upward elasticity ability on several occasions. The contractor’s upward elasticity was stifled in September when the wood-consuming mill applied production quotas. The mill relaxed the quotas in early November, allowing the contractor to increase production.

Production dipped somewhat at the end of the year due to hunting season, weather, Thanksgiving, or the Christmas holidays.

The cusum in Figure 5.3 shows that Contractor 810's wood balance (actual production relative to the average) was positive for the first 6 months of 1995. The 2 weeks with no production started a down turn, which was followed by periods of quota, eroding the wood balance over the next 6 months. An upward trend then started with an opportunity to increase production between February and June of 1996. The effect of production quotas in August and September again caused the downward trend for the next 6 months of the year, then increased production as the mill built inventory, caused production to be above average. A combination of weather, hunting season, and the holidays more than likely caused production to drop, ending the year at the average production level.

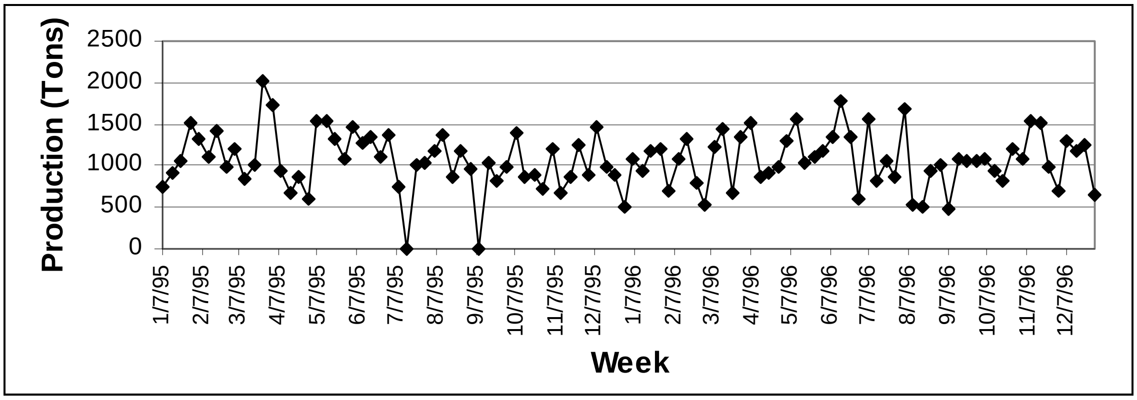


Figure 5.2. Run Chart of 1995-1996 Weekly Production for Contractor 810.

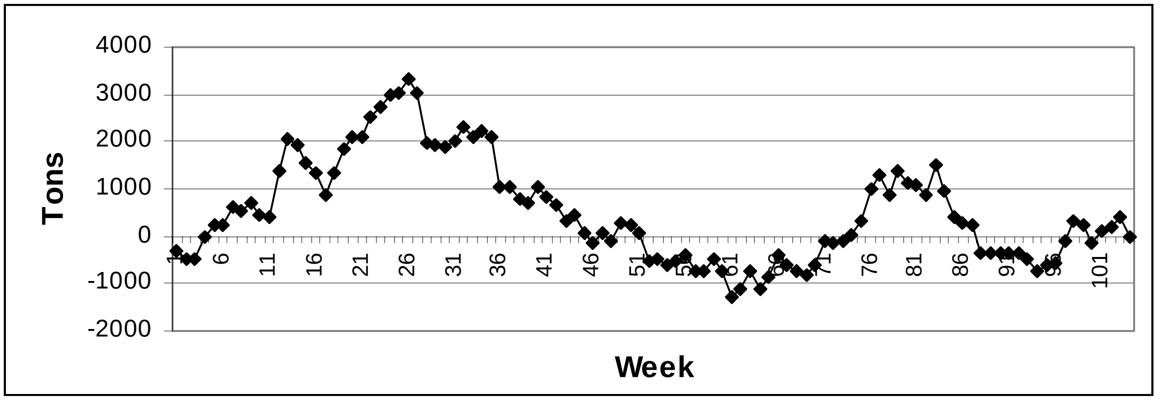


Figure 5.3. Cumulative Sum (Cusum) Chart of 1995-1996 Weekly Production for Contractor 810.

5.1.2 Downwardly Elastic Operation Strategy

The contractors considered downwardly elastic were relatively small contractors geared toward low production, with 3 to 4 woods workers, and 1 to 3 truck drivers. These contractors operated in the mountains and in the piedmont regions. One contractor specialized in plantation pine thinning, making him more sensitive to weather.

These contractors produced between 26,995 and 35,194 tons per year during 1995 and 1996, with coefficients of variation between 38 and 45 percent. Their highest point of production was between 175 and 242 percent of the average. The 25th percentile was located between 22 and 28 percent of the average. Even though these contractors had the ability to increase production, their operations were primarily geared to operate at low production levels. (Figure 5.1).

A run chart and a cusum chart of 1996 production for contractor 102 are included in Figures 5.4 and 5.5. Only 1996 productivity information is shown, as 1995 weekly information was not available.

This contractor chose to operate older equipment. The contractor had two older skidders; one could be left idle during periods of low demand or poor weather, or they both could be pressed into service when the opportunity to produce arose, giving the contractor a certain degree of upward elasticity. Even with this reserve built into the operation, the contractor was capable of operating for extended periods below his average production level. Average production for contractor 102 in 1996 was 645.9 tons per week, with a coefficient of variation of 39.7 percent. The inter-quartile range was between 463.1 and 848.4 tons per week, with the median located at 563.5 tons per week.

Contractor 102 started 1996 slightly below his average weekly production (Figure 5.4). Production increased for the next three weeks before peaking at 190 percent of the average. A cycle of low to high production then began and continued until the beginning of June. The low points of this cycle included 2 weeks with no production, and a week with 252 tons. The high points of this cycle were two weeks with production of 1,566 tons and 1,018 tons. After this cycle, a period of production quota set in, revealing the contractor’s downward elasticity. Only 5 of the next 25 weeks, ending in late November, had production levels above the average. Three of these weeks had production at 50 percent of his average, and the remaining weeks were slightly below average. Production for the remaining 6 weeks of the year increased to at least 122 percent of the average, as the mill began building winter inventories. The year ended with somewhat lower production, likely due to weather and the holidays.

Figure 5.5 shows the 1996 wood balance. The two weeks of extremely high production in the first quarter of 1996 caused production to be well above average at that point in the year. The three weeks of little or no production in March and April eliminated the advantage gained earlier. Two weeks of high production in May and June pushed the balance up. Production quotas during August then caused it to move negative. The contractor recovered from this deficit during November and December, as the mill began building winter inventories.

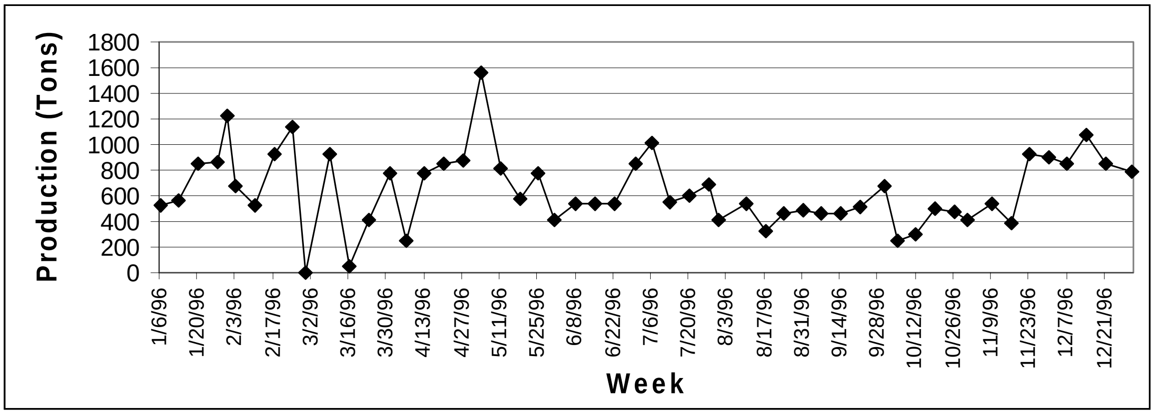


Figure 5.4. Run-Chart of Contractor 102's 1996 Weekly Production.

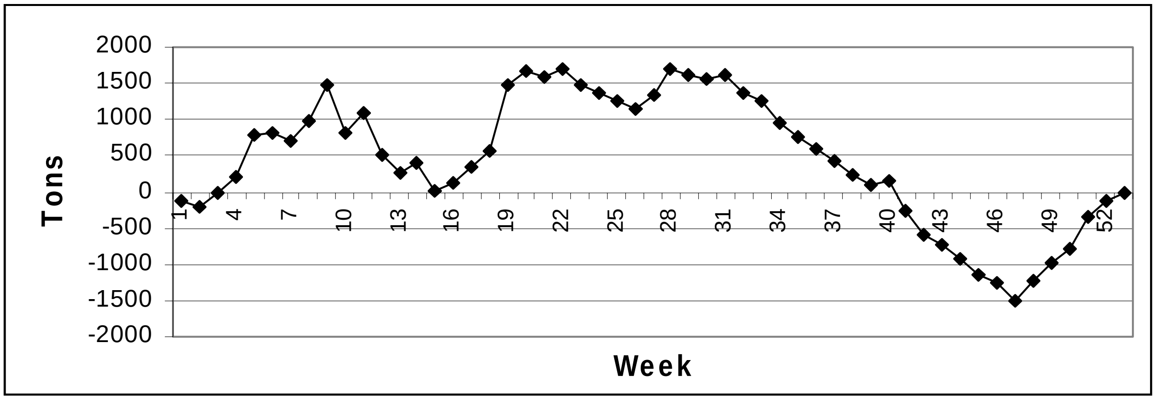


Figure 5.5. Cumulative Sum (Cusum) Chart of Contractor 102's 1996 Weekly Production.

5.1.3 Inelastic Operation Strategy

The contractors who had stable production were considered inelastic. The highest point of production for the contractors included in this group was between 122 and 171 percent of the average. The 25th percentile was located between 4 and 16 percent of the average. The contractors produced between 58,825.74 and 101,352.05 tons per year in 1995 and 1996. The stability of the production of these contractors was evidenced by their relatively low coefficients of variation, ranging from 10 to 24 percent. Each of these contractors was well grounded, had been in the business for some time, and was part of a well-managed wood supply system. Four of the 5 contractors primarily cut plantation pine on company land, likely providing a more stable working environment, allowing the contractors to specialize their operations, thus reducing variability. The remaining contractor harvested a combination of company-owned plantations and privately owned tracts.

Production information for contractor 002 is included as Figures 5.6 and 5.7. His average production for 1995 and 1996 was 1,102.7 tons per week, with a coefficient of variation of 10 percent. The inter-quartile range spanned from 1,058.6 to 1,171.7 tons per week, with the median located at 1,122 tons per week.

The contractor began 1995 at his average production level. Production increased somewhat in the next few weeks and remained slightly above the average until a relatively substantial increase occurred near the end of June. Production then dropped around the July 4th holiday and became more variable. A low of 22 percent of average occurred near the end of November, possibly due to production quota, Thanksgiving, or hunting season. Production then increased in December as the mill began building winter inventory.

The next year began much like 1995, with production slowly increasing to a level slightly above the average. The variable production pattern set in much sooner in 1996 and continued through the end of the year. Production became more variable in November and December. This variability was likely caused by winter rains interrupting the opportunity to increase production as the mill began building winter inventory, hunting season, or the holidays.

The cusum in Figure 5.7 indicates that the wood balance stayed positive for both years. Production steadily increased above the average throughout 1995 until production quotas set in during the later part of the year. Production dropped fairly steadily in 1996, due to the increase in production variability.

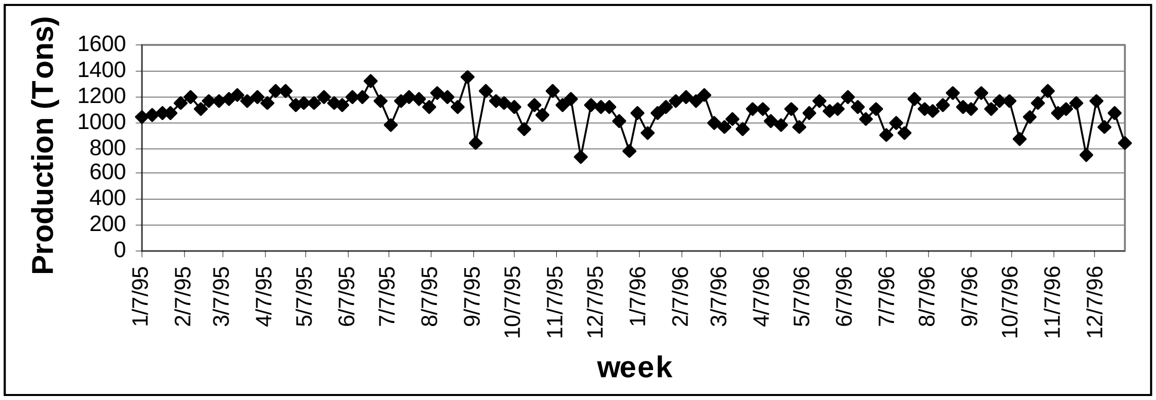


Figure 5.6. Run-Chart of Contractor 002's 1995-1996 Weekly Production.

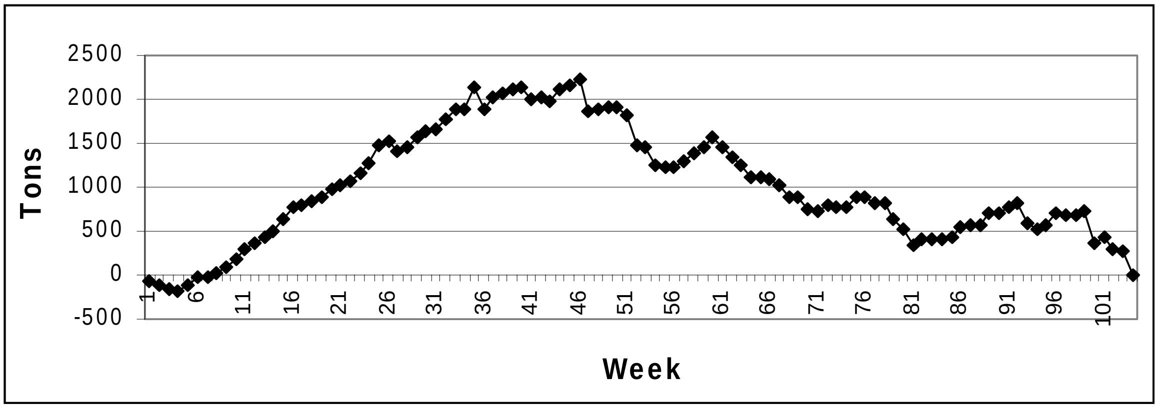


Figure 5.7. Cumulative Sum (Cusum) Chart of Contractor 002's 1995-1996 Weekly Production.

5.2 Productivity Trends

This section explores trends in quarterly and yearly productivity. The quarterly information will be used to determine if one quarter of the year tends to have lower or higher production than the others. Yearly information will be used to give insight into production trends from 1990 through 1996.

5.2.1 Quarterly Productivity Trends

Fifteen contractors provided complete quarterly production information from 1990 to 1996. Their production ranged from 3,700 to 61,416 tons per quarter, with a median of

20,668 tons. The inter-quartile range was between 14,493 and 26,640 tons, with a median of 20,668 tons.

The distributions of the quarterly productivity data were compared using two sample Kolmogorov-Smirnov tests, and cumulative relative frequency or ogive charts. Paired differences for each quarter were also analyzed using Wilcoxon signed rank tests. The cumulative relative frequencies or ogives were calculated by first dividing production data for each quarter into 60 equal classes. The relative frequency for each class was then calculated and summed algebraically.

The Kolmogorov-Smirnov tests indicate that the cumulative distributions of the quarterly data are not significantly different (Table 5.1). Figure 5.8 also shows the similarities associated with the cumulative distributions from each quarter. There were some minor differences in the distributions by quarters, given the effect of weather and quotas. The Wilcoxon signed rank tests were used to look at this more completely.

Production between quarters was significantly different only for 1994 and 1995 (Table 5.2). In 1994, the first, second, and third quarters were all statistically different from the fourth at the 95 percent confidence level. In 1995, the first and the third quarters were labeled statistically different from one another. All of these differences occurred when Best Management Practices were first being implemented, which could have resulted in fewer work days and lower production in several quarters.

Statistically significant differences in quarterly production were found only in isolated cases. This is not intended to imply that weather and other factors do not affect contractor production and mill inventories. The contractors included in this sample had well-equipped, well-managed operations, supported by good procurement forces; and thus, they do not necessarily represent the overall population of contractors in the southeastern United States. These contractors appeared to have had the ability to limit the effects of inclement weather by using all-weather equipment, with good management decisions, and with wet-weather tracts provided by the procurement force. The presence of production quota in the second and third quarters, discussed in the previous section, may have kept the quarters from being significantly different as well.

Table 5.1. Komogorov-Smirnov Test Results Comparing Quarterly Productivity.

Paired Comparisons	P-Values
1st quarter ≅ 2nd quarter	0.20 < p-value<1.0
1st quarter ≅ 3rd quarter	0.20 < p-value<1.0
1st quarter ≅ 4th quarter	0.20 < p-value<1.0
2nd quarter ≅ 3rd quarter	0.20 < p-value<1.0
2nd quarter ≅ 4th quarter	0.20 < p-value<1.0
3rd quarter ≅ 4th quarter	0.20 < p-value<1.0

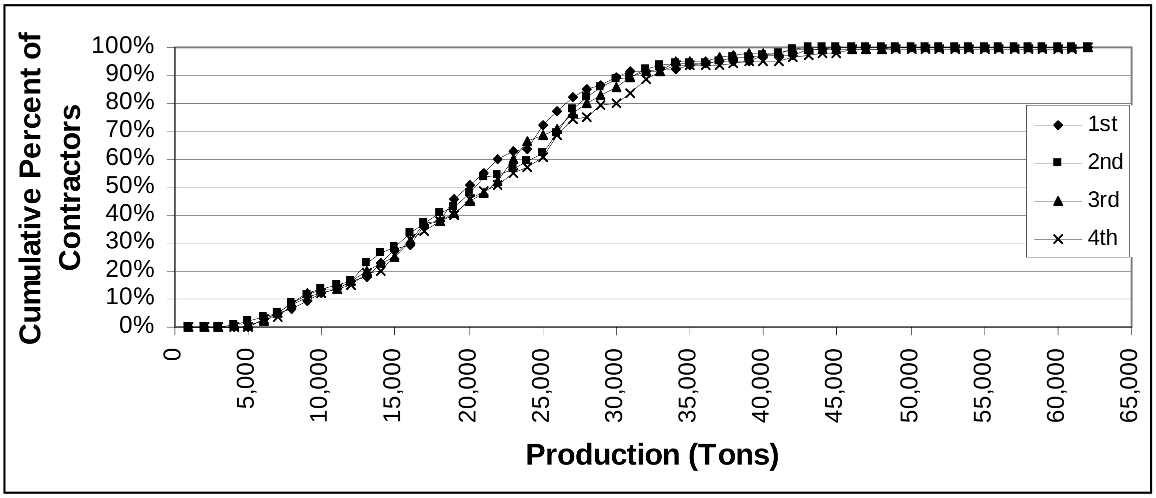


Figure 5.8. Quarterly Cumulative Relative Probability Comparisons for 1990-1996.

Table 5.2. Wilcoxon Signed Rank Test Results Comparing Quarterly Productivity for 1994 and 1995 (Bold letters represent quarters that were statistically different).

Year	Paired Comparisons	P-Value	Year	Paired Comparisons	P-Value
1994	1st Quarter ≅ 2nd Quarter	0.164	1995	1st Quarter ≅. 2nd Quarter	0.106
1994	1st Quarter ≅ 3rd Quarter	0.842	**1995**	**1st Quarter < 3rd Quarter**	**0.038**
1994	**1st Quarter < 4th Quarter**	**0.006**	1995	1st Quarter ≅ 4th Quarter	0.670
1994	2nd Quarter ≅ 3rd Quarter	0.798	1995	2nd Quarter ≅ 3rd Quarter	0.201
1994	**2nd Quarter < 4th Quarter**	**0.003**	1995	2nd Quarter ≅ 4th Quarter	0.887
1994	**3rd Quarter < 4th Quarter**	**0.013**	1995	3rd Quarter ≅ 4th Quarter	0.514

5.2.2 Yearly Productivity Trends

Twenty contractors provided complete yearly production information from 1990 to 1996. Production ranged from 19,194 to 244,950 tons per year. The median production level for the 7-year period was 75,720 tons per year. The inter-quartile range spanned 54,368 to 101,278 tons per year.

Production levels generally increased year to year through 1995 and fell in 1996 (Figure 5.9). The relationship between the median and the 25th and the 75th percentile is of interest. The 25th percentile rose more slowly than the median during the periods of expansion, indicating that production for some contractors stabilized. The 75th percentile rose faster than the median during periods of expansion and fell more rapidly during periods of contraction.

Results from the Wilcoxon signed rank tests suggest that productivity was statistically different for several of the years. (Table 5.3). The years with statistically different productivity levels are shown by the shaded cells in Table 5.4. Productivity was lowest in 1990 and highest in 1995. The early years, 1990 and 1991, were significantly lower than each of the other years, while 1995 was statistically higher than the previous years (Table 5.4). The remaining years were not as extreme but still exhibited the upward trend. These years, 1992-1994 and 1996, were not statistically different from one another, and therefore can be considered as a part of similar populations. The drop off in production in 1996 will be of particular interest in the efficiency analysis. A drop in production of this type could likely adversely affect efficency.

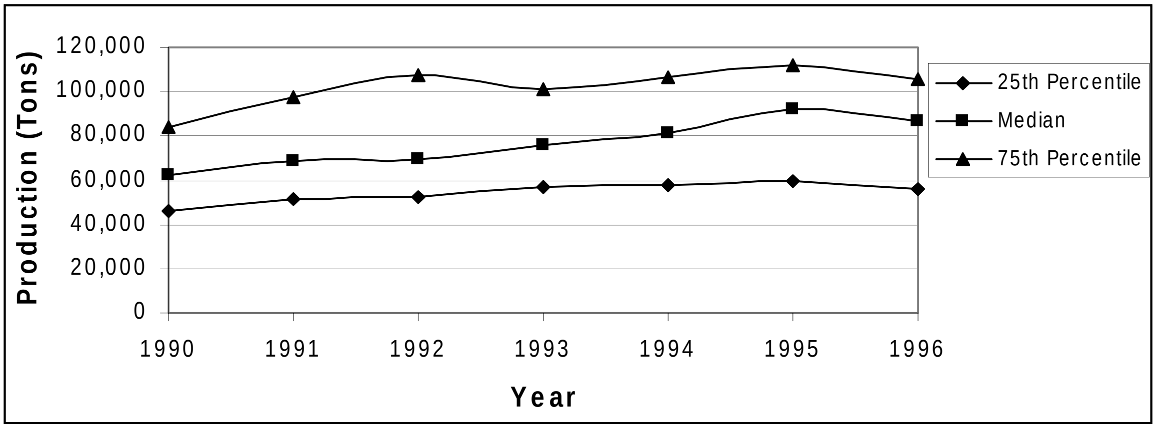


Figure 5.9. Median, 25th, and 75th Percentile Production Levels for the 20 Contractors Providing 1995-1996 Data.

Table 5.3. Wilcoxon Signed Rank Test Results Comparing Yearly Productivity (Shaded Cells Represent Years where Productivity Levels were Significantly Different).

Paired Comparisons	P-Values	Paired Comparisons	P-Values
1990 < 1991	**0.001**	1993 ≅ 1994	0.444
1990 < 1992	**0.003**	**1993 < 1995**	**0.026**
1990 < 1993	**0.001**	1993 ≅ 1996	0.695
1990 < 1994	**0.001**	**1994 > 1990**	**0.001**
1990 < 1995	**0.001**	**1994 > 1991**	**0.008**
1990 < 1996	**0.003**	1994 ≅ 1992	0.185
1991 > 1990	**0.001**	1994 ≅ 1993	0.444
1991 ≅ 1992	0.065	**1994 < 1995**	**0.029**
1991 < 1993	**0.029**	1994 ≅ 1996	0.723
1991 < 1994	**0.008**	**1995 > 1990**	**0.001**
1991 < 1995	**0.002**	**1995 > 1991**	**0.002**
1991≅ 1996	0.059	**1995 > 1992**	**0.012**
1992 > 1990	**0.003**	**1995 > 1993**	**0.026**
1992 ≅ 1991	0.065	**1995 > 1994**	**0.029**
1992 ≅ 1993	0.198	1995 ≅ 1996	0.055
1992 ≅ 1994	0.185	**1996 > 1990**	**0.003**
1992 < 1995	**0.012**	1996≅ 1991	0.059
1992 ≅ 1996	0.360	1996 ≅ 1992	0.360
1993 > 1990	**0.001**	1996 ≅ 1993	0.695
1993 > 1991	**0.029**	1996 ≅ 1994	0.723
1993 ≅ 1992	0.198	1996 ≅ 1995	0.055

Table 5.4. Paired Sample Analysis Results Comparing Yearly Productivity (Shaded Cells Represent Years Where Productivity Levels were Significantly Different).

Year	1990	1991	1992	1993	1994	1995	1996
1990		■	■	■	■	■	■
1991	■			■	■	■	
1992	■					■	
1993	■	■				■	
1994	■	■				■	
1995	■	■	■	■	■		
1996	■						

5.3 Production Capacity Utilization

Production capacity utilization gives a useful description of the economic situation of a firm. The Bureau of Economic Analysis and the Federal Reserve Board regularly report the capacity utilization of U.S. businesses, indicating their economic performance (Garfalo and Malhorta 1997). Capacity utilization is the ratio of actual production to the maximum production level achievable during normal operating conditions. Normal operating conditions refer to a normal work week, the use of normal equipment, and normal down time due to repair and maintenance duties (Garfalo and Malhorta 1997).

A sample of 21 contractors who provided at least some weekly productivity data between 1990 and 1996 was used to analyze capacity utilization by computing the ratio of the median weekly production to the 75th percentile value. This method is similar to the method used by LeBel (1996) to calculate capacity utilization and meets the requirements of the above definition. Capacity utilization ranged from 66 to 97 percent. The inter-quartile range for the sample of contractors spanned from 83 to 89 percent of their available capacity, with a median value of 86 percent.

Contractor 102's 1996 production was the year with the lowest capacity utilization (Figure 5.3). He was able to increase production dramatically in 1996 when conditions allowed but was also able to "hunker down" during periods when weather or quota limited production. These production swings caused the 75th percentile to be much higher than the median, and therefore, capacity utilization suffered.

Contractor 002's 1995 production marked the year with the highest capacity utilization (Figure 5.5). This contractor was able to keep production remarkably stable during 1995 and 1996, allowing him to narrow the space between the median and the 75th percentile, which enabled the contractor to use practically all of his production capacity.

A sample of 16 contractors who provided complete weekly production data from 1990 to 1996 were used to assess yearly trends in capacity utilization. Wilcoxon signed rank tests were used to test for statistically significant differences. There were no major changes in capacity utilization from 1990 to 1996, but there were some interesting trends present. Capacity utilization appeared to have dropped, and became less variable in 1994 through 1996, compared to the previous years. The median capacity utilization levels dropped 1-2 percent from 1993 to 1996 (Figure 5.10). Also the 25th and 75th percentile values seemed to have tightened around the median from 1993 to 1995. Capacity utilization increased from 1995 to 1996, as evidenced by increases associated with the 75th percentile, 25th percentile, and the median values. This suggests that quotas put an low ceiling on production, causing capacity to increase, which is another indicator of the productivity drop in 1996 discussed in section 5.2.2.

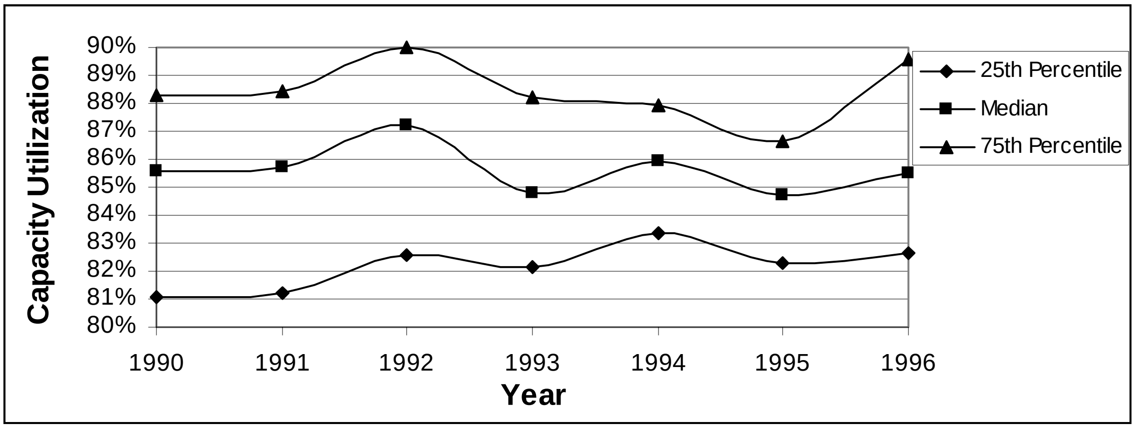


Figure 5.10. Median, 25th, and 75th Percentile Levels for Yearly Capacity Utilization.

5.4 Summary

Productivity variability, quarterly and yearly productivity trends, and production capacity utilization were analyzed in detail. The contractors providing weekly production information were classed as upwardly elastic, downwardly elastic, or inelastic depending on their ability to increase, decrease, or to maintain a relatively constant level of production.

Upwardly elastic contractors accounted for 12 of the 20 contractors in the sample. These contractors were all well-equipped and geared for moderate to high production. Each of these contractors had the ability to increase production under favorable operating conditions.

Downwardly elastic contractors accounted for 3 of the 20. These contractors all operated at relatively low production levels and could withstand periods of low production more readily than the upwardly elastic contractors.

Inelastic contractors accounted for 5 of the 20. Each of these contractors had well-established businesses. They were able to maintain relatively stable levels of production, as evidenced by their low coefficients of variation. Four out of the 5 contractors primarily harvested company-owned pine plantations; all worked in well-managed wood supply systems.

Quarterly and yearly production data were analyzed to determine if productivity trends were present. Results from Kolmogorov-Smirnov tests indicated that quarterly productivity levels within years were not significantly different. Only 1994 and 1995 had significantly different quarterly production levels. The first, second, and third quarter production in 1994 was significantly less than that of the fourth quarter. In 1995, third-quarter production was significantly higher than first-quarter production. These differences all occurred when BMP’s were beginning to be implemented, and before many of the contractors adjusted their operations. It is also possible that the procurement force made an increased effort to build winter inventories, in the third and fourth quarters, to account for reduced winter production.

Analysis of yearly productivity information revealed a general upward trend in production levels between 1990 through 1995, before dropping off in 1996. Production levels for 1990 and 1991 were statistically lower than the other years, and 1995 was statistically higher. The years 1992 through 1994, along with 1996, were not statistically different in the analysis and therefore can be considered to be in the same population. The characteristics and the trends of the productivity data will be extremely helpful in analyzing and understanding the efficiency scores.

The production capacity utilization was measured for all contractors providing at least one year of weekly data from 1990 through 1996. Capacity utilization was measured by taking the ratio of actual production to the production capacity the contractor could reach under normal operating conditions. The median weekly production was considered the actual production, and the 75th percentile was considered the production capacity for each contractor.

The inter-quartile range for the sample of 21 contractors ranged between 83 percent and 89 percent of their available capacity, with a median value of 86 percent. The contractor with the lowest capacity utilization only used 66 percent of his available production capacity, while the highest contractor used 97 percent of his available capacity.

A sample of 16 contractors providing complete weekly production data from 1990 to 1996 were used to look at trends capacity utilization. There were no major changes in capacity utilization over the period, but there were some interesting trends present. Capacity utilization appeared to have dropped and became less variable in 1994 through 1996, compared to the previous years. The median capacity utilization levels dropped 1-2 percent from 1993 to 1996; the 25th and 75th percentile values seemed to have tightened around the median from 1993 to 1995. Capacity utilization increased from 1995 to 1996, which could be another indicator of the productivity drop in 1996.

Chapter 6 COST ANALYSIS

The cost, in dollars, associated with the green tons of wood delivered to market is considered the input of the forest harvesting process in this study. The purpose of this chapter is discuss characteristics of the 6 cost components in detail and to explore quarterly and yearly cost trends, as well as the relationship of logging costs to production.

6.1 Cost Components

There are 6 cost components associated with the forest harvesting process: equipment, consumables, labor, insurance, contract trucking, and administrative overhead (section 3.2). Thirty-one contractors who provided at least 1 year of cost data between 1990 and 1996 were included to analyze the components.

Labor generally accounted for the highest proportion of expenditures, with a median of 37 percent of the total logging costs. Consumables followed with a median of 24 percent, then equipment with a median of 19 percent, contract trucking with a median of 10 percent, insurance with a median of 4 percent, and administrative overhead with a median of 1 percent (Figure 6.1)

The contractors used different mixes of the 6 cost components depending on operating philosophies and strategies. The variability of each component shows the extent of these cost tradeoffs (Figure 6.1). Some loggers preferred to pay a higher percentage in equipment to reduce the proportion associated with consumables, labor, or contract trucking. Other contractors chose to spend a lower percentage on equipment, often with a higher proportion going to consumables, labor, or contract trucking. Some contractors preferred to contract all or a portion of their trucking, which in turn transferred costs associated with equipment, consumables, and labor to contract trucking. Some had full-time secretaries resulting in higher administrative overhead costs. Some chose to spend more on insurance at the expense of the other categories. Cost component tradeoffs can potentially have a significant impact on technical efficiency, which will be discussed further in Chapter 7.

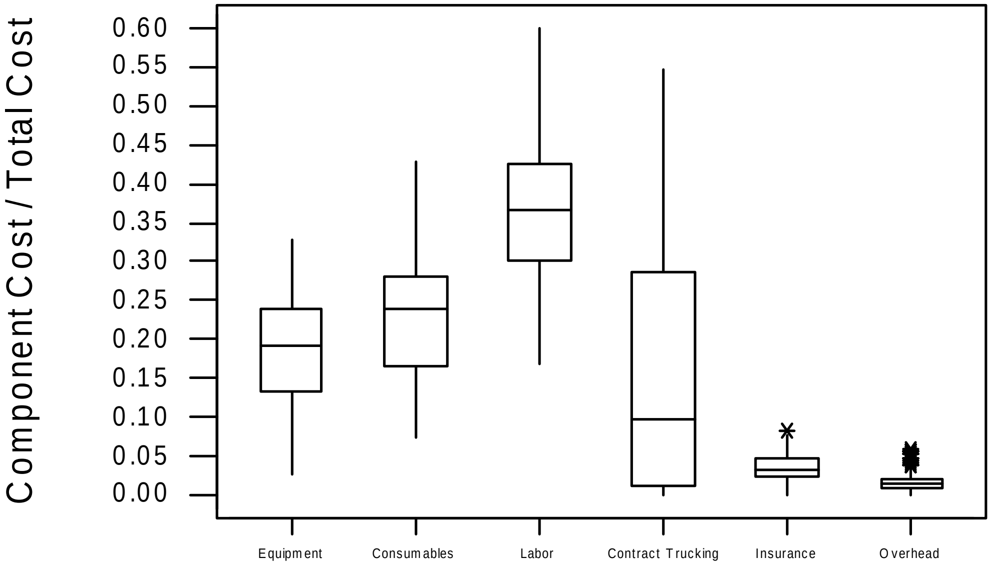


Figure 6.1. Proportion of Total Cost Associated with Equipment, Consumables, Labor, Contract Trucking, Insurance, and Administrative Overhead.

6.2 Logging Cost Trends

Trends in quarterly and yearly costs over several years are effective measures of change in the business environment. Data from a sufficiently large sample of contractors were available to give insight into cost trends from 1990 to 1996.

6.2.1 Quarterly Cost trends

Six contractors provided complete quarterly cost information for the period. These costs ranged from $42,983 to $391,572 per quarter across the contractors. The inter-quartile range was between $164,378 and $264,639 per quarter, with a median value of $220,631 per quarter.

Logging costs generally had an upward trend from the first to the fourth quarter (Figure 6.2). This upward trend generally followed the trend in quarterly production mentioned in section 5.2.1. The Wilcoxon signed rank test was performed on paired differences of the quarterly cost figures to determine if any of the quarters were statistically different. Years with quarterly cost figures that were ruled statistically different at the 90 percent confidence level included 1990, 1991, 1992, 1993, and 1996 (Table 6.1). The third and fourth quarters tended to be significantly higher than the first and second quarters. These differences are likely related to increases in production, employee benefits provided during the holiday season, or the relatively small sample size. The impact of these differences on quarterly technical efficiency will be explored in Chapter 7.

Each of the cost components, except contract trucking, exhibited a similar upward trend as the one shown in Figure 6.2. Consumables had the largest increase in median cost, with an increase of $16,463, followed by labor with an increase of $16,394, equipment with $7,381, insurance with $1,887, and administrative overhead with $851. Contract hauling decreased by $4,020 from the first of the fourth quarter. The relatively large increases in labor and consumables, which are largely variable costs, further suggesting that quarterly differences are related to production increases and employee benefits in this sample.

The contribution of equipment, consumables, labor, and contract trucking toward the cost trend is shown in Figures 6.3 – 6.6. Equipment costs were stable until the fourth quarter, when costs increased, likely due to equipment renewal decisions influenced by tax advantages or other factors (Figure 6.3). Expenditures on consumables made a fairly significant increase from the third quarter, before slightly dropping off in the fourth quarter, likely related to production increases in these quarters (Figure 6.4). Labor expenditures increased slightly in the second and third quarters before making a fairly substantial increase in the fourth quarter (Figure 6.5). The increases in the second and third quarters are likely related to increases in production and day length during spring and summer. Increases in the fourth quarter could partly be related to production increases, but are more likely a result of Christmas salary bonuses. Contract trucking does not seem to significantly contribute to the upward cost trend (Figure 6.6). Expenditures decreased in the third quarter before rebounding somewhat in the fourth. Factors influencing this trend have not been determined.

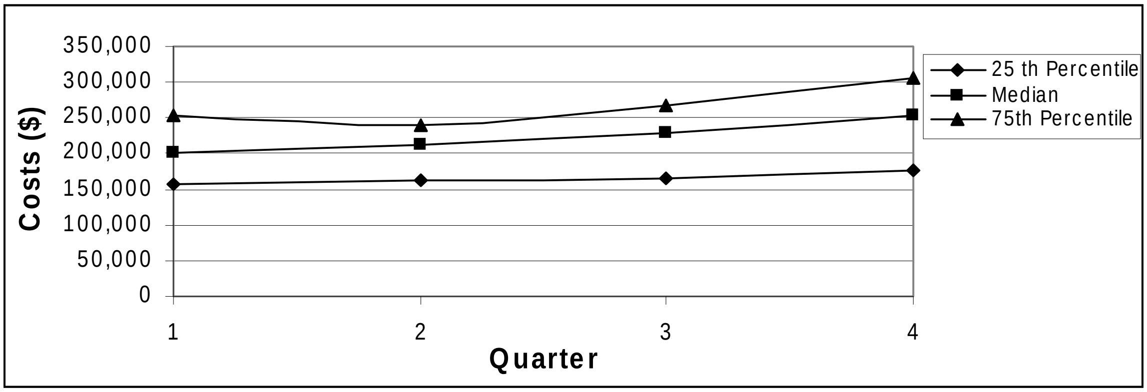


Figure 6.2. Median, 25th, and 75th Percentile Cost Levels for the 6 Contractors Providing Quarterly Data from 1990-1996.

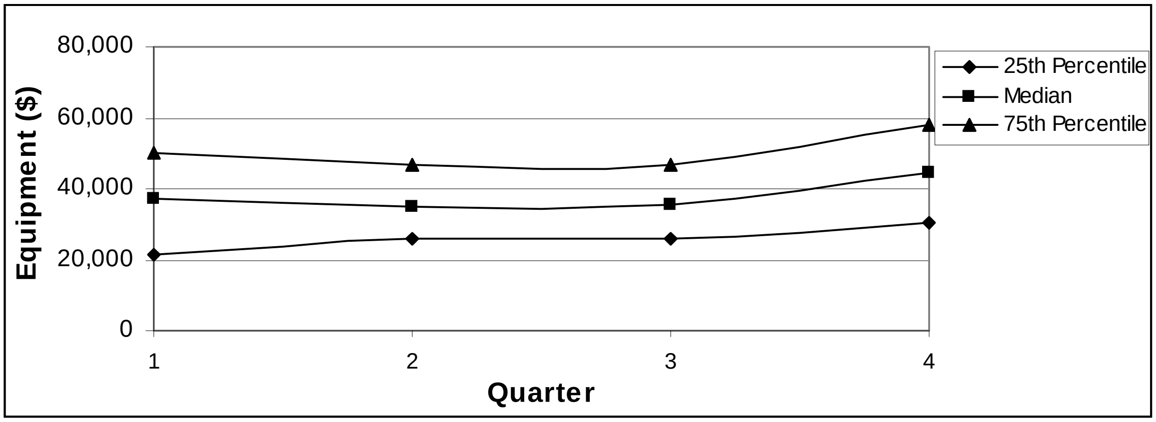


Figure 6.3. Median, 25th, and 75th Percentile Equipment Cost Levels for the 6 Contractors Providing Quarterly Data from 1990-1996.

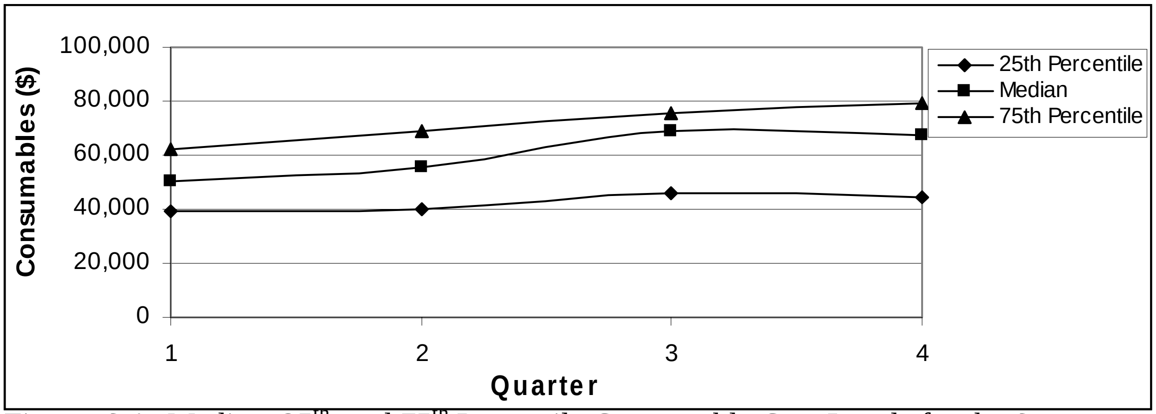


Figure 6.4. Median, 25th, and 75th Percentile Consumable Cost Levels for the 6 Contractors Providing Quarterly Data from 1990-1996.

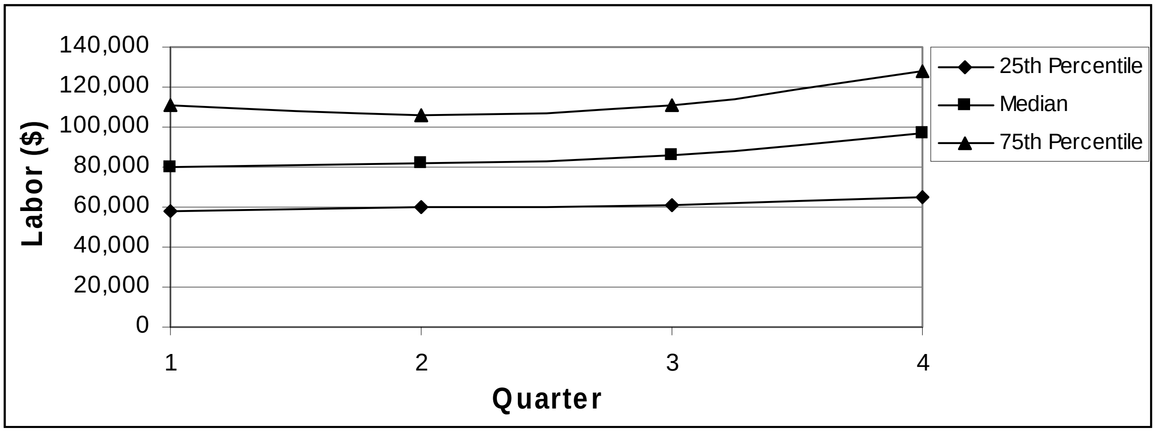


Figure 6.5. Median, 25th, and 75th Percentile Labor Cost Levels for the 6 Contractors Providing Quarterly Data from 1990-1996.

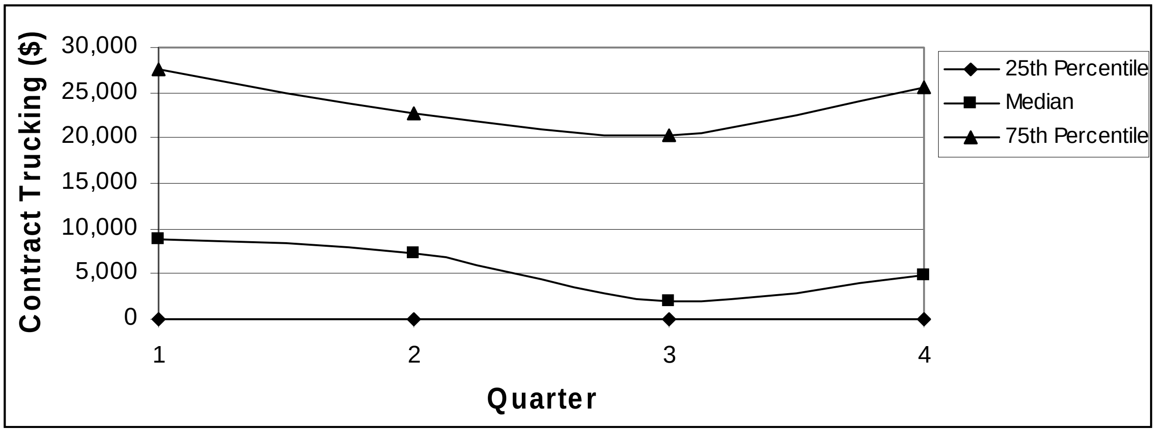


Figure 6.6. Median, 25th, and 75th Percentile Contract Trucking Cost Levels for the 6 Contractors Providing Quarterly Data from 1990-1996.

Table 6.1. Wilcoxon Signed Rank Results from Paired Quarterly Cost Information (Shaded Cells Represent Quarters with Significantly Different Costs Levels).

Year	Paired Comparison	P-Value
1990	1st Quarter ≅ 2nd Quarter	0.142
1990	1st Quarter ≅ 3rd Quarter	0.402
1990	1st Quarter ≅ 4th Quarter	0.402
1990	**2nd Quarter < 3rd Quarter**	**0.036**
1990	**2nd Quarter < 4th Quarter**	**0.036**
1990	3rd Quarter ≅ 4th Quarter	0.834
1991	1st Quarter ≅ 2nd Quarter	1.00
1991	1st Quarter ≅ 3rd Quarter	0.402
1991	1st Quarter ≅ 4th Quarter	1.00
1991	**2nd Quarter ≅ 3rd Quarter**	**0.059**
1991	2nd Quarter ≅ 4th Quarter	0.834
1991	3rd Quarter ≅ 4th Quarter	0.834
1992	1st Quarter ≅ 2nd Quarter	0.295
1992	1st Quarter ≅ 3rd Quarter	0.208
1992	**1st Quarter < 4th Quarter**	**0.093**
1992	2nd Quarter ≅ 3rd Quarter	0.208
1992	**2nd Quarter < 4th Quarter**	**0.059**
1992	**3rd Quarter < 4th Quarter**	**0.093**
1993	1st Quarter ≅ 2nd Quarter	0.675
1993	1st Quarter ≅ 3rd Quarter	0.834
1993	**1st Quarter < 4th Quarter**	**0.059**
1993	2nd Quarter ≅ 3rd Quarter	0.675
1993	**2nd Quarter < 4th Quarter**	**0.036**
1993	**3rd Quarter < 4th Quarter**	**0.036**
1994	1st Quarter ≅ 2nd Quarter	0.402
1994	1st Quarter ≅ 3rd Quarter	0.529
1994	1st Quarter ≅ 4th Quarter	0.295
1994	2nd Quarter ≅ 3rd Quarter	0.529
1994	2nd Quarter ≅ 4th Quarter	0.208
1994	3rd Quarter ≅ 4th Quarter	0.529
1995	1st Quarter ≅ 2nd Quarter	0.834
1995	1st Quarter ≅ 3rd Quarter	0.529
1995	1st Quarter ≅ 4th Quarter	0.208
1995	2nd Quarter ≅ 3rd Quarter	0.834
1995	2nd Quarter ≅ 4th Quarter	0.208
1995	3rd Quarter ≅ 4th Quarter	0.208
1996	1st Quarter ≅ 2nd Quarter	0.675
1996	**1st Quarter < 3rd Quarter**	**0.036**
1996	**1st Quarter < 4th Quarter**	**0.036**
1996	2nd Quarter ≅ 3rd Quarter	0.529
1996	2nd Quarter ≅ 4th Quarter	0.142
1996	**3rd Quarter < 4th Quarter**	**0.059**

6.2.2 Yearly Cost Trends

Fifteen contractors provided complete yearly cost information used in the yearly cost trend analysis. Contractors included had yearly costs ranging from $260,311 to $3,750,703 per year. The inter-quartile range was between $529,975 and $1,061,760 per year, with a median cost figure of $820,972 per year.

Yearly costs had a fairly steady upward trend during the time period analyzed. The median cost level increased by at least $47,626 per year and by as much as $136,732 per year from 1990 to 1995. The median cost level then took a downturn in 1996, dropping $50,148 below the 1995 level (Figure 6.7). It should also be noted that the median cost value moved away from the 25th percentile and moved closer to the 75th percentile from 1993 to 1996 (Figure 6.7). This reinforces that there was an upward movement in costs because it indicates that many contractors in the sample increased expenditures during the period.

The Wilcoxon signed rank test was performed on paired differences of the cost figures provided by the contractors for each year from 1990 to 1996. The test ruled that the majority of the pairs were statistically different (Table 6.2). Only 3 yearly pairs were not ruled statistically different at the 90 percent confidence level. These pairs included 1990 vs. 1991, 1993 vs. 1994, and 1995 vs. 1996 (Table 6.3). Therefore, costs were stable in 1990 and 1991 and increased significantly in 1992. Expenditures increased significantly again in 1993, and remained at relatively the same level in 1994. Then in 1995, costs increased significantly, before dropping in 1996. The upward yearly cost trend revealed in this Section for the most part follows the yearly production trends discussed in section 5.2.2.

Each of the 6 cost categories contributed to the cost trend shown in Figure 6.7. Contract trucking accounted for the largest increase in median cost over the period, with an increase of $122,679, followed by labor with an increase of $111,611, consumables with

$69,368, equipment with 61,402, administrative overhead with $11,958, and insurance with $8,739.

The contribution of equipment, consumables, labor, and contract trucking toward the overall cost trend is shown in Figures 6.8 – 6.11. Equipment expenditures were relatively stable compared to the others (Figure 6.8). There was a downturn in median costs in 1995, but an increase in the location of the 75th percentile, indicating that several loggers reinvested. Median costs then increased slightly in 1996. Consumables and labor had the greatest effect on overall costs (Figures 6.9 – 6.10). Both followed the trend described previously with 1992 -1994 and 1996 having relatively similar cost levels and significant increases occurring in 1995. Contract trucking showed a similar trend, but costs did not decrease in 1996, resulting partly from contractors who divided trucking and logging into separate businesses (Figure 6.11).

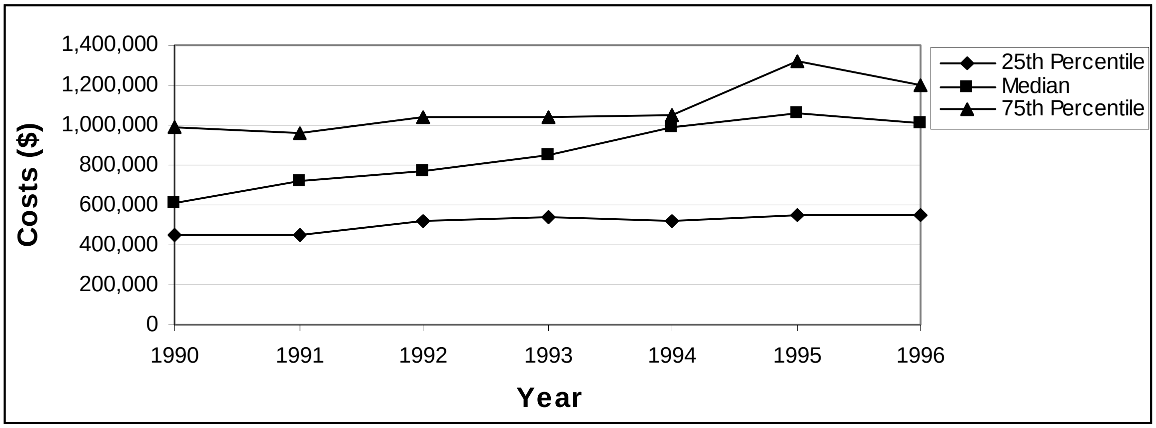


Figure 6.7. Yearly Cost Figures for the Sample of 15 Contractors.

Table 6.2. Results from the Wilcoxon Signed Rank Paired Sample Analyses (Shaded Cells Represent Years where Productivity Levels were Significantly Different).

Paired Comparisons	P-Values	Paired Comparisons	P-Values
1990 ≅ 1991	0.148	1993 ≅ 1994	0.589
1990 < 1992	**0.011**	**1993 < 1995**	**0.003**
1990 < 1993	**0.002**	**1993 < 1996**	**0.018**
1990 < 1994	**0.005**	**1994 > 1990**	**0.005**
1990 < 1995	**0.001**	**1994 > 1991**	**0.003**
1990 < 1996	**0.001**	**1994 > 1992**	**0.033**
1991 ≅ 1990	0.148	1994 ≅ 1993	0.589
1991 < 1992	**0.013**	**1994 < 1995**	**0.001**
1991 < 1993	**0.001**	**1994 < 1996**	**0.094**
1991 < 1994	**0.003**	**1995 > 1990**	**0.001**
1991 < 1995	**0.001**	**1995 > 1991**	**0.001**
1991< 1996	**0.001**	**1995 > 1992**	**0.002**
1992 > 1990	**0.011**	**1995 > 1993**	**0.003**
1992 > 1991	**0.013**	**1995 > 1994**	**0.001**
1992 < 1993	**0.013**	1995 ≅ 1996	0.798
1992 < 1994	**0.033**	**1996 > 1990**	**0.001**
1992 < 1995	**0.002**	**1996> 1991**	**0.001**
1992 < 1996	**0.010**	**1996 > 1992**	**0.010**
1993 > 1990	**0.002**	**1996 > 1993**	**0.018**
1993 > 1991	**0.001**	**1996 > 1994**	**0.094**
1993 > 1992	**0.013**	1996 ≅ 1995	0.798

Table 6.3. Yearly Results from Paired Sample Analyses (Shaded Cells Represent Years where Productivity Levels were Significantly Different).

Year	1990	1991	1992	1993	1994	1995	1996
1990			▨	▨	▨	▨	▨
1991			▨	▨	▨	▨	▨
1992	▨	▨		▨	▨	▨	▨
1993	▨	▨	▨			▨	▨
1994	▨	▨	▨			▨	▨
1995	▨	▨	▨	▨	▨		
1996	▨	▨	▨	▨	▨		

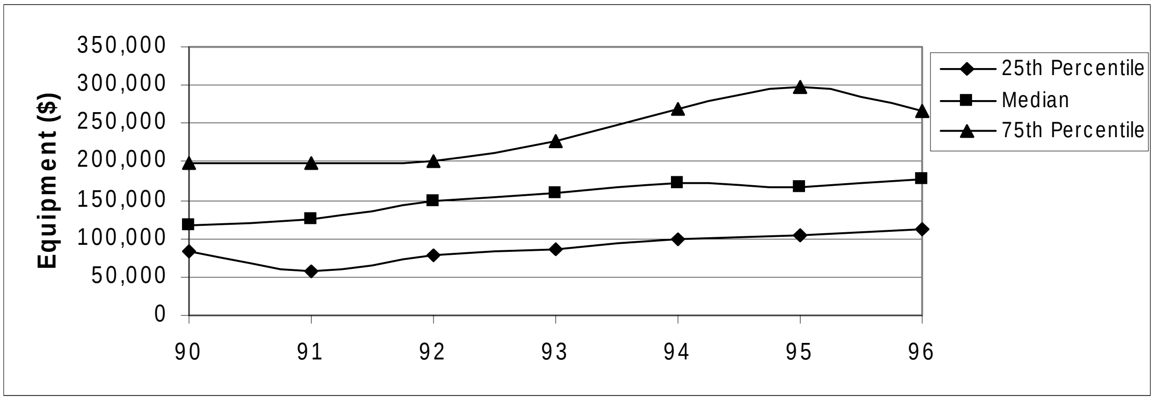


Figure 6.8. Equipment Expenses from 1990 to 1996 for the Sample of 15 Contractors.

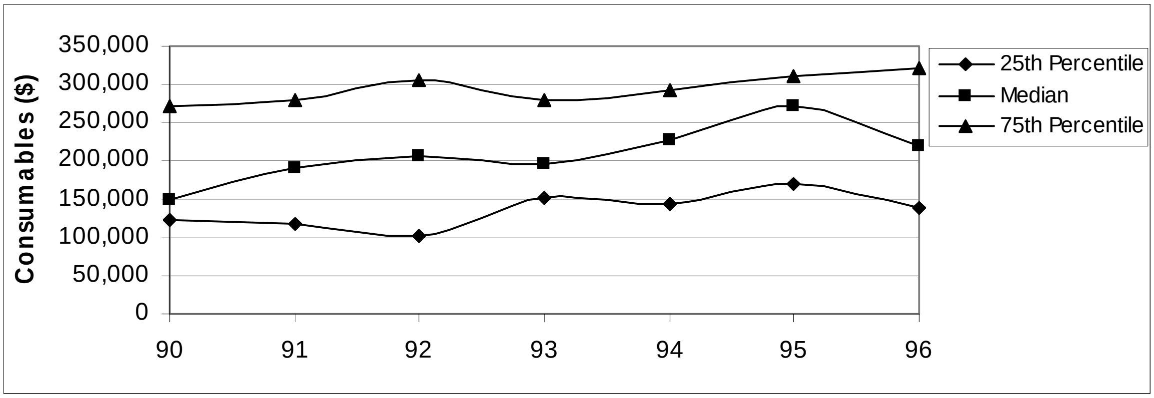


Figure 6.9. Consumable Expenses from 1990 to 1996 for the Sample of 15 Contractors.

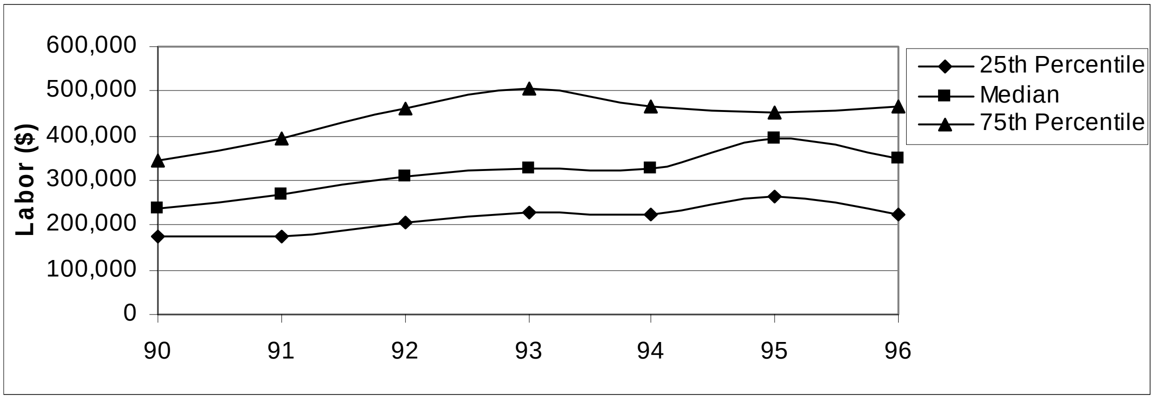


Figure 6.10. Labor Expenses from 1990 to 1996 for the Sample of 15 Contractors.

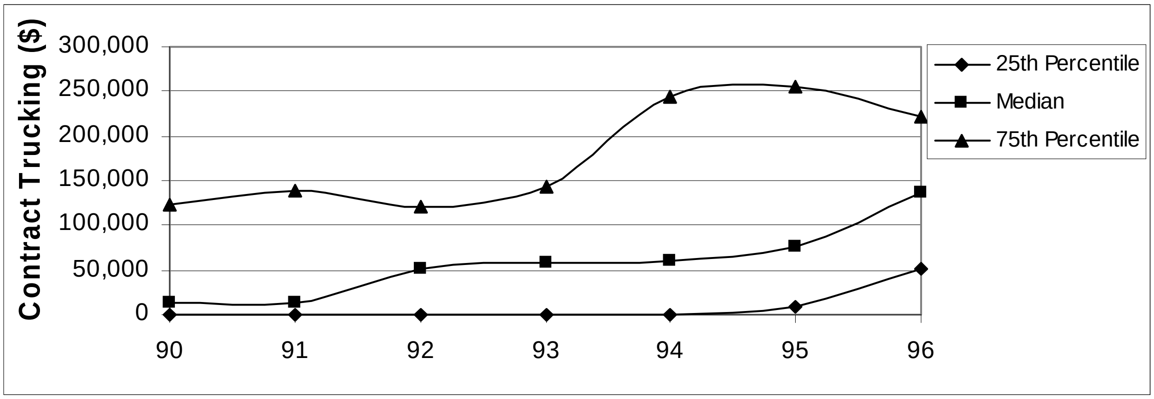


Figure 6.11. Contract Trucking Expenses from 1990 to 1996 for the Sample of 15 Contractors.

6.3 Relationship of Productivity and Costs

Costs and productivity changes may be interesting in isolation, but the relationship between the two on a quarterly and yearly basis are critical in measuring contractor performance. Regression lines representing 1990-1996 were developed from all of the available quarterly and yearly production and cost data (Figure 6.12 – 6.13). This analysis was intended to only explore the relationship between production and costs as a lead into the technical efficiency discussion in Chapter 7. Therefore, differences in the populations were not tested statistically.

The regression lines of quarterly cost as a function of production were very tightly grouped (Figure 6.12). This suggests that only limited differences exist in the relationship of production and costs across quarters exist. The regression lines for each year, other than the one representing 1996, were grouped tightly (Figure 6.13). The 1996 regression line suggests that a drop in tons out per dollar spent occurred in that year. This is expected to have a direct effect on the technical efficiency values for 1996, which will be analyzed in greater detail in Chapter 7.

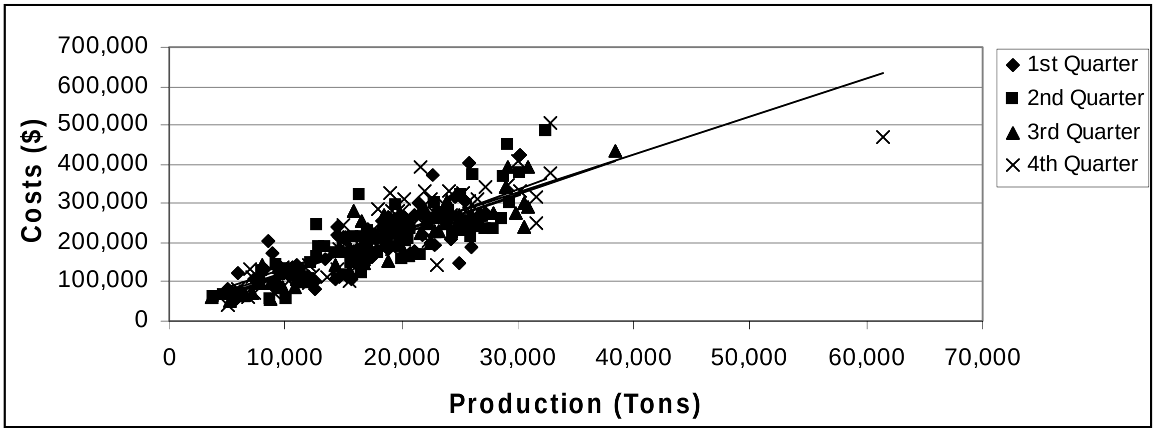


Figure 6.12. Regression Analysis of All Available Quarterly Production and Cost Information.

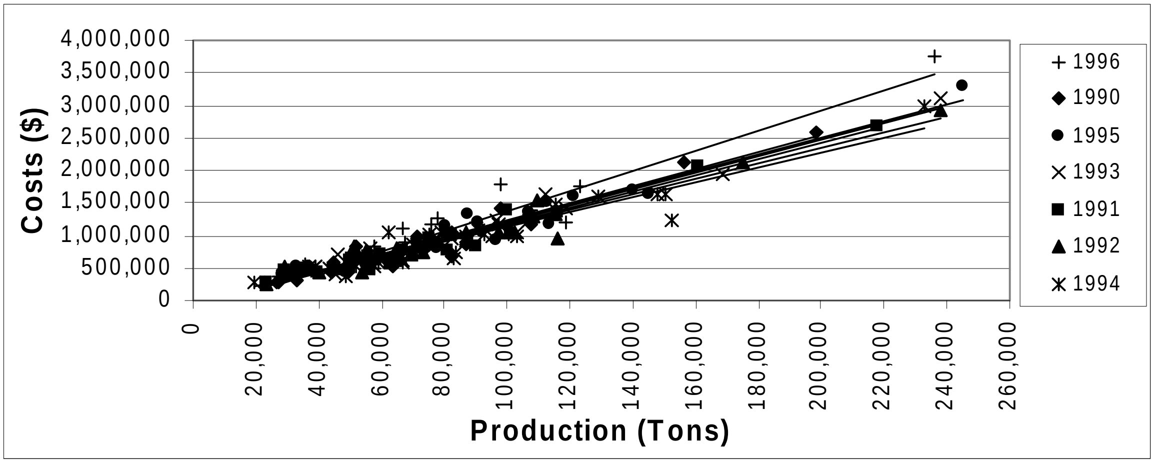


Figure 6.13. Regression Analysis of All Available Yearly Production and Cost Information. **The Order of the regression lines, from top to bottom, is indicated by the order of the years in the legend**

6.4 Summary

Labor accounted for the highest proportion of logging costs, with a median of 37 percent of the total logging costs, followed by consumables with 24 percent, equipment with 19 percent, contract trucking with 10 percent, insurance with 4 percent, and administrative overhead with 1 percent. The contractors used different mixes of these components depending on their operating strategies and philosophies.

Analysis of quarterly cost information from 6 contractors revealed a moderate upward trend from the first to the fourth quarters of the year. Years with quarterly cost figures that were ruled statistically different at the 90 percent confidence level included 1990, 1991, 1992, 1993, and 1996. This gave marginal evidence to declare that quarterly cost figures were significantly different. These differences are likely related to increases in production, employee benefits provided during the holiday season, or the relatively small sample size.

Each of the cost components, except contract trucking, exhibited a general upward trend in quarterly costs. The largest increase in median cost from the first to the fourth quarter, was associated with consumables, which increased by $16,463, followed by labor with an increase of $16,394, equipment with $7,381, insurance with $1,887, and administrative overhead with $851. Contract hauling decreased by $4,020 from the first of the fourth quarter.

Analysis of yearly cost information from 15 contractors, providing data from 1990 to 1996, revealed a fairly steady increase in median costs from 1990 to 1995, with a drop in median costs in 1996. Paired sample analysis using the Wilcoxon signed rank test revealed that all but 3 yearly pairs were statistically different at the 90 percent level of confidence. The pairs not determined to be statistically different included 1990 vs. 1991, 1993 vs. 1994, and 1995 vs. 1996.

Each of the 6 cost categories contributed to the increasing cost trend. Contract trucking marked the largest increase in median cost from 1990 to 1996, with an increase of $122,679, followed by labor with an increase of $111,611, consumables with $69,368, equipment with 61,402, administrative overhead with $11,958, and insurance with $8,739.

Regression lines were drawn through quarterly and yearly production and cost data. The quarterly regression lines were tightly grouped, suggesting that there were only limited differences in the relationship between production and costs across quarters. The regression lines representing 1990 through 1995 yearly production and costs had similar locations. The location of the 1996 regression line was noticeably different from the others, suggesting a drop in tons of produced for each dollar spent.

Chapter 7 TECHNICAL EFFICIENCY ANALYSIS

Technical efficiency, an indicator of the green tons of wood produced per dollar of expenditure, was used to measure the performance of participating contractors. This measure was used to explore the influence of technical, organizational, natural, administrative, and regulatory forces on contractor performance. Quarterly and yearly trends and the relationship between efficiency and profitability were also explored.

7.1 Technical Efficiency Results

Data Envelopment Analysis (DEA), a non-parametric, linear programming procedure, defines an efficiency standard, or production frontier, made up of the most efficient observations (Section 2.4). DEA assigns efficiency scores ranging from 0 to 1, depending on the distance of each observation from the production frontier. An efficiency score of 1 represents a completely efficient observation.

7.1.1 The CCR and BCC Models

Two DEA models were used, the Charnes Cooper Rhodes (CCR), and the Banker Charnes and Cooper (BCC). A complete list of the results obtained from these models is included in Appendix B. The CCR model, referred to as aggregate efficiency, calculates technical efficiency assuming constant returns to scale. Scale size in this study is measured by annual expenditures for the three major inputs, labor, consumables, and equipment. Constant returns to scale implies that a dollar spent by a small contractor generates the same amount of wood as a dollar spent by the largest contractors. This model defines an approximately straight production frontier that runs through the most productive scale size, where the maximum return per unit occurs (Figure 7.1.). The CCR model does not allow for scale inefficiencies.

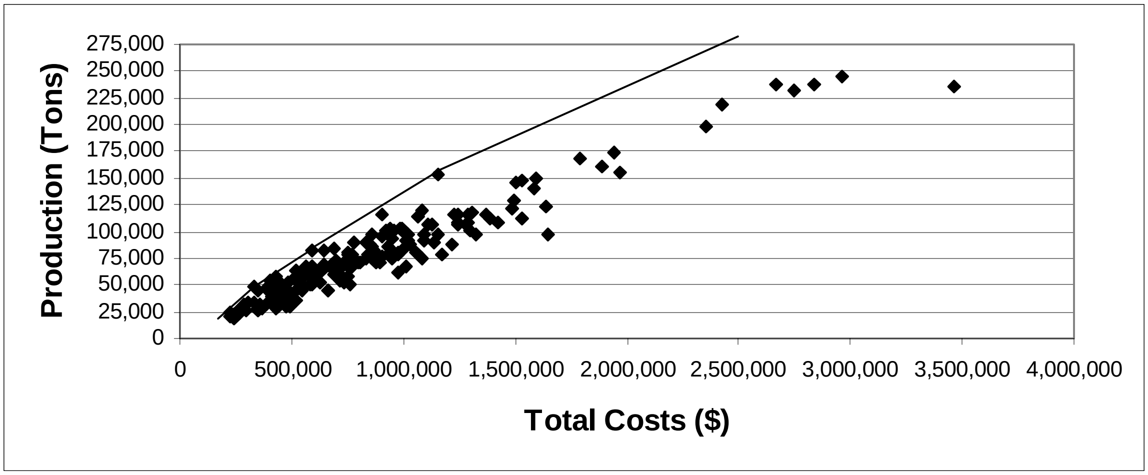


Figure 7.1. The Approximate Location of the CCR Production Frontier (Costs = Equipment + Consumables + Labor).

The BCC model calculates technical efficiency assuming variable returns to scale, referred to as “pure efficiency”. Variable returns to scale occur when an equal increase in inputs leads to an unequal increase in outputs. This model forms a best practice frontier, which is a curved line running through the most efficient observations (Figure 7.2). An observation does not have to be operating at the most productive scale size to be labeled efficient by this model; therefore, it does not include a measure of scale efficiency.

The BCC frontier defines the achievable efficiency for observations relative to operations for the same or similar scale sizes. The BCC was used most often in this study because it is recognized that external factors such as tract size, species mix, and trucking distance do not allow operations to achieve the most efficient scale size.

An observation, located at 152,000 tons per year, pushed the production frontiers obtained from both models outward, causing the other observations to have lower efficiency scores. This observation was analyzed, and its high efficiency was determined to be legitimate.

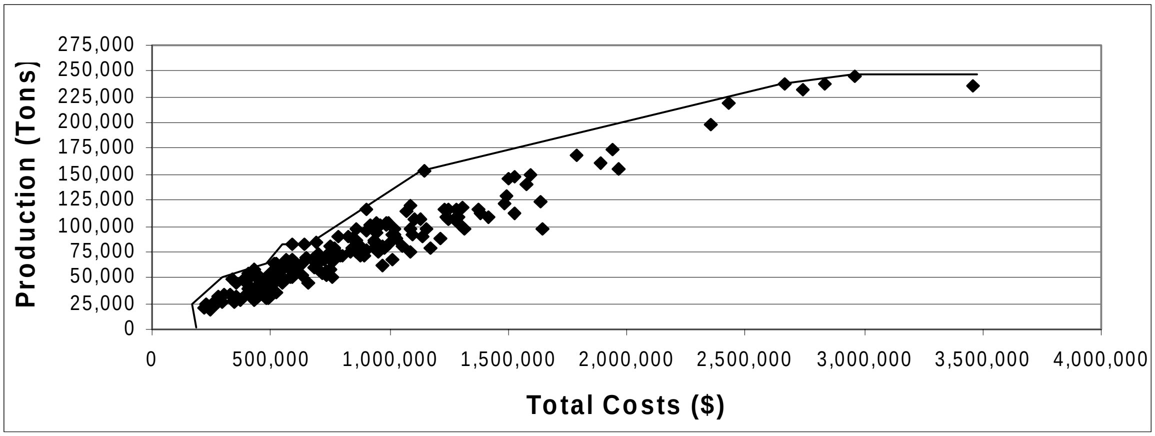


Figure 7.2 Location of the BCC Production Frontier (Costs = Equipment + Consumables + Labor).

The BCC model resulted in higher efficiency scores than the CCR model (Table 7.1). The median, 25th percentile, and the 75th percentile values for the BBC model were 4 to 7 percentage points higher than those from the CCR model. The differences between efficiency scores obtained from the two models were associated with observations that had either low or high production levels (Figures 7.3 and 7.4). These observations strayed from the most productive scale size (which ranged approximately from 60,000 to 80,000 tons per year) and were therefore ruled inefficient by the CCR model (Figure 7.3). The most efficient of these operations were part of the convex production frontier formed by the BCC model, resulting in higher efficiency scores (Figure 7.4).

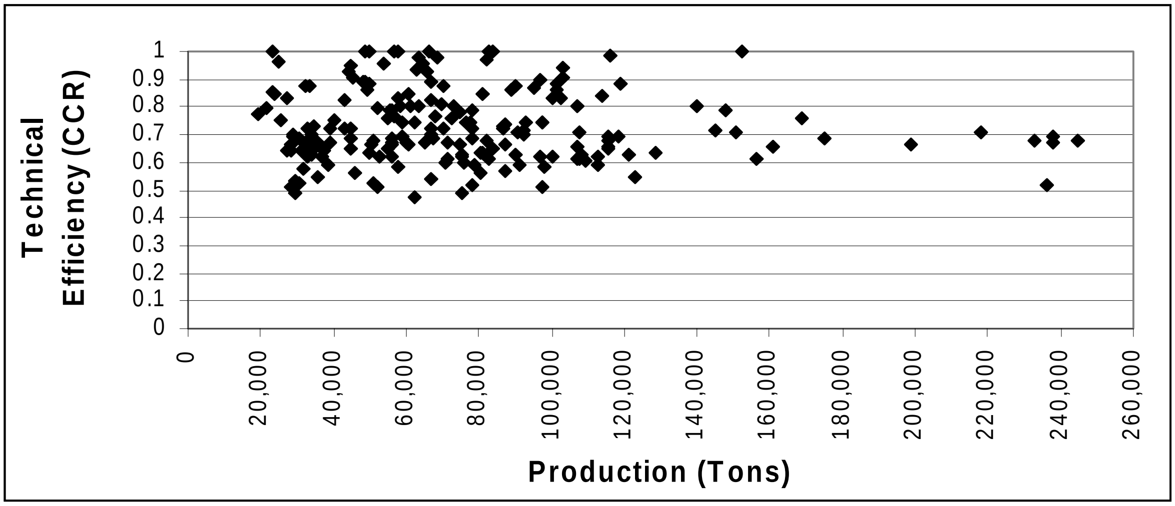


Figure 7.3. Relationship of Technical Efficiency (CCR) to Operation Size.

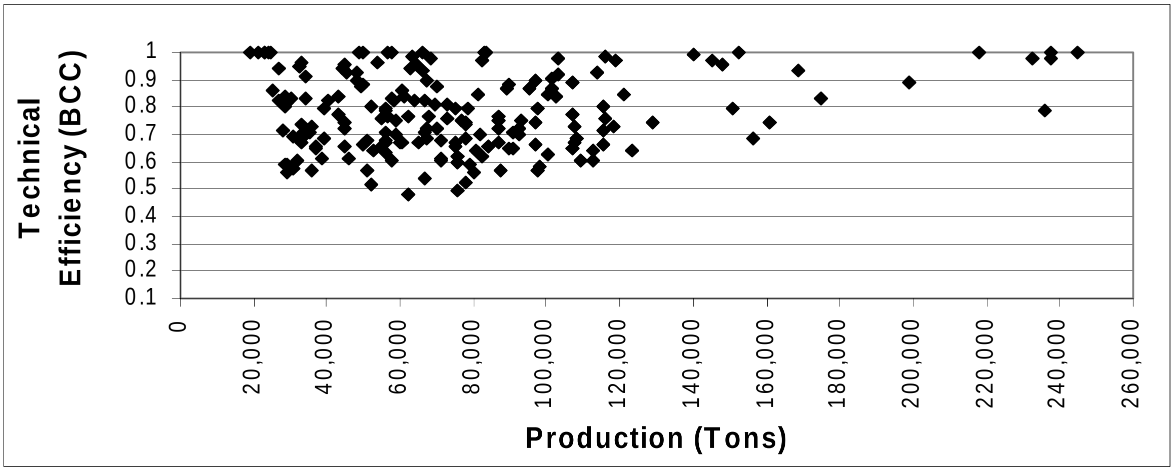


Figure 7.4. Relationship of Technical Efficiency (BCC) to Operation Size.

The efficiency scores were separated into three groups, efficient (0.90 – 1), partially efficient (0.80 – 0.89), and least efficient (obs < 0.79). This sub-division, which follows the example of LeBel (1996), was performed to make the first separation to form a basis for comparison by attempting to eliminate noise created by changes and variability in the wood supply system. The term "least efficient" was used instead of "inefficient" to avoid negative connotations since this category has a larger range than the others do.

The least efficient category included most of the observations obtained from both the CCR model (71%) and the BCC model (59 %) (Figure 7.5). Both models resulted in similar proportions of observations included in the partially efficient category, with 17 percent for the CCR and 18 percent for the BCC. The BCC models included more observations in the efficient category (23%), compared to the CCR model (12%).

Even though there were small differences, both models indicate that the majority of the observations were at least 21 percent less efficient than those located on the production frontier (Figure 7.5). This inefficiency may be a result of effects from technical, organizational, natural, administrative, and regulatory forces.

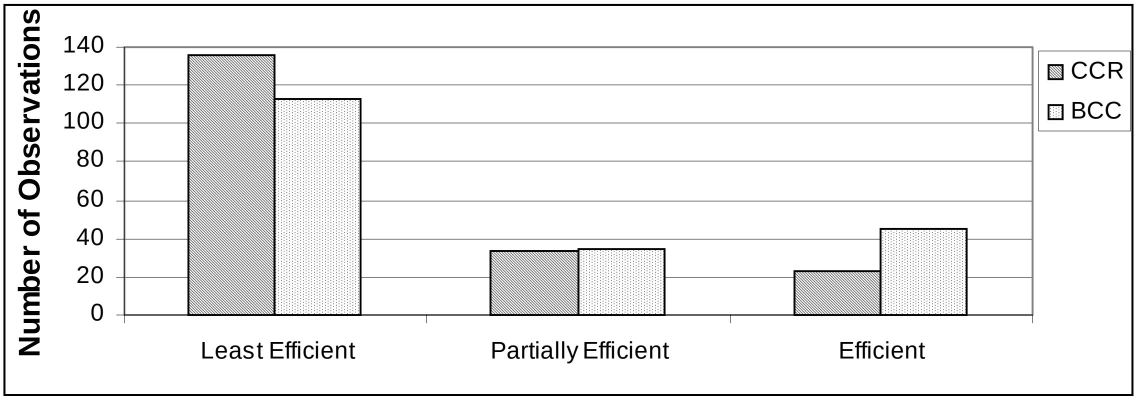


Figure 7.5. Number of Observations Rated Efficient (0.9-1), Partially Efficient (0.80-0.89) and Least Efficient (0.79>Observations) by the BCC and CCR Models.

7.1.2 Input Excesses and Output Slacks

Output slacks or input excesses occur when observations located on the production frontier use excessive amounts of inputs to produce a certain level of output (Triantis 1996). These observations are inefficient even though they are located on the production frontier. These observations are located on the flat portion of the production frontier, which can be identified by using two-stage DEA models. The first stage calculates the efficiency scores of the observations, while the second stage determines if input slacks or output excesses are present (LeBel 1996). The two-stage model was used to determine if any observations were located on a flat portion of the production frontier, to avoid deeming observations with output slacks or input excesses efficient.

Input excesses and output slacks do not pose a problem with these data. No observations on the CCR production frontier had input excesses or output slacks. Each observation on the CCR frontier was truly efficient. Several observations on the BCC frontier had minimal input excesses (Appendix D). Therefore, each observation on the BCC frontier will be considered truly efficient as well.

7.1.3 Färe Lovell and the Asymmetric Färe Models

The Färe Lovell (FL) and the Asymmetric Färe (AF) models are non-radial measures that calculate efficiency scores for each of the three input factors, referred to as partial efficiency scores. The models differ by how the peers or comparison values for the efficiency measurements are selected. The FL model only compares observations with peers located on the efficient part of the frontier, while the AF model compares observations with peer units located both inside and outside the efficient portion of the frontier. As in LeBel (1996), the AF model was preferred and will be used in the remainder of the chapter. Complete results from both the AF and FL models are included in Appendix C.

The FL model, without exception, had higher partial efficiency scores than the AF model (Table 7.1). The median, 25th percentile, and the 75th percentile from the FL model were 9-18 percentage points greater than those from the AF model. The models were the most similar in regard to labor and the most dissimilar in regard to consumables. The sources of these discrepancies are due to the different sets of peers selected by the models.

Even though the results from the two models differed, both showed that consumables were, overall, the most efficient of the three categories, followed by labor and then equipment (Table 7.1). Efficiency of the cost components depends in part on their correlation with production. Components with the highest correlation with production can be expected to be the most efficient. Consumables are the most closely related to production. Variation associated with consumable efficiency is likely related to technical, natural, or organizational forces, including percentage of pine harvested, tract condition, or the use of equipment requiring high repair and maintenance. Labor is also related to production due to the number of loggers paying by the hour or on production basis. Variation in labor efficiency is likely due to fringe benefits such as paid vacations and Christmas bonuses. Equipment costs, in the short run, are independent of production, and therefore are less directly affected by job productivity and days worked.

The results mentioned previously are supported by Figure 7.6, which divides the efficiency scores for consumables, equipment, and labor into the efficient, partially efficient, and least efficient categories. Equipment had the most observations in the least efficient category, followed by labor, and then consumables. In contrast, consumables had the most observations in the efficient and partially efficient category, followed by labor and then equipment.

Table 7.1 Descriptive Statistics of the Results from the Färe Lovell (FL) and Asymmetric Färe (AF) Models.

Variable	Mean	Median	25th Percentile	75th Percentile	Min	Max	Standard Deviation
AF Equipment	0.503	0.413	0.312	0.658	0.183	1	0.244
FL Equipment	0.603	0.544	0.428	0.737	0.299	1	0.215
AF Consumables	0.684	0.650	0.539	0.828	0.237	1	0.187
FL Consumables	0.830	0.823	0.711	1.0	0.345	1	0.148
AF Labor	0.664	0.630	0.525	0.772	0.332	1	0.175
FL Labor	0.748	0.728	0.644	0.855	0.412	1	0.152

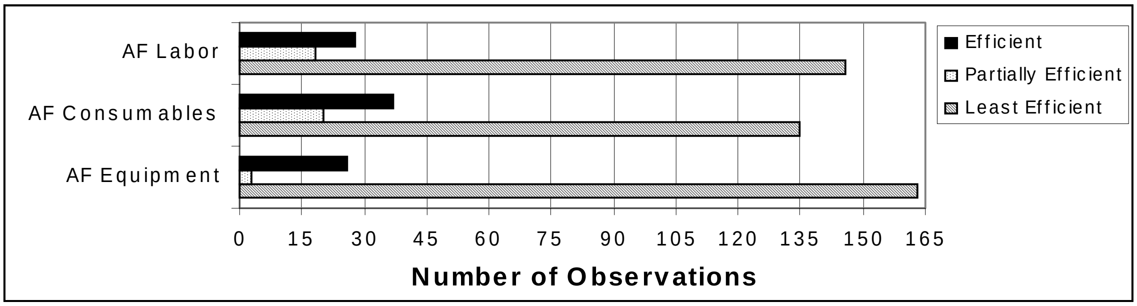


Figure 7.6. Number of Observations Rated Efficient (0.9-1), Partially Efficient (0.80-0.89) and Least Efficient (0.79>observations) by the Asymmetric Färe (AF) Model.

7.2 Demographics and Business Organization

Results obtained from the BCC model were divided into several groups according to issues discussed in Chapter 4. This information was used to assess the performance of the contractors and also the influence of the 5 forces affecting efficiency. The sample size for the groups analyzed varies at times; occasionally, only one contractor's data may make up a group, and therefore, the results should be analyzed with caution. The number of observations for each group can be seen on the figures included. It is difficult to isolate and to quantify the influence of any one force affecting efficiency at this point; therefore only suggestions were made.

7.2.1 Age, Experience, and Education

7.2.1.1 Age

The Pearson product-moment correlation coefficient used to test the relationship between age and technical efficiency was – 0.026, showing a very slight trend for efficiency to decrease with age. This trend was explored by dividing the observations into 5-year age classes, depending on contractor age for each observation. Contractors who have participated in the study since its start were therefore spread across 2 or more age classes. Median efficiency tended to increase with age from 30 to 60 (Figure 7.7). The least efficient contractors were located in the 45, 60, and 65-year classes, with median scores between 0.66 and 0.71, which influenced the negative Pearson correlation coefficient. The drop in median efficiency for these groups is largely unexplained at this point. It is difficult to isolate forces influencing the efficiency differences associated with contractor age; 1 or more of the 5 forces could be influencing the efficiency trends.

7.2.1.2 Experience

The Pearson correlation coefficient testing the relationship between level of experience and technical efficiency was 0.04, showing a very slight tendency for efficiency to increase with experience. This trend was analyzed by dividing the observations into 5-year experience classes. As before, observations for some firms were spread across several experience classes. Observations with over 25 years of experience were generally more efficient than the others (Figure 7.8). Median efficiency dropped for operations located within the 30 and 45-year classes due in part to small sample sizes associated with these groups. Observations with the fewest and the most years experience had the highest efficiency, with median scores ranging from 0.85 to 0.99. The remaining classes had scores ranging from 0.71 to 0.81. Ownership responsibilities had been transferred from father to son in the firms with the fewest years of experience. These operations were established and efficient before the transfer, limiting possible adverse effects of organizational and administrative forces. In other words, these were not "new" operations or inexperienced contractors.

7.2.1.3 Education

The Pearson correlation coefficient for education and technical efficiency was – 0.002, showing basically no relationship between efficiency and education level. This was explored further by dividing the observations by years of education (Figure 7.9). Observations with 11, 12, and 14 years of education had the highest median efficiency, which ranged from 0.77 to 0.80. The remaining observations had median efficiency scores ranging from 0.60 to 0.73. It is difficult to isolate forces influencing the efficiency differences associated with contractor education; one or more of the 5 forces could be influencing these efficiency trends. The difference could also be related to the fact that a relatively few observations were available for contractors who did not complete high school, associate's, or bachelor's degrees.

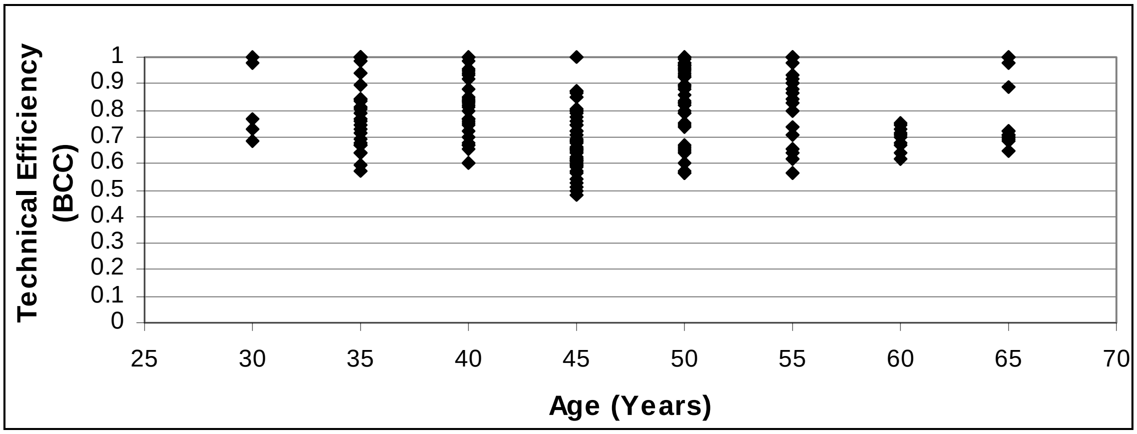


Figure 7.7. Relationship of Technical Efficiency (BCC) and Contractor Age.

Figure 7.8. Relation of Technical Efficiency (BCC) and Level of Experience.

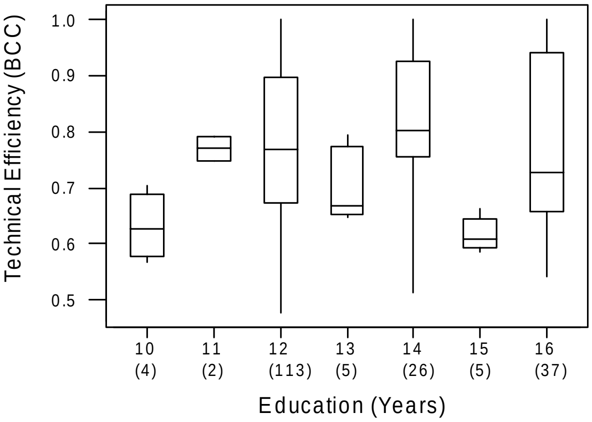


Figure 7.9. Relationship of Technical Efficiency (BCC) and Years of Education.

7.2.2 Region and State of Operation

Efficiency scores were divided into three physiographic regions, the coastal plain, mountain, and piedmont. The coastal plain operations had a slightly higher median efficiency score (0.79), followed by those in the piedmont (0.75), and then the mountains (0.71) (Figure 7.10). Results from Mann-Whitney tests showed that only the piedmont and the coastal plain were statistically different at the 90 percent confidence level, with a p-value of 0.0083. The majority of the mountain contractors harvested plantation pine, resulting in little difference between them and the coastal plain observations.

The influence of region of operation was explored further by dividing the observations into the 7 states represented. The scores from each state were relatively similar. Georgia and Virginia were the most efficient, with median efficiency scores of 0.82 (Figure 7.11). Alabama was next with a score of 0.788, followed by South Carolina with 0.75, North Carolina with 0.70, Florida with 0.70, and Tennessee with 0.65. These rankings were probably influenced by the relative small sample sizes from North Carolina, Florida, and Tennessee.

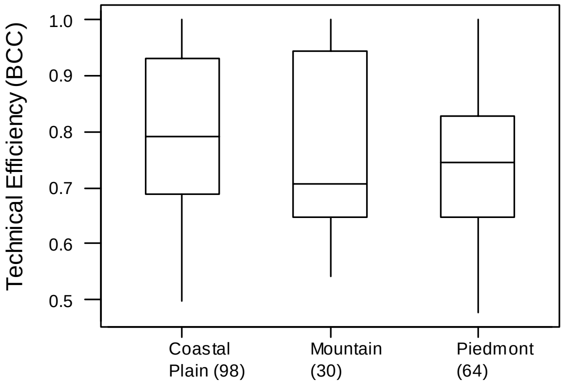


Figure 7.10. Relationship of Technical Efficiency (BCC) and Region of Operation.

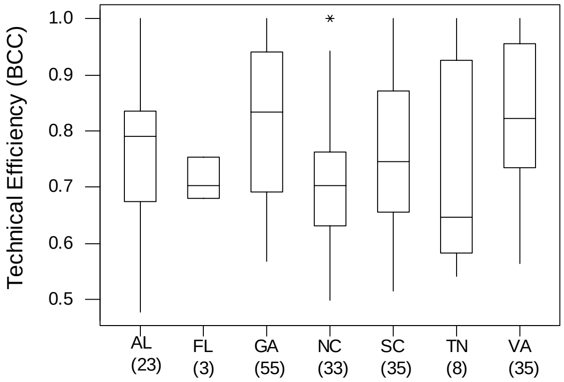


Figure 7.11. Relationship of Technical Efficiency (BCC) and State of Operation.

7.2.3 Business Organization

The influence of business organization on efficiency was analyzed by dividing the observations among the 4 business organization types discussed in section 4.2.1. Subchapter S corporations were the most efficient, with a median score of 0.83 (Figure 7.12). The remaining organization types had similar efficiency scores ranging from 0.72 to 0.75. Mann-Whitney tests were performed to determine if efficiency observations representing the business strategies were statistically different. The results stated that observations using sub S corporations were statistically higher than those organized as either full C corporations or sole proprietorships, with p-values of 0.008 and 0.0132, respectively. General partnerships had a smaller sample size than the others, partially explaining why they were not statistically different from sub S corporations, with a p-value of 0.3367.

Even though differences exist, the efficiency is likely related to organizational issues such as business management strategies, equipment-spread management, and tax advantages. These results simply suggest that contractors using sub S corporations, and to a lesser extent general partnerships, are more likely to be aware of and take advantage of these organizational issues. Full C corporations were expected to show the same awareness as sub S corporations. LeBel (1996) observed similar trends and suggested that the lower efficiency of full C corporations could be related to scale inefficiencies.

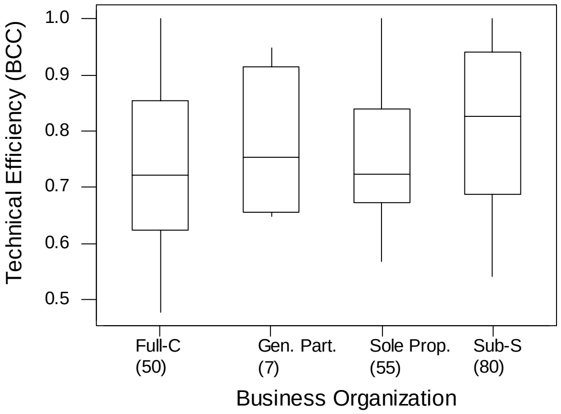


Figure 7.12. Relationship of Technical Efficiency (BCC) and Business Organization.

7.3 Operational Strategies

Operational strategies used by contractors, including markets, business and operations management, can potentially influence technical efficiency. This section will focus on the influence that operational strategies, introduced in Chapters 4–6, have on technical efficiency.

7.3.1 Species Harvested and Stumpage Acquisition

Information regarding the percentage of pine and hardwood harvested was obtained from production data, and also from contractor estimates. The influence of species type harvested was explored by dividing the observations into 10 percent classes, depending on the proportion of pine harvested. For the most part, efficiency increased as the percentage of pine harvested increased (Figure 7.13). The Pearson correlation coefficient was 0.28, suggesting a low to moderate relationship between species harvested and efficiency. The most efficient contractors harvested between 70 and 100 percent pine, with median efficiency scores ranging from 0.80 and 0.85. The upward trend can be noticed between observations harvesting 30 percent pine, with a median score of 0.67, and those harvesting 70 percent pine, with a median score of 0.805. Efficiency dropped fairly substantially for observations harvesting 80 percent pine, due to undetermined reasons, but increased once again for observations harvesting between 90 and 100 percent pine.

The relationship between stumpage acquisition and efficiency was explored by dividing the observations into 5 percent classes, depending on the proportion of company or wood dealer-owned stumpage harvested (Figure 7.14). The Pearson correlation coefficient was 0.24, suggesting that method of stumpage acquisition has a low to moderate impact on efficiency. Efficiency tended to decrease as the percentage of contractor-purchased stumpage increased. Observations harvesting between 15 to 25 percent contractor-owned stumpage had median efficiency scores of 0.69, compared to observations harvesting 0 to 5 percent contractor-owned stumpage, with scores of 0.79. This could be attributed to the fact that contractors harvesting a large share of company-or-dealer owned stumpage may have more access to larger, well-managed tracts. Alternatively, contractors who purchase a considerable share of their own stumpage may be torn between procurement, marketing, and running a logging business, adversely affecting efficiency.

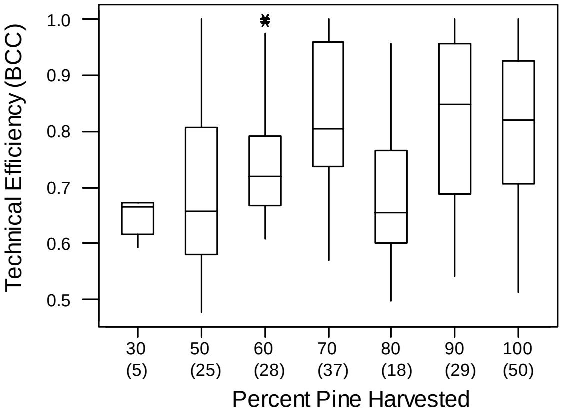


Figure 7.13. Relationship of Technical Efficiency (BCC) and Percentage of Pine Harvested.

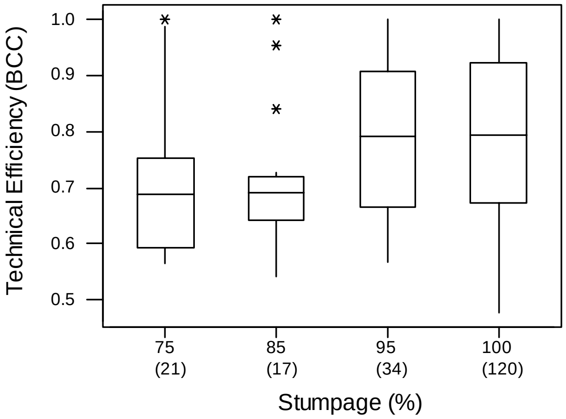


Figure 7.14. Relationship of Technical Efficiency (BCC) and Percent Company-or Wood-Dealer Owned Stumpage Harvested.

7.3.2 Production Capacity Utilization

Production capacity utilization, as defined in section 5.3, is the ratio of actual production to the maximum production level achievable during normal operating conditions. It was calculated taking the ratio of the median to the value of the 75th percentile, using weekly production information provided by 21 contractors.

The relationship between capacity utilization and technical efficiency was explored by grouping the technical efficiency scores into 5 percent capacity utilization classes. The Pearson correlation coefficient was 0.07, indicating a low relationship between capacity utilization and efficiency. Efficiency generally increased with capacity utilization, but the width of the inter-quartile range increased as well (Figure 7.15).

Two of the 3 observations with the lowest capacity utilization had relatively high efficiency scores. The contractor with the lowest capacity utilization rates reduced production but was able to reduce equipment, consumable, and labor expenses accordingly; he was, therefore, able to increase efficiency by downsizing. The other contractor increased production but tightened up the operation by reducing consumable and labor expenses from the previous year. The details of how these contractors were able to achieve respectable efficiency scores despite low capacity utilization rates are largely unknown, but it is clear that the operations had to make major adjustments to "weather the storm."

Four contractors with high capacity utilization rates had relatively low efficiency. Equipment partial efficiencies were low for all 4, indicating machine replacement, company downsizing, or low production in relation to equipment costs. Excluding operations, capacity utilization has a greater influence on efficiency. This trend indicates the negative effect that administrative and natural forces, in the form of wet conditions and production quota, can have on efficiency by reducing deliveries under normal levels.

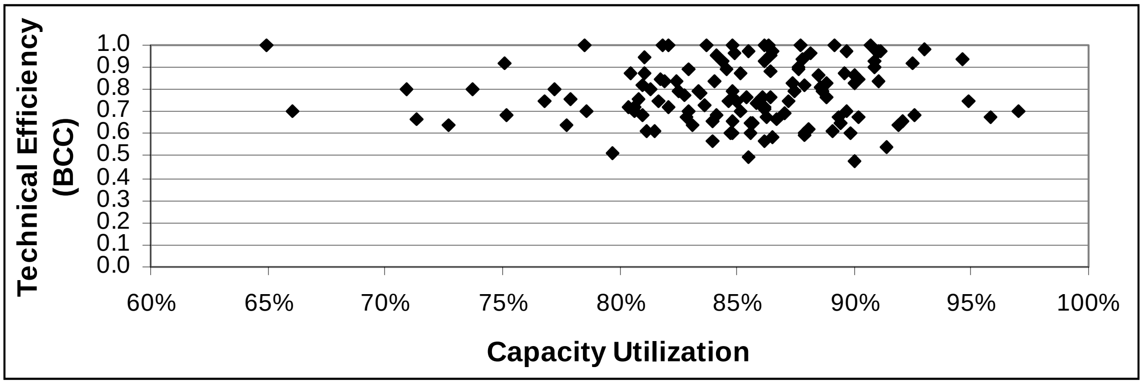


Figure 7.15. Relationship of Technical Efficiency (BCC) and Capacity Utilization.

7.3.3 Operation Size

LeBel (1996) stated that deviation from the most productive size, where the highest return per dollar spent" occurs, is a major cause of inefficiency for southern logging contractors. This was verified by dividing the operations into 40,000-ton production classes and analyzing the resulting CCR technical efficiency scores (Figure 7.16). The CCR model was used because it takes scale inefficiencies into account by comparing all observations to the most productive scale size.

The Pearson correlation coefficient was –0.081, indicating that efficiency, as measured by the CCR model, decreases slightly with production. The 100,000-ton class had the highest median efficiency. This class contains the region of the most productive scale size, which spans from approximately 60,000 to 80,000 tons. Some observations located in the 180,000-ton and higher classes showed relatively high scores, indicating that the CCR model deemed some observations efficient that were located either higher or lower than the most productive scale size. Even though observations with the largest scale sizes were generally less efficient, the contractors may have been concentrating on profitability rather than efficiency, as discussed in Section 1.1. Inefficiencies resulting from scale size are likely a function of organizational and administrative forces.

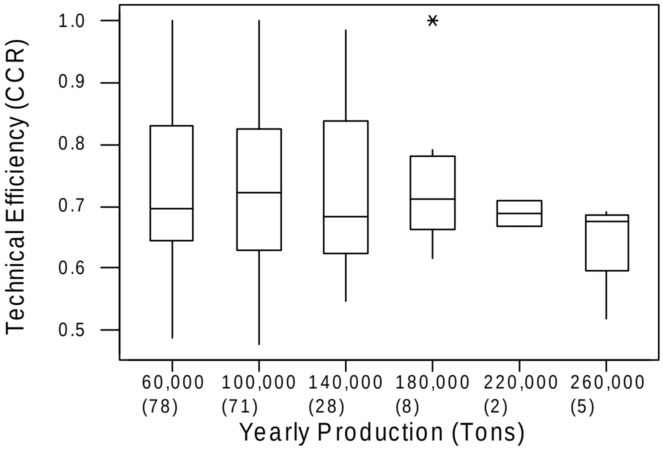


Figure 7.16. Relationship of Technical Efficiency (CCR) and Operation Size.

7.3.4 Productivity Operational Strategies

Three categories were used to classify operational strategies relating to productivity. These categories included upwardly elastic, downwardly elastic, and inelastic. Downward elasticity requires foregoing technology to reduce time-based costs or fixed costs. Upward elasticity requires maintaining extra resources for use when the opportunity arises. Inelastic refers to operations that maintain a fairly consistent level of production and manage the operation around that level of output. Twenty contractors, classified in Section 5.1, were used to explore the relationship between operating strategy and efficiency. Mann-Whitney tests showed no statistical differences across operating strategy at the 90 percent confidence level. The inelastic operation strategy had the highest efficiency with a median score of 0.835, followed by downwardly elastic with 0.809, and upwardly elastic with 0.760 (Figure 7.17). These results show that contractors with stable productivity were the most efficient, suggesting that variability is an enemy of efficiency.

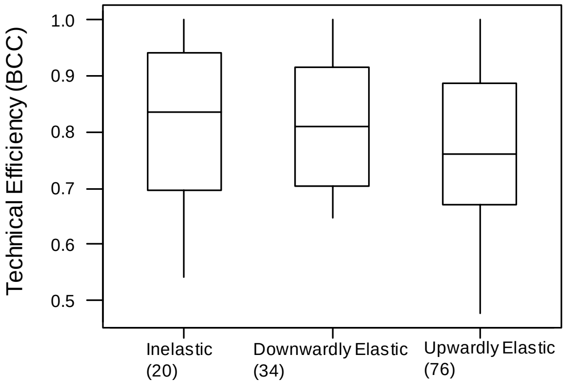


Figure 7.17. Relationship of Technical Efficiency (BCC) and Productivity Operational Strategy.

7.3.5 Cost Component Tradeoffs

Contractors use different combinations of the six cost components discussed in Section 6.1. The effect of cost allocations among equipment, consumables, and labor on technical efficiency was analyzed. Contract trucking expenses were divided evenly among the three components to ensure that all costs associated with the logging process were included.

The proportion of the total costs associated with the three components in each observation was found, ranked, and divided into four quartiles. The first group, referred to as low 1, includes observations in the first quartile. The second group, referred to as low 2, includes observations in the second quartile. The third group, referred to as high 1, includes observations in the third quartile. The last group, referred to as high 2, includes observations in the fourth quartile. A complete list of the proportion of the cost components associated with each observation is included in Appendix C.

7.3.5.1 Equipment

Equipment, in general, accounted for the lowest proportion of total costs. The Pearson correlation coefficient was – 0.25, indicating a low to moderate tendency for efficiency to decrease as the proportion of total costs relating to equipment increased. This was verified by dividing the observations into the cost strategy quartiles. Observations in the low 1 equipment strategy were the most efficient with a median score of .85, followed by low 2 with 0.75, high 2 with 0.75, and then high 1 with 0.74 (Figure 7.18).

The Mann-Whitney statistical test was used to determine if efficiency scores for the equipment strategies were statistically different. Efficiency scores for low 1 were significantly higher than the other strategies at the 90 percent confidence level (Table 7.2). Efficiency scores for the other strategies were not significantly different. These results suggest that contractors who spend a lower percentage of total cost during a particular year on equipment, i.e., to avoid time-based costs or fixed costs, are likely more efficient. Contractors who spend a lower percentage likely operate older equipment, have spread reinvestment overtime, or have downsized their operation.

Figure 7.19 shows that observations with a lower proportion of total costs associated with equipment were more efficient in regard to consumables. Low 1 was the most efficient in regards to consumables, with a median score of 0.86, followed by low 2 and high 1 with 0.76, and then high 2 with a score of 0.63. These results are related to the proportion of costs spent on labor, region of operation, and stand conditions.

Labor efficiency was fairly constant across equipment strategies (Figure 7.20). Contractors with lower costs relating to equipment tended to have slightly higher labor partial efficiency scores. The median labor efficiency scores for each category were similar, but low 1 and low 2 had higher scores at the 75th percentile.

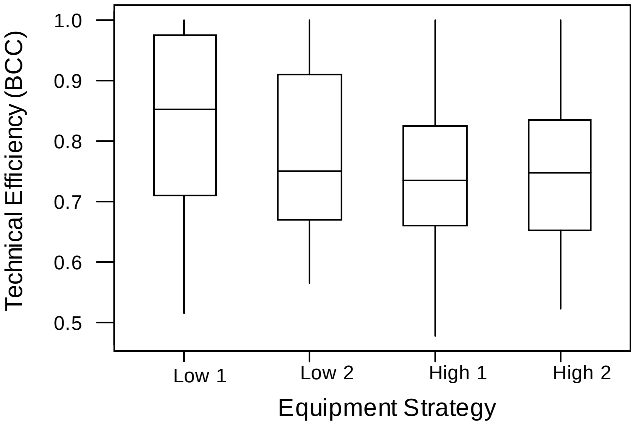


Figure 7.18. Relationship of Technical Efficiency (BCC) to the Percentage of Total costs Associated with Equipment.
(Low 1 = 7.5% - 20.1%, Low 2 = 20.2% – 23.9%,
High 1 = 24% - 27%, High 2 = 27.1% - 35.8%)

Table 7.2. Results from the Mann-Whitney Tests Relating to Equipment Strategy.

Comparison	P-Values
Low 1 vs. Low 2	**0.074**
Low 1 vs. High 1	**0.004**
Low 1 vs. High 2	**0.004**
Low 2 vs. High 1	0.302
Low 2 vs. High 2	0.307
High 1 vs. High 2	0.840

(P-values in bold are statistically significant at the 90 percent confidence level)

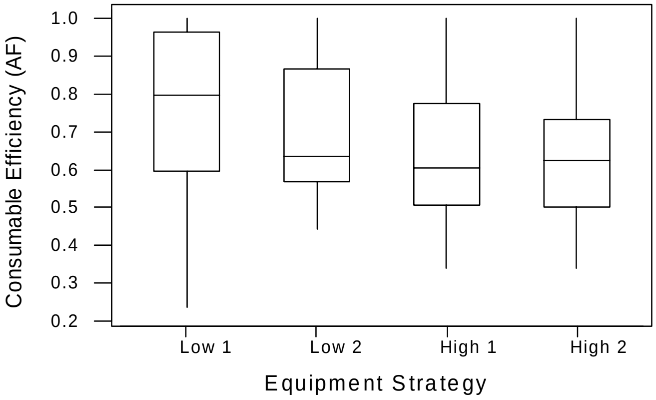


Figure 7.19. Consumable Partial Efficiency (AF) in Relation to Equipment Strategy.
(Low 1 = 7.5% - 20.1%, Low 2 = 20.2% – 23.9%,
High 1 = 24% - 27%, High 2 = 27.1% - 35.8%)

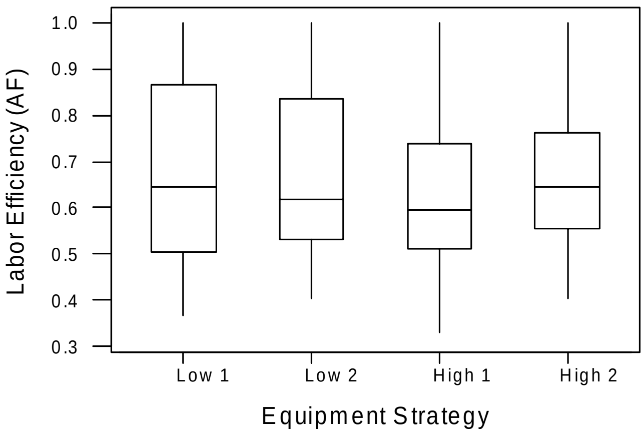


Figure 7.20. Labor Partial Efficiency (AF) in Relation to Equipment Strategy.
(Low 1 = 7.5% - 20.1%, Low 2 = 20.2% – 23.9%,
High 1 = 24% - 27%, High 2 = 27.1% - 35.8%)

7.3.5.2 Consumables

Consumables accounted for the second highest percentage of total costs. The Pearson correlation coefficient was – 0.17, indicating a low to moderate trend for efficiency to decrease as the proportion of total costs relating to consumables increased. This was verified by dividing the observations into the cost strategy quartiles. Low 1 was the most efficient consumable strategy with a median efficiency score of 0.83, followed by high 2 with 0.77, low 2 with 0.76, and then high 1 with 0.74. (Figure 7.21).

Results from the Mann-Whitney statistical test stated that low 1 was significantly more efficient than the low 2, high 1, and high 2 strategies at the 90 percent confidence interval (Table 7.3). These results state that contractors who spent a lower percentage of total cost on consumables were the most efficient, which is likely related to the proportion of total costs spent on equipment, region of operation, and stand conditions.

Observations spending a higher proportion on consumables were the most efficient in regard to equipment (Figure 7.22). The contractors who were the most efficient in regard to equipment were operating older equipment, had spread reinvestment overtime, or had downsized their operation, suggesting that more was spent on consumables in the form of repair and maintenance. Labor efficiency was higher for observations in the low 1 and the high 2 groups than the others (Figure 7.23).

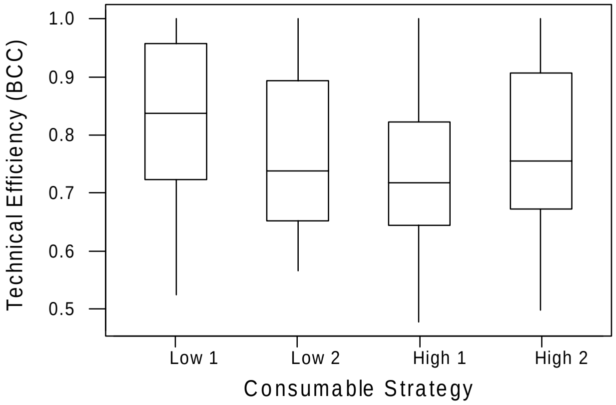


Figure 7.21. Relationship of Technical Efficiency (BCC) to the Percentage of Total costs Associated with Consumables.
(Low 1 = 19% - 24%, Low 2 = 24.1% – 27.6%,
High 1 = 27.7% - .30.4%, High 2 = 30.5% - 45.6%

Table 7.3. Results from the Mann-Whitney Tests Relating to Consumables.

Comparison	P-Values
Low 1 vs. Low 2	**0.011**
Low 1 vs. High 1	**0.0004**
Low 1 vs. High 2	**0.028**
Low 2 vs. High 1	0.553
Low 2 vs. High 2	0.600
High 1 vs. High 2	0.214

(P-values in bold are statistically significant at the 90 percent confidence level)

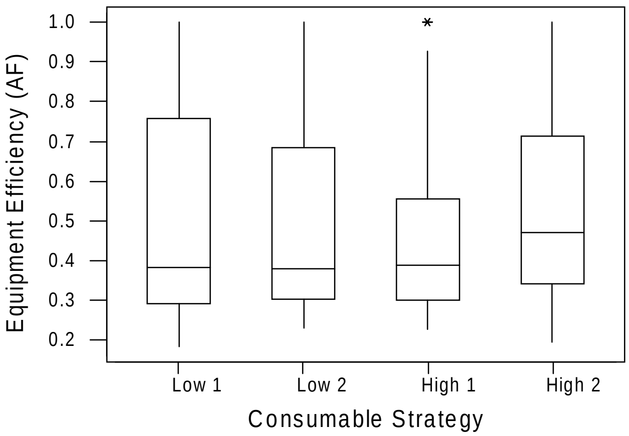


Figure 7.22. Equipment Efficiency (AF) Relating to Consumable Strategy.
(Low 1 = 19% - 24%, Low 2 = 24.1% – 27.6%,
High 1 = 27.7% - .30.4%, High 2 = 30.5% - 45.6%)

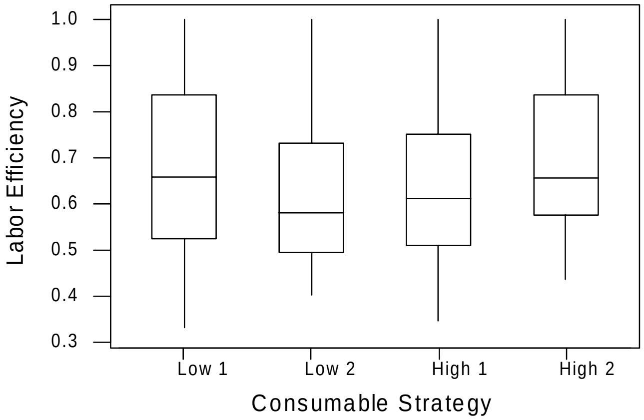


Figure 7.23. Labor Efficiency (AF) Relating to Consumable Strategy.
(Low 1 = 19% - 24%, Low 2 = 24.1% – 27.6%,
High 1 = 27.7% - .30.4%, High 2 = 30.5% - 45.6%)

7.3.5.3 Labor

Labor accounted for the highest proportion of total costs. The Pearson correlation coefficient was 0.31, suggesting a low to moderate trend for efficiency to increase with the proportion of total costs associated with labor. Observations included in the high 2 category had a median efficiency score of 0.87, followed by high 1 with 0.75, low 2 with 0.75, and then low 1 with a score of 0.74 (Figure 7.24).

Results from the Mann-Whitney statistical test stated that contractors with the highest proportion of total costs for labor were significantly more efficient than observations with lower percentages (Table 7.4). The high 2 group was significantly more efficient than the low 1, low 2, and high 1 strategies (Table 7.4). Scores from the other strategies were not ruled statistically different. The most efficient observations in the high 2 group were associated with observations that had consumables and equipment with the lowest possible proportions. This suggests the advantages gained from a qualified workforce and the importance of investing in the future by paying competitive salaries and benefits.

Observations with higher proportions of costs related to labor also appeared to be more efficient in regard to equipment and consumables (Figures 7.25 and 7.26). This trend could be associated with investing in the workforce or it could be associated with contractors who are delaying reinvestment.

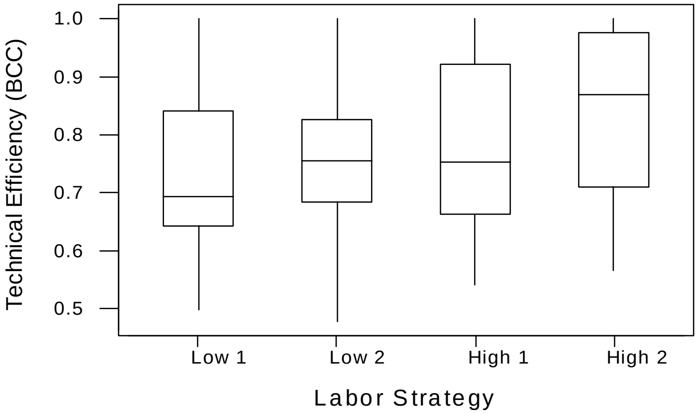


Figure 7.24. Relationship of Technical Efficiency (BCC) to the Percentage of Total Costs Associated with Labor.
(Low 1 = 26.6%- 38.0%, Low 2 = 38.2% – 41.9%,
High 1 = 42.0% - 45.2%, High 2 = 45.6% - 60.6%)

Table 7.4. Results from the Mann-Whitney Tests Relating to Labor.

Comparison	P-Values
Low 1 vs. Low 2	0.293
Low 1 vs. High 1	0.155
Low 1 vs. High 2	**0.001**
Low 2 vs. High 1	0.521
Low 2 vs. High 2	**0.004**
High 1 vs. High 2	**0.05**

(P-values in bold are statistically significant at the 90 percent confidence level)

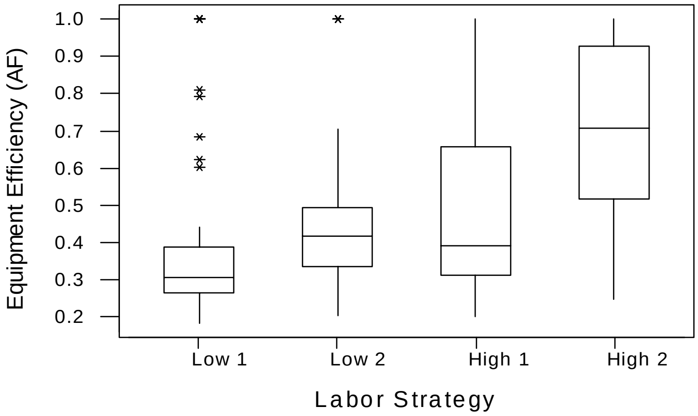


Figure 7.25. Equipment Efficiency (AF) Relating to Labor Strategy.
(Low 1 = 26.6%- 38.0%, Low 2 = 38.2% – 41.9%,
High 1 = 42.0% - 45.2%, High 2 = 45.6% - 60.6%)

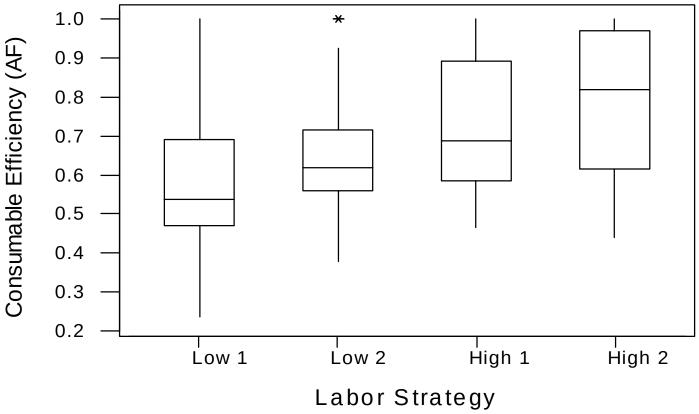


Figure 7.26. Consumable Efficiency (AF) Relating to Labor Strategy.
(Low 1 = 26.6%- 38.0%, Low 2 = 38.2% – 41.9%,
High 1 = 42.0% - 45.2%, High 2 = 45.6% - 60.6%)

7.3.5.4 Most Efficient Combinations

Component efficiencies are interesting, but the telling measure is the most efficient combination. The observations, along with the proportion of total cost associated with each component, were sorted according to efficiency scores and then divided into the efficient, partially efficient and least efficient categories used previously. This information was then used to determine the strategies associated with each efficiency group.

As expected, the efficient observations had low equipment and consumable costs and high proportions relating to labor (Table 7.5). Partially efficient observations had relatively high equipment, low consumables, and high labor (Table 76). Least efficient observations had relatively high equipment and consumables and low labor (Table 7.7).

The Mann-Whitney test was performed to determine if the efficiency categories had significantly different input mixes at the 90 percent confidence level (Table 7.8). The efficient observations had significantly lower equipment and higher consumables and labor than the partially efficient category. Efficient observations had significantly lower equipment and consumables and higher labor than the least efficient group. The partially efficient category had significantly lower consumables than the least efficient category. The partially efficient and least efficient categories were not significantly different in regard to equipment and labor.

Table 7.5. Cost Component Combinations for the Efficient Category

Component	Strategy	N	Median	25th Percentile	75th Percentile	Mean	Standard Deviation
Equipment	Low 2	45	0.216	0.155	0.247	0.202	0.061
Consumables	Low 2	45	0.260	0.233	0.311	0.271	0.050
Labor	High 1	45	0.452	0.403	0.505	0.454	0.081

Table 7.6. Cost Component Combinations for the Partially Efficient Category

Component	Strategy	N	Median	25th Percentile	75th Percentile	Mean	Standard Deviation
Equipment	High 1	34	0.260	0.214	0.322	0.259	0.011
Consumables	Low 2	34	0.241	0.224	0.277	0.251	0.067
Labor	High 1	34	0.418	0.390	0.453	0.420	0.009

Table 7.7. Cost Component Combinations for the Least Efficient Category

Component	Strategy	N	Median	25th Percentile	75th Percentile	Mean	Standard Deviation
Equipment	High 1	113	0.242	0.213	0.271	0.243	0.048
Consumables	High 1	113	0.283	0.255	0.308	0.286	0.041
Labor	Low 2	113	0.403	0.372	0.443	0.405	0.054

Table 7.8. Mann-Whitney Test Results.

Comparison	Equipment P-Values	Consumables P-Values	Labor P-Values
Efficient vs. Partially Efficient	**0.0003**	**0.079**	**0.0256**
Efficient vs. Least Efficient	**0.0001**	**0.042**	**0.0001**
Partially Efficient vs. Least Efficient	0.1348	**0.000**	0.139

(P-values in bold are statistically significant at the 90 percent confidence level)

7.3.6 Trucking Strategies

Three trucking strategies were used by the contractors:those who did all trucking i-house, those who contracted a portion of their trucking, and those who contracted out all of their trucking. The observations were divided into two groups, depending on whether the observations included contract trucking. Separate DEA analyses were done on both groups, using variable returns to scale (VRS) models from the OnFront™ software package. Separate analyses were done because the contract trucking included an extra input category for the trucking expense. The production frontiers obtained for the groups were similar (Figures 7.27 and 7.28).

Mann-Whitney tests were performed on production and cost observations located on both frontiers, resulting in p-values of 0.30 and 0.40. There is practically no difference in efficiency between jobs, with and without contract trucking. Therefore, it appears that the use of contract trucking did not appear to bring about gains in technical efficiency but is used instead to provide legal advantages, tax advantages, and to fill in trucking gaps without purchasing extra equipment.

A majority of the loggers contract out at least a portion of their trucking. The contract trucking group included all the larger operations (production > 100,000 tons per year). One of the larger contractors had trucking and logging organized into separate businesses and the others contracted a portion of their trucking.

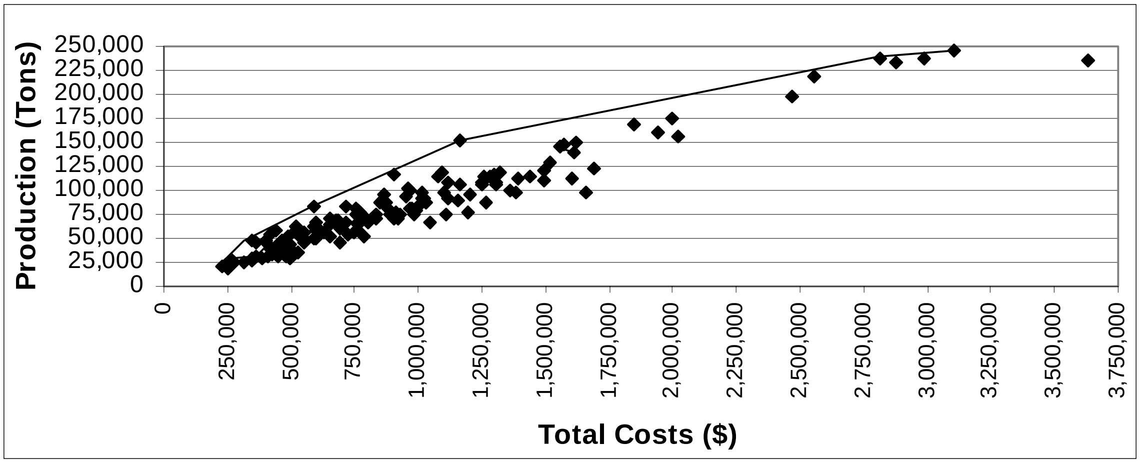


Figure 7.27. Location of the VRS Production Function for Observations using Contract Trucking.

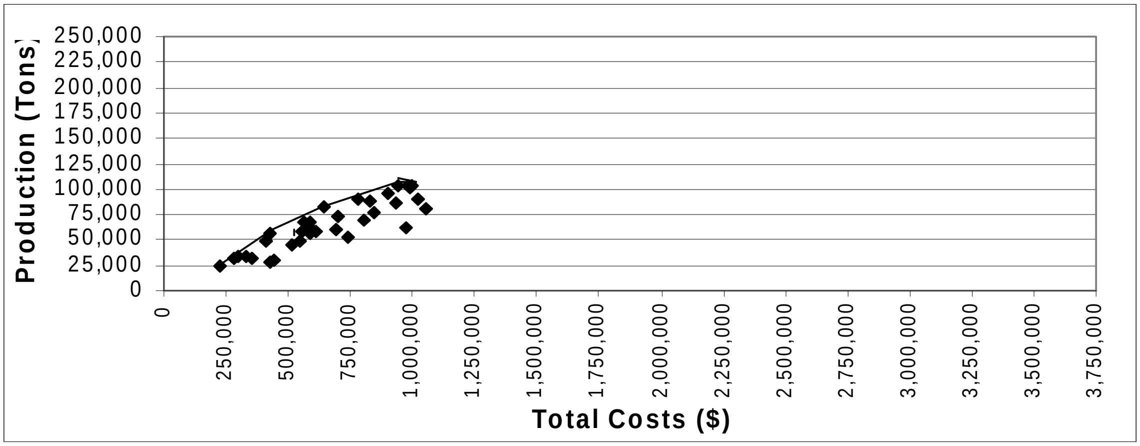


Figure 7.28. Location of the VRS Production Function for Observations not using Contract Trucking.

7.4 Technical Efficiency Trends

The database permitted exploration of yearly and quarterly efficiency trends from 1990 to 1996 to track contractor performance and to integrate cost and productivity trend analyses conducted in Chapters 5 and 6.

7.4.1 Quarterly Efficiency Trends

The available data were divided into two groups for the quarterly analysis. The first group included 6 contractors who provided complete productivity and cost data from 1990 through 1996. The second group included 15 contractors who provided at least two years of data for the period. Both groups showed the same general efficiency trends. The first group formed the basis for tracking efficiency of contractors across the entire period. Results obtained from the second group are included in Appendix D.

Technical efficiency tended to increase slightly from the first to the third quarter, before dropping off somewhat in the fourth quarter. The drop-off occurred mainly due to equipment and labor inefficiencies relating to employee benefits and operation downtime associated with hunting season, Thanksgiving and Christmas holidays (Figures 7.29 and 7.30). The Wilcoxon signed rank test was performed on paired quarterly efficiency scores to determine if any were significantly different. Only 1995 included quarters that were ruled statistically different at the 90% confidence level (Table 7.9). The differences are likely related to increases in productivity levels in the second and third quarters of 1995 (Section 5.2.1). Overall, there is no convincing evidence that efficiency varies with calendar quarter.

The contribution of equipment, consumables, and labor toward the efficiency trend is shown in Figure 7.30. Median partial efficiency relating to consumables remained fairly constant across each quarter. A slight decrease was shown in the second quarter, possibly from natural or administrative forces, before increasing in the third and fourth quarters. Equipment and labor median efficiency remained fairly steady through the third quarter, before dropping off in the fourth. Low efficiency for labor in the fourth quarter could be related to Christmas benefits. The decrease in equipment efficiency for the fourth quarter is likely related to year-ending tax advantages or accounting issues.

The Wilcoxon signed rank test was performed on the partial efficiency scores to find any significant differences across quarters. Each cost component had four quarters that were statistically different, indicating that each component was affected fairly equally (Table 7.10). The partial efficiencies in the first, second, and third quarters tended to be higher than those in the fourth, complementing the results shown in Figure 7.29. Most of the statistically different quarters occurred in 1995. The three cost components were fairly evenly represented, but consumables and labor had the lowest p-values.

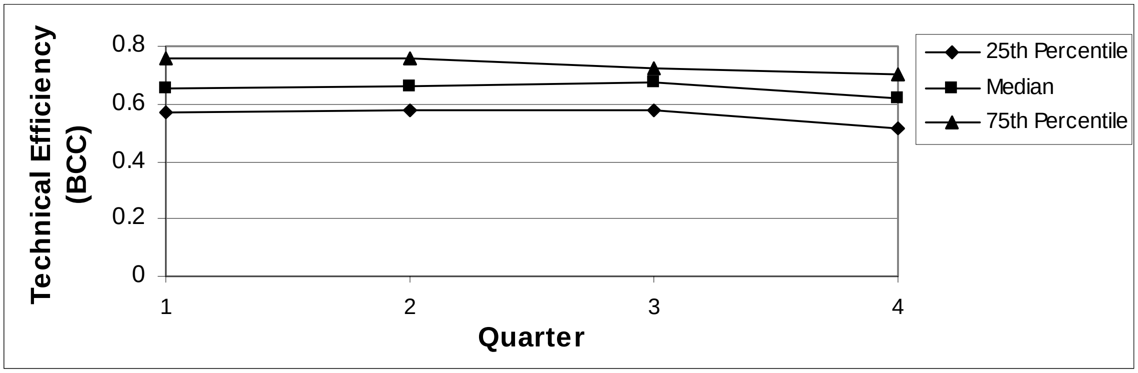


Figure 7.29. Quarterly BCC Technical Efficiency Scores (1990 – 1996).

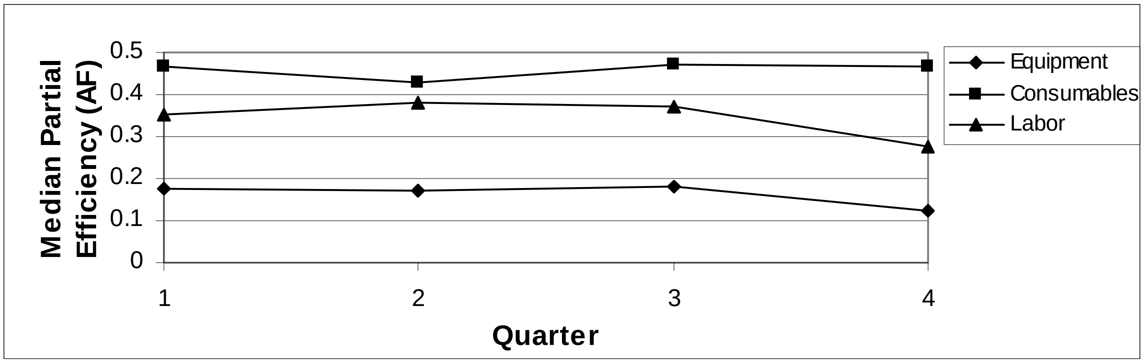


Figure 7.30. Quarterly Median AF Partial Efficiency (1990 – 1996)

Table 7.9 Paired Comparisons of Quarterly BCC Efficiency Scores (1990 - 1996).

Year	Comparison	N	P-Value	Median Difference	90% Confidence Low	Interval High
1990	Qtr.1 ≅ Qtr. 2	6	0.281	-0.03027	-0.105	0.012
1990	Qtr.1 ≅ Qtr. 3	6	1	0.001228	-0.153	0.151
1990	Qtr.1 ≅ Qtr. 4	6	0.834	0.003289	-0.112	0.14
1990	Qtr 2 ≅ Qtr. 3	6	0.295	0.01665	-0.048	0.155
1990	Qtr 2 ≅ Qtr. 4	6	0.142	0.04243	-0.016	0.156
1990	Qtr. 3 ≅ Qtr. 4	6	0.834	-0.0032	-0.0281	0.0685
1991	Qtr.1 ≅ Qtr. 2	6	0.529	-0.01822	-0.0547	0.018
1991	Qtr.1 ≅ Qtr. 3	6	0.675	0.01413	-0.0317	0.0506
1991	Qtr.1 ≅ Qtr. 4	6	0.834	-0.04035	-0.242	0.109
1991	Qtr 2 ≅ Qtr. 3	6	0.402	0.04798	-0.0192	0.0651
1991	Qtr 2 ≅ Qtr. 4	6	0.834	-0.03184	-0.25	0.129
1991	Qtr. 3 ≅ Qtr. 4	6	1	-0.093	-0.3	0.09
1992	Qtr.1 ≅ Qtr. 2	6	0.2187	0.2187	0.06916	-0.04
1992	Qtr.1 ≅ Qtr. 3	6	0.2187	0.2187	0.04221	-0.005
1992	Qtr.1 ≅ Qtr. 4	6	0.6875	0.6875	0.127	-0.041
1992	Qtr 2 ≅ Qtr. 3	6	0.6875	0.6875	-0.02331	-0.109
1992	Qtr 2 ≅ Qtr. 4	6	0.6875	0.6875	0.02083	-0.09
1992	Qtr. 3 ≅ Qtr. 4	6	0.6875	0.6875	0.09892	-0.079
1993	Qtr.1 ≅ Qtr. 2	6	0.675	-0.0162	-0.095	0.051
1993	Qtr.1 ≅ Qtr. 3	6	0.834	0.01514	-0.11	0.153
1993	Qtr.1 ≅ Qtr. 4	6	0.142	0.1236	-0.04	0.251
1993	Qtr 2 ≅ Qtr. 3	6	0.402	0.05292	-0.063	0.151
1993	Qtr 2 ≅ Qtr. 4	6	0.059	0.131	0.012	0.265
1993	Qtr. 3 ≅ Qtr. 4	6	0.208	0.0821	-0.025	0.211
1994	Qtr.1 ≅ Qtr. 2	6	0.834	0.01173	-0.092	0.165
1994	Qtr.1 ≅ Qtr. 3	6	1	0.004694	-0.145	0.16
1994	Qtr.1 ≅ Qtr. 4	6	0.675	0.02351	-0.1	0.226
1994	Qtr 2 ≅ Qtr. 3	6	1	0.008229	-0.161	0.096
1994	Qtr 2 ≅ Qtr. 4	6	0.675	0.03088	-0.053	0.115
1994	Qtr. 3 ≅ Qtr. 4	6	0.208	0.05122	-0.013	0.108
1995	Qtr.1 ≅ Qtr. 2	6	0.295	-0.04083	-0.103	0.019
1995	Qtr.1 ≅ Qtr. 3	6	0.142	-0.07335	-0.16	0.005
1995	Qtr.1 ≅ Qtr. 4	6	0.402	0.04295	-0.061	0.144
1995	Qtr 2 ≅ Qtr. 3	6	0.208	-0.03724	-0.087	0.029
1995	**Qtr 2 > Qtr. 4**	**6**	**0.059**	**0.06224**	**0.017**	**0.126**
1995	**Qtr. 3 > Qtr. 4**	**6**	**0.036**	**0.1078**	**0.033**	**0.182**
1996	Qtr.1 ≅ Qtr. 2	6	0.834	-0.01861	-0.131	0.075
1996	Qtr.1 ≅ Qtr. 3	6	1	0.000948	-0.077	0.044
1996	Qtr.1 ≅ Qtr. 4	6	0.295	-0.01414	-0.08	0.056
1996	Qtr 2 ≅ Qtr. 3	6	0.834	0.007809	-0.063	0.113
1996	Qtr 2 ≅ Qtr. 4	6	1	0.01507	-0.081	0.094
1996	Qtr. 3 ≅ Qtr. 4	6	0.402	-0.0154	-0.0374	0.0121

(Bold letters represent significantly different quarters at the 90% confidence level).

Table 7.10 Quarters with Significantly Different AF Partial Efficiencies (CI = 90%).

Year	Comparison	Cost Component	P-Value	Median Difference	90% Confidence Low	Interval High
1991	**Qtr 2 > Qtr. 3**	**Consumables**	**0.059**	**0.06396**	**0.007**	**0.145**
1992	**Qtr.1 > Qtr. 4**	**Equipment**	**0.093**	**0.13**	**0.002**	**0.483**
1993	**Qtr 2 > Qtr. 4**	**Labor**	**0.059**	**0.1953**	**0.049**	**0.339**
1995	**Qtr.1 < Qtr. 2**	**Equipment**	**0.093**	**-0.03235**	**-0.0574**	**-0.0033**
1995	**Qtr 2 > Qtr. 4**	**Equipment**	**0.059**	**0.05037**	**0.0221**	**0.1142**
1995	**Qtr 2 < Qtr. 3**	**Consumables**	**0.036**	**-0.07851**	**-0.149**	**-0.024**
1995	**Qtr. 3 > Qtr. 4**	**Consumables**	**0.036**	**0.1334**	**0.059**	**0.213**
1995	**Qtr.1 > Qtr. 4**	**Labor**	**0.059**	**0.09369**	**0.022**	**0.163**
1995	**Qtr 2 > Qtr. 4**	**Labor**	**0.036**	**0.1273**	**0.0822**	**0.1724**
1995	**Qtr. 3 > Qtr. 4**	**Labor**	**0.036**	**0.128**	**0.077**	**0.242**
1996	**Qtr 2 > Qtr. 4**	**Equipment**	**0.059**	**0.03971**	**0.005**	**0.142**
1996	**Qtr. 3 < Qtr. 4**	**Consumables**	**0.093**	**-0.0644**	**-0.139**	**-0.002**

(Bold letters represent significantly different quarters at the 90% confidence level).

7.4.2 Yearly Efficiency Trends

The available yearly data were divided into 2 groups similar to the quarterly data. The first group included 15 contractors providing complete productivity and cost data for 1990 through 1996. The second group included 32 contractors providing at least two years of data for the period. Results from the first group tended to be more conservative, but both groups showed the same general efficiency trends. The first group will be used to track efficiency across the entire period. Results obtained from the second group are included in Appendix D.

Yearly efficiency fluctuated somewhat but was in a general state of decline from 1990 to 1996 (Figure 7.31). Efficiency dropped somewhat in 1992 and 1993 before increasing in 1994 and 1995. Efficiency then dropped to the lowest point in 7 years in 1996.

Wilcoxon signed rank tests ruled that 1996 was statistically different from the previous 6 years at the 90% confidence level (Table 7.11). There is a larger efficiency difference between 1996 and the early years, evidenced by the p-values associated with the comparisons. The efficiency drop could imply that contractors were focusing on profitability rather than efficiency, but the drop in productivity experienced in 1996 discounts this. The efficiency decline is likely in part related to the inability of productivity increases to keep pace with inflation throughout the 1990's and the period of pulp and paper market oversupply in the mid-1990's.

The contribution of equipment, consumables, and labor toward the efficiency trend is shown in Figure 7.32. All three components experienced declines in median efficiency during the period: consumables experienced 0.18 decline in median efficiency, followed by labor with 0.13, and equipment with 0.12. Equipment had the most years that were significantly different with 7, followed by labor with 6, and consumables with 3 (Table 7.12). These data indicate that consumables and labor had less dramatic shifts than equipment in efficiency after 1992. Equipment efficiencies were by far the most cyclic in nature, showing the impact of equipment reinvestments in 1994 and 1996. Therefore, equipment appears to have had the largest impact on efficiency since 1992.

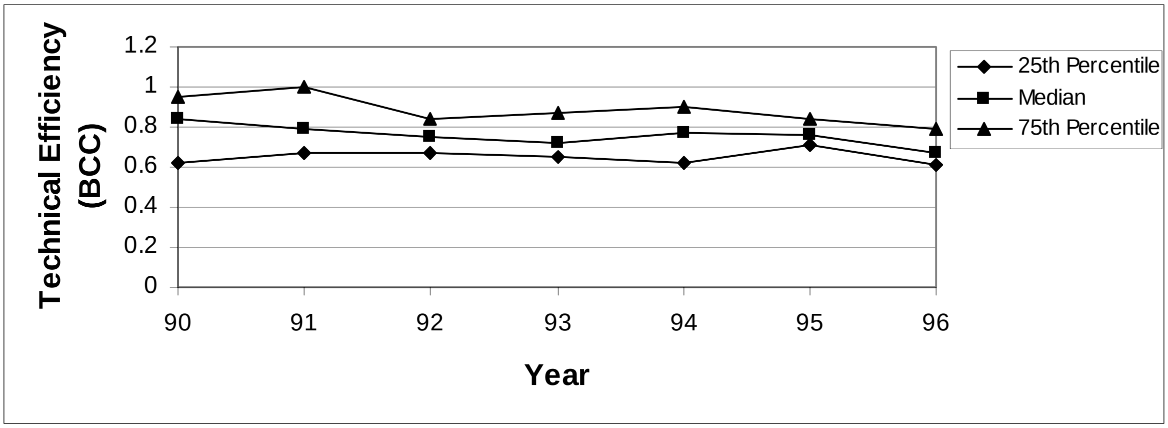


Figure 7.31. Yearly BCC Technical Efficiencies (1990 – 1996).

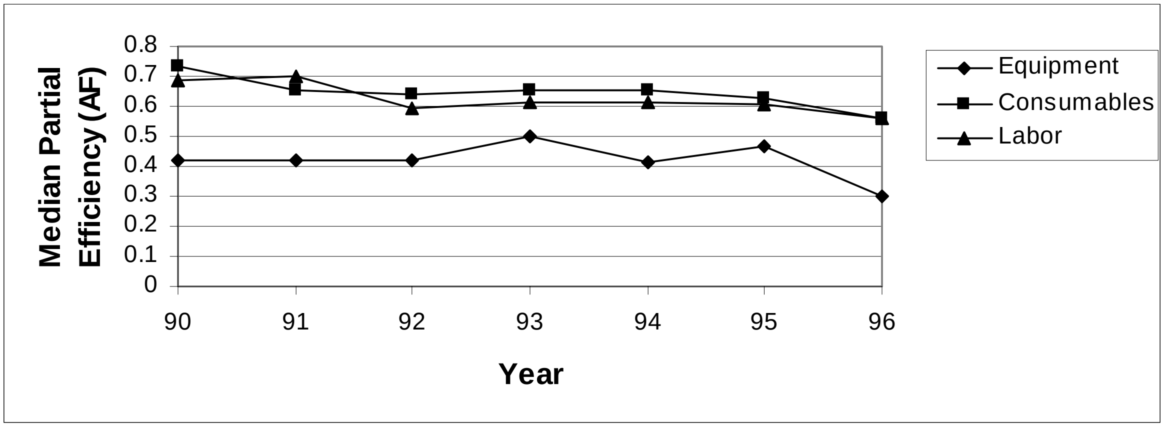


Figure 7.32. Median Yearly AF Partial Efficiencies (1990 - 1996).

Table 7.11. Paired Comparisons of Yearly BCC Efficiency Scores (1990 - 1996).

Comparison	N	P-Value	Median Difference	90% Confidence Low	Interval High
1990 ≅ 1991	15	0.222	-0.0234	-682	0.0222
1990 ≅ 1992	15	0.379	0.0284	0.047	0.091
1990 ≅ 1993	15	0.551	0.0201	0.046	0.095
1990 ≅ 1994	15	0.629	0.0267	-0.059	0.136
1990 ≅ 1995	15	0.551	0.0302	-0.104	0.14
1990 > 1996	**15**	**0.025**	**0.0973**	**0.015**	**0.208**
1991 ≅ 1992	15	0.132	0.0283	0.014	0.116
1991 ≅ 1993	15	0.346	0.0276	0.027	0.095
1991 ≅ 1994	15	0.451	0.0274	0.041	0.146
1991 ≅ 1995	15	0.514	0.0304	0.052	0.145
1991 > 1996	**15**	**0.018**	**0.117**	**0.021**	**0.21**
1992 ≅ 1993	15	0.851	-0.00439	0.0442	0.0267
1992 ≅ 1994	15	1	4.35E+00	0.0404	0.0572
1992 ≅ 1995	15	0.95	0.00447	0.067	0.073
1992 > 1996	**15**	**0.065**	**0.0703**	**0.001**	**0.141**
1993 ≅ 1994	15	0.616	0.00722	0.0231	0.0452
1993 ≅ 1995	15	0.67	0.0136	-0.046	0.07
1993 > 1996	**15**	**0.016**	**0.0813**	**0.022**	**0.141**
1994 ≅ 1995	15	0.755	-0.00812	-0.077	0.051
1994 > 1996	**15**	**0.083**	**0.0583**	**0.009**	**0.134**
1995 > 1996	**15**	**0.044**	**0.0688**	**0.004**	**0.12**

(Bold letters indicate statistically different yearly efficiency scores).

Table 7.12. Years with Significantly Different AF Partial Efficiencies (CI = 90%).

Comparison	Component	P-Value	Median Difference	Confidence Low	Interval High
1990 > 1996	**Equipment**	**0.044**	**0.1298**	**0.034**	**0.278**
1991 > 1996	**Equipment**	**0.033**	**0.1625**	**0.036**	**0.32**
1992 > 1996	**Equipment**	**0.021**	**0.0886**	**0.041**	**0.196**
1993 > 1994	**Equipment**	**0.209**	**0.04717**	**-0.013**	**0.099**
1993 > 1996	**Equipment**	**0.003**	**0.118**	**0.08**	**0.201**
1994 >1996	**Equipment**	**0.025**	**0.09353**	**0.035**	**0.155**
1995 > 1996	**Equipment**	**0.044**	**0.04883**	**0.012**	**0.162**
1990 > 1996	**Consumables**	**0.083**	**0.09514**	**0.011**	**0.205**
1991 > 1996	**Consumables**	**0.05**	**0.1237**	**0.025**	**0.23**
1993 >1996	**Consumables**	**0.025**	**0.09072**	**0.032**	**0.146**
1990 > 1996	**Labor**	**0.018**	**0.1293**	**0.053**	**0.215**
1991 > 1993	**Labor**	**0.033**	**0.06925**	**0.015**	**0.156**
1991 > 1996	**Labor**	**0.029**	**0.156**	**0.066**	**0.242**
1992 > 1996	**Labor**	**0.01**	**0.06252**	**0.0283**	**0.1189**
1993 > 1996	**Labor**	**0.065**	**0.04572**	**0.0076**	**0.0862**
1995 >1996	**Labor**	**0.033**	**0.07902**	**0.0177**	**0.1083**

7.5 Efficiency and Profitability

Marginal analyses were performed to analyze the relationship between efficiency and profitability. These analyses served to point out the approximate scale size associated with maximum efficiency and revenue. Efficiency is an important prerequisite of profitability, but the point of maximum efficiency is not always where efficiency is maximized, when green tons of wood produced is the output of the process. For example, contractors harvesting a larger proportion of hardwood may have lower efficiency but will be more profitable if high value species and products are encountered. The relationship between the most efficient operation size, also referred to as the most productive scale size (mpss), and profitability was also explored to make this point.

Marginal and average cost curves were found using methods discussed in LeBel (1996). Least squares regression procedures were used to develop quadratic equations that expressed total costs as a function of yearly production for observations located in the efficient, partially efficient, and least efficient groups. The residuals associated with these regression lines were analyzed, and it was determined that a non-constant variance problem was present. Weighted least squares, using one over the square root of production (x) as the weight, was used to remedy the non-constant variance problem.

Marginal cost and average cost curves were then developed from the resulting regression equations (Figures 7.33 – 7.35).

The average cost curve is concave upward in each of the three figures, showing differences in scale efficiency relating to high and low production (Stuart 1997). The rapid drop of the average cost curves on the left-hand side of the figures is due in part to the distribution of fixed costs. The average cost curve is negatively sloped until the point of least cost is reached, which represents the general location of the operation size where efficiency is maximized (mpss). DEA deemed several observations efficient that had average costs higher than the least cost point. These observations had relatively low or high production levels; therefore, the differences were due in part to variable returns to scale.

The average cost curve then rises as it moves beyond the area of lowest average cost, which, for the most part, signified a loss in efficiency. The marginal cost curve is a straight line with a positive slope, suggesting that costs, including equipment, are variable. The study included multiple contractors over multiple years, allowing all costs to become variable. The marginal revenue line was chosen arbitrarily to be $12 per ton, which is represented by a straight line across each figure.

Marginal analyses of the least efficient observations showed that the point where marginal costs equals marginal revenue at $12 per ton is located at a scale size lower than the area of least cost (Figure 7.33). Therefore, these observations must increase efficiency, by reducing average cost per ton, to minimize losses. To be profitable, these observations would have to receive a marginal revenue rate higher than $12 per ton.

Figures 7.34 and 7.35 show that the point of maximum profitability, where marginal costs equals marginal revenue, is located at a larger production level than that of the most efficient operation size (mpss). In this example, for contractors operating at the most efficient operation size to maximize profits, they must increase production. This production increase would result in higher average cost per ton, thus lowering efficiency.

A larger number of observations included in the partially efficient group were located near the scale where marginal revenue equals marginal costs (Figure 7.34). It is likely that these observations are focusing on profits rather than maximum efficiency. Several observations in the least efficient category have moved beyond the area of least cost as well, perhaps because of the relatively low slope of the marginal cost curve.

As in Stuart (1997), more observations were located in the area of least costs on the average cost curve. It is possible that these operations are being constrained to operate in this region from administrative, managerial, or natural forces. It is important for all parties involved that contractors produce as close to the point of maximum profits as possible, to guarantee future participation. Contractors in this position could, in turn, be able to provide increased production during periods of high demand, and reduce production during periods of low demand without being driven to the point of bankruptcy.

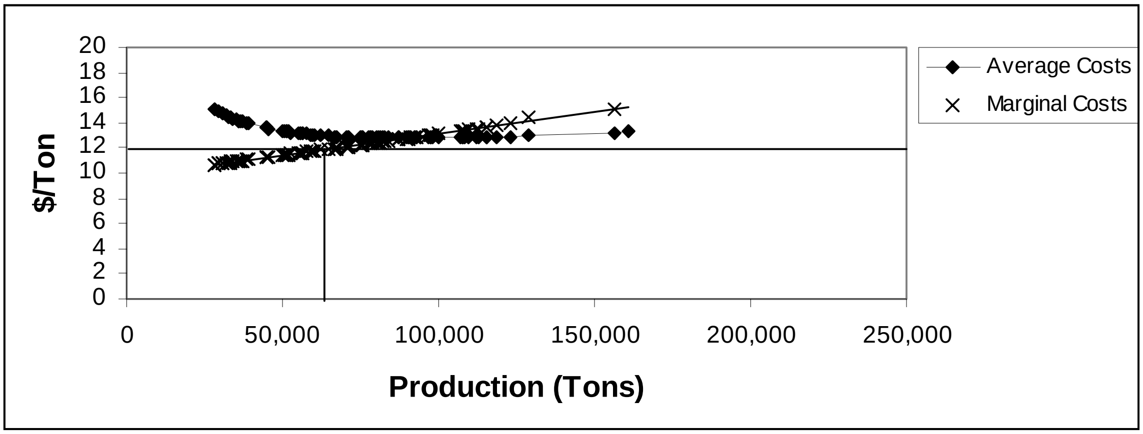


Figure 7.33. Marginal and Average Cost Curves for Least Efficient Observations. (TE < 0.74). (Total Cost = 1.6562E-05x^2 + 9.9755x + 138004)

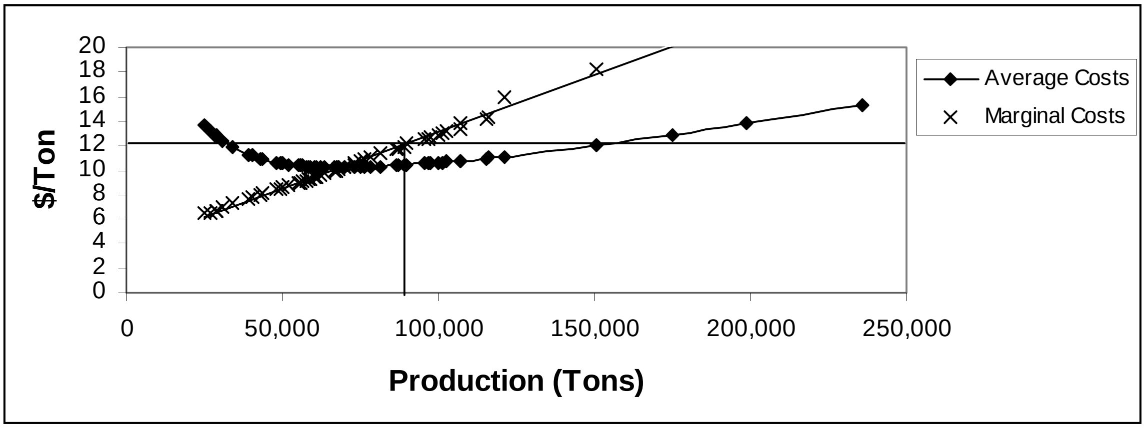


Figure 7.34. Marginal and Average Cost Curves for Partially Efficient Observations. (0.89 > TE > 0.75). (Total Cost = 4.2979E-05x^2 + 4.178488x + 211747)

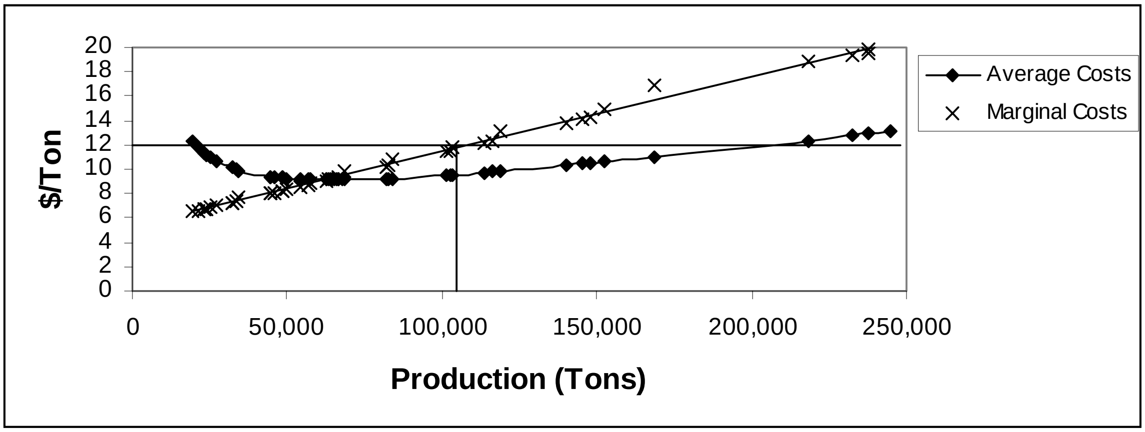


Figure 7.35. Marginal and Average Cost Curves for Efficient Observations (TE > 0.90). (Total Cost = 2.9980E-05x^2 + 5.238750x + 125517)

7.6 Summary

Technical efficiency, an indicator of the green tons of wood produced per dollar of expenditure, was used to measure the performance of participating contractors. This information was used to explore the influence of technical, organizational, natural, administrative, and regulatory forces on contractor performance. Quarterly and yearly efficiency trends and the relationship between efficiency and profitability were also explored.

The efficiency scores were separated into three groups, efficient (0.90 – 1), partially efficient (0.80 – 0.89), and least efficient (obs < 0.79). The least efficient category included most of the observations obtained from the BCC model (59%), followed by the efficient (23%) and the partially efficient categories (18%). Efficiency scores for consumables and labor were considerably higher than those for equipment. This difference indicates that equipment reinvestments have a considerable impact on technical efficiency.

Middle-age contractors tended to be slightly more efficient than the others. Contractors with the most experience tended to more efficient as well. Contractors with at least a high school education were also more efficient than the others. It is difficult to isolate forces influencing the efficiency differences associated with contractor age, education, or experience.

Separation of the observations according to state and region of operation showed that Georgia and Virginia were the most efficient, followed by Alabama, South Carolina, North Carolina, Florida, and Tennessee. The coastal plain was the most efficient physiograhpic region, followed by the mountains and the piedmont. The majority of the mountain contractors harvested plantation pine; therefore, little difference was found between them and the coastal plain. Small sample sizes restricted rankings of contractors from North Carolina, Florida, and Tennessee.

Analysis of the influence of business organization on efficiency showed that observations using sub chapter S corporations were the most efficient, followed by general partnerships, full C corporations, and sole proprietorships. These results suggest that contractors using sub S corporations and general partnerships to a lesser extent, are more likely to be aware of and take advantage of business management, and tax strategies. Full C corporations were expected to show the same trends as sub S corporations, but scale inefficiencies are likely affecting these scores.

Efficiency generally increased as the percentage of pine harvested increased. This trend can be attributed in part to technical or natural forces relating to more difficult conditions encountered when harvesting hardwood in the southeastern U.S. Contractors who purchased a significant portion of their stumpage tended to have lower efficiencies. This could be attributed to the fact that contractors harvesting a large share of company-or-dealer owned stumpage may have more access to larger, well-managed tracts. Alternatively, contractors who purchase a considerable share of their own stumpage may be torn between procurement, marketing, and running a logging business, adversely affecting efficiency.

Excluding operations that were making adjustments or under producing efficiency tended to increase with higher capacity utilization. This trend indicates the negative effect that administrative and natural forces, in the form of wet conditions and production quota, can have on efficiency by reducing deliveries under normal levels.

Contractors producing between 60,000 and 100,000 tons per year had the highest median CCR technical efficiency. This range includes the most productive scale size, which spans approximately 55,000-85,000 tons. Even though observations with larger scale sizes were generally less efficient, contractors may have been focusing on profitability rather than efficiency. Inefficiencies resulting from scale size are likely a function of organizational and administrative forces.

Observations were classified by operational strategies relating to productivity, including upwardly elastic, downwardly elastic, and inelastic strategies. The inelastic operation strategy was the most efficient, followed by downwardly elastic, and upwardly elastic. These results state that contractors with stable productivity were the most efficient, strongly suggesting that variability is indeed the enemy of efficiency.

The most efficient observations had relatively low equipment and consumable costs, and higher proportions associated with labor. Observations with lower efficiency tended to have higher proportions of their costs associated with equipment and/or consumables.

Separate DEA analyses were conducted on observations with and without contract trucking, using variable returns to scale (VRS) models from the OnFront™ software package. The production frontiers obtained for the groups were similar. There does not appear to be a major difference in efficiency associated with trucking strategy. Therefore, it appears that the use of contract trucking does not represent gains in technical efficiency, but was used instead to provide legal advantages, tax advantages, and to fill in trucking gaps without purchasing extra equipment.

Technical efficiency tended to increase slightly from the first to the third quarter, before dropping off somewhat in the fourth quarter, mainly due to inefficiencies relating to equipment and labor inefficiencies associated with the holiday season. Wilcoxon signed rank tests were performed on paired quarterly efficiency scores to determine if any of the quarters were significantly different. Only 1995 included quarters that were ruled statistically different at the 90% confidence level. The differences are likely related to increases in productivity levels in the second and third quarters of 1995, as mills increased inventories. Overall, there is no convincing evidence that efficiency varies with calendar quarter.

Yearly efficiency fluctuated somewhat but appeared to be in a general state of decline for the period. Significant differences existed between 1996 and the previous 6 years at the 90% confidence level. The efficiency decline is due in part to the inability of productivity increases to keep pace with inflation throughout the 1990’s and the period of pulp and paper market oversupply in the mid-1990’s. All three cost components experienced median efficiency declines during the period. Consumables and labor had less dramatic declines in efficiency after 1992 than did equipment. The cyclic nature of equipment therefore appeared to have had the largest impact on efficiency after 1992.

Efficiency is an important prerequisite to the ultimate goal of any business, but profits and efficiency are not always maximized at the same point. Many observations were located in the area of least costs on the average cost curve, indicating that profits were not being maximized for these observations. It is possible that these operations are being constrained to operate in this region from administrative, managerial, or natural forces. It is important for all parties involved for contractors to produce as close to the point of maximum profits. Contractors in this position could in turn provide added benefits to the wood supply system, including increased flexibility, safety, and professionalism.

Chapter 8 SUMMARY AND CONCLUSIONS

A data set including 35 loggers contributing 192 logger years of productivity and cost information was compiled. Information including logger demographics, business, and operational data was also collected through an interview process with the participants.

The data set was used to measure the performance of the participating loggers to give indicators of the overall economic health of the southeastern U.S. logging industry. A variety of quality control tools were used to analyze the demographic, organizational, business, productivity, and cost information. Data Envelopment Analysis, a non-parametric statistical tool, was used to measure the technical efficiency associated with each logger year. Technical efficiency was the primary criterion along with profitability considerations used to evaluate the performance and overall economic health of the participating loggers.

8.1 Demographics, Business Organization, and Efficiency

Demographic factors that included age, experience, and education appeared to have only minimal impacts on contractor efficiency, indicating that business, operational, and environmental factors likely have greater influence on efficiency. Analysis of the influence of business organization on efficiency showed that observations using sub chapter S corporations were the most efficient, followed by general partnerships, full C corporations, and sole proprietorships, indicating the positive impacts of wise business management, and tax strategies.

8.2 Operational Strategies and Efficiency

Groups of observations with low proportions of total cost relating to equipment and consumables tended to have the highest median efficiency scores. Observations with lower median efficiency tended to have higher proportions of their costs associated with equipment and/or consumables. These trends indicate that efficiency, or operating in the area of least costs, is not necessarily in the best interest of the logging contractors or the wood supply system as a whole. Contractors with low proportions related to equipment and consumables are not in the process of building equity, which is important to maintain a productive supplier force.

8.3 Productivity, Costs, and Efficiency

Analysis of yearly productivity information revealed a general upward trend in production levels between 1990 through 1995, before dropping off in 1996. Wilcoxon signed rank tests showed that production levels for 1990 and 1991 were statistically lower than the others and that 1995 was statistically higher than the others. The years 1992 through 1994, along with 1996, were not statistically different.

Analysis of yearly cost information revealed a fairly steady increase in median costs from 1990 to 1995, with a drop in median costs in 1996. Paired sample analysis using the Wilcoxon signed rank test revealed that all but 3 yearly pairs were statistically different. The pairs not determined to be statistically different included 1990 vs. 1991, 1993 vs. 1994, and 1995 vs. 1996.

Each of the 6 cost categories contributed to the increasing cost trend. Contract trucking marked the largest increase in median cost from 1990 to 1996, with an increase of $122,679, followed by labor with an increase of $111,611, consumables with $69,368, equipment with 61,402, administrative overhead with $11,958, and insurance with $8,739. Median costs for contract trucking and equipment increased in 1996 from 1995. The increase in contract hauling is due in part to the trend for contractors to separate logging and trucking. Equipment and contract trucking represent a higher proportion of fixed or time-based costs than do labor and consumables. These time-based costs or fixed costs continue to accumulate during periods with little or no production, negatively affecting efficiency.

Yearly efficiency fluctuated somewhat but appeared to be in a general state of decline for the period. The year with the lowest efficiency was 1996, which was ruled to be statistically lower than the previous 6 years at the 90% confidence level. The efficiency decline is due in part to the inability of productivity increases to keep pace with inflation throughout the 1990's, the increase in fixed costs, and the period of pulp an paper market oversupply in the mid 1990's.

All three cost components experienced median efficiency declines during the period. Consumables and labor had less dramatic declines in efficiency after 1992 than did equipment. The cyclic nature of these fixed costs related to equipment appeared to have had the largest impact on efficiency after 1992. Reinvestments during the mid-1990's, therefore, had a major impact on the observed efficiency trend.

Efficiency is expected to normally decrease in years in which fixed costs increase. When increases in fixed costs are coupled with a decline in productivity, as in 1996, drops in efficiency, and profitability are much more profound. It is therefore important to continue to track contractor performance and efficiency to determine if the drop in efficiency shown has any lasting affects on performance and productivity.

8.4 Efficiency and Profitability

Efficiency is an important prerequisite for profitability, but maximum profits and efficiency do not always occur at the same point. The average cost curves in chapter 7 indicate that unit costs are higher at the point where maximum profits occur. More observations were located in the area of least costs on the average cost curves, indicating that profits were not being maximized in those observations.

It is important for all parties involved for contractors to produce as close to the point of maximum profits as possible to ensure future productivity gains and participation. Operations working at the point of maximum profitability can offer several benefits to the wood supply system including, flexibility during periods of high and low demand, improved safety performance, improved environmental performance, and increased professionalism.

8.5 Suggestions for Future Research

1. The number of loggers producing in excess of 100,000 tons per year should be increased. This will provide a better understanding of the relationship scale size to efficiency and profitability.

2. Further research should be conducted oriented toward finding specific influences and trends associated with the 5 forces affecting efficiency, possibly by explicitly modeling these factors as part of deriving the results.

3. Yearly technical efficiency and partial efficiency should continue to be tracked, especially in regards to equipment and the production frontiers. Equipment appeared to have the most influence on efficiency from 1992 to 1996, and therefore deserves extra attention in the future. Yearly production frontiers should be compared to track standards of efficiency overtime.

4. The participating contractors used three harvesting systems, which were made up of similar equipment. Each system was assumed to be part of the same technology. These systems should be explored further to determine if they actually constitute different technologies.

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Appendix A. Interview Form

Name of Logger:
Name of Logging Company:
Primary Paper Company:
Contractor Age:
Education:
Business Start Date:
Organization Style:
Changes:
Family Business?

Other Businesses?

phone numbers

house

shop

mobile

Address

The Business
A. Radius of Operations from shop/office. Trends over the years. Affect on trucking.

Markets:	**Product / Species.**	**Relative Haul Distance**

B. Delivery Point and Contractor's Production Information for Periods of Interest:

1. Maximum production (loads per week) - contractor's assessment
2. Average production (loads per week)

C.   Means of stumpage acquisition
   1. % Paper company purchased
   2. % Contractor purchased

D. Species harvested
   1. % Pine
   2. % Hardwood

D. Business records (books) maintained by: (family member, hired bookkeeper, etc.)
   1. Is a computer used in the business?
      If so, how exactly?
      What software is used?

   2. Does an accountant prepare taxes for the business?

G. Other business-related questions:

* What is the organization style of the business? years and dates. reasons.

Sole Proprietorship	
Partnership	
Sub chapter S Corporation	
Full C Corporation	

1. The business owns and operates an office?
2. The business maintains it's own shop?

Crew Organization, Tasks and Safety

A. Total number of employees at time of visit

1. In-woods:
2. Truck drivers:
3. Support employees:

B. Breakdown of crew organization, tasks, and time with crew:

C. Turnover problems - past present, and future:

D. Employment and layoff strategies - past, present, and future:

E. Normal work week/day:

F. Compensation - wages and salaries:

1. Method by which crew is paid:
2. Why current method of payment?
3. Method by which contractor pays self, partners, or shareholders?
4. Are any key or support employees paid a salary?
5. How many relatives are employed?

G. Fringe Benefits for Employees:
  1. Transportation
  2. Uniforms
  3. Paid Vacation / Holidays
  4. Christmas Bonuses
  5. Loans / Financing
  6. Health Insurance
  7. Production Bonuses
  8. Pension Plans

Equipment Spread and Operation

Overall Equipment Strategy:
1. New “high brass” job - roll over equipment every 2-3 years
2. Middle of the road - take full depreciation, then roll over every 5-6 years.
3. Buy and run used equipment - emphasize repair and maintenance
4. Combo of the above.

A. Logging Equipment Spread, Models, and Years:

B. Truck and trailer spread:

C. Support equipment:

D. Trucking - own vs. subcontracting?

  1. Why current philosophy?
  2. Plans for the future?
  3. Range of average haul distance:

E. Operating philosophies and insights

F. Plans for next 1 - 2 years with regard to spread changes, expansions or contractions

G. Other insights with regard to machinery and transportation

The Contractors Stump:

A. Quotas:

  1. Contractor's situation at time of visit:

  2. Contractor's view of past present and future?

  3. Contractors suggestions for improving the current quota situation:

B. Insurance

  1. Workers' compensation

    a. Carrier

    b. Experience modification factor and rate

  2. Fire / Theft / Vandalism:

    a. Fire insurance: carrier and status

    b. Incidents of vandalism and theft.

  3. Liability

Appendix B. Results from the BCC, and CCR Models

Observation	ID	Yr.	BCC	CCR	Observation	ID	Yr.	BCC
1	2	94	0.75	0.75	98	808	91	0.64
2	2	95	0.70	0.69	99	808	92	0.75
3	2	96	0.68	0.67	100	808	93	0.71
4	101	89	0.84	0.83	101	808	94	0.72
5	101	90	0.95	0.95	102	808	95	0.72
6	101	91	1.00	1.00	103	808	96	0.70
7	101	92	0.66	0.65	104	809	92	0.96
8	101	93	0.64	0.62	105	809	93	0.93
9	101	94	0.62	0.62	106	809	94	1.00
10	101	95	0.57	0.57	107	809	95	0.93
11	101	96	0.54	0.54	108	809	96	1.00
12	102	88	0.71	0.65	109	810	90	0.88
13	102	89	0.67	0.62	110	810	91	1.00
14	102	90	0.73	0.67	111	810	92	0.77
15	102	91	0.71	0.64	112	810	93	0.83
16	102	92	0.69	0.65	113	810	94	0.80
17	102	93	0.65	0.62	114	810	95	0.76
18	102	94	0.68	0.67	115	810	96	0.79
19	102	95	0.71	0.66	116	811	96	0.52
20	102	96	0.70	0.63	117	812	91	0.67
21	103	88	0.95	0.67	118	812	92	0.76
22	103	89	0.92	0.73	119	812	93	0.69
23	104	88	0.86	0.75	120	812	94	0.72
24	104	89	1.00	0.79	121	812	95	0.67
25	301	92	0.99	0.99	122	812	96	0.69
26	301	93	0.73	0.69	123	813	90	0.67
27	301	94	1.00	1.00	124	813	91	0.67
28	301	95	0.64	0.62	125	813	92	0.67
29	301	96	0.57	0.51	126	813	93	0.64
30	303	90	0.67	0.66	127	813	94	0.59
31	303	91	0.83	0.80	128	813	95	0.77
32	303	92	0.82	0.81	129	813	96	0.65
33	303	93	0.79	0.79	130	814	90	0.75
34	401	90	0.84	0.81	131	814	91	0.66
35	401	91	0.85	0.85	132	814	92	0.67
36	401	92	0.74	0.74	133	814	93	0.65
37	401	93	0.72	0.72	134	814	94	0.79
38	401	94	0.48	0.48	135	815	90	0.69
39	401	95	0.56	0.56	136	815	91	0.75
40	401	96	0.61	0.59	137	815	92	0.83
41	402	88	0.68	0.68	138	815	93	0.93
42	402	89	0.76	0.75	139	815	94	0.96
43	402	90	0.73	0.70	140	815	95	1.00
44	402	91	0.76	0.66	141	816	90	0.97
45	402	92	0.69	0.63	142	816	91	0.88
46	402	93	0.72	0.68	143	816	92	0.84
47	402	94	0.75	0.63	144	816	93	0.97
48	402	95	0.84	0.63	145	816	94	0.92

Observation	ID	Yr.	BCC	CCR	Observation	ID	Yr.	BCC
49	402	96	0.67	0.61	146	816	95	0.90
50	403	90	0.94	0.93	147	816	96	0.87
51	403	91	0.89	0.88	148	817	90	0.98
52	403	92	0.90	0.89	149	817	91	0.94
53	403	93	0.86	0.85	150	817	92	0.93
54	403	94	1.00	1.00	151	817	93	0.81
55	501	90	0.94	0.83	152	817	94	0.77
56	501	91	1.00	0.85	153	817	95	0.79
57	501	92	1.00	1.00	154	817	96	0.61
58	501	93	1.00	0.96	155	901	88	1.00
59	501	94	1.00	0.77	156	901	89	0.95
60	501	95	0.80	0.69	157	901	90	0.97
61	501	96	0.83	0.70	158	901	91	0.79
62	502	90	0.64	0.62	159	901	92	0.82
63	502	91	0.70	0.68	160	901	93	0.83
64	502	92	0.57	0.52	161	901	94	0.90
65	502	93	0.61	0.57	162	901	95	0.74
66	701	93	0.81	0.70	163	901	96	0.66
67	701	94	0.83	0.69	164	902	90	0.59
68	701	95	0.84	0.66	165	902	91	0.59
69	701	96	0.82	0.64	166	902	92	0.56
70	801	90	0.60	0.60	167	902	93	0.57
71	801	91	0.67	0.66	168	902	94	0.60
72	801	92	0.60	0.60	169	902	95	0.73
73	801	93	0.70	0.68	170	902	96	0.57
74	801	94	0.77	0.73	171	904	88	0.98
75	801	95	0.65	0.59	172	904	89	0.96
76	801	96	0.50	0.49	173	904	90	1.00
77	802	90	0.58	0.58	174	904	91	0.88
78	802	91	0.63	0.62	175	904	94	1.00
79	802	92	0.61	0.61	176	904	95	0.89
80	802	93	0.60	0.59	177	904	96	0.85
81	802	94	0.66	0.65	178	905	88	0.75
82	803	93	0.79	0.79	179	905	89	0.67
83	803	94	0.75	0.74	180	905	90	0.51
84	804	90	0.89	0.67	181	905	91	0.70
85	804	91	1.00	0.71	182	905	92	0.81
86	804	92	1.00	0.69	183	905	93	0.87
87	804	93	0.97	0.67	184	905	94	0.79
88	804	94	0.98	0.68	185	905	95	0.92
89	804	95	1.00	0.68	186	905	96	0.97
90	804	96	0.79	0.52	187	906	91	0.75
91	806	91	0.87	0.86	188	906	92	0.72
92	806	92	0.80	0.69	189	906	93	0.77
93	806	93	0.66	0.62	190	906	94	0.61
94	806	94	0.89	0.80	191	906	95	0.66
95	806	95	0.97	0.72	192	906	96	0.66
96	806	96	0.64	0.55				
97	808	90	0.62	0.61				

Appendix C. Results from the AF, and FL Models.

Obs.	ID	Yr.	Equipment (AF)	Consumables (AF)	Labor (AF)	Equipment (AF)	Consumables (FL)	Labor (FL)
1	2	94	0.44	0.61	0.63	0.64	0.77	0.80
2	2	95	0.33	0.53	0.60	0.60	0.72	0.70
3	2	96	0.34	0.50	0.58	0.52	0.71	0.74
4	101	89	0.57	0.79	0.43	0.82	0.98	0.46
5	101	90	0.96	0.82	0.69	1.00	0.92	0.69
6	101	91	1.00	1.00	1.00	1.00	1.00	1.00
7	101	92	0.56	0.55	0.37	0.60	0.85	0.43
8	101	93	0.54	0.52	0.37	0.58	0.82	0.43
9	101	94	0.37	0.47	0.40	0.50	0.69	0.54
10	101	95	0.30	0.47	0.40	0.37	0.68	0.52
11	101	96	0.23	0.48	0.33	0.33	0.70	0.44
12	102	88	0.30	0.64	0.58	0.44	0.72	0.81
13	102	89	0.30	0.57	0.55	0.46	0.69	0.73
14	102	90	0.29	0.68	0.52	0.42	0.86	0.66
15	102	91	0.29	0.60	0.58	0.44	0.74	0.76
16	102	92	0.34	0.58	0.57	0.51	0.68	0.77
17	102	93	0.32	0.54	0.51	0.49	0.77	0.56
18	102	94	0.36	0.58	0.49	0.57	0.75	0.60
19	102	95	0.28	0.65	0.53	0.43	0.81	0.67
20	102	96	0.25	0.65	0.53	0.38	0.80	0.69
21	103	88	0.60	0.62	0.95	0.60	0.65	1.00
22	103	89	0.62	0.68	0.91	0.66	0.79	0.97
23	104	88	0.40	0.84	0.72	0.44	0.89	1.00
24	104	89	1.00	1.00	1.00	1.00	1.00	1.00
25	301	92	0.93	0.98	0.94	0.97	1.00	0.96
26	301	93	0.38	0.69	0.67	0.41	0.81	0.74
27	301	94	1.00	1.00	1.00	1.00	1.00	1.00
28	301	95	0.35	0.58	0.59	0.38	0.70	0.67
29	301	96	0.30	0.24	0.59	0.30	0.35	0.73
30	303	90	0.32	0.50	0.54	0.48	0.72	0.71
31	303	91	0.44	0.75	0.63	0.61	1.00	0.66
32	303	92	0.36	0.70	0.62	0.54	0.99	0.68
33	303	93	0.42	0.66	0.56	0.55	0.93	0.71
34	401	90	0.42	0.74	0.64	0.57	1.00	0.68
35	401	91	0.50	0.72	0.70	0.69	1.00	0.71
36	401	92	0.34	0.64	0.49	0.44	0.95	0.66
37	401	93	0.31	0.65	0.45	0.42	0.96	0.60
38	401	94	0.23	0.38	0.35	0.34	0.55	0.46
39	401	95	0.25	0.43	0.50	0.51	0.61	0.50
40	401	96	0.23	0.50	0.44	0.43	0.70	0.51
41	402	88	0.42	0.51	0.56	0.67	0.70	0.63
42	402	89	0.49	0.61	0.67	0.70	0.74	0.82
43	402	90	0.42	0.62	0.73	0.48	0.76	0.83
44	402	91	0.33	0.63	0.77	0.36	0.73	0.85
45	402	92	0.35	0.56	0.69	0.39	0.68	0.79
46	402	93	0.42	0.62	0.72	0.46	0.72	0.79
47	402	94	0.33	0.65	0.76	0.35	0.72	0.81

Obs.	ID	Yr.	Equipment (AF)	Consumables (AF)	Labor (AF)	Equipment (AF)	Consumables (FL)	Labor (FL)
48	402	95	0.25	0.59	0.88	0.32	0.65	0.89
49	402	96	0.30	0.56	0.67	0.34	0.69	0.77
50	403	90	0.78	0.89	0.83	0.85	1.00	0.89
51	403	91	0.57	0.80	0.62	0.81	1.00	0.64
52	403	92	0.61	0.81	0.65	0.84	1.00	0.67
53	403	93	0.58	0.80	0.69	0.71	1.00	0.71
54	403	94	1.00	1.00	1.00	1.00	1.00	1.00
55	501	90	0.70	0.85	0.87	0.71	1.00	0.98
56	501	91	1.00	1.00	1.00	1.00	1.00	1.00
57	501	92	1.00	1.00	1.00	1.00	1.00	1.00
58	501	93	1.00	1.00	1.00	1.00	1.00	1.00
59	501	94	1.00	1.00	1.00	1.00	1.00	1.00
60	501	95	0.32	0.74	0.66	0.40	0.84	0.91
61	501	96	0.28	0.78	0.68	0.34	0.97	0.81
62	502	90	0.26	0.47	0.57	0.44	0.65	0.64
63	502	91	0.30	0.54	0.57	0.53	0.75	0.66
64	502	92	0.20	0.34	0.57	0.33	0.47	0.63
65	502	93	0.18	0.49	0.50	0.31	0.68	0.53
66	701	93	0.33	0.76	0.66	0.41	0.86	0.91
67	701	94	0.30	0.72	0.82	0.34	0.95	0.91
68	701	95	0.27	0.70	0.85	0.32	0.92	0.94
69	701	96	0.26	0.71	0.76	0.36	0.79	1.00
70	801	90	0.31	0.35	0.57	0.41	0.52	0.77
71	801	91	0.32	0.38	0.67	0.64	0.53	0.69
72	801	92	0.29	0.43	0.57	0.59	0.61	0.59
73	801	93	0.38	0.45	0.66	0.47	0.66	0.89
74	801	94	0.41	0.53	0.77	0.46	0.71	1.00
75	801	95	0.30	0.44	0.65	0.54	0.59	0.65
76	801	96	0.26	0.34	0.46	0.34	0.50	0.63
77	802	90	0.27	0.55	0.49	0.32	0.72	0.59
78	802	91	0.30	0.61	0.49	0.35	0.79	0.58
79	802	92	0.33	0.58	0.52	0.37	0.72	0.60
80	802	93	0.33	0.58	0.49	0.37	0.71	0.55
81	802	94	0.38	0.63	0.60	0.42	0.75	0.66
82	803	93	0.41	0.66	0.58	0.51	0.93	0.78
83	803	94	0.38	0.63	0.63	0.45	0.87	0.79
84	804	90	0.74	0.88	0.84	0.74	0.92	0.84
85	804	91	1.00	1.00	1.00	1.00	1.00	1.00
86	804	92	1.00	1.00	1.00	1.00	1.00	1.00
87	804	93	0.93	0.96	0.92	0.93	1.00	0.93
88	804	94	0.91	0.97	0.93	0.91	1.00	0.94
89	804	95	1.00	1.00	1.00	1.00	1.00	1.00
90	804	96	0.70	0.71	0.80	0.70	0.75	0.80
91	806	91	0.52	0.83	0.76	0.58	1.00	0.88
92	806	92	0.33	0.68	0.81	0.36	0.78	0.90
93	806	93	0.28	0.54	0.63	0.49	0.69	0.64
94	806	94	0.32	0.87	0.83	0.40	1.00	0.83
95	806	95	1.00	1.00	0.98	1.00	1.00	1.00
96	806	96	0.28	0.53	0.65	0.31	0.61	0.70

Obs.	ID	Yr.	Equipment (AF)	Consumables (AF)	Labor (AF)	Equipment (AF)	Consumables (FL)	Labor (FL)
97	808	90	0.34	0.45	0.48	0.43	0.67	0.65
98	808	91	0.42	0.50	0.44	0.54	0.68	0.59
99	808	92	0.56	0.67	0.55	0.66	0.79	0.67
100	808	93	0.58	0.63	0.49	0.59	0.83	0.60
101	808	94	0.52	0.63	0.50	0.64	0.77	0.64
102	808	95	0.52	0.64	0.50	0.63	0.77	0.63
103	808	96	0.52	0.61	0.51	0.62	0.74	0.63
104	809	92	0.79	0.94	0.90	0.84	1.00	0.94
105	809	93	0.81	0.85	0.90	0.95	0.90	0.91
106	809	94	1.00	1.00	1.00	1.00	1.00	1.00
107	809	95	0.68	0.83	0.92	0.73	0.85	0.96
108	809	96	1.00	1.00	1.00	1.00	1.00	1.00
109	810	90	0.70	0.79	0.76	0.95	0.85	0.78
110	810	91	1.00	1.00	1.00	1.00	1.00	1.00
111	810	92	0.61	0.59	0.70	0.62	0.85	0.80
112	810	93	0.64	0.73	0.71	0.65	0.99	0.83
113	810	94	0.47	0.67	0.61	0.67	0.87	0.71
114	810	95	0.47	0.63	0.61	0.71	0.78	0.73
115	810	96	0.49	0.67	0.62	0.73	0.83	0.73
116	811	96	0.20	0.46	0.40	0.42	0.65	0.41
117	812	91	0.38	0.52	0.46	0.62	0.73	0.52
118	812	92	0.36	0.65	0.50	0.46	0.96	0.67
119	812	93	0.33	0.55	0.52	0.42	0.81	0.71
120	812	94	0.32	0.61	0.51	0.44	0.90	0.68
121	812	95	0.35	0.52	0.50	0.47	0.77	0.67
122	812	96	0.29	0.60	0.48	0.40	0.88	0.64
123	813	90	0.26	0.49	0.61	0.42	0.67	0.67
124	813	91	0.29	0.57	0.47	0.43	0.82	0.62
125	813	92	0.24	0.51	0.60	0.46	0.71	0.66
126	813	93	0.29	0.50	0.54	0.37	0.74	0.72
127	813	94	0.26	0.44	0.55	0.53	0.62	0.56
128	813	95	0.25	0.60	0.79	0.37	0.71	0.79
129	813	96	0.23	0.53	0.59	0.43	0.72	0.59
130	814	90	0.42	0.59	0.67	0.51	0.80	0.87
131	814	91	0.39	0.44	0.57	0.51	0.63	0.77
132	814	92	0.27	0.61	0.52	0.34	0.88	0.67
133	814	93	0.44	0.50	0.64	0.49	0.61	0.73
134	814	94	0.41	0.79	0.80	0.42	0.80	0.81
135	815	90	0.44	0.68	0.65	0.44	0.70	0.65
136	815	91	0.50	0.74	0.73	0.50	0.77	0.73
137	815	92	0.66	0.81	0.84	0.66	0.84	0.84
138	815	93	0.59	0.94	0.82	0.59	0.97	0.82
139	815	94	0.41	0.97	0.77	0.41	1.00	0.77
140	815	95	1.00	1.00	1.00	1.00	1.00	1.00
141	816	90	0.86	0.96	0.86	0.96	1.00	0.88
142	816	91	0.75	0.83	0.74	0.78	1.00	0.80
143	816	92	0.73	0.80	0.63	0.74	0.95	0.69
144	816	93	0.95	0.99	0.68	0.98	1.00	0.70
145	816	94	0.74	0.90	0.66	0.82	1.00	0.72

Obs.	ID	Yr.	Equipment (AF)	Consumables (AF)	Labor (AF)	Equipment (AF)	Consumables (FL)	Labor (FL)
146	816	95	0.71	0.89	0.58	0.79	1.00	0.64
147	816	96	0.64	0.82	0.62	0.78	0.94	0.70
148	817	90	0.92	0.97	0.91	1.00	1.00	0.91
149	817	91	0.74	0.90	0.70	0.89	1.00	0.76
150	817	92	0.74	0.91	0.64	0.80	1.00	0.83
151	817	93	0.50	0.72	0.52	0.67	0.91	0.66
152	817	94	0.57	0.66	0.55	0.78	0.79	0.65
153	817	95	0.72	0.72	0.58	0.74	0.93	0.64
154	817	96	0.40	0.46	0.42	0.55	0.65	0.56
155	901	88	1.00	1.00	1.00	1.00	1.00	1.00
156	901	89	0.76	0.91	0.88	0.76	1.00	1.00
157	901	90	0.72	0.94	0.92	0.72	1.00	1.00
158	901	91	0.36	0.65	0.70	0.49	0.88	0.77
159	901	92	0.40	0.69	0.68	0.51	0.95	0.74
160	901	93	0.50	0.72	0.61	0.61	0.94	0.80
161	901	94	0.62	0.82	0.76	0.76	1.00	0.80
162	901	95	0.48	0.58	0.60	0.61	0.74	0.81
163	901	96	0.35	0.48	0.56	0.43	0.72	0.75
164	902	90	0.24	0.47	0.58	0.34	0.69	0.64
165	902	91	0.25	0.49	0.53	0.36	0.72	0.58
166	902	92	0.20	0.49	0.48	0.30	0.57	0.66
167	902	93	0.25	0.49	0.47	0.38	0.58	0.64
168	902	94	0.36	0.48	0.49	0.54	0.70	0.54
169	902	95	0.72	0.44	0.46	0.86	0.64	0.49
170	902	96	0.29	0.47	0.44	0.46	0.67	0.48
171	904	88	0.90	0.97	0.86	1.00	1.00	0.86
172	904	89	0.85	0.94	0.77	1.00	1.00	0.77
173	904	90	1.00	1.00	1.00	1.00	1.00	1.00
174	904	91	0.58	0.80	0.60	0.73	1.00	0.74
175	904	94	1.00	1.00	1.00	1.00	1.00	1.00
176	904	95	0.64	0.84	0.74	0.71	1.00	0.86
177	904	96	0.49	0.84	0.73	0.65	1.00	0.73
178	905	88	0.39	0.59	0.59	0.51	0.84	0.80
179	905	89	0.30	0.56	0.46	0.43	0.81	0.62
180	905	90	0.30	0.38	0.39	0.49	0.53	0.46
181	905	91	0.38	0.55	0.49	0.53	0.79	0.66
182	905	92	0.42	0.68	0.58	0.53	0.95	0.77
183	905	93	0.58	0.82	0.65	0.66	1.00	0.77
184	905	94	0.27	0.76	0.66	0.43	0.98	0.66
185	905	95	0.53	0.93	0.84	0.59	1.00	0.84
186	905	96	0.68	0.98	0.85	0.69	1.00	0.86
187	906	91	0.37	0.59	0.63	0.58	0.81	0.68
188	906	92	0.33	0.57	0.60	0.53	0.80	0.65
189	906	93	0.63	0.59	0.60	0.68	0.88	0.71
190	906	94	0.31	0.48	0.52	0.49	0.69	0.56
191	906	95	0.34	0.56	0.48	0.55	0.71	0.59
192	906	96	0.38	0.50	0.51	0.62	0.71	0.55

Appendix D. Efficient Observations and Slacks (BCC).

Observation	Overall Slacks	Equipment Slacks	Consumable Slacks	Labor Slacks
6	5.07x10^-11	0	6.3x10^-12	-5.7x10^-11
24	2.6x10^-10	-2.6x10^-12	0	0
27	-1.2x10^-10	0	4.0x10^-11	7.6x10^-11
54	0	0	0	0
56	7.4x10^-12	-8.97x10^-12	0	0
57	0	0	0	0
58	-3.3x10^-12	0	-3.3x10^-13	3.0x10^-12
59	-1.0x10^-12	0	0	0
86	-4.13x10^-11	1.37x10^-11	1.5x10^-11	1.2x10^-11
89	-1.2x10^-10	3.0x10^-11	2.7x10^-11	6.8x10^-11
106	-4.2x10^-12	0	-4.3x10^-12	0
108	3.6x10^-12	-2.2x^-11	-1.5x10^-12	0
110	0	0	0	0
155	0	0	0	0
173	5.24x10^-12	0	0	
175	0	0	0	0

Appendix E. Proportions of Total Cost.

ID	Yr.	Equipment	Consumables	Labor	Insurance	C. Trucking	A. Overhead
2	94	0.23	0.33	0.37	0.05	0.00	0.02
2	96	0.26	0.33	0.35	0.05	0.00	0.01
2	95	0.28	0.32	0.34	0.04	0.00	0.01
101	90	0.07	0.25	0.59	0.06	0.02	0.01
101	91	0.08	0.24	0.60	0.06	0.00	0.02
101	93	0.08	0.25	0.47	0.04	0.16	0.01
101	94	0.10	0.17	0.34	0.02	0.34	0.02
101	92	0.10	0.26	0.51	0.05	0.07	0.01
101	95	0.12	0.15	0.33	0.03	0.36	0.02
101	96	0.16	0.13	0.34	0.03	0.33	0.02
102	94	0.07	0.11	0.32	0.03	0.48	0.00
102	92	0.08	0.12	0.33	0.03	0.44	0.00
102	93	0.08	0.11	0.30	0.02	0.47	0.00
102	91	0.11	0.09	0.29	0.02	0.48	0.00
102	95	0.13	0.09	0.31	0.07	0.40	0.00
102	90	0.15	0.08	0.32	0.03	0.41	0.00
102	96	0.15	0.07	0.30	0.05	0.43	0.00
301	94	0.11	0.30	0.46	0.06	0.07	0.00
301	92	0.16	0.30	0.46	0.05	0.02	0.01
301	96	0.17	0.43	0.25	0.05	0.09	0.02
301	93	0.22	0.25	0.40	0.05	0.07	0.01
301	95	0.22	0.27	0.40	0.06	0.04	0.01
303	93	0.19	0.19	0.32	0.03	0.25	0.02
303	90	0.20	0.24	0.29	0.04	0.22	0.01
303	91	0.22	0.14	0.32	0.03	0.27	0.01
303	92	0.27	0.17	0.30	0.03	0.22	0.01
401	94	0.26	0.28	0.40	0.04	0.00	0.03
401	92	0.26	0.24	0.44	0.05	0.00	0.02
401	93	0.27	0.22	0.45	0.03	0.00	0.02
401	96	0.28	0.23	0.34	0.03	0.08	0.04
401	95	0.29	0.28	0.36	0.04	0.00	0.03
401	90	0.31	0.22	0.37	0.03	0.06	0.01
401	91	0.32	0.24	0.38	0.03	0.02	0.01
402	93	0.19	0.28	0.37	0.03	0.07	0.06
402	90	0.20	0.29	0.37	0.02	0.11	0.01
402	94	0.22	0.25	0.33	0.03	0.17	0.01
402	92	0.22	0.29	0.36	0.02	0.09	0.01
402	96	0.24	0.26	0.34	0.05	0.10	0.01
402	91	0.25	0.28	0.34	0.02	0.10	0.01
402	95	0.30	0.27	0.27	0.04	0.09	0.02
403	91	0.11	0.14	0.35	0.04	0.34	0.01
403	92	0.12	0.14	0.38	0.02	0.32	0.01
403	90	0.14	0.12	0.35	0.05	0.34	0.01
403	93	0.20	0.12	0.32	0.05	0.30	0.01
403	94	0.22	0.09	0.30	0.03	0.34	0.01
501	93	0.03	0.22	0.51	0.03	0.20	0.01
501	94	0.04	0.16	0.51	0.04	0.23	0.02
501	92	0.05	0.11	0.53	0.06	0.24	0.01

ID	Yr.	Equipment	Consumables	Labor	Insurance	C. Trucking	A. Overhead
501	90	0.11	0.19	0.39	0.04	0.26	0.01
501	91	0.18	0.12	0.41	0.05	0.23	0.01
501	95	0.20	0.13	0.36	0.06	0.22	0.02
501	96	0.27	0.12	0.33	0.04	0.23	0.02
502	91	0.15	0.15	0.21	0.05	0.43	0.00
502	90	0.20	0.20	0.22	0.04	0.34	0.00
502	93	0.21	0.11	0.21	0.02	0.45	0.00
502	92	0.22	0.24	0.17	0.03	0.33	0.01
701	93	0.25	0.18	0.41	0.07	0.08	0.01
701	94	0.29	0.21	0.32	0.08	0.09	0.01
701	95	0.31	0.22	0.32	0.08	0.06	0.02
701	96	0.33	0.20	0.37	0.04	0.05	0.01
801	90	0.16	0.27	0.22	0.05	0.28	0.02
801	91	0.18	0.29	0.22	0.05	0.24	0.02
801	93	0.20	0.30	0.28	0.04	0.15	0.03
801	96	0.20	0.28	0.29	0.03	0.19	0.02
801	92	0.20	0.25	0.26	0.03	0.22	0.03
801	95	0.21	0.26	0.26	0.04	0.22	0.02
801	94	0.21	0.29	0.27	0.04	0.16	0.02
802	93	0.08	0.12	0.32	0.01	0.45	0.01
802	94	0.09	0.14	0.30	0.03	0.43	0.01
802	92	0.09	0.12	0.30	0.01	0.47	0.01
802	91	0.13	0.11	0.32	0.01	0.43	0.01
802	90	0.13	0.12	0.29	0.01	0.44	0.01
803	93	0.22	0.23	0.37	0.05	0.08	0.05
803	94	0.25	0.27	0.40	0.04	0.01	0.04
804	92	0.07	0.11	0.28	0.01	0.51	0.02
804	93	0.08	0.10	0.30	0.01	0.49	0.02
804	95	0.08	0.10	0.32	0.02	0.44	0.04
804	91	0.08	0.11	0.29	0.02	0.48	0.03
804	90	0.08	0.12	0.30	0.02	0.46	0.02
804	94	0.09	0.11	0.30	0.02	0.46	0.02
804	96	0.10	0.13	0.27	0.01	0.46	0.02
806	91	0.14	0.14	0.30	0.02	0.36	0.05
806	92	0.16	0.17	0.24	0.02	0.40	0.01
806	93	0.18	0.17	0.25	0.02	0.37	0.01
806	96	0.18	0.21	0.28	0.03	0.28	0.01
806	95	0.19	0.19	0.23	0.03	0.34	0.01
806	94	0.28	0.14	0.26	0.05	0.26	0.02
808	93	0.15	0.30	0.51	0.02	0.00	0.02
808	96	0.17	0.30	0.48	0.03	0.00	0.02
808	95	0.17	0.29	0.49	0.03	0.00	0.02
808	92	0.17	0.31	0.50	0.01	0.00	0.02
808	94	0.18	0.30	0.47	0.03	0.00	0.02
808	91	0.20	0.31	0.46	0.02	0.00	0.01
808	90	0.24	0.31	0.41	0.02	0.00	0.02
809	93	0.10	0.24	0.27	0.04	0.33	0.01
809	94	0.12	0.24	0.26	0.03	0.29	0.06
809	92	0.16	0.22	0.26	0.03	0.32	0.01

ID	Yr.	Equipment	Consumables	Labor	Insurance	C. Trucking	A. Overhead
809	95	0.17	0.25	0.23	0.02	0.27	0.05
809	96	0.22	0.23	0.19	0.03	0.28	0.05
810	91	0.13	0.42	0.39	0.06	0.00	0.01
810	92	0.13	0.36	0.35	0.06	0.10	0.01
810	93	0.14	0.31	0.39	0.04	0.11	0.01
810	90	0.20	0.35	0.40	0.05	0.00	0.00
810	95	0.20	0.31	0.38	0.03	0.06	0.02
810	96	0.21	0.31	0.41	0.02	0.02	0.03
810	94	0.22	0.28	0.38	0.05	0.06	0.01
811	96	0.25	0.17	0.32	0.01	0.21	0.04
812	95	0.10	0.14	0.26	0.02	0.45	0.03
812	93	0.11	0.12	0.24	0.04	0.47	0.02
812	91	0.12	0.19	0.34	0.03	0.29	0.04
812	94	0.13	0.11	0.26	0.03	0.44	0.03
812	96	0.16	0.11	0.27	0.03	0.37	0.06
812	92	0.17	0.15	0.34	0.04	0.29	0.02
813	93	0.23	0.22	0.32	0.02	0.20	0.02
813	91	0.26	0.23	0.37	0.03	0.10	0.01
813	94	0.26	0.26	0.30	0.03	0.12	0.03
813	95	0.28	0.22	0.25	0.03	0.21	0.01
813	90	0.29	0.28	0.30	0.02	0.10	0.01
813	96	0.30	0.22	0.30	0.03	0.14	0.01
813	92	0.31	0.26	0.29	0.03	0.09	0.02
814	93	0.20	0.35	0.41	0.03	0.01	0.01
814	94	0.20	0.26	0.40	0.00	0.12	0.01
814	90	0.23	0.30	0.37	0.02	0.08	0.01
814	91	0.23	0.36	0.38	0.02	0.00	0.01
814	92	0.31	0.24	0.42	0.01	0.00	0.01
815	92	0.13	0.20	0.35	0.04	0.26	0.02
815	90	0.13	0.21	0.38	0.03	0.23	0.02
815	91	0.13	0.20	0.36	0.04	0.25	0.02
815	93	0.14	0.17	0.37	0.03	0.28	0.01
815	94	0.16	0.15	0.36	0.03	0.28	0.01
815	95	0.17	0.14	0.46	0.03	0.19	0.01
816	95	0.14	0.26	0.54	0.05	0.00	0.01
816	92	0.14	0.30	0.52	0.03	0.00	0.01
816	94	0.15	0.28	0.53	0.03	0.00	0.01
816	91	0.15	0.31	0.48	0.05	0.00	0.01
816	93	0.15	0.24	0.56	0.05	0.00	0.01
816	96	0.16	0.28	0.49	0.06	0.00	0.02
816	90	0.17	0.31	0.47	0.04	0.00	0.01
817	96	0.12	0.23	0.37	0.02	0.23	0.03
817	95	0.13	0.31	0.50	0.02	0.01	0.03
817	92	0.15	0.25	0.50	0.03	0.04	0.03
817	94	0.16	0.30	0.45	0.03	0.01	0.04
817	90	0.18	0.28	0.49	0.02	0.03	0.01
817	93	0.18	0.26	0.46	0.01	0.05	0.03
817	91	0.19	0.29	0.47	0.00	0.01	0.04
901	96	0.09	0.14	0.21	0.02	0.55	0.00

ID	Yr.	Equipment	Consumables	Labor	Insurance	C. Trucking	A. Overhead
901	95	0.21	0.34	0.40	0.03	0.01	0.00
901	92	0.25	0.23	0.37	0.03	0.11	0.01
901	91	0.25	0.25	0.36	0.02	0.12	0.00
901	93	0.26	0.28	0.39	0.03	0.04	0.00
901	90	0.27	0.26	0.45	0.02	0.00	0.01
901	94	0.30	0.28	0.38	0.03	0.00	0.00
902	95	0.05	0.29	0.50	0.04	0.10	0.02
902	94	0.16	0.25	0.49	0.02	0.08	0.01
902	96	0.18	0.24	0.44	0.03	0.09	0.01
902	93	0.21	0.22	0.45	0.01	0.10	0.01
902	91	0.24	0.25	0.46	0.04	0.00	0.01
902	92	0.25	0.20	0.42	0.02	0.10	0.01
902	90	0.26	0.27	0.42	0.04	0.00	0.01
904	90	0.20	0.22	0.50	0.07	0.00	0.01
904	95	0.23	0.23	0.42	0.05	0.05	0.02
904	91	0.24	0.24	0.45	0.05	0.01	0.01
904	96	0.27	0.22	0.41	0.04	0.04	0.01
904	94	0.27	0.31	0.32	0.07	0.01	0.03
905	90	0.20	0.30	0.39	0.05	0.00	0.06
905	96	0.22	0.21	0.41	0.07	0.07	0.02
905	91	0.23	0.28	0.41	0.06	0.01	0.02
905	93	0.23	0.24	0.46	0.06	0.00	0.02
905	95	0.25	0.21	0.38	0.07	0.07	0.02
905	92	0.25	0.26	0.41	0.05	0.00	0.02
905	94	0.32	0.19	0.35	0.05	0.07	0.02
906	93	0.14	0.34	0.44	0.03	0.02	0.03
906	95	0.21	0.25	0.48	0.04	0.00	0.03
906	96	0.21	0.30	0.43	0.04	0.00	0.03
906	94	0.23	0.29	0.42	0.04	0.00	0.03
906	91	0.25	0.29	0.38	0.05	0.00	0.03
906	92	0.26	0.28	0.39	0.04	0.01	0.02

Vita

James T. Shannon

James Shannon was born in New Albany, Mississippi on October 13, 1973. Upon graduation from High School he enrolled and Mississippi State University where he earned a Bachelor of Science in Forestry degree. He then enrolled at Virginia Tech in 1996 to pursue industrial forestry education. He received a Master's of Science in Forestry in May of 1998.

James T. Shannon