

## Chapter 5

### Comparisons of Economic Efficiencies

Annual cost and production information was matched from twenty-three contractors. Figure 5.1 illustrates the relationship found between annual production and annual costs for all 109 contractor-years compiled. The expenditure per job ranged from two hundred twenty thousand dollars annually to more than three million. Sixty-five percent of the sample came from business spending less than one million annually. The fit of a straight line fit to the scatter plot ( $R^2 = 0.9553$ ) indicates no apparent economies of scale for large or small operations.

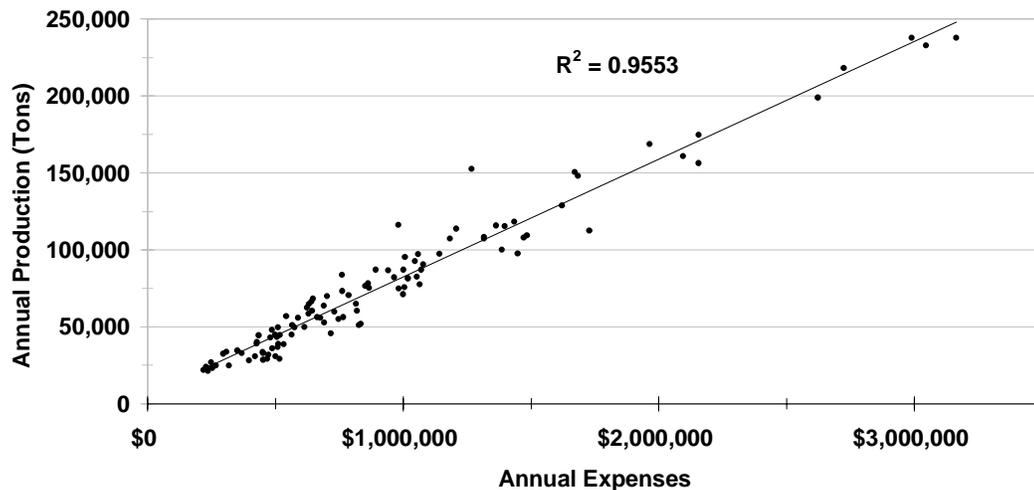


Figure 5.1 Annual production as a function of total annual expenditures.

If the scatter plot showed a tendency to curve upward, increasing returns to scale would be present. If this were the case, the high production observations would have proportionally less annual expenses than low production observations. If the scatter plot had a tendency to curve downward then decreasing returns to scale would be indicated.

## 5.1 Economic Efficiency Ratios

Economic efficiency ratios<sup>1</sup> were derived by dividing total tons delivered by total expenditures on an annual basis for each contractor-year. This is a ratio of outputs to inputs. Larger ratios indicate higher efficiency.

Figure 5.2 illustrates the distribution of the 109 total economic efficiency ratios for the population. The histogram shows 78% of the observations falling in the .07 to .10 bins, defining the normal operating range. Most observations outside this range were the exceptionally efficient years or exceptionally inefficient years of a contractor in some type of business transition. The range of the data set is .0638, spanning from the minimum observation of .0565 to the maximum observation of .1203. At the fringes of the range, some contractor-years exhibit twice the level of production for the same inputs.

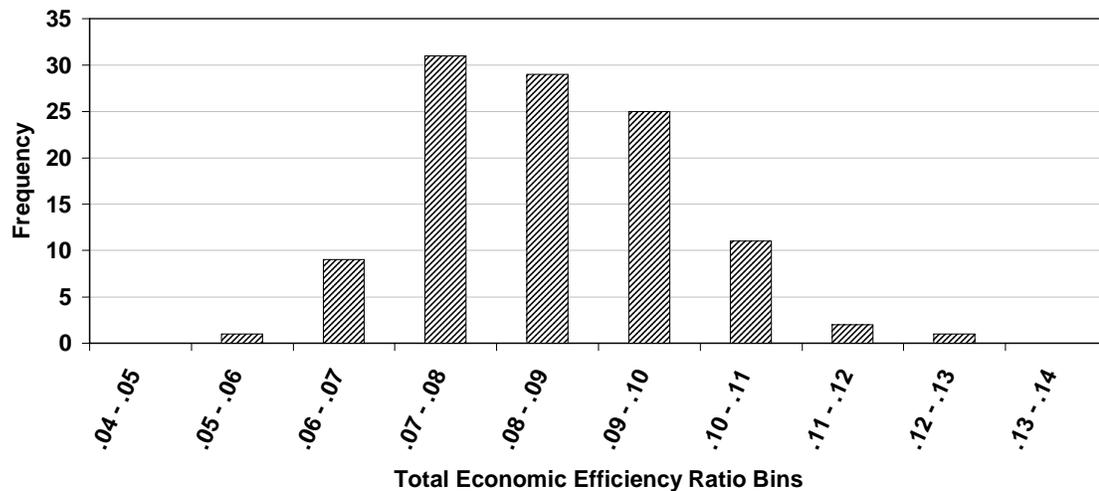


Figure 5.2 Histogram of 109 total economic efficiency ratios.

The distribution has a skewness of + 0.262 indicating an asymmetric distribution with a right tail extending toward the higher ratios. However, the closeness of the mean (0.0851) and median (0.0849) indicate the distribution is not highly skewed. There was not a “hard” floor or ceiling observed at the extremes of the range, but rather a gradual taper.

<sup>1</sup> Also known as technical efficiency ratios or simply “tons per dollar”.

The Kolmogorov-Smirnov normality test determined an approximate p-value of 0.15, indicating that the null hypothesis that the data are normal can not be rejected at the 90 percent confidence level.

This chapter will break down the data set of 109 contractor cost-production years into subsets, to provide some explanation of the variation and better understand what factors contribute to higher than average efficiency ratios.

## **5.2 Efficiency over Time**

Examining efficiency trends over time is a cardinal step in a study spanning seven years and a key objective of the ongoing project. Since the cost data have not been adjusted for inflation, it is important to recognize that inflation will cause economic efficiency to decrease over time as the dollar loses value. If the economic efficiency does not decline over time then the external influence of inflation is less than internal efficiency improvements in the contractors' individual jobs and the wood supply system at the mills. Consider the economic efficiency ratio to measure the net effect on the value of the dollar to produce wood in light of inflation and operational efficiency improvements. If the influence of inflation becomes greater than offsetting factors such as higher production with the same labor and machines then the net result will be declining economic efficiency ratios across all contractors.

The 95% confidence intervals shown in figure 5.3 were developed using with the Wilcoxon signed ranks procedure. Confidence intervals constructed by the t-statistic would yield slightly narrower yet similar intervals. While there is some overlap in the confidence intervals, it appears that a major downward shift occurs between 1989 and 1990 that was not regained. However, the sample sizes listed under the year indicate that nine new contractors began providing cost information in 1990.

Figure 5.4 illustrates efficiency averages over the years for all contractors and a subset of five contractors to better understand to what extent this drop in efficiency from 1989 to

1990 can be attributed to the influx of nine new contractors. For the five contractors, there is a peaking of the median economic efficiency (solid line) in 1989, returning to 1988 or better levels by 1993. The mean for the five contractors (solid circle) does not take such a dramatic path across the years, however it also decreases from 1989 to 1990 for the five contractors. The Mann-Whitney test found no significant difference between 1989 and any other year for the five contractors. No p-values of less than 0.53 were calculated.

The median (dashed line) and mean (square) economic efficiencies of all contractors appears to deepen the decline from 1989 to 1990, that was noted in the five contractors. It seems to be a reasonable conclusion that to a large extent the downward shift in average efficiency was due to the generally lower efficiencies of the nine new contractors added to the data set in 1990. Although there may be other factors that drove down efficiency in 1990, they were rated insignificant by the Mann-Whitney test.

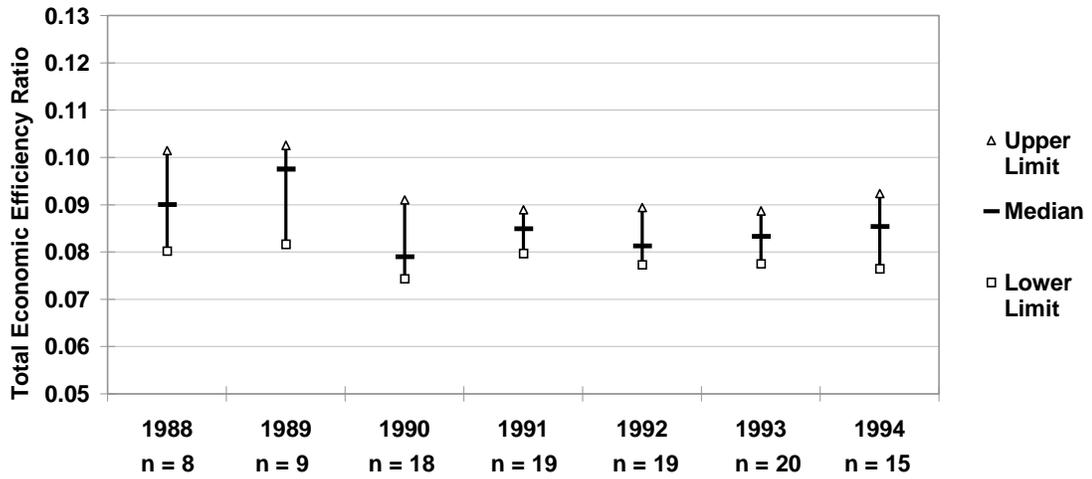


Figure 5.3 95% Confidence intervals, medians and sample sizes by year.

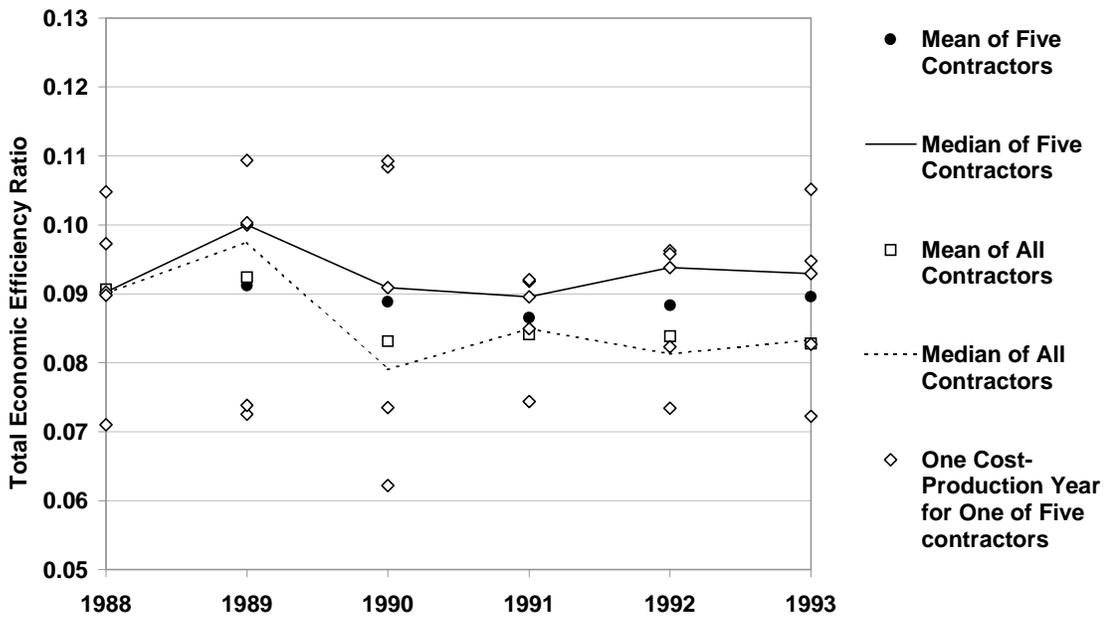


Figure 5.4 Total economic efficiencies for all and five contractors across six years.

While economic efficiency in the aggregate seems to be stable for these years, there is evidence of a substantial drop in efficiency in more recent years. Table 5.1 shows data collected from 15 contractors by Shannon (1998). Their total production and total costs were examined on a yearly basis. 1990 was used as an index year and production and costs in following years were referenced to it. For example, the total of all contractor production had increased 10% over 1990 levels, while costs had increased 6%. This indicates a favorable increase in economic efficiency. It is shown that production and costs continue to grow at an equal pace through 1994, indicating a fairly stable average economic efficiency. However, in 1995 there is a disproportionate gain in costs that decreases efficiency. The decline in efficiency is further exacerbated by the large composite drop in production in 1996. Since inflation levels have not been greater in 1995 and 1996 than they were in the rest of the 1990s then there is other global influences at work.

Table 5.1 Relative production and costs for 15 contractors.

<u>Year</u>	<u>Relative Total Production</u>	<u>Relative Total Cost</u>
1990	1.00	1.00
1991	1.1	1.06
1992	1.15	1.15
1993	1.23	1.23
1994	1.28	1.25
1995	1.36	1.44
1996	1.27	1.42

### 5.3 Efficiency and Business Size

Chapter 4 discussed the range in business sizes that were sampled in the study. The trend line in figure 5.1 indicated no apparent economies of scale as annual production increased or decreased. Contractor years were grouped by annual production level to further explore the effect of business size on efficiency. Figure 5.5 shows the medians, interquartile ranges, overall ranges and sample sizes of three arbitrary classifications of annual production. There is clearly a high degree of overlap of efficiency between operation sizes and only slight differences between their median efficiencies.

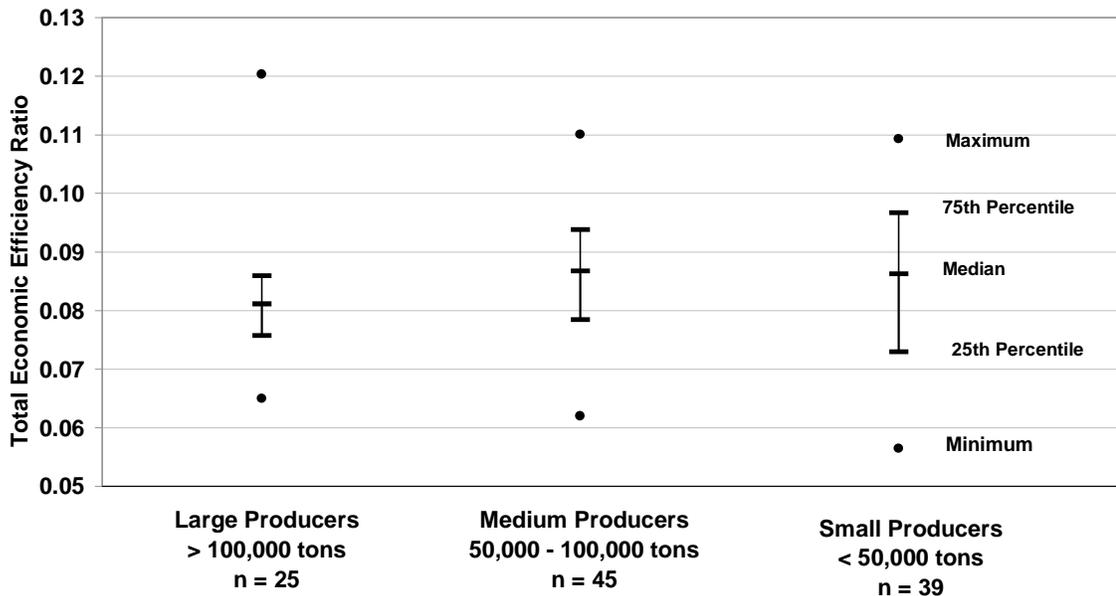


Figure 5.5 Economic efficiency ratio ranges for three levels of annual production.

The interquartile ranges are basically symmetrical and become wider as business size decreases. The large producers tended to vary only slightly from their median and their median was the lowest of the three groups. However, the highest efficiency measurement occurred in the large producers group indicating a rather skewed distribution. Small producers seem to experience about twice the variability in efficiency as the large

producers. Medium sized producers were the most common in the study and achieved the highest median efficiency.

Ranking the three groups from the most efficient to the least efficient gives the same order using either the median or mean: 1.) medium producers 2.) small producers 3.) large producers. The Mann-Whitney test was used to test this ranking. The tests between small producers and large producers as well as small producers and medium producers resulted in large p-values and no significant differences. However, the test between medium producers and large producers produced a p-value of 0.0955 indicating that the two samples were not equal at the 90 percent level.

## 5.4 Efficiency and Business Strategy

The contractors were divided into two groups based on their patterns of production over the period. Interview data were also used to identify contractors' business strategies. Nine of the twenty-three contractors were categorized as growth contractors and the remaining fourteen contractors were categorized as stable contractors. Growth contractors had expanded their operations either by adding equipment or increasing the size or number of their crews. Examination of production data showed growth contractors achieved mean annual production increases of 6.75% or more over the course of the years that they participated in the study. Comparisons were made to the "base year" or first year of participation. Stable contractors sometimes produced more than 6.75% of the previous year but kept the same crew and equipment and experienced lower or higher production based on capacity utilization.

Relative production-efficiency graphs illustrate year to year changes in total economic efficiency and annual production. A relative scale is used to protect the cost information of the contractors. The y-axis is based on the percentage change in yearly production and efficiency from the base year. Figure 5.6 shows the trends in relative production and relative efficiency for the nine growth contractors coded G1 through G9. The dotted lines show production relative to the base year, moving up as production increases and to the right with each year. Similarly changes in total economic efficiency are graphed with solid lines below. Growth contractors increased production as much as 252% of the base years' levels, with a median of 156%, and a minimum of 119% from contractor G9, who joined the study in 1993 and had a substantial one year production increase. Contractor G9 had been in logging for twenty years and recent events had encouraged him to carefully expand his business. His two sons had finished school and were actively involved in the business. He had also negotiated a preferred supplier cut-and-haul contract with a major forest products company. He bought a new loader, keeping the old one as a spare and second deck loader.

Trends in efficiency are volatile for growth contractors. As production increased, the business may endure ten to fifteen percent losses in efficiency. If production stayed the same or decreased from base year levels, efficiency losses of thirty percent were observed.

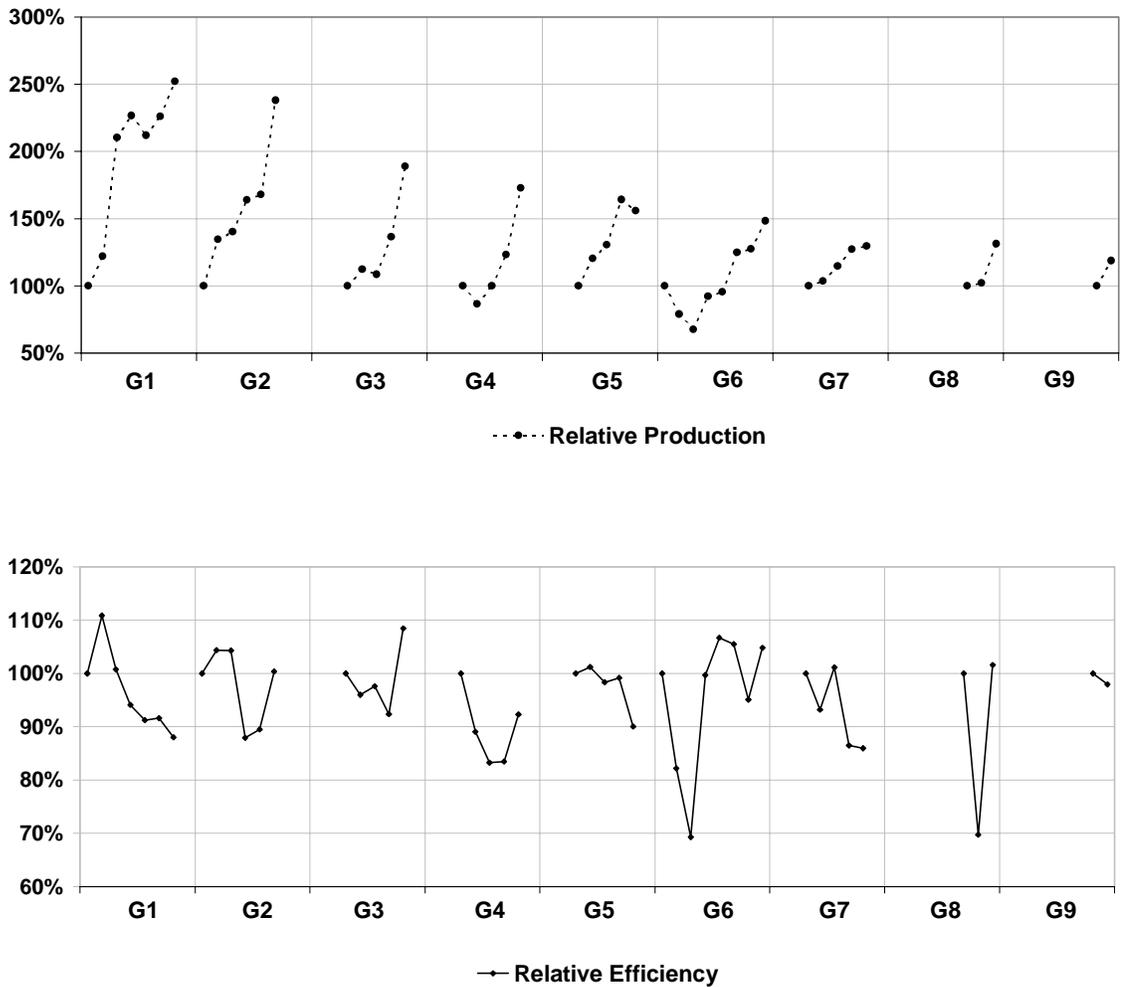


Figure 5.6 Relative production and efficiency of nine growth contractors.

Ten stable contractors expanded production by the last year of the study, while the remaining four stable contractors decreased production from the base year's level. Figure 5.7 shows seven stable contractors S1 through S7 that increased production the most over the duration of the study. These contractors updated equipment over the study period but were not looking to expand their operations. They strove to be more efficient and often accomplished this by taking advantage of production opportunities. Efficiency changes often track with production changes. Note that efficiency rarely fell from base year levels and when it did, it was contained within six percent of base year efficiency.

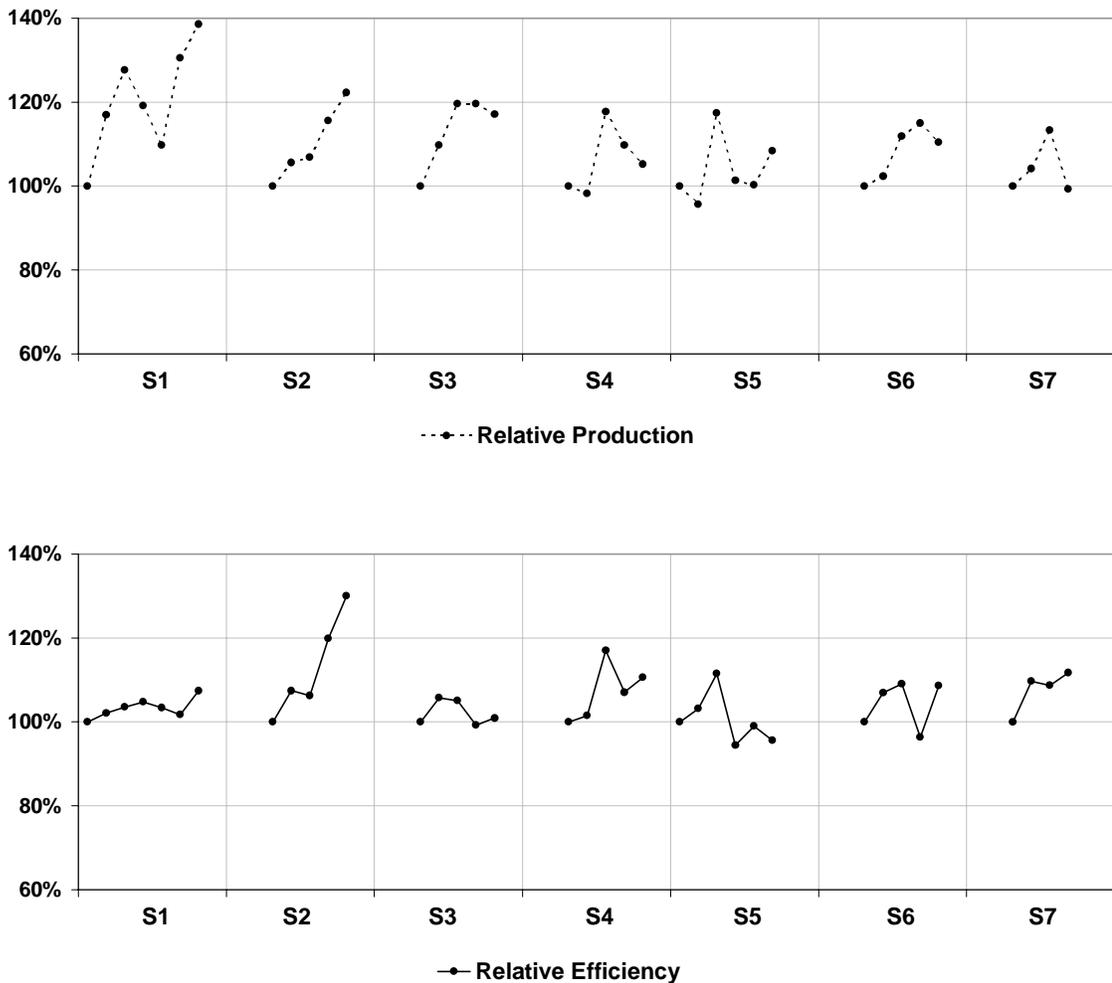


Figure 5.7 Relative production and efficiency of first set of seven stable contractors.

Figure 5.8 shows seven stable contractors S8 through S14 that experienced the least production growth through the study. Four experienced production declines that were not regained during the study. Two of the four were able to improve efficiency with production decreases while the other two suffered efficiency losses of about 20% from base year levels.

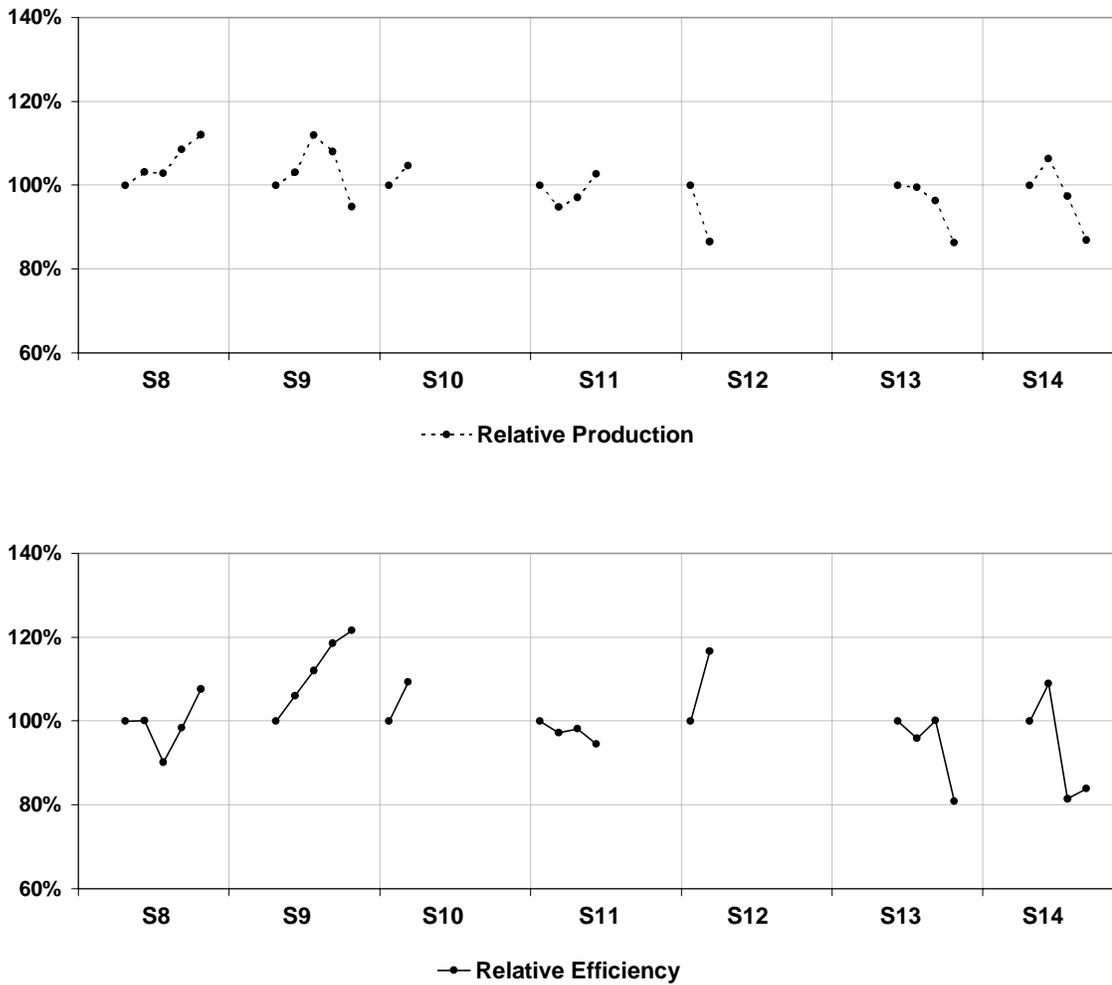


Figure 5.8 Relative production and efficiency of second set of seven stable contractors.

Figure 5.9 shows the efficiency ranges experienced by growth and stable contractors over the period. The median range for the stable contractors was 0.012 while the median range for the growth contractors was 0.016. The number of years of observation per contractor is displayed under the contractor code. Since the mean observations from growth contractors (5.1 years) exceeded stable contractors (4.5 years), testing of the hypothesis that growth contractors experience a wider range of efficiency over the period was hampered. However, by discarding contractors with shorter term observations of less than five years, the ranges of seven growth contractors were compared with the ranges of eight stable contractors. Contractor G4 was the median observation for the growth contractors with a range of 0.0163. The median range for the eight stable contractors was between S4 and S8 at 0.0121. The mean ranges for the seven growth contractors and eight stable contractors were 0.0180 and 0.0121, respectively. The range differences are somewhat subtle and the sample sizes are small, therefore finding statistical verification for this hypothesis was difficult. Consequently, the Mann-Whitney test did not show these two groups to be significantly different at the 90% level with a p-value of 0.1476.

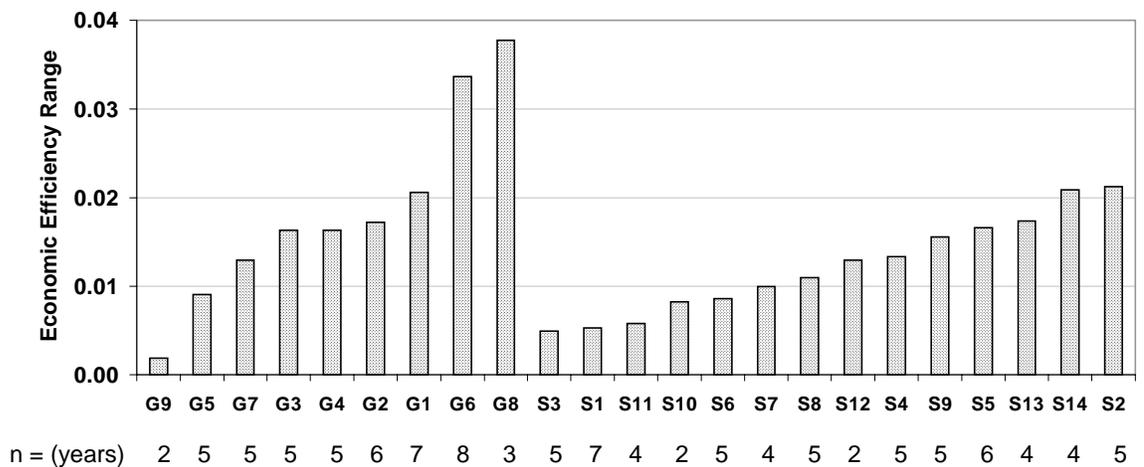


Figure 5.9 Efficiency ranges of growth and stable contractors.

It seems reasonable that the growth contractors would experience a wider range of efficiency. A growing business is poised to take advantage of increased production opportunities that tend to increase efficiency. However, such a business is also vulnerable to quotas, weather or other problems. Growing businesses usually have large capital expenses. High fixed costs will dramatically lower efficiency if not offset by high production. When asked if he intended to grow his 80,000 tons per year business, one coastal plain contractor remarked that he was not. *The bigger you are the harder you fall, but he added, I don't think smaller is the answer, in the past I was small. Now I wouldn't call myself big. This crew can surge and that's what gets us through the tough times. When you're too small, you are always struggling.*

Figure 5.10 shows a relative production-efficiency graph for a growth contractor. This coastal plain contractor had the largest increase in production of any business in the study. He started in 1989 to increase the production of his single pine crew. In 1990 he added a crew specializing in hardwood logging which was outfitted with an excavator based feller-buncher and wide tired skidders. He also increased his trucking capacity. He has many obstacles to maximizing his weekly production including wet weather, quotas and tract availability. He has very skilled operators and keeps his crew size large enough to produce at full capacity when opportunities arise. While production increases have been substantial, there has been an apparent slight decrease in economic efficiency. The decrease in efficiency can probably be attributed to both inflation and the higher cost of specialized logging equipment.

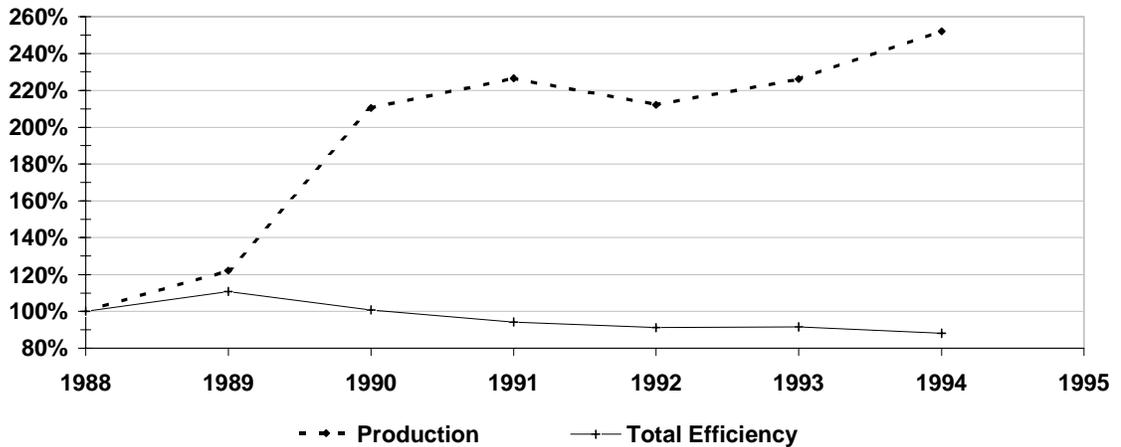


Figure 5.10 Relative production-efficiency graph of growing contractor G1.

Figure 5.11 shows a contractor that was categorized as a stable contractor. His production increases averaged less than 6.75% per year. This contractor was able to make considerable efficiency gains as production increased thanks to flexible quota policies.

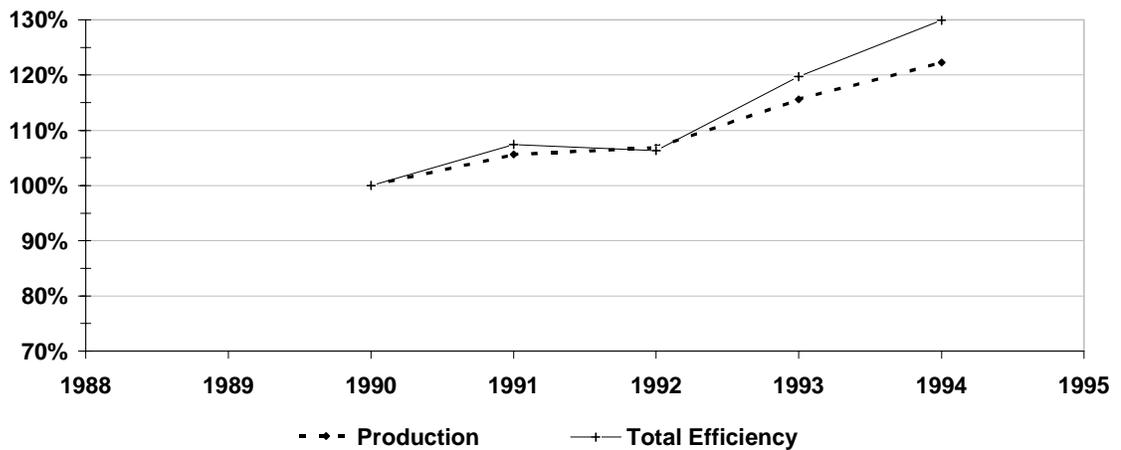


Figure 5.11 Relative production-efficiency graph of stable contractor S2.

Figure 5.12 shows a stable contractor for whom both throughput and efficiency have suffered. The contractor was involved in more thinnings during the years of decreased production.

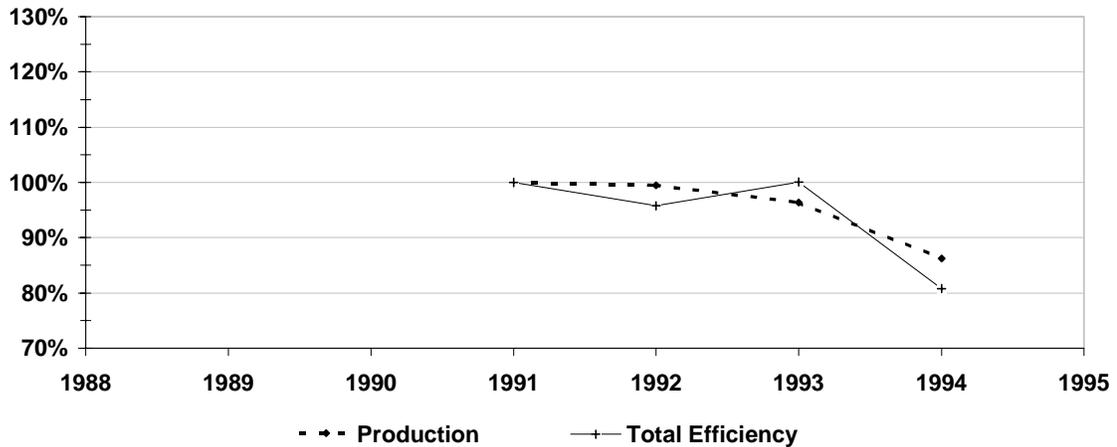


Figure 5.12 Relative production-eficiency graph of stable contractor S13.

A simple analysis was performed to study any overall trends that might be occurring in the relative production-eficiency graphs of the twenty-three contractors. Each year on the graph is plotted relative to the base year. If production is greater than the base year then production would be over 100% or “up” and vice versa. Efficiency was graphed in the same way. The following analysis counted the years where production was up or down from the base year and whether efficiency that same year was up or down from the base year. For example, in figure 5.12, there are three production observations below the base year. The production for 1992 is just slightly less than the base year 1991. The efficiency in 1993 was just slightly above the base year. The resulting tally is two years for production down, efficiency down and one year for production down, efficiency up. The base year is not tallied. This procedure was used to examine the production and efficiency relationships for each contractor. The results are displayed in table 5.2.

While this table does not quantify the changes in efficiency and production some general observations about shifts in production and efficiency can be made. First, as a general trend for production increased: 68 increases in production were tallied, while only 18 decreases were tallied. Increases in efficiency relative to the base years, have occurred more often than not, but the overall ratio is much weaker than production increases: 47 years up to 39 years down. In 71% of the observations of stable contractors production

and efficiency changes were directly correlated. Production increases occur with efficiency increases and production decreases occur with efficiency decreases. This occurs at a much less frequency in growth contractors (43%). As one examines the relative production-efficiency graphs, this trend seems to be reinforced. Production increases in stable contractors likely represent higher capacity utilization with existing equipment and labor spreads, resulting in improved efficiency. Growth contractors are expanding their equipment spread and hiring more labor. They need to produce more just to keep capacity utilization and efficiency the same as the base year.

Table 5.2 Correlation in relative production and efficiency changes.

<u>Production</u>	<u>Efficiency</u>	Number of instances		
		<u>Stable Contractors</u>	<u>Growth Contractors</u>	<u>All Years</u>
Up	Up	29	11	40
Up	Down	8	20	28
Down	Up	6	1	7
Down	Down	6	5	11

Looking back at figure 5.10, when contractor G1 pushed the production of his single crew in 1989, he improved his efficiency, arguably because he improved his capacity utilization. However after he organized a second crew and began to “find” his new capacity level and learn how to manage twice the production and costs, his efficiency declined slightly. The goal of higher production is not always to improve efficiency. The business strategy of a growing contractor may emphasize production to achieve greater net income instead of increasing the margin of profit on every ton produced. Stable contractors experiencing a downturn in production seem to be better able to control efficiency. They may avoid purchases of new equipment and delay major repairs. For growth contractors only one out of the six observations of declining production resulted in an improvement in efficiency.

## 5.5 Efficiency and Production Variation

Annual production by contractor is a useful variable in comparisons between businesses and business years. However, there is a dimension of weekly variability that is lost in the summation. Weekly variation is affected by a complex of natural, technical and administrative forces. Weather, quotas, markets, woodyard procedures, mechanical breakdowns, labor problems, trucking capacity are the main factors influencing weekly variability. Variation in weekly deliveries were analyzed, for those business where such data were available, to help understand how this variation may impact overall production and efficiency.

Figure 5.13 shows the relative production-efficiency graph of a growth contractor who rapidly expanded production through 1993. The run chart in figure 5.14 shows the weekly deliveries. During 1994, production losses mainly due to quotas and weather cut total annual production. Deliveries during many weeks particularly in the second and third quarters fell back to average levels for 1990 and 1991. The business had grown by 1994 and production at this lower level resulted in lower efficiency due to the high fixed costs of equipment and labor. Fortunately, during the fourth quarter quotas were lifted and deliveries came up and stayed up until a drop off around the holiday season. Otherwise the efficiency decline for the year would have been greater.

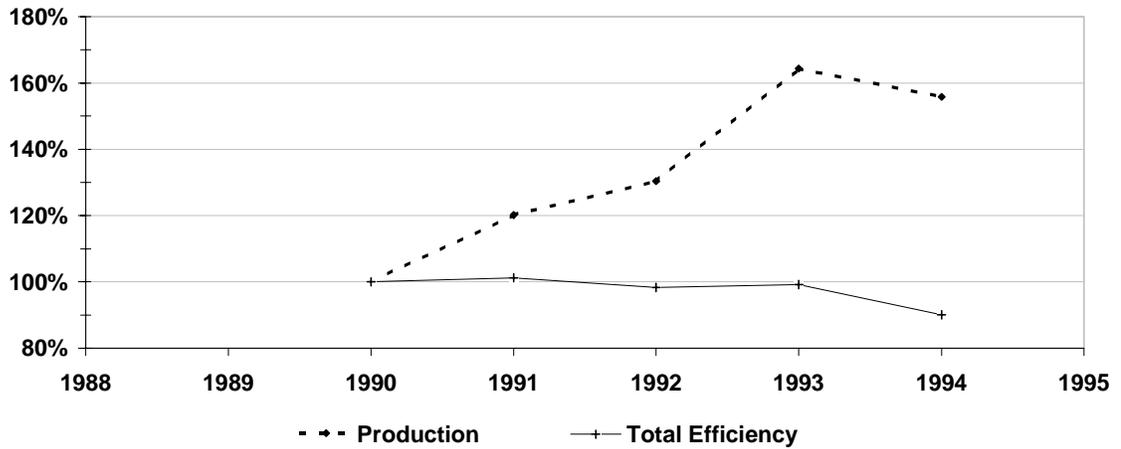


Figure 5.13 Relative production-efficiency graph of growth contractor G5.

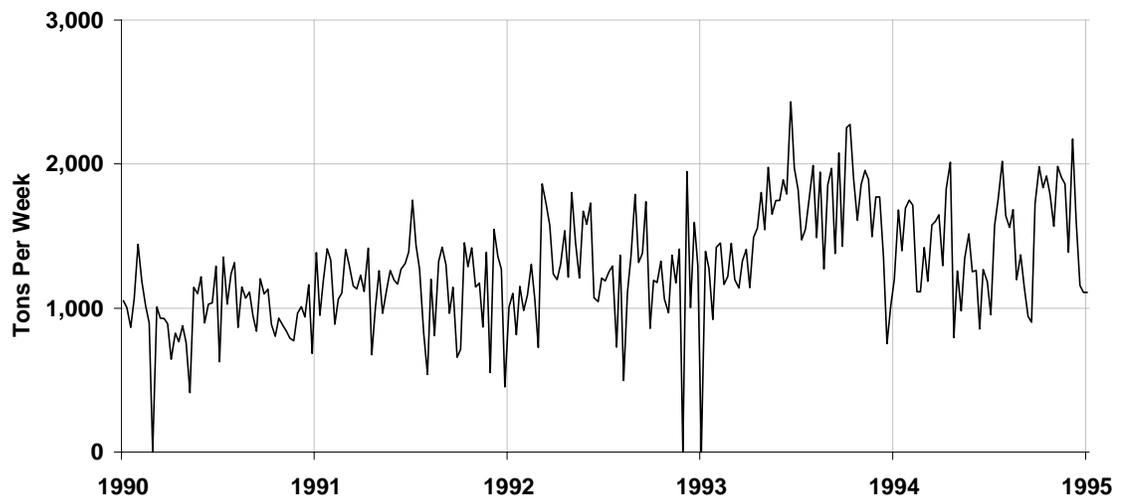


Figure 5.14 Run chart of growth contractor G5.

Figure 5.15 is a modified box and whisker plot that summarizes the variability contained in the run chart. The middle band shows the 75<sup>th</sup> percentile, median, and 25<sup>th</sup> percentile. There are five dots above the band marking the production levels of the best weeks and five dots below representing the worst weeks.

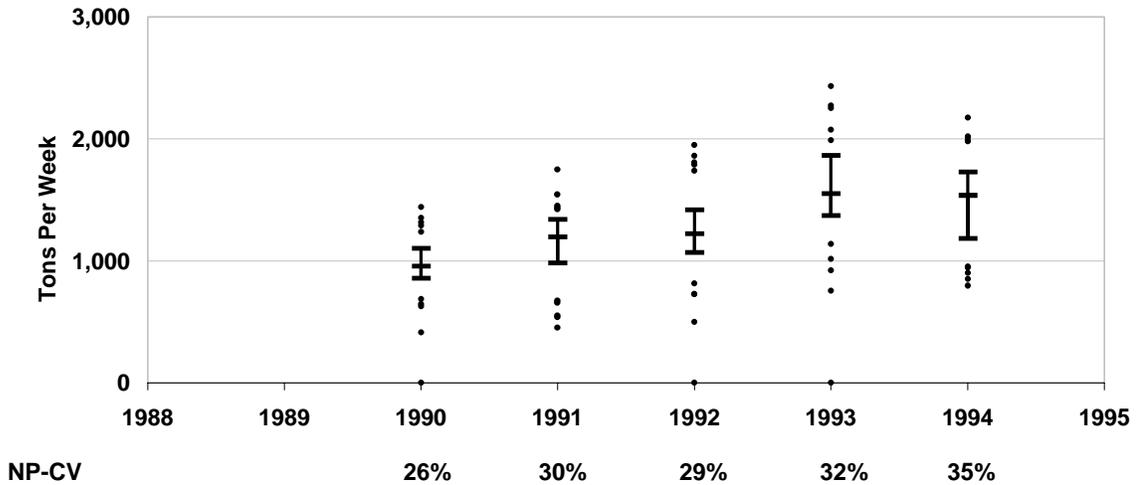


Figure 5.15 Modified box and whisker plot of growth contractor G5.

Variation can be summarized two ways. The parametric coefficient of variation, calculated by dividing the standard deviation by the mean, is a summary statistic commonly used to compare samples with different means. Its use requires the assumption of a normal distribution. If the distribution is not symmetrical or 69% of the observations are not included within one standard deviation of the mean then the basic characteristics of a normal distribution are not present. A non-parametric coefficient of variation (referred to in this report as the NP-CV) is calculated by dividing the interquartile range by the median. This statistic does not require an assumption of symmetry and is less influenced by extreme values. The statistic summarizes the middle fifty percent of the variation in relation to the median.

The NP-CVs for contractor G5 are listed below the year in the box and whisker plot in figure 5.15. This contractor is experiencing increasing levels of variation. Certain types of variation are more difficult for growing contractors to deal with. This can be shown by comparing 1993 and 1994. The median weekly delivery in 1993 was 1,551 tons while the median in 1994 was 1,538 tons. The medians differ by only half a load. The NP-CVs of the two years are also similar, with only a 3% difference. The primary difference between the two years is the nature of the variation. In 1993, the contractor experienced upward variation. Although the first quarter was slow, he has achieved regular

production with several high weeks. The distance between the median and 75<sup>th</sup> percentile is greater than the distance between the median and 25<sup>th</sup> percentile. In 1994, the contractor experienced downward variation. The bounds of the 25<sup>th</sup> and 75<sup>th</sup> percentile of weekly deliveries were much lower than the previous year. Furthermore, the dots above the 75<sup>th</sup> percentile show his best weeks in 1994 fell short of those in 1993. The box and whisker plot in 1993 indicates an upwardly elastic mode. This type of growing contractor is geared up to take advantage of opportunities to produce. The revenues generated are needed to keep his business healthy and efficiency high. The box and whisker plot in 1994 shows a typical downward variation pattern that can have serious consequences for a growing contractor.

Figure 5.16 shows the relative production-efficiency graph of a growing contractor. Figures 5.17 and 5.18 show his run and modified box and whisker charts for the same period. This coastal plain contractor found ways to control variation, allowing him to improve productivity and stabilize efficiency. The annual NP-CVs listed below the box and whisker chart are the highest observed in the study.

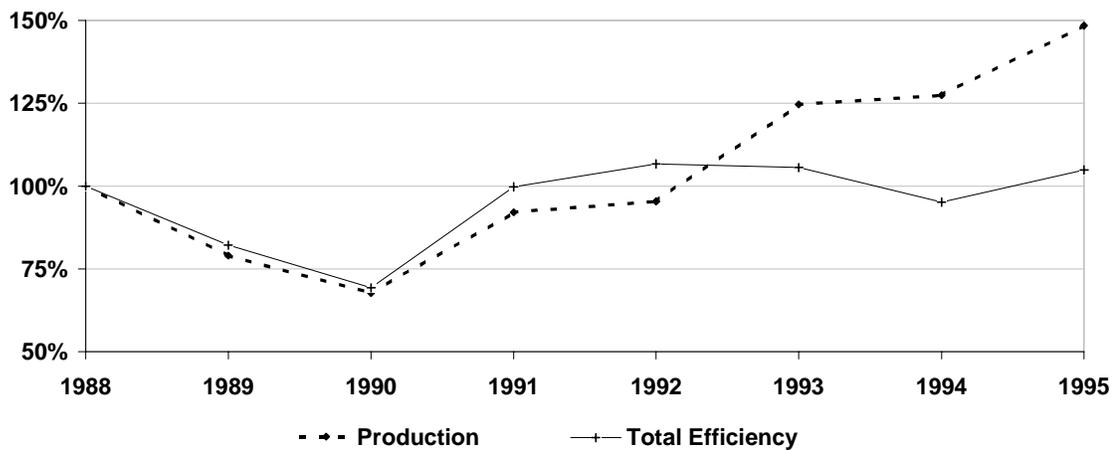


Figure 5.16 Relative production-efficiency graph of growth contractor G6.

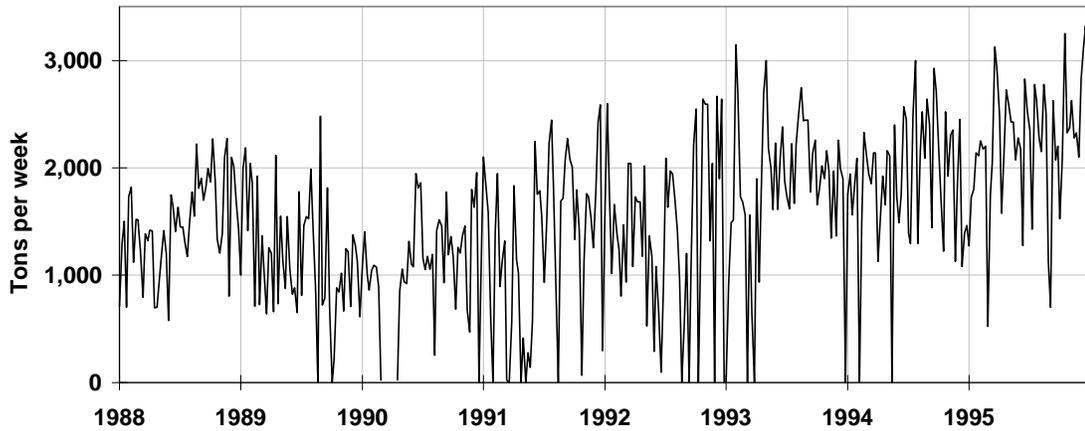


Figure 5.17 Run chart of growth contractor G6.

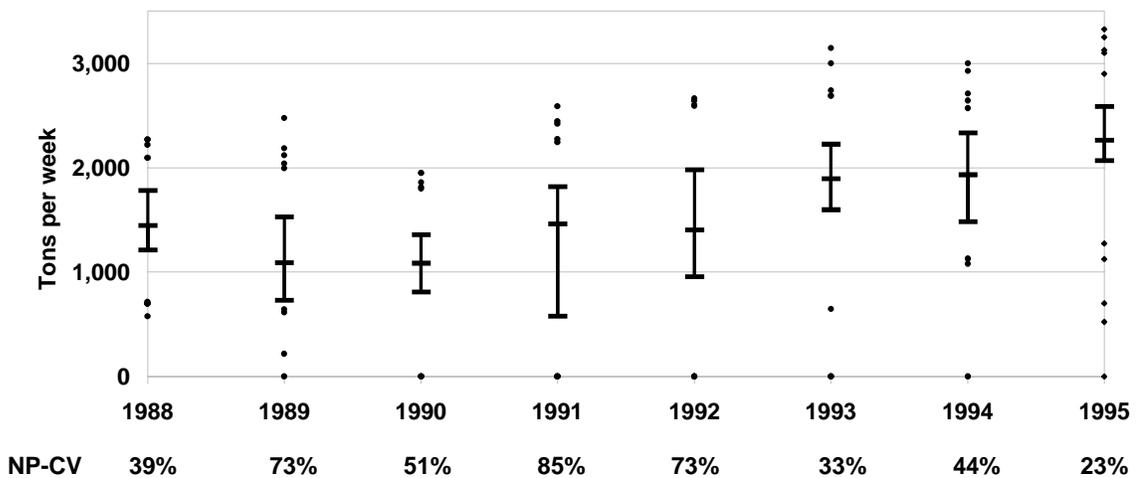


Figure 5.18 Modified box and whisker chart of growth contractor G6.

The contractor was classified as a “growth contractor” however it has been the emphasis on *stabilizing* production that has helped his business realize 50% more production. The single crew operation has stayed between six and seven productive in-woods employees and the number of skidders has varied between two and three. The operation primarily harvests pine plantations and been capable of moving 100 loads a week throughout the eight years of the study. Instead of trying to grow beyond that, he has found ways to

more often realize his weekly production potential. Wet weather was a major obstacle to capacity utilization for this contractor. Heavy rains could stop production for a week while the ground dried out. Hurricane Hugo hit in September 1989, saturating the coastal plain and causing substantial production losses for this contractor in 1989 and 1990. A period can be observed on the run chart in 1990 where the contractor shut down his conventional job and assisted in some helicopter logging as part of the salvage effort. His procurement organization was also becoming increasingly concerned about soil disturbance and compaction, especially on company owned timberlands. Furthermore, the implementation of best management practices (BMPs) began in 1991. The losses due to weather mounted causing a high incidence of low or zero production weeks.

In early 1993, the contractor became a preferred supplier to his procurement organization and agreements were made regarding future quotas, allowing more stable production. In late 1993, the contractor invested over two hundred thousand dollars to bolster the “weather resistance” of his job. He bought a tracked loader to be used for shovel logging. The impacts of this machine were confined to a smaller area than the impacts caused by skidders, allowing less expensive site preparation. The shovel technique allowed the logger to harvest the lower wetter areas of the tracts. This reduced the number of moves, because with conventional equipment these areas would be harvested only during extremely dry periods. By leaving three hundred foot swaths of roadside timber during dry times, this contractor created a place to retreat to in times of extended wet weather. Cooperation with his procurement organization was the critical to the success of this wet-weather strategy.

## 5.6 Efficiency and Environment

Three factors of the loggers production environment commonly assumed to have an effect on efficiency were assessed for each of the 109 observations. It was expected that changes in these factors could help explain differences in contractor efficiencies.

1. Average haul distance from the tract to the mill.
2. Capacity utilization.
3. Percentage of pine harvested.

LeBel (1996) found that any one of these parameters taken individually could not explain the observed variation in efficiency. He reasoned that it is likely that a logger might benefit from a positive change in one parameter while being hurt by a shift of another, causing these factors to average out. For instance, short hauls should improve efficiency but increasing hardwood is thought to decrease efficiency because of extra delimiting work. Therefore the benefits of the short haul might not materialize if hardwood can't be produced at fast enough rate. Therefore LeBel combined these three environmental parameters into a "complexity factor" to help take into account any interactions.

The effect of changes in each of these three factors was tested by developing regression equations of economic efficiency as a function of the range of variation of each of the assumed controlling factors (figures 5.19, 5.20 and 5.21). The trend lines, determined by the least squares method, have relatively low  $R^2$  values due to the wide spread of the data.

Haul distance had a significant negative correlation with total economic efficiency based on the F-statistic ( $p$  value  $< .001$ ). The regression line explains only 18% of the variation in economic efficiency. Eighty percent of the haul distances were at 40 miles and less, forming a cluster with a wide range of efficiency in the scatter plot. The regression equation indicates that the total economic efficiency can be expected to decline 0.018 tons per dollar as the haul distance increases from 20 miles to 110 miles. However, lacking more data from the medium and longer haul distances, it is not certain if this efficiency decreases uniformly as haul distances increases as a straight line suggests. It

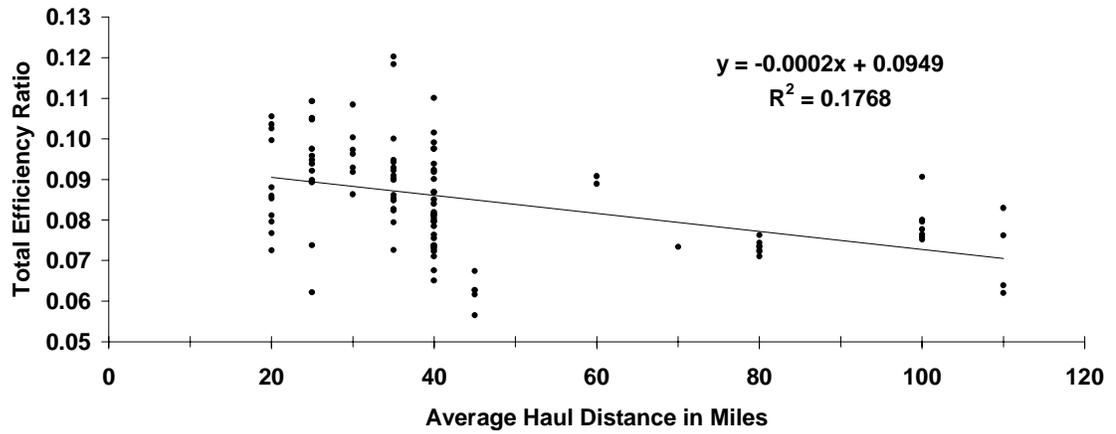


Figure 5.19 Total efficiency as a function of average haul distance.

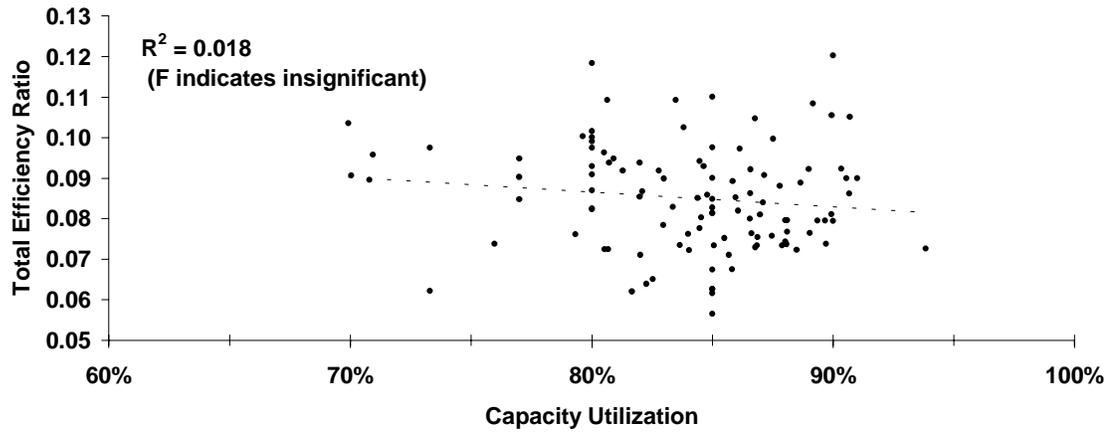


Figure 5.20 Total efficiency as a function of capacity utilization.

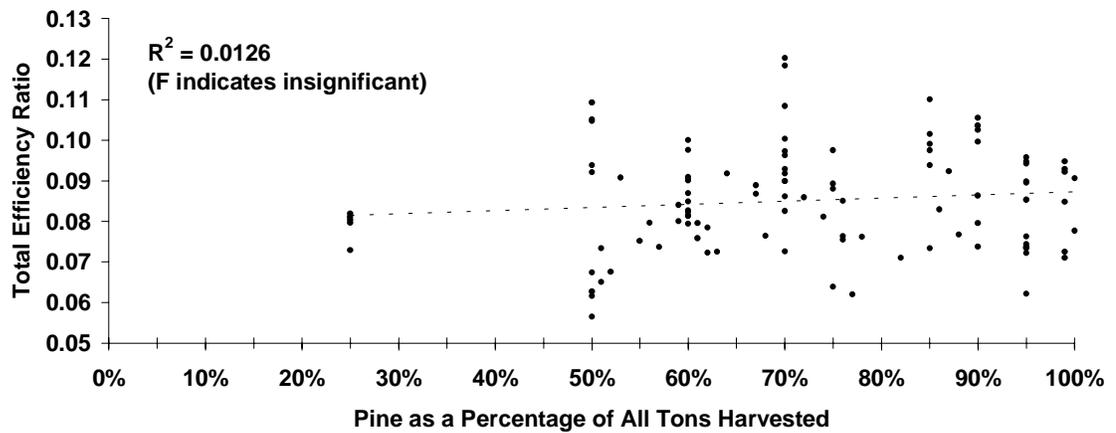


Figure 5.21 Total efficiency as a function of percentage of pine harvested.

may be a “step function” such that efficiency drops at certain points where the number of loads that can be hauled per day decreases by one.

The effect of capacity utilization and percent pine were ambiguous with these global analyses, resulting in F- statistics (p-values 0.16 and .25 respectively) that were not significant. In other words, the null hypothesis that the correlation is zero could not be rejected.

A simple grouping analysis was done to better understand how these parameters might be interacting. LeBel (1996) listed in Appendix B of his dissertation the parameter values for each of the 109 contractor years. Table 5.3 shows the median and range for each parameter.

Table 5.3 Distribution of three logging environment parameters in the data set.

<u>Parameter</u>	<u>Minimum</u>	<u>Median</u>	<u>Maximum</u>
Percentage of pine	25%	70%	100%
Haul Distance (miles)	20	40	110
Capacity utilization	70%	85%	94%

Two categories were created for each parameter. The contractor years were categorized on the “good” or “poor” side of the parameter depending on which side of the parameter median they fell on. For instance, a contractor-year was assessed as harvesting 60% pine, hauling on the average 35 miles to the mill and averaging a capacity utilization of 80%. That contractor-year would be classified as on the poor side of the pine percentage parameter (Mixed species), on the good side (Short) of the hauling distance parameter and on the poor side (Low) of the capacity utilization parameter. Treatment of those observations equaling the median required an arbitrary decision as shown in table 5.4.

Table 5.4 Grouping of contractor-years based on parameter value.

<u>Parameter</u>	<u>"good" side</u>	<u>"poor" side</u>
Percentage of Pine	Pine $\geq 70\%$ n = 63	Mixed $< 70\%$ n = 46
Haul Distance	Short $< 40$ n = 52	Long $\geq 40$ n = 57
Capacity utilization	High $\geq 85\%$ n = 58	Low $< 85\%$ n = 51

Creating two groups from each of the three parameters yields eight groups, accounting in a very basic way for interactions between the parameters. These eight groups are displayed from left to right by decreasing median in figure 5.22.

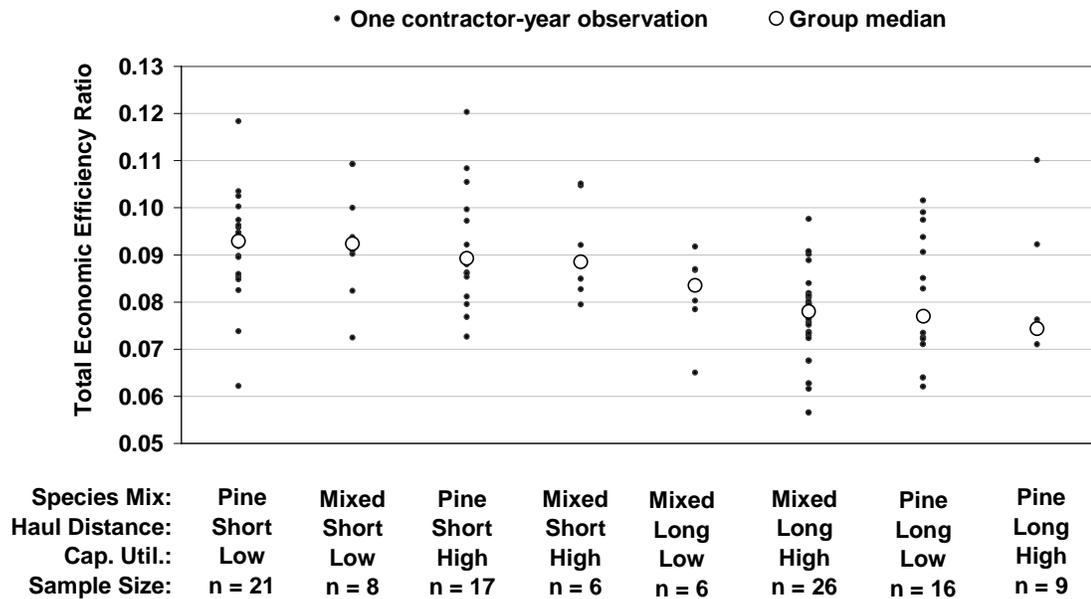


Figure 5.22 Efficiency for eight groups defined by three environmental parameters.

There is a large overlap across stratifications. The factor that surfaces as the most influential is hauling distance. The ranking puts the four short hauling distance groups as the most efficient and the four long hauling groups as least efficient. Capacity utilization and species mix did not play into the rankings within this division by hauling distance as expected. Low capacity utilization ranked better than high utilization within the short hauling distances. However subtle influences can be observed in the ranges. Note that the minimum observations in pine-short-high and mixed-short-high are greater than the minimums observed in pine-short-low and mixed-short-low. High utilization in the long hauling set brought the pine groups' minimums up, but did not seem to improve efficiency for the mixed species group. Mixed species ranked higher than the pine groups in the long hauling set, however the maximums were higher in the pine groups.

Although species did not show a major impact on efficiency in this grouping analysis, most contractors indicated a preference to cut pine. Hardwood often requires more chainsaw delimiting work, can require increased loading time if the trees are crooked, and may require more sorting and merchandising. However, the actual processing of hardwood may only be part of the problem with production in hardwood. "Hardwood" may be a surrogate for other tract-related variables that are a detriment to production. Hardwood sites are often the wetter sites causing losses due to wet weather to be more severe and moves off the tract more common. Hardwood tracts are usually less managed than pine stands, resulting in heavier underbrush and lower volumes per acre. In many cases hardwood tracts have poorer access than pine tracts. This was observed on many visits to contractors logging operations. Many coastal plain hardwood tracts lay behind a peanut or cotton field, therefore roads are impassable in wet weather without extensive mat laying. Such hardwood tracts tend to be oddly shaped and elongated causing increased skidding distance.

The scatter plot in figure 5.21 did not show a strong relationship between percent pine and efficiency, and the group ranking analysis in figure 5.22 did not show species to be as detrimental to efficiency as commonly assumed. For several contractors detailed weekly information allowed analysis of species impact on an individual contractor basis. Figure

5.23 shows the percentage of pine harvested on an annual basis below the corresponding year of the relative production-efficiency graph. The impact of total production on efficiency seems to be over-riding in this case. In 1991, production fell and efficiency improved, but the percentage of pine went down. In 1994, pine as a percentage of total production was the highest for the five years, but whether that is the cause of the efficiency improvement would be speculative.

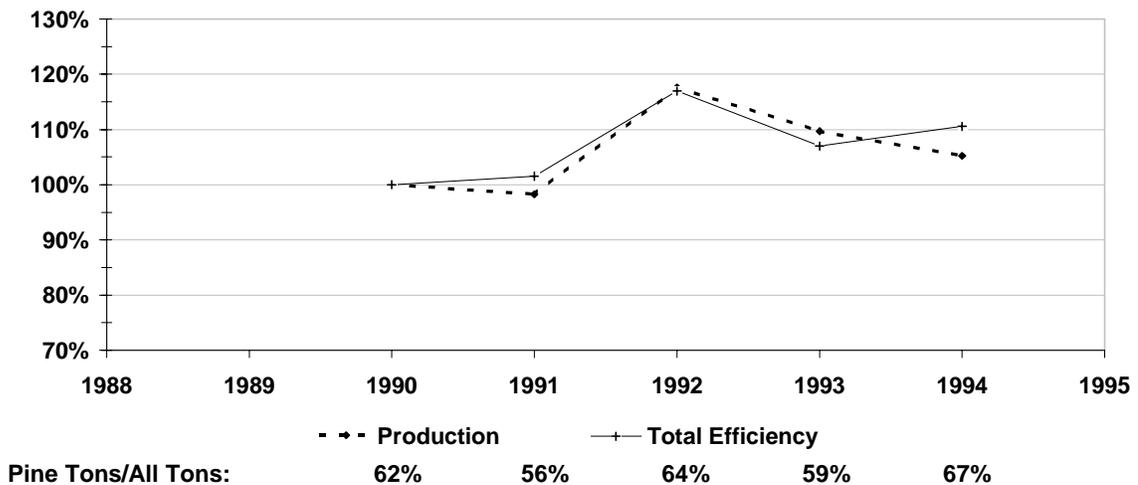


Figure 5.23 Relative production-efficiency graph of stable contractor S4.

The impact of species mix on contractor production and efficiency is vague and inconsistent on a year-to-year basis, however examined on weekly basis it becomes clearer. Figure 5.24 shows a scatter plot developed from five years weekly production information for this stable contractor. The trend line shown is much stronger than the one in figure 5.21, the difference being the dependent variable in figure 5.21 is economic efficiency for all the 109 contractor-years, where as the dependent variable in figure 5.24 is production per week for one contractor.

This logger did not express a strong dislike for cutting hardwood. *Pine loads faster and straighter and the cutter can lay it down faster, but I really don't mind cutting good hardwood.* The trend line explains only about 12% of the variation observed across various levels of pine production. The slope of the line is 742 tons, meaning the trend line climbs 742 tons from a week of all hardwood production to a week of all pine production.

This is a gross over-simplification of the true production trend, since there is considerable variation about the trend line as shown by the dots. Analysis of six other contractors (one with two crews) for which weekly hardwood and pine data are available shows similar  $R^2$  values and slopes (table 5.5). Consideration of the F-statistics from the analyses of variation showed that the regressions are valid.

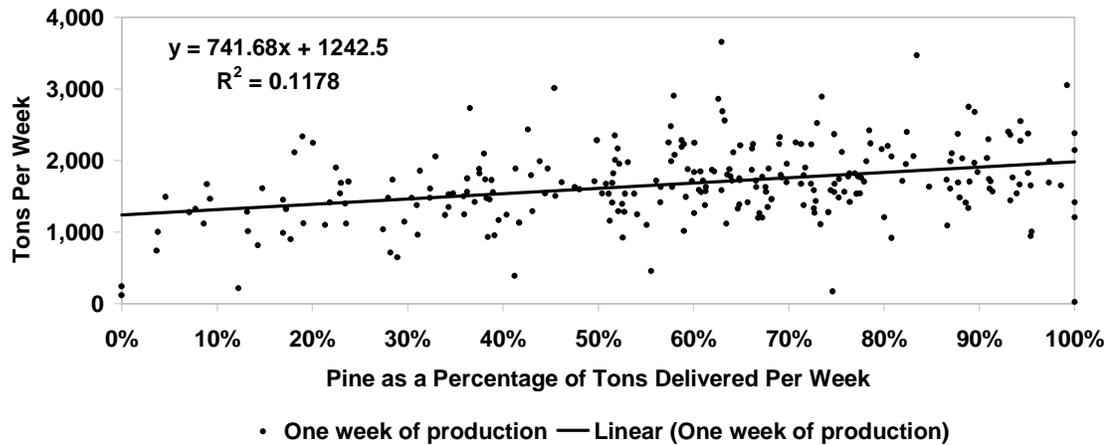


Figure 5.24 Weekly tons as a function of percentage pine for stable contractor S4.

Table 5.5 Regression analysis of percentage pine relationship with weekly production.

Years of data	Operation and Mean Pine Week	Mean Weekly Production (tons)	$R^2$	Slope (tons)	Y-intercept (tons)	Percent increase in weekly production for a 1% pine increase
5	S4, 59%	1,680	0.12	741	1,243	0.60%
5	S6, 52%	2,022	0.09	828	1,595	0.52%
5	S2, 78%	1,560	0.10	739	986	0.75%
5	S9, 72%	3,105	0.13	1,154	2,280	0.51%
5	S3a, 62%	2,142	0.15	893	1,588	0.56%
5	S3b, 55%	2,154	0.04	453	1,907	0.24%
2	G9, 42%	1,532	0.15	706	1,235	0.57%

Capacity utilization, calculated by dividing the mean week of production by the 75<sup>th</sup> percentile for the year, showed essentially no global impact on technical efficiency. The scatter plot of all contractor-years efficiencies and capacity utilizations plotted together (figure 5.20) yield an insignificant trend line. LeBel (1996) had also expected to find a stronger relationship between efficiency and capacity utilization for the composite of contractor-year observations. However, LeBel did demonstrate the expected relationship between capacity utilization and efficiency was apparent when analyses focused on a single logger on a quarterly basis.

If capacity utilization could be shown to have an impact on annual efficiency the best chances of finding it would be with the stable contractors. The ever increasing production of growing contractors makes it difficult to establish a baseline for measuring capacity utilization. In figure 5.25, the annual capacity utilizations have been plotted on the x-axis against the corresponding economic efficiency on the y-axis, stratified by logger. The sample includes six stable loggers for whom five or more years of weekly production data was attained. Note that contractors seem to overlap in capacity utilization more than total economic efficiencies. This tendency added to the difficulty in finding a global impact of capacity utilization on total economic efficiency. While five of the six regressions for the six contractors showed the expected direct relationship, only one was found to be significant. The exception was contractor S4. This line trended downward, indicating decreased efficiency with increased capacity utilization. The trend line for contractor S3 showed the expected relationship quite strongly with an  $R^2$  of 0.89.

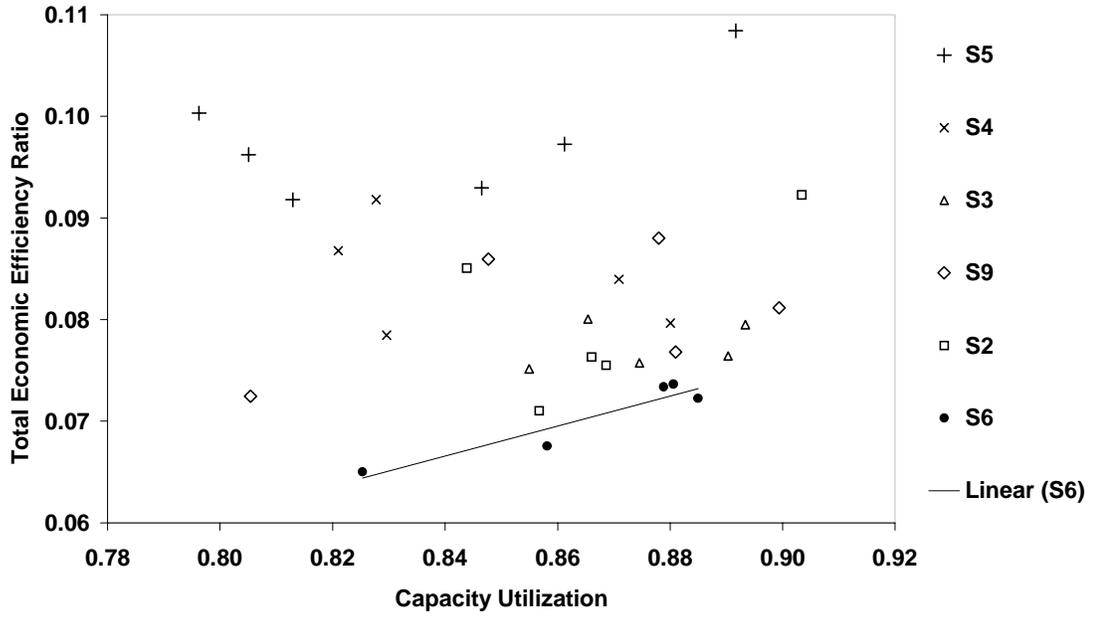


Figure 5.25 Total efficiency as a function of capacity utilization stratified by contractor.

## 5.7 Efficiency and Trucking Strategy

The data set was broken down into two subsets based on trucking strategy. The first group was the *cut-and-haul group*, where all functions were performed by the same business entity. They may contract out some trucking. In their accounting records, most or all hauling costs were included in the equipment, consumables, and labor cost categories. This accounted for 68 out of the 109 observations or about 62%. The remaining 41 observations were categorized in *logging-only group*. These loggers contract out all their trucking and focus only on the cut-skid-load phase. Some of these loggers sub-contracted out to their own separate trucking business. In their accounting records, hauling costs were wholly contained in the contract hauling category.

Figure 5.26 differentiates yearly observations by trucking strategy. It shows an even spread of both strategies across all years of the study.

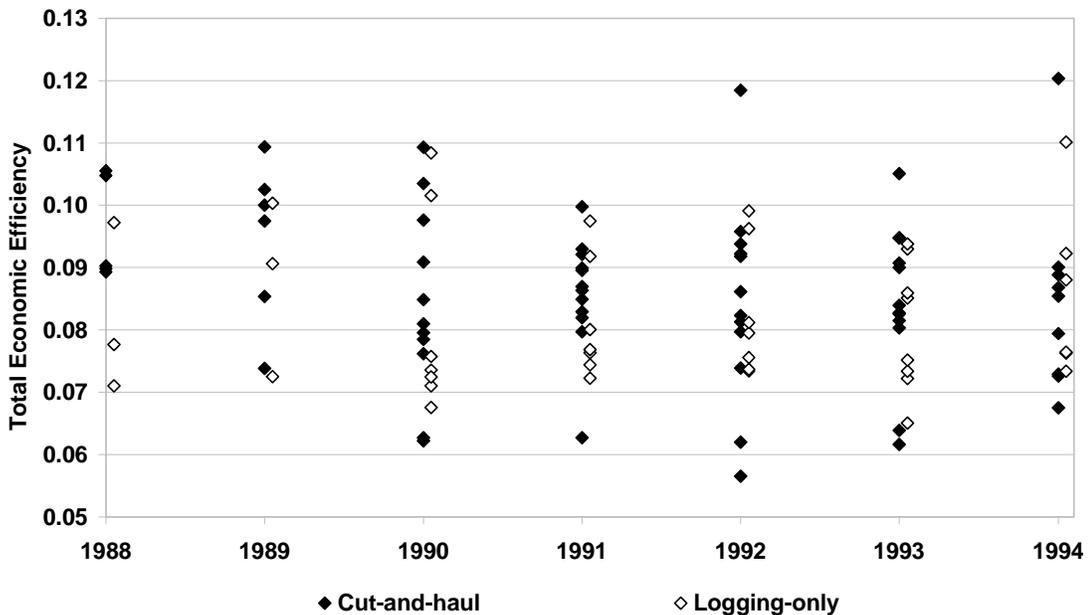


Figure 5.26 Efficiency ratios across years of study by trucking strategy.

The cumulative frequency distribution graphs in figure 5.27 compares the distribution of total efficiencies of the two hauling strategies. The range for the cut-and-haul contractors is so wide that some contractors were found to be twice as efficient as others in terms of tons delivered per dollar inputs. The logging-only group has an asymmetric distribution, with the median not centered in its range. The mean is greater than the median indicating a cluster of performers in the 0.07 to 0.08 range and then a scattering of better performers in the 0.08 to 0.11 upper range. This can also be observed in figure 5.26.

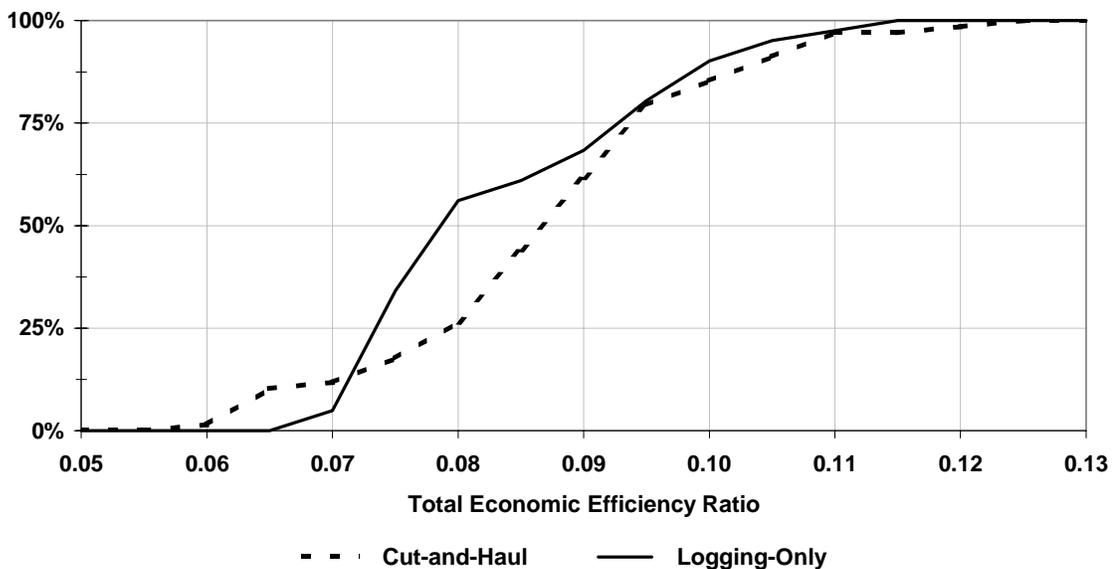


Figure 5.27 Economic efficiency distributions by trucking strategy.

Table 5.6 Descriptive statistics of economic efficiencies by trucking strategy.

	<u>Cut-and-haul</u>	<u>Logging-only</u>
number of observations	68	41
Maximum	0.1203	0.1101
Minimum	0.0565	0.0650
Range	0.0638	0.0451
75 <sup>th</sup> percentile	0.0939	0.0923
25 <sup>th</sup> percentile	0.0797	0.0734
Interquartile range	0.0142	0.0189
Median	0.0865	0.0768
Mean	0.0866	0.0826

While there is considerable overlap in the two distributions, the cut-and-haul group has a wider range and has a higher median efficiency ratio value than the logging only group. It might seem to indicate that on a total cost basis the cut-and-haul contractors are more efficient in the whole process of delivering wood to the mill than the logging-only group. The Mann-Whitney test was used to compare the medians of the two distributions. The null hypothesis that the two medians are equal could be rejected at the 90% confidence level, with a p-value of 0.0552.

The first factor to explain the difference in efficiency between hauling strategies is hauling distance. The logging-only group had a median of 40 miles to haul to the mill, while the cut-and-haul group had a 35 mile average haul distance. In consideration of the other logging environment parameters of species mix and capacity utilization, the two trucking strategies have similar medians. The logging-only group harvested 76% pine, while the cut-and-haul group was heavier to hardwood at 67%. Both groups had a median capacity utilization of 85%. Since hauling distance was shown to have a significant correlation with efficiency, the five mile differential gives further explanation of the efficiency superiority of the cut-and-haul group.

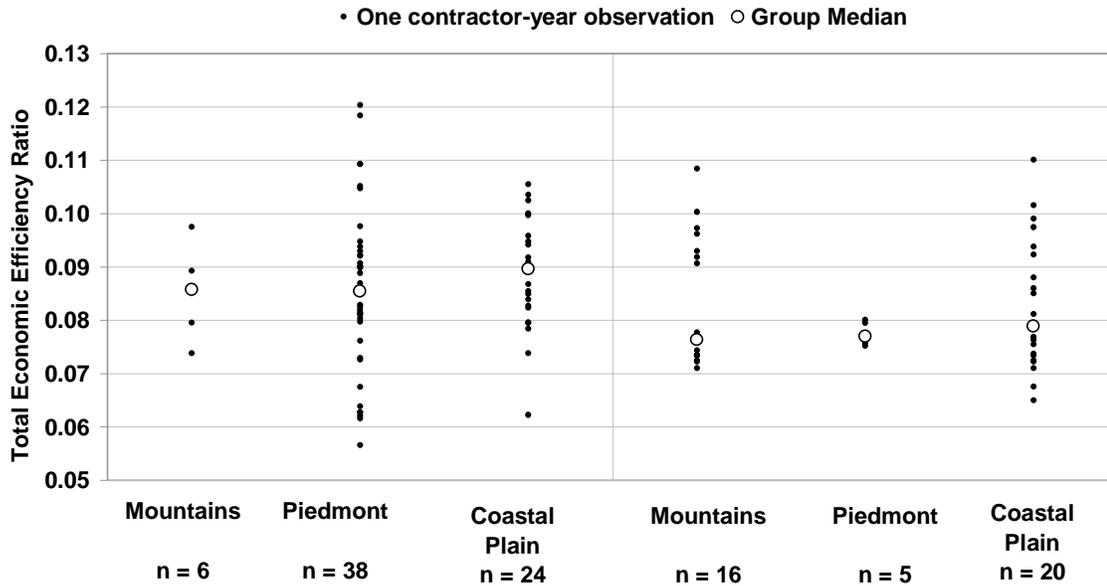
For six contractors in the logging-only group, hauling was sub-contracted to a firm independent of their own logging firm. It could be argued that the logger who contracts out his trucking is accepting a higher cost than if it was done “in house”. By contracting out trucking, a logger relinquishes control of about 40% of his costs and may accept a higher cost and less control, depending on the situation. However, some loggers said sub-contracting the hauling fits their business better. There is less liability exposure, less capital to manage, and less repairs and maintenance. There are fewer employees to manage as well and many contractors pointed out that management of truck drivers presented a whole different set of challenges compared to woods help. In short, for many contractors, sub-contracting hauling meant fewer headaches.

Three of the contractors (fifteen observations) in the logging-only group sub-contracted hauling to a wholly owned subsidiary. These contractors were large producers that strategically divided their business for maximum profit and minimum liability exposure.

Total efficiencies are compared by physiographic region by trucking strategy in figure 5.28. Analysis was hampered by a small sample size in the mountains region of the cut-and-haul group. Only six years based on two contractors were observed. Similarly, a disproportionally small sample size occurs in the piedmont region of the logging only group. All five of these observations were from the same contractor.

The total efficiencies are quite close for all three regions within their respective trucking strategy group. For both trucking strategies it was observed that the order of increasing efficiency is piedmont, mountain foothills and coastal plain. The Mann-Whitney test revealed no significant differences at the 80% confidence level between physiographic regions within their respective trucking strategy. While the piedmont ranked the lowest of the three regions for both trucking strategies, it also had the longest median haul distances and lowest median pine percentages of annual production.

The cut-and-haul strategy dominates in the piedmont. The observations of logging-only in the piedmont are a case of a contractor with a wholly owned subsidiary. However in the mountains the trend is to contract out trucking to a separate hauling business. The mountain logging business were shown earlier to be the smaller businesses in the study. The coastal plain is fairly evenly split between the two strategies.



	Cut-and-haul			Logging-only		
<u>Medians</u>	<u>Mountains</u>	<u>Piedmont</u>	<u>Coastal Plain</u>	<u>Mountains</u>	<u>Piedmont</u>	<u>Coastal Plain</u>
Efficiency	.0858	.0855	.0897	.0770	.0764	.0790
Haul distance	25	40	35	80	100	40
Pine Percentage	90%	60%	79%	95%	61%	76%

Figure 5.28 Efficiency by trucking strategy and region with environmental influences.

## 5.8 Summary

109 annual total economic efficiency ratios were calculated from cost and production information from twenty-three contractors. The data span from 1988 to 1994 (also one observation in 1995). The mean and median ratio was 0.085 tons per dollar. The most significant deviation from the median was in 1989 when the highest median occurred of .098. After 1989, the overall median declined with an influx of new contractors joining the study in 1990. While no significant trends in efficiency over the time period 1988 to 1994 were observed, this is an aspect of the project that requires careful monitoring to note comprehensive swings in all contractors' efficiency, such as occurred late in 1995 and 1996 as the project expanded.

A wide range of business sizes was sampled. There was no strong indication of economies of scale in a comparison of annual expenditures and annual production. However, contractor-years with production exceeding 100,000 tons had a significantly lower (90% confidence level) total economic efficiency than contractor-years in the 50,000 to 100,000 tons per year range.

Relative production graphs illustrated individual contractor histories. Overall they reveal that eighteen of the twenty-three (78%) contractors increased production from their first year in the study. The largest increase was 252% from base year levels or an increase of about 78,000 tons over seven years. The median contractor produced 117% of the base year level, increasing production by 34,000 tons.

Based on production history and contractor business information collected during interviews, the contractors were categorized as growth contractors and stable contractors. Relative efficiency graphs showed that year-to-year efficiency swings appeared to rather volatile for growth contractors. The greatest maximum improvement in efficiency for a growth contractor was 108% from base year levels. The greatest relative loss in efficiency was 88%. The median efficiency change was 98%.

Efficiency changes in individual stable contractors did not range significantly less than growth contractors, however the graphs gave the appearance of more moderate efficiency changes in stable contractors. Efficiency seems to track with production in stable contractors, probably indicating improved capacity utilization with increases in production. The greatest maximum improvement in efficiency for a stable contractor was 139% from base year levels. The greatest relative loss in efficiency was 86%. The median efficiency change was 108%.

Weekly production variation was illustrated in run charts and box and whisker charts and summarized with a non-parametric coefficient of variation (interquartile range / median). Efficiency losses were shown to occur in years with excessive variation within the

interquartile range. Sub-capacity yearly production is usually the result of a high frequency of low production weeks often due to weather and quota. Downward variation or variation in the lower half of the interquartile range can be especially problematic for growth contractors and therefore efficiency.

Average haul distance from the tract to the mill was shown to have a global impact on total economic efficiency, explaining about 18% of the variation observed in the 109 observations. While total economic efficiency decreases as haul distance increases, as would be expected, the relationship may be a step function instead of a straight line.

Pine as a percentage of total tons harvested did not show a significant trend line in the scatter plot of all 109 observations and therefore no global impact. An analysis of the impact percentage pine on weekly production on an individual operations basis did reveal species mix had a significant impact on production. For the seven contractors analyzed the median impact is that a 1% increase in the pine mix would correlate with a 0.56% increase in mean weekly production. It is doubtful that the drop in production with decreases in pine and increases in hardwood can be attributed to extra processing work only. "Hardwood" logging often occurs on wetter, less managed, and more difficult to access tracts.

Capacity utilization, calculated by dividing the annual mean by the 75<sup>th</sup> percentile, did not show any correlation with total economic efficiency. However, the relative production efficiency graphs of stable contractors tended to show a direct relationship between changes in production and changes in efficiency.

Contractor years were segregated by two trucking strategies. Those contractor years where most or all hauling costs were included in the equipment, consumables, and labor costs were categorized as cut-and-haul. Those contractor-years where hauling costs were wholly contained in the contract hauling category were categorized as logging-only. At the 90% confidence level, the cut-and-haul group had a significantly higher median (0.0865) than the logging-only group (0.0768). The median haul distance of the logging-

only group was five miles greater than the cut-and-haul group. Logging-only contractors have direct control over a smaller portion of their costs and may be accepting a higher cost for trucking than those who take care of hauling “in-house”. Establishing the efficiencies of these two groups is useful for further analysis of partial efficiencies by trucking strategy in Chapter 6.