Chapter 6

Comparisons of Partial Efficiencies

6.1 Relationship of Partial Efficiency and Total Efficiency

Partial efficiency ratios, calculated by dividing the total tons produced by the dollars spent in a particular cost category, are used to quantify the efficiency of a particular input. The expenditure for a particular input relative to total spending is also a useful measurement of the cost management strategy. The product of these two measurements is total economic efficiency, thus they have an inverse relationship. As spending in one category goes up, the partial efficiency goes down. Though not complex, the relationship between cost structure and partial efficiency can be clarified by looking at the numerators and denominators which make up these ratios:

$$\text{\% spent in Category} \times \text{partial economic efficiency ratio} = \text{total economic efficiency ratio}$$

$$\frac{\text{Input (cost) category}}{\text{Total input (total cost)}} \times \frac{\text{total output (tons)}}{\text{input (cost) category}} = \frac{\text{Total output (tons)}}{\text{Total input (total cost)}}$$

$$\frac{\cancel{\text{Input (cost) category}}}{\text{Total input (total cost)}} \times \frac{\text{total output (tons)}}{\cancel{\text{input (cost) category}}} = \frac{\text{Total output (tons)}}{\text{Total input (total cost)}}$$

Likewise the percentage spent in a particular category can be determined from the partial efficiency ratio and the total efficiency ratio:

$$\text{\% spent in category} \times \text{partial economic efficiency ratio} = \text{Total economic efficiency ratio}$$

$$\text{\% spent in category} = \frac{\text{total economic efficiency ratio}}{\text{partial economic efficiency ratio}}$$

The partial efficiency ratio gives the added dimension of sensitivity to tons produced. If a contractor maintains the same spending strategies year to year, but experiences production variations his partial efficiencies will change.

6.2 Defining the Ranges of Partial Efficiencies

The final section of Chapter 5 segregated contractors into logging-only and cut-and-haul trucking strategies. In the logging only group, hauling costs are wholly contained in a separate contract hauling category. For the cut-and-haul group hauling costs are contained in the equipment, consumables, and labor categories.

Figures 6.1 and 6.2 show the cumulative frequency distributions of the partial efficiencies for the cut-and-haul and logging-only groups. Since logging-only contractors are paying contract hauling costs, their dollars spent in the equipment, consumables and labor categories will be less and therefore their efficiencies will be greater. Their cumulative frequency distribution could be considered the same efficiency range for the woods-only operations of the cut-and-haul contractors.

The partial efficiency for labor is somewhat higher for the logging-only contractors, but the range is narrow for both groups. The partial efficiency for consumables is higher for the logging-only contractors and the range is three times that for that cut-and-haul group. The partial efficiency for capital is also higher for the logging-only contractors, but the range is approximately the same for both groups.

The shape of the cumulative frequency distribution for contract hauling shows two distinct groups. About 44% of the contractor-year observations fell in the range of 0.15 and 0.18, and the other grouping of observations (39%) fell in the range of 0.31 to 0.37. The contractor-years in the lower range showed contract hauling expenses running between 40% and 50% of total costs and average haul distances ranging from 40 to 100 miles with a median of 80 miles. The contractor-years in the upper range showed contract hauling expenses running between 22 and 33% of total costs and average haul distances ranging from 20 to 40 miles with a median of 30 miles.

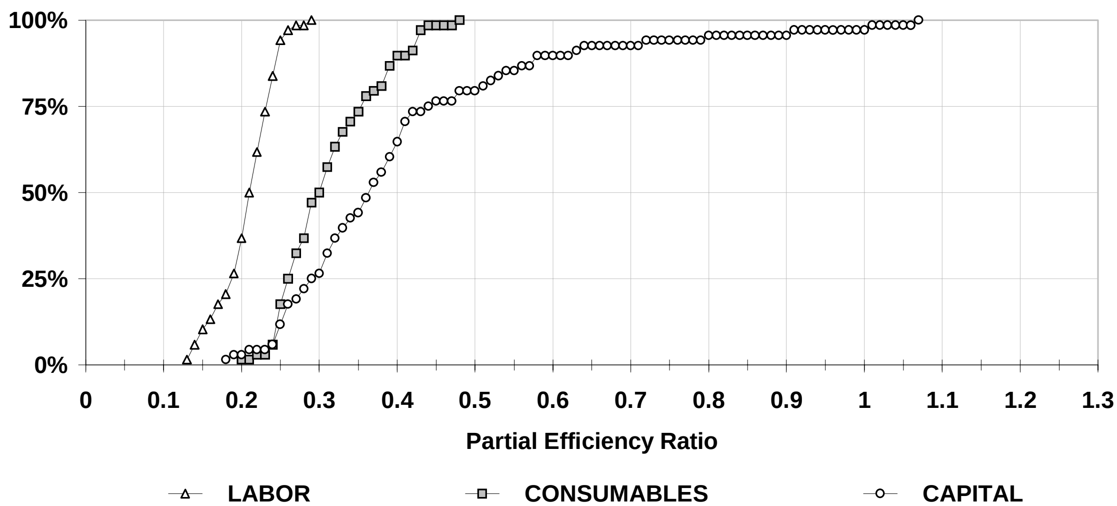

Figure 6.1 Partial economic efficiencies of cut-and-haul operations.

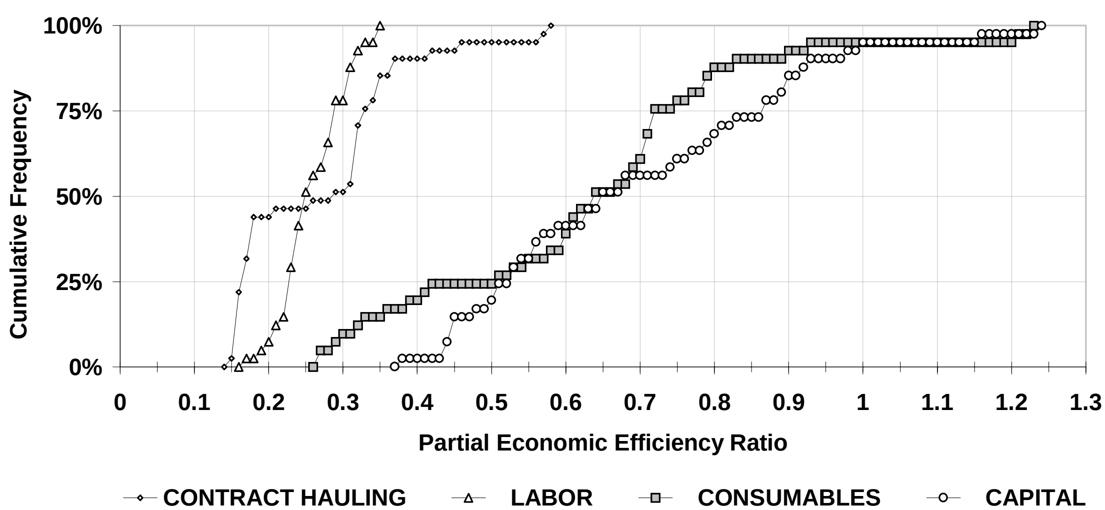

Figure 6.2 Partial economic efficiencies of logging-only operations.

Tables 6.1 and 6.2 present the same information in numeric form. The range for each category defines the limits of efficiency for each input. While the average and median values for labor is higher for those using contract trucking, the range for the two groups is about the same. This indicates that there is little difference in the available efficiency for either type of contractor.

The cut-and-haul group does most of their own trucking, but hires contract truckers when needed, so this group is not as "pure" as the other. Some contract trucking was used in 50 of the 68 contractor-years of the cut-and-haul group. The amount was relatively small (median of 8% of total costs). A simplifying assumption that contract trucking costs could be distributed evenly across the three major categories was made to avoid distorting the cost structure of the firm. This analysis indicates that that assumption should be revisited.

As an overview, the labor input as a percentage of total spending is generally high. For 94% of the observations in the cut-and-haul group, labor was the largest input. Labor, as a percentage of total spending had a median of 41%, followed by consumables at 29% and capital at 25%. For the logging-only group the results were proportional. For 44% of the loggers in this group, labor was the greatest input. As a median percentage of total costs, contract hauling was the greatest at 33%, followed closely by labor at 32%, followed by capital and consumables at 13% and 12% respectively.

Table 6.1 Descriptive statistics for partial efficiencies of cut-and-haul operations.

	Labor	Consumables	Capital
Maximum	0.280	0.478	1.067
Minimum	0.128	0.179	0.178
Range	0.153	0.299	0.889
75th percentile	0.231	0.352	0.440
25th percentile	0.187	0.261	0.295
Interquartile range	0.044	0.091	0.145
Median	0.210	0.299	0.362
Mean	0.206	0.310	0.402

Table 6.2 Descriptive statistics of partial efficiencies of logging-only operations.

	Contract Hauling	Labor	Consumables	Capital
Maximum	0.575	0.348	1.226	1.230
Minimum	0.145	0.163	0.263	0.375
Range	0.429	0.186	0.963	0.855
75th percentile	0.330	0.287	0.719	0.864
25th percentile	0.165	0.227	0.510	0.522
Interquartile range	0.165	0.060	0.209	0.342
Median	0.288	0.248	0.636	0.649
Mean	0.267	0.258	0.627	0.691

6.3 Partial Efficiencies by Physiographic Region

Figure 5.28 in the previous chapter, showed the total economic efficiency ratios by trucking strategy and physiographic region. The cut-and-haul group had higher total efficiencies than the logging-only group. There was no statistically significant difference between physiographic regions within their respective hauling strategy groups.

Table 6.3 compares the medians of partial efficiencies and cost category percentages of total costs for the three physiographic regions within trucking strategies. While the different regions within a trucking strategy achieved median total efficiencies within 5% of each other, the median partial efficiencies differed by as much as 43%. The sample sizes for the piedmont-logging-only and mountain-cut-and-haul are small. There are no major trends to point out; the table is included to document the findings using the medians to show the average tendencies. Both trucking strategies are common in the coastal plain, cut-and-haul appears to be favored in the piedmont and contract trucking in the mountains. Neither the partial efficiencies or the percent of cost distributions provide any immediate insight for these purposes.

The coastal plain and piedmont regions in the cut-and-haul group show similar central tendencies in cost structure. The piedmont observations show slightly more investment in capital. The type of equipment this capital is invested in is unknown, it could be in the form of more hauling trucks or road maintenance equipment. In the logging-only group, the percentage spent in contract hauling drives percentage spent in the other categories and therefore the partial efficiencies. The contract hauling percentages make sense given the median hauling distances listed in figure 5.28.

Table 6.3 Median partial efficiencies and cost trade offs by region by trucking strategy.

Cut-and-Haul

	Coastal Plain	Piedmont	Mountains
Number of observations	24	38	6
Total economic efficiency	0.0897	0.0855	0.0858
Partial efficiencies			
Capital	0.40	0.32	0.54
Consumables	0.30	0.30	0.29
Labor	0.21	0.22	0.15
Percent of total cost			
Capital	22%	26%	15%
Consumables	29%	28%	28%
Labor	42%	41%	52%
Administrative overhead	2%	1%	2%
Insurance	4%	3%	6%

Logging-Only

	Coastal Plain	Piedmont	Mountains
Number of observations	20	5	16
Total economic efficiency	0.0790	0.0764	0.0770
Partial efficiencies			
Capital	0.55	0.98	0.68
Consumables	0.56	0.72	0.70
Labor	0.25	0.24	0.25
Contract hauling	0.32	0.17	0.19
Percent of total cost			
Capital	14%	8%	12%
Consumables	14%	11%	11%
Labor	33%	31%	32%
Contract hauling	29%	47%	43%
Administrative overhead	1%	2%	0%
Insurance	3%	2%	3%

6.4 Cost Component Trade offs and Total Efficiency

LeBel (1996) prepared several analyses by dividing contractor-year observations into three groups based on efficiency performance. The same format was used here, with contractor-years sorted by trucking strategy and then total economic efficiency. The range of total efficiencies observed was broken down into three roughly equal tiers, labeled as A, B and C, for both trucking strategies. The total economic efficiency breaks points were as follows:

Cut-and-haul: A > 0.090 > B > 0.075 > C
Logging-only: A > 0.091 > B > 0.082 > C

The 68 cut-and-haul observations were broken down into groups of 23, 23, and 22 (figure 6.3). The 41 logging-only observations were broken down into groups of 14,14, and 13 (figure 6.4). The cumulative frequency graph at the top of each figure show the ranges of economic efficiency within the tier. The middle graph is a scatter plot of the partial efficiencies for the three major inputs for each efficiency tier. The bottom graph is a scatter plot of the percentage of total cost spent in each of the three cost categories for each tier.

The objective is to explore possible tendencies in cost category allocation and partial efficiency at different levels of total economic efficiency. The partial efficiencies for each cost category show a general tendency to move toward the low end as the total efficiency decreases. Individual observations of very high partial efficiency, especially in capital, can be observed in the A, B, and C levels. These partial efficiency observations are tied to those outliers in the bottom graph of very low cost category spending.

The spread of the data points in the bottom graph of figure 6.3 and figure 6.4 show the wide range of the cost allocation decisions. There are no strong consistent differences between the A, B, and C levels. All had a fairly wide range, usually spending the most on labor, then consumables, closely followed by capital.

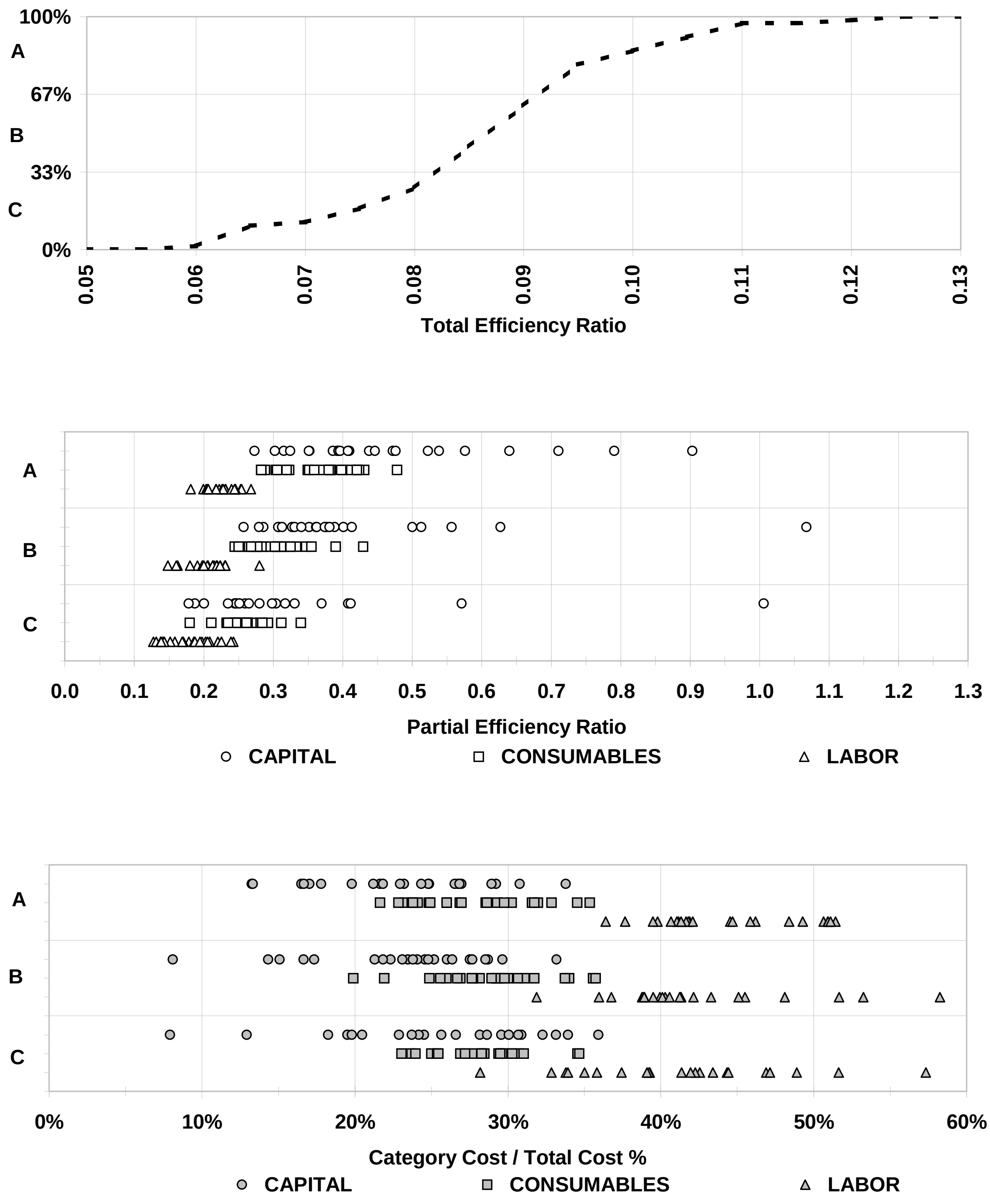

Figure 6.3 Distributions of Partial Efficiencies and Cost Category spending percentages by three tiers of efficiency in the cut-and-haul contractors.

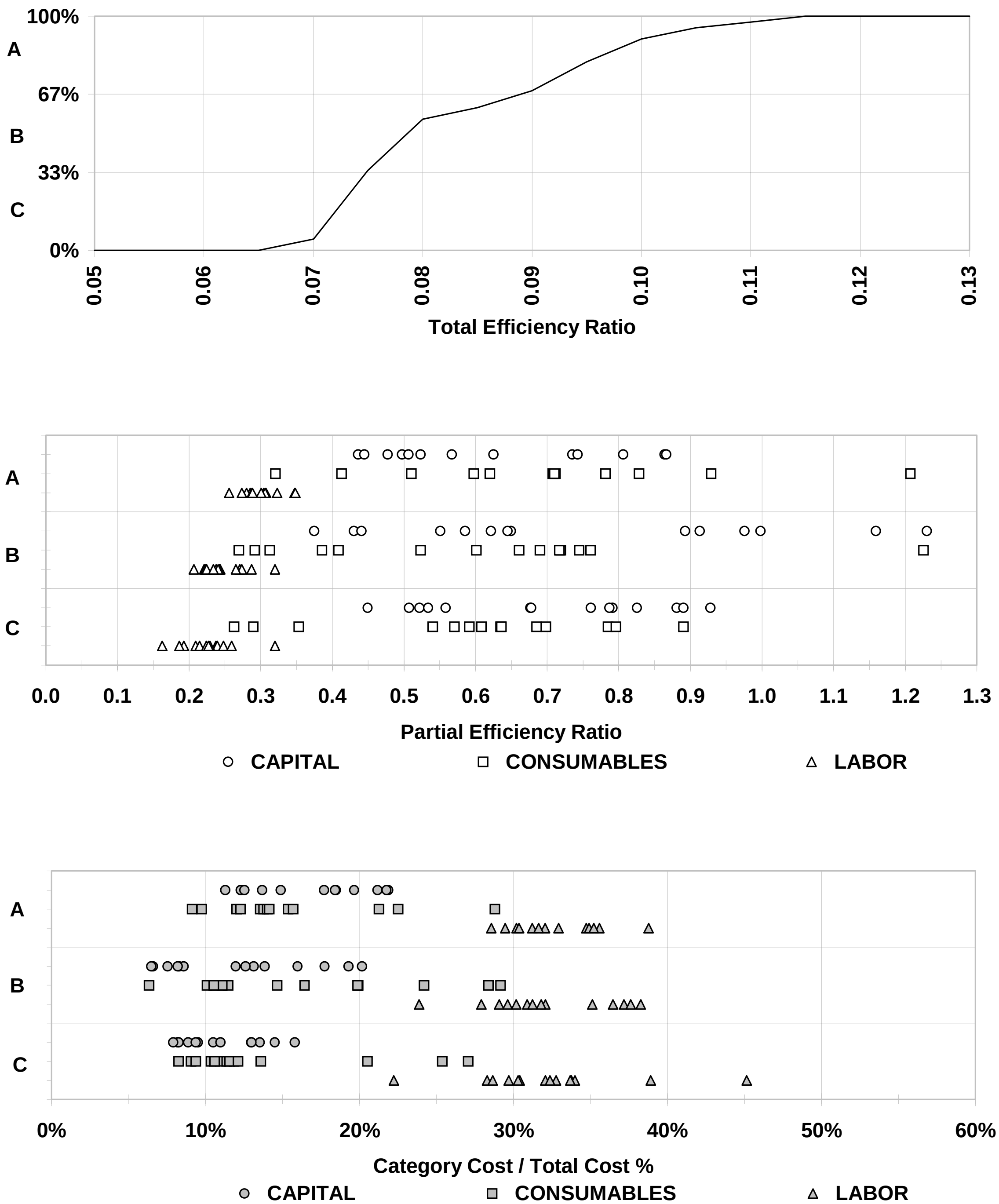

Figure 6.4 Distributions of Partial Efficiencies and Cost Category spending percentages by three tiers of efficiency in the logging-only contractors.

Table 6.4 shows the medians for the cost category percentages and the partial efficiencies. In the cut-and-haul group, the similarity of the medians of cost category percentages indicate that, there is no single optimum cost allocation strategy about which the tier A observations converge. The median partial efficiencies in each category show improvement going from tier C to tier A. This partial and total efficiency improvement must be coming from increased production per dollar and not cost allocation strategies. The efficient operators tailor their expenditures to their location and the wood supply niche they serve.

Table 6.4 Input efficiency at three levels of efficiency by trucking strategy.

Cut-and-haul

Medians of Partial Efficiencies

Tier	Capital	Consumables	Labor
A	0.410	0.379	0.228
B	0.362	0.302	0.213
C	0.262	0.251	0.182

Medians of Cost Category Spending Percentages

Tier	Capital	Consumables	Labor	Big 3%
A	23%	27%	42%	92%
B	24%	29%	41%	94%
C	26%	28%	42%	96%

Logging-only

Medians of Partial Efficiencies

Tier	Capital	Consumables	Labor
A	0.567	0.708	0.300
B	0.647	0.631	0.241
C	0.719	0.622	0.228

Medians of Cost Category Spending Percentages

Tier	Capital	Consumables	Labor	Big 3%	Contract Hauling
A	18%	14%	32%	64%	30%
B	12%	13%	32%	57%	36%
C	10%	11%	32%	54%	44%

In the logging-only group, the trend of decreasing spending in the big three from A to C coincides with the increasing spending in contract hauling. While the bottom graph of figure 6.4 shows the range of labor percentage spending widening from A to C, the median spending remains the same. Consumables and capital percentage spending decrease with the increased contract hauling, but labor remains fixed. Capital seems to decrease more than consumables.

The relationship between the percentage of cost allocated in one category was compared with the spending in each of the other two main categories per contractor-year for each of the 68 cut-and-haul observations. The scatter plots in figure 6.5 illustrate trade-offs in cost allocation by efficiency tier. There is no obvious grouping by efficiency tier, which supports the hypothesis of no optimum cost allocation strategy.

The most noteworthy cost allocation trade-off, in the composite, is between labor and capital (the middle graph in figure 6.5). Increasing the percentage of total cost in labor tends to decrease the percentage spent in capital and vice versa. This relationship has to be interpreted conservatively, since an increase in one cost center must be affected by a decrease in another. A trend line fit to all 68 observations together has a R^2 of 0.70, suggesting a fairly strong relationship. Labor costs are subject to two pressures, the competitive wage rates in the local area and increased costs of mandatory withholding, workers compensation and other benefits. Consumable supplies are required to operate, so an increase in labor costs can only be offset by a decrease in capital.

This also indicates a strategy of substituting machine power for man-power. The most common example of this is the addition of a pull through delimber to eliminate one or two sawhands. Often a more powerful loader is required with the delimber, significantly increasing capital costs. Loggers sometimes will pay experienced operators premium wages. This may make less money available for capital investment, however several loggers commented a skilled operator kept the machine in better repair so that it was possible to run a machine a few more years to control capital costs if necessary.

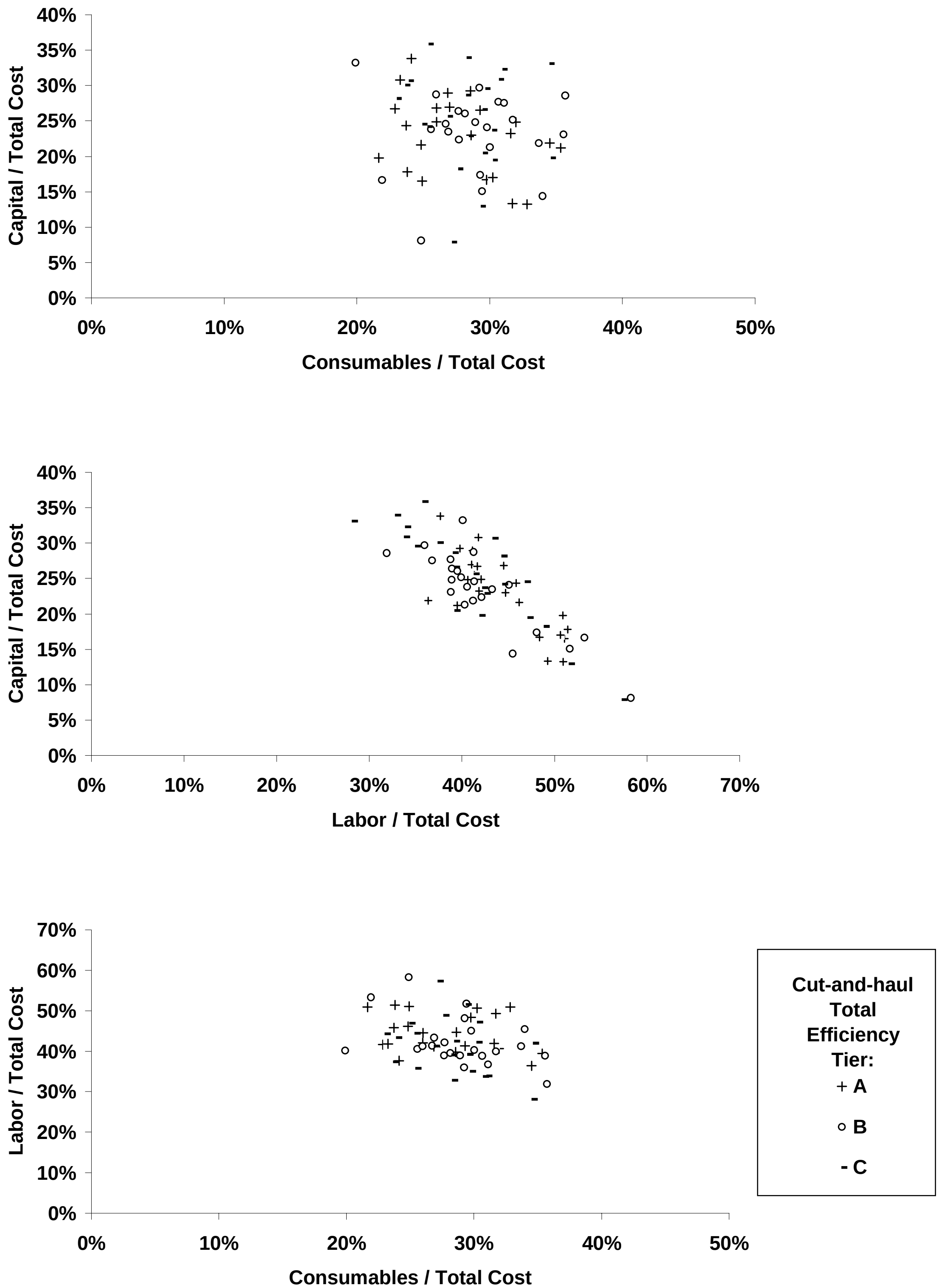

Figure 6.5 Scatter diagrams of cost allocation relationships by total efficiency level.

The substitution of increased repair and maintenance (consumable) costs while capital investment is delayed is usually quite evident on an individual contractor basis. However, in the composite, the relationship appears weak. One reason might be that increased capital spending sometimes drives up consumable spending. The delimber example is relevant again here. The fuel consumption in delimbing is likely to increase with loader delimbing compared to chainsaws.

6.5 Defining the Room of Partial Efficiencies

Trends in partial efficiencies by the three performance tiers can be further explored in terms of interactions or "trade-offs". Scatter plots were used to explore trade-offs in two dimensions for the cut-and-haul group (figure 6.6). These measure partial efficiencies whereas those in figure 6.5, dealt with cost allocation. Each observation in its respective tier is represented with a symbol, and then the ellipses enclose observations within performance tiers. The trend in the ellipses is up and to the right from tier C tier to tier B to tier A, indicating more effective use of inputs. The intersections of the ellipses show that while there is a trend, it is not strong enough to fully separate the tiers.

Figure 6.5 had shown a fairly strong inverse relationship between labor and capital spending. It would be expected that the increased mechanization through capitalization would improve labor output measured in tons per man hour. However, in terms of labor partial efficiency, the trade off does not appear to be strong. Even in these highly mechanized and capitalized firms it appears that the lowest capital partial efficiencies were higher than the most efficient labor partial efficiency. Labor has a high burden of overhead costs, in addition to the direct cost, such as workers compensation insurance and fringe benefits, which make it more difficult to control. More expensive, more technical machines may reduce the number of employees but require more highly skilled thus higher paid workers. This dilutes the labor partial efficiency gains.

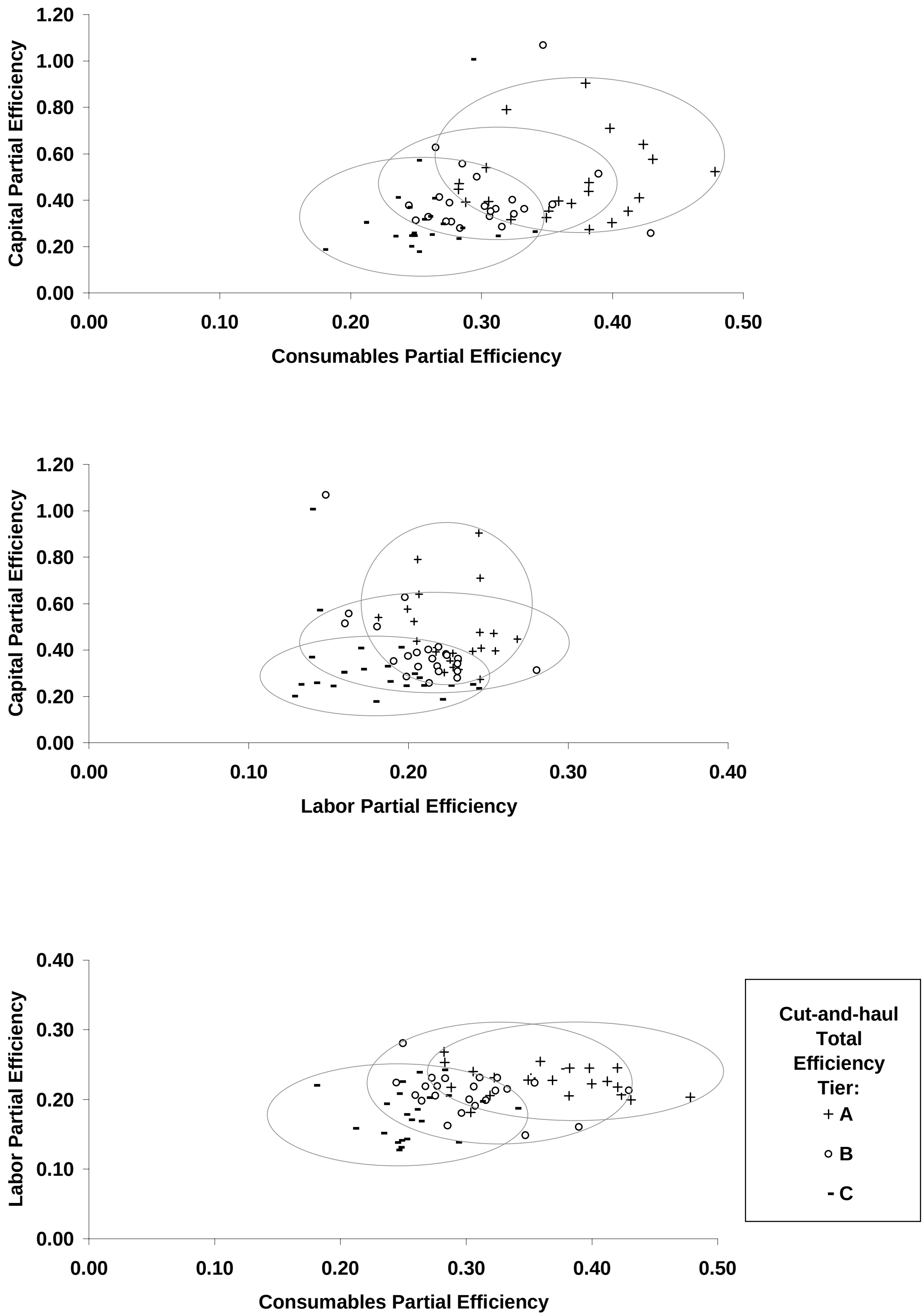

Figure 6.6 Scatter diagrams of partial efficiency relationships by total efficiency level.

The limits of partial efficiencies were explored by selecting six contractor-years of observations. Three representing the minimum partial efficiency in each cost category: MIN CAP, MIN CON, MIN LAB, and three reflecting the maximum partial efficiencies: MAX CAP, MAX CON, MAX LAB. The vector diagram (figure 6.7) illustrates the trade-offs for each of the selected observations. The sample showing the highest capital efficiency (MAX CAP) also had the second highest consumables efficiency, but the next to lowest labor efficiency. In general, maximizing the efficiency of one input usually results in minimum efficiency in another, as in the case of MAX CAP or moderate efficiencies as shown in the other two as shown in MAX LAB. Minimal efficiencies in one category are usually accompanied by only moderate efficiencies in the others. No logger was observed to have the lowest observed partial efficiency in any of the two categories in the same year, although MIN LAB and MIN CON came close. Also no logger was observed to have the highest partial efficiency in more than one category. For this case it was not as close.

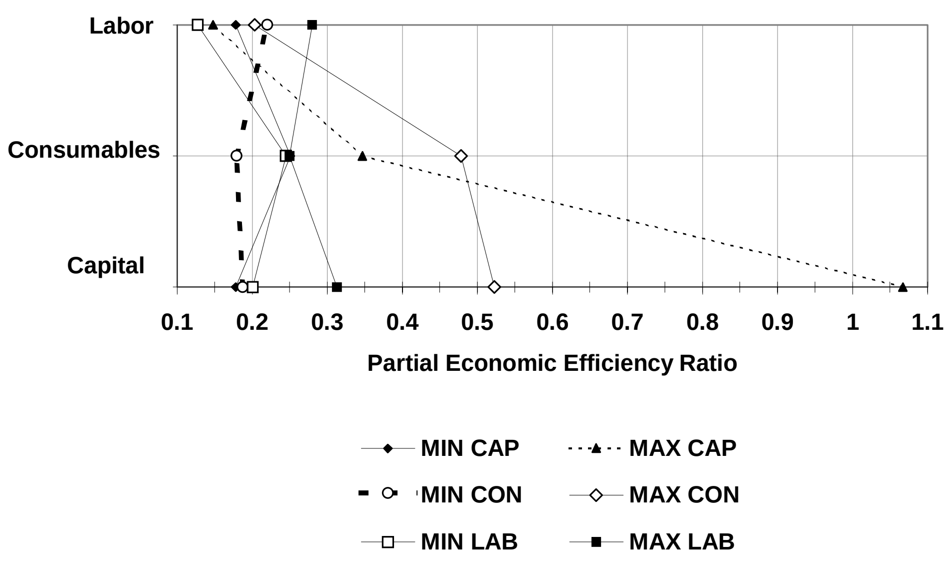

Figure 6.7 Vector diagram of partial efficiencies of six cut-and-haul contractors.

The location, size and total economic efficiencies for each of the selected operations are shown in table 6.5. The minimum group is drawn completely from the piedmont, while the maximum group is split between the mountains and coastal plain. Total economic efficiency trends increase across samples but no obvious trends are apparent.

Labor partial efficiency plays a key part in total efficiency. This is due to the fact that labor comprises the highest percentage of total cost. The logger MAX CAP not only had an impressive capital efficiency, he also had a very good consumable partial efficiency. However, his labor efficiency was in the lower quartile. The end result was a total efficiency (.0863) that was average (median .0865) for the cut-and-haul group. The logger MAX CON also managed to keep capital efficiency very good. Unlike MAX CAP, he was able to keep labor efficiency high and had the highest total efficiency rating of the six contractors. The logger MIN LAB was not able to boost efficiency in the other categories above the median. Consequently he had the lowest total efficiency observed for the 68 cut and haul observations.

Table 6.5 Ranking of six cut-and-haul contractors by total efficiency.

Physiographic Region	Approx. Annual Production	Logger	Total Efficiency
Piedmont	30,000	MIN LAB	0.0565
Piedmont	50,000	MIN CON	0.0620
Piedmont	50,000	MIN CAP	0.0639
Mountains	50,000	MAX CAP	0.0863
Mountains	30,000	MAX LAB	0.0893
Coastal Plain	70,000	MAX CON	0.1035

Table 6.6 shows a similar list of 6 contractors from the logging-only group. It is interesting that the ranking by total efficiency puts these contractors in exactly the same order as the cut and haul contractors.

Table 6.6 Ranking of six logging-only contractors by total efficiency.

Physiographic Region	Approx. Annual Production	Logger	Total Efficiency
Coastal Plain	70,000	MIN LAB	0.0710
Mountains	55,000	MIN CON	0.0734
Coastal Plain	70,000	MIN CAP	0.0755
Mountains	25,000	MAX CAP	0.0777
Piedmont	200,000	MAX LAB	0.0795
Coastal Plain	80,000	MAX CON	0.1101

A three-dimensional response surface model was developed to help illustrate the inter-relationships of the three major cost inputs for the cut-and-haul group. It simply illustrates the concept of trade-offs and helps define the range of feasible alternatives. Figure 6.8 is based on the averages and ranges observed in the study. The primary inputs are total efficiency, the percentage of total costs in the big three categories and the partial efficiency ranges. The model is restricted to the range of total economic efficiencies observed in this study (0.0565 to 0.1203) and to the range of percentage of spending in the big three (88% to 99%).

The axes of the chart, defining the room of partial efficiencies, are the ranges observed for the three major inputs as noted in the cumulative frequency distributions for the cut-and-haul group in figure 6.1. The ranges are not equal, thus the room is not a perfect cube. Capital, the height, is the largest dimension at 0.889 (the difference between the maximum observation of 1.067 and the minimum of 0.178). Consumables, the length, is the next longest dimension at 0.299 (0.478 - 0.179). Labor, the width, is the narrowest dimension is at 0.153 (.280-.128). The origin of the graph, where the three axes are minimized, is located in the rear of the chart, at the bottom to the left.

The axes are graduated by a seemingly random increment. One self-imposed requirement for the three-dimensional room was that it express only the observed ranges, which begin and end at irregular numbers, such as 0.128 instead of 0.10. From there is was simply a limitation of the software that only the increments used to create a smooth three-dimensional surface could be displayed on the axes instead of more conventional breakpoints such as 0.15, 0.25, 0.25, etc.

The plow shaped surface in figure 6.8 represents the possible partial efficiency trade-offs for a contractor achieving the median total economic efficiency for the cut-and-haul group of 0.087 tons per dollar with 95% (median) of total costs in the capital, consumables and labor categories.

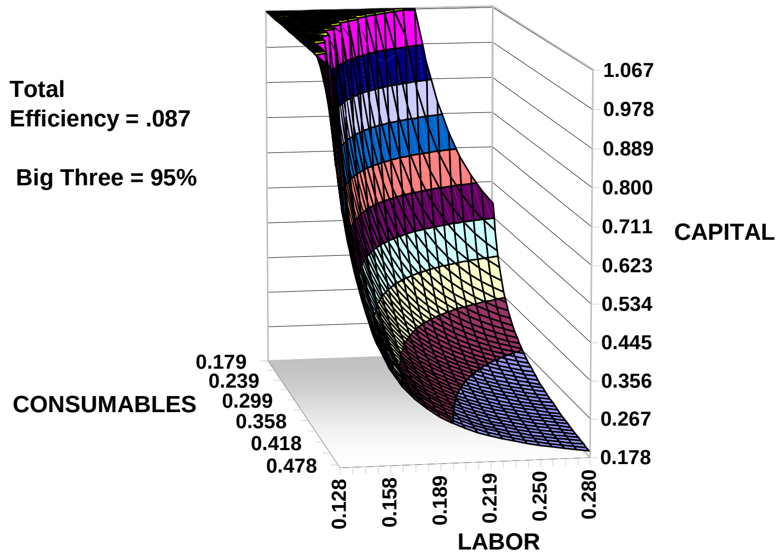

Figure 6.8 Room of partial efficiencies for average total efficiency.

The flat shelf at the top of the surface or “ceiling” represents an infeasible zone of capital efficiencies, higher than any observed in this study. In essence, one corner of the room has been truncated. This corner is located where low labor partial efficiencies and low consumable efficiencies intersect, creating a zone of “off-the-chart” high capital partial efficiencies.

Figure 6.9 shows the surface of a logging operation at a higher efficiency level such as might be observed in tier A of an earlier analysis. The surface moves away from the origin because higher total efficiency coincides with higher partial efficiencies. As the surface moves away from the origin, the ceiling becomes larger.

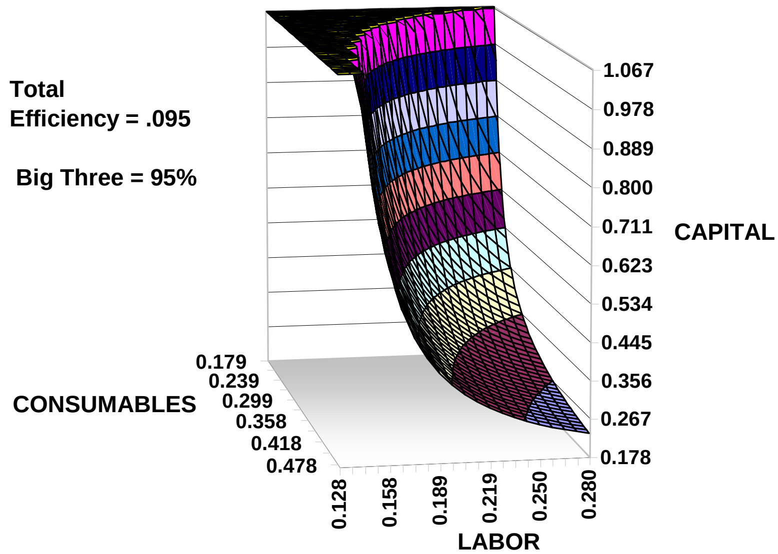

Figure 6.9 Room of partial efficiencies for above average total efficiency.

If the total economic efficiency of a logger was in the bottom tier (tier C) of the cut-and-haul group, the surface would resemble that in figure 6.10. The flat shelf at the bottom or "floor" of the graph represents an area of extremely low capital efficiency, lower than any observed in this study. This floor occurs at the intersection of high consumable efficiency and high labor efficiency. The floor truncates the room in a similar fashion as the ceiling. As the total efficiency ratio is decreased, the surface will move down, increasing the size of the floor. This could be interpreted as the higher ranges of partial efficiencies in consumables and labor are not "available" to the logger performing at low efficiency. In order to achieve high levels of consumable and labor partial efficiency, he would have to have a capital partial efficiency less than any observed in this study. The ceiling is still present but quite small at the junction of extremely low consumable efficiencies and extremely low labor efficiencies.   A contractor-year was selected as an example for this surface with a total efficiency ratio of 0.0729 and big three spending of 94.3%. A capital partial efficiency of 0.247, consumables partial efficiency of 0.245 and labor partial efficiency of .208 put this observation on the lower part of the surface slope, near the floor.

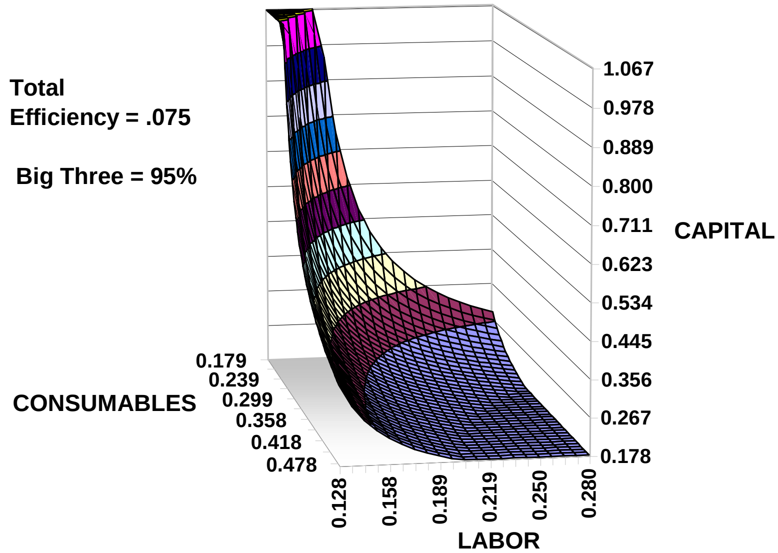

Figure 6.10 Room of partial efficiencies for below average total efficiency.

The focus of this analysis has been to illustrate that efficiencies of the three major inputs are limited and pushing one or the other to the extreme will likely result in less efficient use of the others and lower overall efficiency. No graphs illustrating surface changes as the percentage spent in the big three increases or decreases are included in the interest of brevity. However, it is a simple inverse relationship. As the percentage of costs spent on the big three decreases, the surface moves away from the origin and vice versa. The reasoning for this effect is straightforward. If the logger's total costs and total production stay the same, his total efficiency stays the same. If he spends less in labor, consumables and capital then his partial efficiencies in those inputs must improve. Hence the surface moves "up".

The contractor-year MAX CAP from the previous analysis defined the upper limit of capital efficiency for the cut-and-haul group. Total efficiency for the observation was 0.0863 tons per dollar - close to that in figure 6.8. Adjusting for a decrease in spending in the big three of 91%, would move the surface down, toward the origin. His consumables partial efficiency was 0.347 and labor was .148, putting his capital efficiency on the "rim" of the surface next to the ceiling.

6.6 Case Study

Figure 6.11 is a graph of the percentage change in both production and efficiency of a stable contractor. Figure 6.12 shows year to year changes in partial efficiencies that contribute to total economic efficiency in figure 6.11. The contractor's total efficiency gains follow production gains except in 1993. During 1993 the contractor's labor payments rose from 27% to 32% of total costs. The partial efficiency chart shows the corresponding decrease in labor partial efficiency.

There are several reasons why labor costs increased. The contractor's pine percentage of the total production fell from 57% in 1992 to 51% in 1993. The contractor achieved high production by paying his labor to work more hours. The highest levels of weekly production variation occurred 1993 as indicated in the NP-CVs under the graph in figure 6.13. Looking within the interquartile range, the downward variation is 2% greater than the upward variation. This indicates a downward mode of elasticity, which is against the contractor's business strategy. This contractor produces 100,000 tons in the average year and is relatively inelastic. One of his basic philosophies of managing his business is that achieving targeted production levels usually assured revenues would exceed costs. *If you get the loads, everything else comes along with it.* During down weeks the contractor paid workers to perform repairs on aging equipment in addition to their usual operator roles.

The increases in capital efficiency after 1991 offset the declines in consumables. This type of inter-change is observed frequently between these two categories. As depreciation schedules run out, capital costs decline, resulting in higher capital partial efficiencies if replacements are not purchased. Concurrently the cost of maintenance and repairs on aging equipment increases, causing the consumables expense to increase. The result is decreasing consumables efficiency. Total efficiency may decrease, stay the same or increase with this strategy depending on the state of the equipment and the level of production.

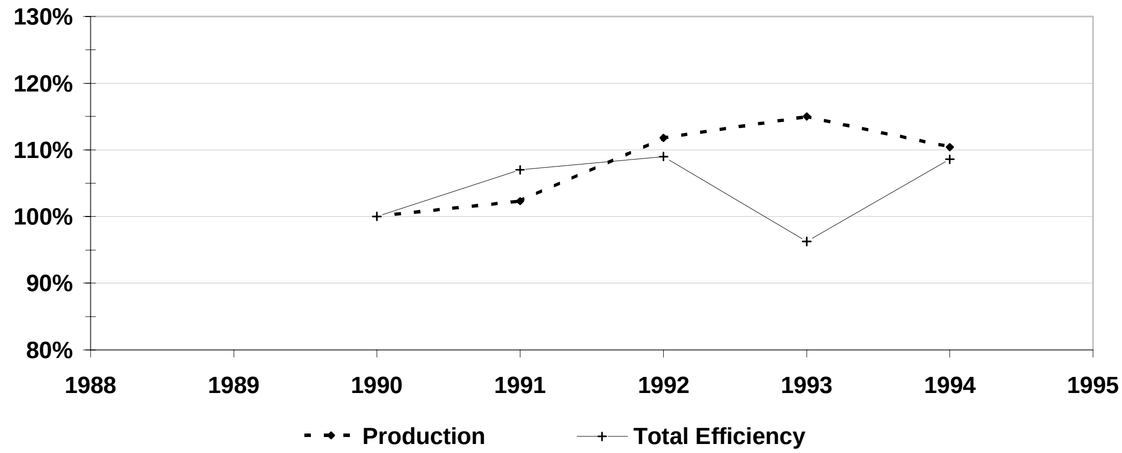

Figure 6.11 Relative production-efficiency graph of stable contractor S6.

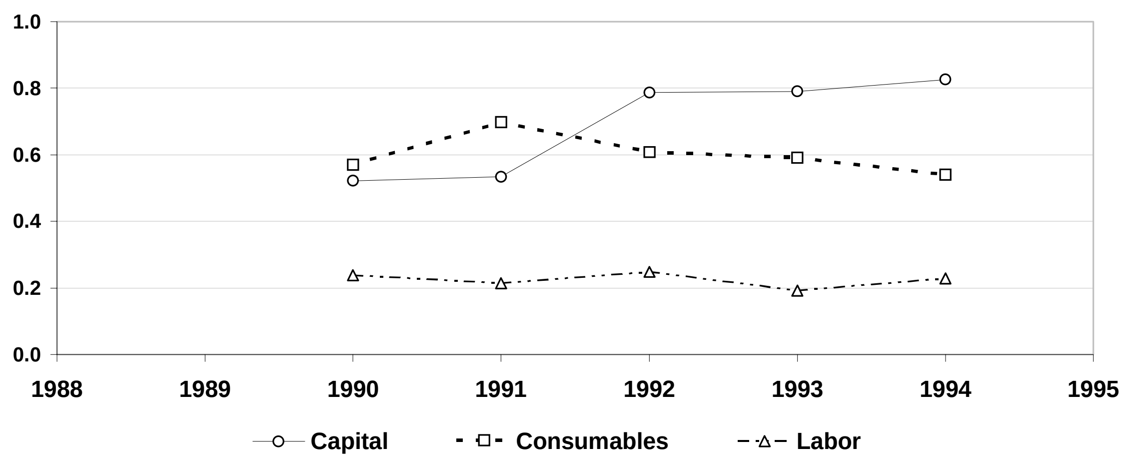

Figure 6.12 Annual partial efficiencies of stable contractor S6.

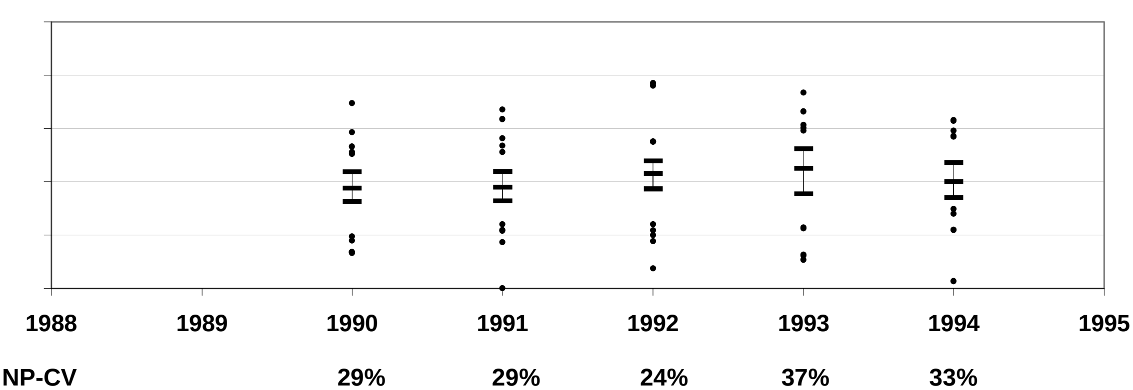

Figure 6.13 Modified box and whisker plot of contractor S6.

6.7 Summary

Loggers combine the inputs of capital, labor and consumables at different rates to achieve production and profits. Cost allocation decisions are a key part of logging business management. This chapter used partial efficiencies to measure the returns for dollars spent on the three major inputs and contract hauling. Partial efficiencies ratios have an inverse relationship to the percentage spent in a cost category.

For the cut-and haul contractors, labor partial efficiencies are the lowest and have the narrowest range, implying contractors have the least flexibility in managing labor costs. There seems to be a definite upper limit on labor partial efficiency. While, it appears loggers trade-off capital and labor spending, increased capitalization reflected by low capital partial efficiency did not appear to consistently raise labor partial efficiency. Whether this is the result of fewer operators being paid more or the productivity limits of the current technology is speculative. It simply appears from the data that loggers seem to bump up a against a common barrier in labor efficiency and labor partial efficiency has a substantial impact on total efficiency because labor is usually the largest cost category.

Cut-and-haul contractors seem to have a narrow range of efficiency for consumable supplies, although not as constraining as labor. Both cut-and-haul and logging-only contractors have the widest range for capital efficiency, reflecting the most flexibility in spending decisions.

For the logging-only group the percentage spent in contract hauling influenced the level of spending in the other three major inputs. There were basically two levels of spending in contract hauling. One group on longer hauls, spent 40-50% of total cost on contract hauling, the other group on shorter hauls spent 22-33% on contract hauling. Labor appears to have a limited range of partial efficiency in the woods only operations as well. Capital and consumables occupy similarly wide ranges indicating more substitution opportunities. Logging-only operations may have more flexibility on capital spending than cut-and-haul contractors perhaps because they do not have to replace over-the-road trucks which have to comply with more regulations and inspections than in-woods equipment.

Higher levels of total economic efficiency are associated with higher partial efficiencies for cut-and-haul contractors in all three inputs. In other words, total efficiency is not the result of improving performance in one or two categories only. Furthermore, the top third of total economic efficiency observations did not appear to have different cost allocations from the middle and bottom thirds. This implies efficiency results from higher production per dollar spent, not allocating inputs in any one certain way.

A three dimensional model called the "room of partial efficiencies" was presented to show the ranges of partial efficiencies available for a given total economic efficiency and percentage spending in the big three.

A case study graphed the trends in annual partial efficiency against the relative production-efficiency graph for a stable contractor. First, it showed the powerful negative impact that a dip in labor partial efficiency had on total economic efficiency. Secondly, it showed how capital efficiency improves as equipment becomes depreciated but consumables partial efficiency declines as repairs and maintenance costs accumulate.