AN ABSTRACT OF THE THESIS OF

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Title: THE EFFICIENCY OF RESOURCE USE IN THE LOGGING INDUSTRY

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The logging industry is defined as being comprised of firms which combine capital and labor resources in a production process for converting stumpage into industrial roundwood. The industry occupies an important position in a series of inter-connected markets and manufacturing processes which links stumpage producers with wood product manufacturers and final consumers of wood and wood fiber products. Consequently, a knowledge of the efficiency of resource use in the logging industry is important to those who are concerned with the economic performance of this industry and the forest-based sector of the economy.

The objectives of the study were to: (1) evaluate the efficiency of the capital and labor resources used in the national logging industry and its two major sectors, the southern pine and Douglas fir sectors and, (2) to complete an inter-regional comparison of the

resource efficiencies evaluated under the first objective.

The analytical framework for evaluating resource efficiency in the logging industry was derived from the theory of aggregate production economics. The theory suggested the single-equation Cobb-Douglas function was an appropriate model for describing the aggregate relationships between capital and labor resources used in production and the roundwood output produced by the industry. This model and U. S. Bureau of the Census cross-section data for Logging Camps and Contractors, SIC 2411, for the 1963 Census year were used to empirically estimate aggregate production functions for the industry and its two major sectors. The structural parameters of the estimated industrial production functions provided the bases for deriving three indicators of resource efficiency. These three indicators were: (1) the elasticity of production for each resource input, (2) the marginal productivity of each resource input, and (3) the condition of returns to scale prevailing in the production process.

The empirical results of the analyses undertaken to achieve the first objective of the study were not entirely satisfactory. As a consequence, new sets of input variates were defined and used to estimate additional production functions. Five production functions were estimated for the industry and for each of the two sectors. While some improvement in results was obtained through the additional estimates, the overall results precluded achieving the first objective for the southern pine and Douglas fir sectors. As a consequence, the second objective of the study was not achieved.

The empirical results obtained for the national industry provided divergent indicators of resource efficiency. This divergency was dependent on the specification of the capital input variate considered in the industrial production functions. In the case where the production function contained the capital variate defined in terms of gross book value of depreciable assets or a stock concept, the empirical evidence indicated the industry used resources efficiently. Constant returns to scale were estimated and the estimated marginal productivities of capital and labor resources closely approximated marginal costs for these resources. However, in the case where the production function contained the capital variate defined in terms of new capital expenditures or a flow concept, the empirical evidence indicated the industry did not use resources efficiently. Increasing returns to scale were estimated. Additionally, as the estimated marginal productivity of capital exceeded the estimated marginal cost of capital, it was concluded the industry was under-capitalized. Conversely, as the estimated marginal productivity of labor was less than the estimated marginal cost of labor it was concluded the industry employed excessive amounts of labor.

The question of resource productivity in the logging industry was not resolved. However, the results of the study indicated the role of capital in the industry must be investigated more fully before further progress can be expected.

The Efficiency of Resource Use
in the Logging Industry

by

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THE EFFICIENCY OF RESOURCE USE IN THE LOGGING INDUSTRY

I. INTRODUCTION

Logging is a production process which uses capital and labor to convert stumpage or standing timber into industrial roundwood. This process is undertaken by many individual organizations which in the aggregate constitute the logging industry. Being the sole producer of industrial roundwood, the logging industry occupies an important position in a series of inter-connected markets and manufacturing processes which links stumpage producers with wood product manufacturers and final consumers of wood and wood fiber products. Consequently, the efficiency of aggregate resource use in the logging industry concerns not only those interested specifically in this industry but also those interested in stumpage production, wood products manufacturing, and society's wood and wood fiber requirements.

The lumber, veneer and plywood, and wood pulp industries are the major consumers of roundwood and perform the initial breakdown or conversion of roundwood into manufactured wood products. These conversion industries have recently experienced a period of expansion and together with the logging industry contribute significantly to the national economy (Hair, 1963). The potential for future physical expansion in wood products manufacturing appears favorable. This outlook is based in part on the large forest resource base available for use and the expected increases in consumption of manufactured wood products (U. S. F. S., 1965). However, realization of future growth potentials depends on favorable economic conditions. Wood products must be produced efficiently; firstly, to assure maintenance of market shares with competing non-wood commodities and secondly, to provide acceptable earnings which encourage continued investments in new production technology.

Wood product conversion industries depend on the logging industry to provide an adequate and stable flow of low cost roundwood. Some recent evidence suggests the logging industry may not be performing this task satisfactorily. There may be inefficiencies in the logging industry which are unfavorable for continued economic growth. The evidence indicates a cost-revenue squeeze is occuring in wood products manufacturing. The rapidly increasing cost of industrial roundwood, the logging industry's output, is a significant factor contributing to the cost-revenue squeeze experienced by the conversion industries (Hair and Ulrich, 1969). Additional evidence on the stability of the log production process indicates the volume of roundwood output fluctuates considerably around the level of roundwood consumption (Post, 1966). This situation forces the conversion industries to plan consumption from widely fluctuating roundwood inventories. Irrespectively of what level of inventory is considered desirable, the conversion industries face recurring wood shortages or excessive inventory charges because roundwood deliveries are neither stable nor consistently adequate.

Stumpage producers, whether they are public agencies or private tree farmers, grow the standing timber which becomes an input for the logging industry. These producers expect the logging industry to convert stumpage into roundwood in an efficient manner. Any inefficiencies in the roundwood production process which are passed back to stumpage producers in the form of lower stumpage prices discourage forest management investments and ultimately reduce the volume of stumpage available for use.

The adequacy of the stumpage production process on federally administered lands has been questioned recently by national policy makers. The federal Housing and Development Act of 1968 established as a national goal the construction of 2.6 million new housing units each year during the following decade. Subsequently in 1968 and 1969, wood products building materials which constitute a major cost component in house construction were subject to dramatic price increases. These price increases, allegedly due to a stumpage shortage, suggested that the housing goal may be economically unattainable. In reaction to this situation, the United States Congress proposed legislation under the National Forest Conservation and Management Act of 1969 which would have dedicated 65 percent of the revenues generated by stumpage sales from within the national forest system for reinvestment in timber management practices on these lands. The intent of the Act was to increase timber yields on the national forests through intensive management programs and thereby prevent excessive wood product price increases in the future. However, by convention, the appraised value of stumpage is established as the residual amount remaining after all logging costs have been subtracted from the price for logs. Therefore, as logging efficiency is reflected in logging costs, and as logging costs affect stumpage prices or gross returns to stumpage production and consequently the amount which can be justified for investment in timber management practices, the success of the National Forest Conservation and Management Act program would depend in part on this logging efficiency.

Stumpage production and wood products manufacturing are common throughout the nation. However, these activities constitute particularly important sectors of the economies of two regions in the country, the South Atlantic and Gulf states, hereafter referred to as the southern pine region, and the western portions of Oregon and Washington, hereafter referred to as the Douglas fir region. Not only do timber based activities constitute an important segment of all economic activity in these two regions, but also, most of the nation's timber based activities are located here. As the predominant species utilized in both of these regions are softwoods, the characteristics of many of the manufactured wood products are similar.

Consequently, as there is competition in many of the large national markets between products from each region, the relative efficiency of regional production is a matter of considerable interest.

Concern for efficiency of resource use in logging develops from a fundamental problem confronting our society. That is, we express an unlimited desire for goods and services in an environment of scarcity or limited means of production (Weiss, 1961). To ensure that waste of our limited means of production is minimized, production processes must be organized to permit the optimal contribution of resources to comprehensive social goals. The task of organizing a production process in this manner requires (1) an understanding of what are the desirable social goals, (2) the identification of the major policy issues confronting decision-makers responsible for achieving an optimal production organization, (3) a knowledge of the prevailing resource relationships in the production process, especially those relationships which detract from an optimal contribution to the stated social goals and finally, (4) the identification of appropriate decision criteria for determining optimal resource allocation in production. These requirements deserve articulation within the context of the logging industry because they constitute the framework for this study.

The comprehensive social goals to which the industrial roundwood production process ought to contribute can be presented within a normative context. That is, it is socially desirable to produce the nation's long-term wood and wood fiber requirements at least-cost. The achievement of a least-cost production process ought to be subject to a constraint. That is, it is socially desirable to compensate resource services consumed in production on the basis of an equitable division of product output (Heady, 1964, p. 589).

The major policy issues confronting decision-makers responsible for the performance of the logging industry have been alluded to in the opening discussion of this introduction. Generally, these issues are concerned with the organization of the roundwood production process and the influence of this organization on the resources used in production and on the output produced. More specifically, the policy issues of major concern are how to best organize the roundwood production process: (1) to ensure the least-cost supply of an adequate and stable flow of industrial roundwood to the nation's wood conversion industries, (2) to employ and compensate both capital and labor resources in a manner consistent with their contribution to production, and (3) to ensure the costs of roundwood production are such that returns to stumpage producers are conducive to continuous stumpage production. One appropriate method for developing the necessary information base to support policy decisions on these issues is through application of the theory of production economics to the logging industry.

The theory of production economics is a body of knowledge which is particularly useful both for evaluating resource relationships in the production process and establishing decision criteria for ascertaining optimal resource use in production. The theory lays the foundation for analysis of costs, resource pricing and employment, resource allocation, and product distribution (Leftwich, 1966, p. 109), through the concept of the production function. The production function specifies explicitly the quantitative relationship existing between total output produced and resources consumed in production. Indicators of how effectively resources are used are derived from the production function. The major indicators which refer to individual input resources are the elasticity of production or output and the marginal productivity while the indicator referring to all input resources used together is the condition of returns to scale in the production process.

While production theory is most commonly associated with analyses and decision making at the firm level, there is, as Heady (1964, p. v) has stated, "nothing unique about application of production or efficiency principles to producing units of any size . . ." Production theory can be applied to an industry or higher level of producing unit using the concept of the aggregate or manufacturing production function (Hildebrand and Liu, 1965). At these levels the problem becomes one of ascertaining how effectively resources are allocated within countries or regions of countries and within industries or sectors of industries. The decision-maker in the macro or aggregate applications of production theory can assume a wide range of guises; an industry, a region, a sector, a legislative assembly, a public administrator, or any entity concerned with public policy (Headley, *et al.*, 1966).

Applying production theory to problems of aggregate resource allocation in the forest product industries is a legitimate activity for the forest economist. However, a review of the literature in forest economics reveals studies of this type are not common. This study represents an attempt to apply the theory to the logging industry for the purpose of developing an information base to aid decisions respecting the major policy issues confronting those concerned with the performance of this industry. The logging industry has not been studied on this basis, nor any comparable basis, and subsequently reported in the literature.

Objectives

The major objective of this study is to evaluate the efficiency of the labor and capital resources used in the national logging industry and in this industry's two important sectors, the southern pine region, and the Douglas fir region. The secondary objective of the study is to undertake an inter-regional comparison of the resource efficiencies evaluated under the major objective.

Scope

The efficiency of resource use in the logging industry is evaluated through application of received econometric theory. This theory suggests that the single-equation Cobb-Douglas function is an appropriate model for describing the aggregate relationship between the capital and labor resources used and the roundwood output produced by the logging industry. Estimates of the structural parameters of this model provide the bases for three measures of resource efficiency to be investigated in the study. These three measures of efficiency are:

1. The elasticity of production for each resource input.
2. The marginal productivity of each resource input.
3. The condition of returns to scale in the industry.

Three separate analyses are undertaken, one for each of the national, southern pine, and Douglas fir areas. Within each area the variates relevant to the roundwood production process are defined. Observations on these variates are used to estimate the aggregate production functions which provide the basis for resource efficiency analysis.

More specifically, the study is developed in the following manner. Chapter II presents a brief discussion of the roundwood production process and the socio-economic and ecological characteristics which constrain the technologies that can be used to produce roundwood. There is a section devoted to discussion on what is presently known about the aggregate production process in the logging industry. Much of what is known is developed from U. S. Bureau of the Census data. These data and the method used in acquiring them are discussed. Two sections are then presented which attempt to outline the institutional settings within which the structures of the southern pine and Douglas fir sectors have developed.

Chapter III reviews the theory of aggregate production analyses and, as a result of the literature reviewed, presents a justification for the methodology used in this study. The review opens with a section presenting the conceptual differences between the production function as used in the theory of the firm and in industrial analysis. The second section presents the arguments of those theoreticians who favor multi-equation models as the basis for aggregate production analysis and those who favor single-equation models. Following this, there is a section on the major arguments in favor of and against the use of cross-section and time-series data. The characteristics of the Cobb-Douglas function are then presented. The last section of this chapter presents several theoretical issues to be considered when developing data appropriate for aggregate empirical analysis.

Chapter IV contains the details of the analysis of the national logging industry. Generally, the chapter is developed in four parts.

In the first part an aggregate production function is estimated for the industry. However, as the properties of the function are considered to be less than satisfactory, four additional production functions are estimated. Two of the five functions are eliminated for statistical and economic reasons. The second part of the chapter considers resource productivity. Mean marginal productivity estimates are derived for all resource inputs in each of the three production functions retained for further study. The empirical estimates of productivity are compared with available evidence suggesting marginal resource cost to the industry. The third part of the chapter presents the estimates on the condition of returns to scale prevailing in the industry. Finally, the relative merits of each production function and associated productivity estimates are reviewed.

Chapters V and VI attempt to present analyses for the southern pine and Douglas fir sectors, respectively, which are comparable to the national analyses. However, economic and statistical deficiencies in the regional results prevent completion of the productivity analyses. In each chapter five aggregate production functions are estimated together with five estimates on the condition of returns to scale in the sector.

Chapter VII, the final chapter, presents a summary of the study, the major conclusions of the study, and a brief discussion of the study's shortcomings with recommendations for improvements that could be incorporated into future studies of this type.

II. INDUSTRIAL ROUNDWOOD PRODUCTION

The physical production process undertaken by the logging industry may be described as a specialized transportation or materials handling process. Two stages in this process have been identified. The first stage, referred to as harvesting or the primary transport function (Bjerklund, 1967), encompasses all operations[1] undertaken on the logging site for converting standing timber into roundwood and preparing the roundwood for removal from the site. The second stage, referred to as hauling or the secondary transport function (Lachance, 1967), encompasses all operations[2] necessary to deliver roundwood from the logging site to conversion plants.

Several alternative logging techniques have been developed to accomplish each of the operations in the harvesting and hauling stages. The specific techniques selected by an individual producer represent, in the context of his entire production process, a logging system. Most logging managers strive to implement a least-cost system. As specific logging techniques are best suited to specific logging conditions, similar systems or technologies tend to be used in areas

[1] These operations are commonly referred to as falling, bucking, yarding, decking, and loading.

[2] These operations usually include hauling, intransit transfers, unloading, and sorting.

where the logging conditions encountered are similar.

The Logging Environment

A homogeneous logging environment may be described as an area where a distinct set of ecological and socio-economic characteristics prevails. It is recognized that in reality the characteristics of these two factors are frequently inter-related and that they occur as a continuum bounded by extremes. However, in practice it is useful to consider them as occurring in more or less distinguishable classes. A particular class of characteristics from both factors provides the characteristics of one logging environment. The scope of this thesis does not permit a thorough documentation of the ecological and socio-economic characteristics of the study area. They are discussed briefly to illustrate how they determine the conditions encountered in the logging environment, and more importantly, how they influence the technologies that may be used in the industrial roundwood production process.

The Ecological Characteristics

Three closely associated aspects of the ecology of the forest which establish the physical conditions of a logging area and hence influence logging practices are physiography, climate, and forest cover.

Physiographic provinces describe topography or terrain. Atwood (1940, p. 11) has described seven major provinces throughout the United States. These provinces vary from young, rugged mountains to flat lowlands. Within these major provinces there are variations in the frequency and type of water drainages, swamp and rock outcroppings, and slopes.

Climatic characteristics are usually described separately as precipitation regimes and temperature regimes. Precipitation regimes are delineated according to the amount of annual rainfall and the variation in rainfall over the seasons. Atwood (1940, p. 5) has separated the annual rainfall in the United States into five arbitrarily defined rainfall zones. These range from less than ten inches to over eighty inches. Superimposed on the rainfall zones are seven variations in the seasonality of rainfall. These range from nearly even rainfall every month, or little variation, to relatively heavy rainfall in one specific season. Temperature regimes are defined similarly to precipitation regimes. Firstly, they are differentiated by average annual temperatures, and secondly, by the variation in temperature throughout the seasons. Temperature and precipitation regimes together result in 10 climatic types through the United States (Atwood, 1940, p. 7).

Forest cover describes the composition of forest stands occupying an area (S. A. F., 1954, p. 2). Forest cover types are designated according to the dominant species growing in the stand. The Society of American Foresters differentiates approximately 140 forest cover types throughout the nation. The important characteristics of these types include acreage, age, number of stems per acre, distribution of height and diameter sizes, and quality condition.

The Socio-Economic Characteristics

The major socio-economic characteristics which contribute to the logging environment derive from the prevailing market institutions in which roundwood producers must compete for factor inputs and product outputs.

For example, the distribution of the ownership of forest land among public, large corporate, and small private owners affects stumpage markets and equipment used. Public owners are usually obligated to sell stumpage continuously and in sufficiently large tracts to permit producers with sophisticated logging systems to harvest these tracts. Corporate owners, usually integrated forest product firms, are free to sell tracts of any size. Small owners often offer tracts with such low volumes that only producers with relatively unsophisticated systems can harvest them.

The characteristics of the market for woods labor has an important influence on the logging environment. Historically, logging has been a labor intensive production process which paid low wages and was conducted in what was considered by many persons to be a disagreeable working environment. Growth in the other sectors of the industrial economy has attracted many competent woods workers to more pleasant and higher paying working environments. Consequently, the labor force available for woods work has decreased in quality and quantity. This labor scarcity is increasing labor costs and forcing a substitution of capital for labor in the roundwood production process. The highly mechanized logging systems coming into use require fewer but more highly skilled workers. These equipment operators and maintenance men must be provided competitive wages and working conditions to encourage them to remain in logging employment. As there is considerable regional variation in the characteristics of the markets for labor, there is variation in the rate of mechanization.

The changing characteristics of the markets for woods labor is forcing roundwood producers to enter the credit markets, to finance equipment purchases more frequently and for larger investment funds than they have traditionally needed. These producers must compete for credit with potential borrowers from all sectors of the economy. The ability to compete successfully and borrow the required funds depends on the characteristics of the credit market. Successful borrowers are those who have demonstrated they are relatively more efficient and less likely to sustain financial losses than are their competitors. The need to establish financial stability for the acquisition of credit is forcing improvements to be made in roundwood production technology. As Thompson and Richards (1969, p. 17) have stated,

> The trend toward capital intensive operations is changing the industry's cost structure from one with a low fixed to variable cost-ratio to one with a high fixed to variable cost-ratio. Since most of the cost, interest on investment and depreciation, associated with the new systems is fixed, the cost must be paid even if no logging takes place. To compete successfully with other economic endeavours for large capital investments, logging must demonstrate improved productivity. One method of improving productivity is to spread the high fixed cost over more units of output. Therefore, just as the pulp mill operates its machinery 24 hours per day, seven days per week, logging, to be successful, must operate its equipment on a more continuous basis.

As a consequence, the technology is now being developed to permit logging operations two and three shifts per day.

The characteristics of the markets for roundwood are additional determinants of the logging environment. Roundwood may be traded as pulpwood, sawlogs, peeler logs, or poles and piling depending on its relative value in each market. Rigid specifications have been developed in most regions for wood that is acceptable in each of these markets. These specifications constrain the type of logging system that can be used to produce this wood. For example, roundwood destined for a pole and piling market must be logged with a long-wood or tree-length system. A short-wood system is appropriate where roundwood is going to a pulp-wood market but is not acceptable for wood going to a sawlog market.

In summary, this section has illustrated how ecological and socio-economic factors affect the environment in which logging operations take place. As the specific characteristics of these two factors vary considerably throughout the nation, many more or less well defined logging environments result. Each logging environment is best logged by a particular system. The aggregate of these systems represents the technology of the logging industry. A more complete description of this technology is presented by Erickson (1968), Hevey (1966), and Wackerman, Hagenstein, and Mitchell (1966). It is not the purpose here to expand on the presentations of those authors but to emphasize that logging technology includes many diverse logging systems, and to present the major reasons for this diversity. The importance of this issue will become apparent later in the development of this thesis.

The Logging Industry

Practically no empirical research effort has been devoted to aggregate analyses of economic relationships in the nation's logging industry. It is suggested that a major reason for this situation is the high cost of basic data collection over all the producing units coupled with the low priority that has been placed on a better understanding of this industry as compared with other manufacturing industries. However, a considerable understanding of the logging industry can be developed through use of secondary data collected and published by the U. S. Bureau of the Census. Logging is considered by Census to be a manufacturing industry and is surveyed under the Census of Manufactures as Logging Camps and Contractors, Standard Industrial Classification 2411. The logging industry is defined (U. S. B. C., C.M., 1966, p. 24A-1) as being comprised of

> establishments primarily engaged in cutting timber and producing rough, round, hewn, or riven primary forest or wood raw materials. Independent contractors engaged in estimating or trucking timber but who perform no cutting operations, are classified in non-manufacturing industries. Logging and woods operations conducted in combination with sawmills, pulpmills or other converting establishments, and not separately reported, are classified in their respective industry groups . . .

To properly understand the scope of this definition, one must be cognizant of what Census means by the term establishment. Census describes the establishment as just that part of a producing organization's manufacturing operation which is devoted to producing one commodity at one location. Therefore, the concept of the establishment is not synonymous with either the firm or the plant but is comparable to the single location enterprise.

It is apparent from this definition that Census does not include all roundwood production activities in its survey of Logging Camps and Contractors. For example, roundwood production activities undertaken by integrated firms who are not able to separate data for each enterprise are reported to the industrial classification which is most representative of the firm's major activity. This may not be the logging industry. Additionally, the roundwood transportation activities performed by independent hauling contractors, are reported elsewhere. However, the Census survey of Logging Camps and Contractors, SIC 2411, published in 1966 included all establishments which conformed to the definition of logging establishment and which employed one or more workers. As it turned out, that survey also encompassed those establishments which shipped 90 percent of all industrial roundwood shipments from all industries. Consequently, the data developed from the survey are not only the best data available but also are considered to describe adequately the logging industry of the real world.

General Statistics

The basic data on the industrial roundwood production process collected from each establishment and published by Census on a geographic basis are referred to as the general statistics. A full description of each general statistic is presented in Logging Camps, Sawmills, and Planing Mills (U. S. B. C., C. M., 1966). A brief description of the more important of these statistics is presented here.

1. Number of Establishments includes all establishments, as described above, operating in the industry and covered by the survey. The number of establishments with 20 or more employees is also presented.

2. All Employees includes all full-time and part-time employees recorded on the establishment's payroll, excluding those absent for military or pension reasons. Corporate officers are included but proprietors and partners are not included.

3. Total Payroll shows the gross annual earnings of all employees described above. It includes salaries, wages, commissions, bonuses, dismissal pay, vacation and sick leave pay, and any compensation in kind.

4. Production Workers includes all workers up through the working foreman level who are closely associated with the establishment's production operations. Supervisory workers are excluded.

5. Man-Hours presents the total number of man-hours worked by production workers on both straight-time and over-time bases.

6. Wages reports the total wage bill for the man-hours worked reported above.

7. Cost of Materials shows the costs for materials, supplies, semi-finished goods, fuels, and electrical energy actually consumed

in the production process.

8. New Capital Expenditures presents the amount in dollars spent for permanent additions and major alterations to plants, and for new equipment and machinery classified as fixed assets for which depreciation accounts are maintained.

9. Value of Shipments presents the total value of product, net of discount allowances, shipped by establishments.

10. Value Added by Manufacture indicates the net value of production which remains after all costs of materials used in production have been deducted from the value of shipments.

These statistics form the bases for almost all the descriptive work that has been undertaken on the logging industry or its major sectors.

Industrial Structure

As the logging industry is comprised of a large number of small firms it may be described as having an atomistic structure. Census reports there are approximately 13,600 establishments operating in the industry and fewer than 5 percent of these, or 557 establishments, have 20 or more employees. The remaining general statistics for the industry attest further to this atomistic structure (Table 1). An analysis of only the larger establishments suggests that on a nation wide basis, no establishment or company has sufficient size to

Table 1. General statistics for the national logging industry, 1963.

General Statistics	National Total	Average per Establishment
Establishments	13, 588	----
Employees	73, 130	5. 4
Payroll ($1, 000)	281, 845	20. 7
Production workers	65, 790	4. 8
Wages ($1, 000)	254, 122	18. 7
Supervisory workers	7, 340	. 5
Salaries ($1, 000)	27, 723	2. 0
Cost of materials ($1, 000)	630, 182	46. 4
New capital expenditures ($1, 000)	94, 602	7. 0
Value added in manufacture ($1, 000)	520, 457	38. 3
Value of shipments ($1, 000)	1, 154, 693	84. 9

Source: U. S. B. C., C. M., 1966.

dominate economic activity. This analysis, developed in the form of concentration ratios, shows that even the 50 largest companies when taken together account for a relatively small percentage of the industry's total economic activity (Table 2). On the basis of available evidence it appears that the logging industry approaches the conditions presented by economic theory for an industry operating in competitive markets.

Industrial Location

As stumpage is the stationary input for roundwood production, logging must necessarily take place on commercial forest land. The U. S. Forest Service (1965, p. 223) defines commercial forest land as

> forest land which is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. Includes areas suitable for management to grow crops of industrial wood generally capable of producing in excess of 25 cubic feet per acre of annual growth. Includes both accessible and inaccessible areas.

Each of the 48 contiguous states contains some commercial forest land (Table 3). A portion of this land is not adequately stocked, or is inaccessible. Consequently, not all commercial forest land can support logging operations. However, there is a sufficient stumpage volume available on the commercial forest lands in each state to

Table 2. Concentration ratios on selected general statistics for the national logging industry, 1963.

	General Statistics						
	Employees		Production Workers		New Capital	Value Added in	Value of
	Number	Payroll	Number	Wages	Expenditures	Manufacture	Shipments
Percent of total accounted for by the							
4 largest companies	5	7	5	7	7	8	11
8 largest companies	9	13	8	12	10	11	19
20 largest companies	11	16	10	15	11	15	25
50 largest companies	14	21	13	19	16	20	31

Source: U. S. Congress, 1966.

Table 3. Distribution of commercial forest land area by state, 1963.

State	Commercial Forest Land[1]	Percent of Total Area[2]
Alabama	21, 742	67
Arizona	3, 870	5
Arkansas	21, 530	64
California	17, 391	17
Colorado	12, 275	18
Connecticut	1, 873	63
Delaware	391	31
Florida	18, 474	53
Georgia	26, 298	71
Idaho	15, 823	30
Illinois	3, 761	11
Indiana	3, 960	17
Iowa	2, 595	7
Kansas	1, 664	3
Kentucky	10, 840	42
Louisiana	16, 512	57
Maine	17, 169	87
Maryland	2, 897	46
Massachusetts	3, 259	65
Michigan	19, 121	52
Minnesota	17, 056	33
Mississippi	17, 976	59
Missouri	14, 977	34
Montana	17, 300	19
Nebraska	1, 140	2
Nevada	109	--[3]
New Hampshire	4, 907	85
New Jersey	2, 120	44
New Mexico	6, 083	8
New York	12, 002	39
North Carolina	20, 216	64
North Dakota	424	1
Ohio	5, 121	20
Oklahoma	5, 299	12
Oregon	26, 613	43
Pennsylvania	15, 089	52
Rhode Island	430	64
South Carolina	11, 559	60

Table 3. Continued

State	Commercial Forest Land[1]	Percent of Total Area[2]
South Dakota	1, 706	3
Tennessee	13, 643	51
Texas	11, 991	7
Utah	3, 999	8
Vermont	3, 713	63
Virginia	15, 829	62
Washington	19, 510	46
West Virginia	11, 389	74
Wisconsin	15, 396	44
Wyoming	4, 853	8
United States	401, 995	26

[1] Area expressed in thousands of acres.

[2] Commercial forest land area expressed as a percentage of total land area.

[3] Less than 0. 5 percent.

Source: U. S. F. S. , 1965.

provide the necessary input for roundwood production. Table 4 presents the distribution of logging establishments and annual cuts by states. These data indicate that the logging industry operates throughout most of the nation. However, most of the activity occurs in two regions of the country, the southern pine region and the Douglas-fir region.

The Southern Pine Sector

The southern pine sector of the logging industry is defined for the purposes of this study to be that part of the logging industry operating in the following states:

Alabama	Georgia	North Carolina
Arkansas	Louisiana	South Carolina
Delaware	Maryland	Texas
Florida	Mississippi	Virginia

The broad characteristics of this area, discussed below, suggest that for all practical purposes one homogeneous logging environment extends over the region.

Atwood (1940) has classified the physiography and climate of this area. Briefly, the region is comprised of three physiographic provinces, the lowlands of the Atlantic and gulf coastal plains, the uplands and plateaus of the Piedmont, and the old, worn-down mountains of Appalachia. Most of the region lies within the coastal plain and Piedmont. A small area extending along the western borders of

Table 4. Distribution of logging establishments and roundwood output by state, 1963.

State	Number of Establishments	Roundwood Output (Mcf)
Alabama	806	477, 189
Arizona	41	64, 369
Arkansas	531	387, 498
California	703	821, 558
Colorado	49	42, 134
Connecticut	10	22, 519
Delaware	20	8, 439
Florida	540	257, 476
Georgia	1, 168	576, 025
Idaho	276	229, 445
Illinois	39	39, 658
Indiana	37	47, 232
Iowa	19	26, 112
Kansas	13	10, 468
Kentucky	97	120, 663
Louisiana	470	370, 406
Maine	886	251, 103
Maryland	78	58, 955
Massachusetts	22	28, 511
Michigan	531	193, 819
Minnesota	349	164, 456
Mississippi	370	363, 877
Missouri	61	119, 634
Montana	230	192, 079
Nebraska	2	5, 928
Nevada	5	846
New Hampshire	157	50, 540
New Jersey	26	29, 949
New Mexico	34	47, 808
New York	168	152, 525
North Carolina	734	524, 186
North Dakota	---	1, 744
Ohio	75	65, 841
Oklahoma	13	48, 263
Oregon	1, 439	1, 773, 542
Pennsylvania	267	192, 028
Rhode Island	1	3, 118
South Carolina	621	357, 230

Table 4. Continued

State	Number of Establishments	Roundwood Output (Mcf)
South Dakota	11	14, 655
Tennessee	181	180, 314
Texas	284	240, 744
Utah	13	14, 096
Vermont	112	38, 955
Virginia	432	394, 111
Washington	1, 030	898, 672
West Virginia	208	117, 249
Wisconsin	329	199, 196
Wyoming	38	19, 075
Total	13, 588	10, 319, 884

Source: U. S. B. C., C. M., 1966.
U. S. F. S., 1965.

the Atlantic states and into north Georgia falls within the mountain province. The humid sub-tropical climatic type extends over most of the region.

There are approximately 190 million acres of commercial forest land in the region. Most of this acreage is owned privately and in small tracts. Forty percent is owned by farmers and 33 percent is owned by miscellaneous private owners, usually absentee owners (U. S. F. S., 1965, p. 141). Another 18 percent is owned by industrial forest organizations. As a result of purchases of old agricultural properties, much of the industrial ownership is held in small tracts also.

Two major forest cover types dominate the region. These are the loblolly-shortleaf pine type and the longleaf-slash pine type. Of lesser regional importance are the mixed oak types which do contain some pine. These mixed types are located in the mountains and along the river bottom-lands (S. A. F., 1954). The volume of wood in growing stock throughout the region averages 700 cubic feet per acre. Sixty percent of this volume is distributed on small stems ranging from 5 to 13 inches in diameter.

As the timber grows in fairly open stands, on small stems, and on flat or undulating terrain, there are no major physical obstacles to hinder industrial roundwood production. Historically, while the region industrialized at a slow rate, agriculture adopted capital intensive practices. As a consequence, a large unskilled labor force with few employment alternatives has been available to work in the logging industry. The abundance of labor has maintained the capital requirement in roundwood production at a low level. This situation together with the large number of small timber tracts available for logging has permitted easy entry of firms into the logging industry. Consequently, the industry is composed of a large number of small producers most of whom use labor intensive production systems (Davis and Richards, 1967).

During the past decade, several changes have occurred in the determinants of the industry's structure in this region. Roundwood consumption has increased tremendously. Between 1960 and 1967, lumber production, which reflects the consumption of sawlogs, increased 11 percent to 10 billion board feet while pulpwood consumption increased almost 50 percent to 34 billion cords. In 1962, 18 million board feet of pine peeler logs were consumed by the veneer and plywood industry. By 1967, pine peeler log consumption increased to 1 billion board feet. The increases in consumption occurred while a shortage of labor for woods work was developing. Alternative employment opportunities for woods workers occurred not only in nonforest based industries but also in the expanding wood conversion industries. To satisfy increased consumption while labor was becoming scarce, many producers were forced to substitute capital for labor in their roundwood production systems. As a result, new logging technologies were developed. Three situations have deterred wide-spread implementation of the new technologies. First, much of the residual labor force in woods work was not capable of operating or maintaining the new, sophisticated machines (Quaile, 1965). Second, many producers had neither sufficient financial resources of their own nor access to the necessary credit to purchase and operate these machines. Third, many of the timber tracts available for logging were too small to permit efficient use of the new, high capacity machines.

Characteristically, the major firms operating in the lumber, veneer and plywood, and woodpulp industries in this region have integrated to include stumpage production, roundwood conversion, and wood product distribution or marketing enterprises. These firms did not complete the vertical integration process to include the roundwood production enterprise while there were available independent producers who would perform this function adequately. However, labor shortages, high capital costs, and undesirable ownership patterns have impaired the performance of the logging industry as traditionally structured. To assure an adequate and stable flow of roundwood to their conversion plants, the major roundwood converters are now entering the logging industry by integrating a roundwood production enterprise into their organizations. These firms have the capability to consolidate forest ownerships into large contiguous tracts and to mobilize the labor and capital necessary to produce roundwood with the best technology available. Notwithstanding these recent developments, this study examines the southern pine sector's resource allocation situation in 1963 when 4 billion plus cubic feet of roundwood, representing about 40 percent of the nation's total output, was produced almost entirely by small, independent producers.

The Douglas-Fir Sector

The Douglas-fir sector of the logging industry is defined for the purposes of this study to include that part of the nation's logging industry operating in that portion of western Oregon and Washington lying west of the summit of the Cascade mountains. Two physiographic provinces occur in the region (Atwood, 1940). These are the young rugged mountains of the Cascade and Coast ranges, and the lowlands adjacent the major river channels. The marine west coast climatic type prevails over the entire region.

There are approximately 26 million acres of commercial forest land in the region. Fifty percent of this area is publicly owned and is administered by various public agencies, notably the U. S. Forest Service and the Bureau of Land Management. The forest industry owns an additional 33 percent of the area. Most of the forest land in these ownerships is held in large tracts.

Four major forest types occur over the region. These are the Douglas-fir, hemlock-sitka spruce, hardwood, and true fir-hemlock-spruce types which cover 56, 15, 14 and 8 percent of the area, respectively (Worrell, 1967). The net volume of wood in growing stock averages 4, 700 cubic feet per acre over the region. Sixty-five percent of this volume is distributed over stems which are 19 inches in diameter and larger.

The large stems, high volumes per acre, and rugged terrain present a considerable physical constraint on the choice of technologies that may be used in roundwood production, especially on the labor intensive technologies. Consequently, highly mechanized logging systems frequently based on cable works and operated by a skilled or semi-skilled labor force are used in the region.

The traditional technologies used in the region have been discussed by Wackerman, Hagenstein, and Mitchell (1966). Some of the more recently innovated systems are discussed by Erickson (1968). The development and implementation of these technologies has been facilitated by the large size of timber tracts available for harvest and the considerable financial capabilities of the large roundwood producers. Many of these producers are enterprises integrated within large wood products manufacturing firms.

It is apparent the logging environment of the Douglas fir region is considerably different from that prevailing in the southern pine region. As a consequence, the technologies developed in each region are different. One aspect of this study is to ascertain if these different technologies lead to differences in the efficiency of resources used.

III. THE THEORY OF AGGREGATE PRODUCTION ANALYSIS

Generally, the production function defines the physical or technological input-output relationship existing between resources used in a production process and the product forthcoming. Specifically, it defines the path of the maximum output response for a homogeneous product that can be obtained under constant technology from the application of varying levels of input services, each input being a homogeneous entity. The production function pertains to a specific time period and hence the measures of the inputs and output during the period are flows or rates per unit time.

As indicated earlier, the production function is usually associated with the input-output relationship prevailing at the level of the firm. However, when the concept is used in aggregate analysis as an industrial production function, it is based on the activities of all the firms in the industry, and therefore describes an interfirm relationship. In this case, the industrial production function should be developed by aggregating the individual production functions of all firms in the industry. However, data suitable for estimating each firm's production function usually are not available. Consequently, industrial or aggregate production functions are estimated from global data, such as those published by the U. S. Bureau of the Census in their Census of Manufactures. This latter approach results in a production function which is conceptually different from that encountered in the theory of the firm (Klein, 1962, p. 87). The industrial production function describes the relationship between the aggregated output forthcoming from various levels of aggregated inputs. Not only does this function combine all the different technologies existing in the industry but also, its surface represents the real points of operation of all firms in the industry which are included in the aggregation.

It should be recognized that it is a difficult task to devise equations which adequately express the very complicated "true relationships" prevailing in any manufacturing industry (Carter, 1956, p. 168). Several models have been proposed as being appropriate for describing and empirically analyzing manufacturing processes. As Love (1966, p. 874) indicates, in selecting the model and estimating the economic relationship involved, one is estimating an approximation. Nerlove (1965, p. 1), emphasizing this suggestion for caution when undertaking an empirical production analysis, states that the econometric investigation has its place as a first step, and a first approximation to, a full understanding of the relation called the production function.

The Single-Equation Model

Several writers have suggested that to obtain unbiased and consistent estimates of the parameters of a production function using ordinary least squares (OLS) techniques, it is not sufficient to consider just the production function. Rather, they believe that the simultaneous solution of a model containing not only the production function but the entire system of equations which specify all profit maximizing conditions underlying the basic input-output relationship is necessary (Hilderbrand and Liu, 1965; Nerlove, 1965; and Walters, 1963). A basic assumption held by those who argue in favor of the multi-equation model approach appears to be that profit is a non-stochastic concept. More recently, however, Zellner, Kmenta, and Dreze (1966) have argued that profit is a stochastic variable; that due to variable weather conditions, unpredictable behavior of factor input services, and the time lag between factor employment and output produced, the commitment of resources to any production process necessarily occurs before profit accrues. As profit is uncertain, that is, it is a stochastic concept, the single-equation production model is adequate for productivity analysis and when this model is presented in a linear form, its parameters may be estimated by OLS techniques. A full discussion of this argument may be found in Moroney (1967). Griliches (1967), and Moroney (1967). have used the single-equation model approach in their analyses of production in selected manufacturing industries. Considering both the many desirable aspects of the single-equation model, discussed below, and the intent of this research study as being an application of received econometric theory rather than a theoretical evaluation of existing approaches to aggregate production analysis, this writer has selected the single-equation model as an appropriate model for evaluating resource use in the logging industry.

Cross-Section and Time-Series Analyses

The fundamental difference between cross-section and time-series production analysis is that the former is restricted to analysis of production relationships which prevail at one point in time, while the latter analyzes production relationships which exist over two or more points in time. While analyses of resource use in manufacturing industries based on cross-section data appear to be more common than those based on time-series data, the latter do receive considerable attention. However, there are several characteristics of data used in time-series analysis which raise some question as to the usefulness of the results derived from these data. Some of these characteristics are:

1. Time-series analyses frequently force the aggregation and comparison of non-homogeneous items. Changes in the quality of

capital, labor, and output become accentuated over the time span of a long data series. In reality, the characteristics of the input and output units measured by the data at the start of the series may have little resemblance to the characteristics existing at the end of the series. This situation casts some doubt on the meaning of the condition of returns to scale which is frequently estimated in manufacturing production analyses (Ferguson, 1967, p. 211).

2. The bases for collecting and recording descriptive economic statistics frequently change over time. Most time-series data, especially those covering long time periods, have been collected on the bases of several changing criteria. While these changes may be well documented, the elements of non-comparability in the data complicate the interpretation of the results (Stigler, 1963).

3. Time-series data frequently span varying portions of the business cycle. In some years capital assets are utilized near capacity while in other years they are utilized well below capacity. The problem of how to correct capital input data for differing levels of capacity utilization has yet to be resolved (Eisner, 1967, p. 431).

4. Economic statistics for one point in time tend to be serially correlated with those for adjacent points in time. Parameter estimates based on these data and derived from OLS techniques do not possess minimum variance properties (Johnston, 1960, p. 179).

For these reasons and others discussed later which pertain to the adequacy of historical data available for the logging industry, this study is restricted to a cross-sectional analysis of production characteristics at one point in time.

The Cobb-Douglas Function

The Cobb-Douglas function is frequently used as the single-equation model in empirical studies evaluating efficiency of aggregate resource use in manufacturing industries because the function possesses several desirable properties. This function has the form, $V = TL^{A} K^{B}$, where:

- V = the measure of commodity output
- T = the intercept parameter
- L = the measure of labor input
- A = the elasticity of production parameter for labor
- K = the measure of capital input
- B = the elasticity of production parameter for capital.

The properties of this function which have contributed to its frequent use are:

1. It satisfies the three neo-classical criteria required of a production function: that is, output increases as the application of inputs increases; marginal productivity decreases as the application of inputs increases; and it does not specify *a priori* the condition of returns to scale prevailing in the production process (Brown, 1966, p. 31).

2. It is statistically efficient; that is, it is economical in use

of degrees of freedom in comparison with other functional forms used in productivity analyses (Klein, 1962, p. 92).

3. It is easily converted into a linear form through logarithmic transformation. The parameters of the linear form can then be estimated using OLS techniques (Tintner, 1956, p. 128).

4. The OLS estimates of the parameters yield, directly, unbiased and consistent estimates of the elasticities of production for each factor input when maximization of expected value of profit is specified (Moroney, 1967, p. 41).

5. The marginal productivities of each input factor are derived easily as the product of the elasticity of production times the geometric average productivity (Klein, 1962, p. 64).

6. It is homogeneous of degree $(A + B)$; consequently, the condition of increasing, constant, or decreasing returns to scale is established as $(A + B)$ equals more than one, one, or less than one, respectively (Klein, 1962, p. 62).

In spite of these desirable properties this model has been subjected to some severe criticisms (Douglas, 1967, p. 17). The original version of the model appeared in the form $V = TL^{A} K^{1-A}$ and was used in a pioneering study (Cobb and Douglas, 1928) to empirically estimate efficiency in United States manufacturing industries. Durand (1937) criticized the constraint in this model which, by forcing the exponents to sum to unity; that is, $A + (1-A) = 1$, specified *a priori* that constant returns to scale must prevail in the manufacturing process. He recommended a model unrestricted in the sum of the exponents which would then permit tests of hypotheses on the condition of returns to scale. Consequently, the model was revised to incorporate this increased flexibility and used in the first empirical interindustry productivity study (Bronfenbrenner and Douglas, 1939). Since that time the unrestricted model of the form $V = TL^A K^B$, now commonly referred to as the Cobb-Douglas function, has been used frequently as a manufacturing production function. Some recent examples of these are Murti and Sastry (1957), Hildebrand and Liu (1965), Griliches (1967), and Moroney (1967). The restricted form is still used where certain statistical difficulties develop in the analysis. This situation is discussed later.

Other criticisms of this model have disappeared over the years or have proven to be unfounded as researchers learned more of the theoretical aspects of the model. Most researchers have accepted, reluctantly, the few undesirable properties of this model as they recognized the many more difficulties associated with alternative models. The following characteristics of the Cobb-Douglas model are considered to be the most undesirable for contemporary researchers.

1. The elasticity of production for each factor input is constant over the full range of input levels. Therefore, the function cannot describe increasing, constant, and decreasing returns to scale as

the levels of input application increase (Carter, 1956, p. 168).

2. The isoquants derived from the function are asymptotic to the input axes. Carter (1956, p. 169) has suggested that even though this feature implies an unlimited range over which proportions of inputs can be varied in the production of one level of output, in reality, the capacity of labor limits the amount of capital it can handle. After this capacity is reached, the marginal productivity of capital becomes zero or negative.

3. The elasticity of substitution between factor inputs is held constant at unity. This restrictive characteristic of the function has generated more criticism than has any other characteristic, especially among those researchers concerned with economic growth. As a result, a new function has been developed (Arrow, et al., 1961) which, although restricting the elasticity of substitution to a constant, does not specify a priori that it must be equal to unity. This function, known as SMAC after Solow, Minhas, Arrow, and Chenery, or alternatively, known as CES for constant elasticity of substitution, has been used frequently in recent productivity studies. However, not only is the CES function more difficult to use in an empirical analysis in that it cannot be solved in one step as can the Cobb-Douglas function but also, it requires that data on returns to capital be available for each unit under observation (Hildebrand and Liu, 1965, p. 32). These data are nearly impossible to obtain, especially for studies

utilizing Census Bureau data. Recent results of CES studies now lead economic theoreticians to question the function's alleged superiority over the Cobb-Douglas function. For example:

(a) Griliches (1967) reporting on the results of an industrial production function study using Census Bureau cross-section data concludes that his results do not prove the Cobb-Douglas function is the correct form of the industrial production function. However, he continues his conclusion by stating that there is no strong evidence against this function, and until better evidence appears, there is no reason to give it up as the maintained hypothesis.

(b) Walters (1963) in reviewing the econometric aspects of production and cost functions states that, because of the unsubstantiated claim that the elasticity of substitution does not equal one, the Cobb-Douglas function should not yet be disposed of.

(c) Maddala and Kadane (1967) present this proposition. Suppose the true production function is the CES function with constant returns to scale and with an elasticity of substitution significantly different from unity, but the Cobb-Douglas function is used instead for estimating purposes. They conclude that if labor and capital are independent, log normally distributed, as is the usual assumption, then on the basis of their study there is no appreciable bias in the estimates of returns to scale derived from the Cobb-Douglas approximation of the CES function. Shen (1965) has shown that the distributions of capital, labor, and output in manufacturing industries are approximately log normal.

It is not the intent of this study to present a comparative evaluation, based on the hypotheses and near-theories of practicing researchers, of the available models that may be appropriate for aggregate production analyses, but rather to complete a piece of applied research using one model which appears to be appropriate. Therefore, as the available evidence does not refute the appropriateness of the Cobb-Douglas model for achieving the objectives of this study, this function is used as the model in the analyses to follow.

Application of the Cobb-Douglas Model to Empirical Analyses

The Cobb-Douglas function as presented above indicates the form of the relationship which exists among the output (V), labor (L), and capital (K) variates in the industrial production process. The exact relationship among these variates is specified by the value of the parameters T, A, and B. However, these parameters are unknown population characteristics which must be estimated statistically from observations on the variates drawn from a sample. To facilitate empirical analysis, the Cobb-Douglas function is modified to the form, $V = TL^A K^B E$, and then transformed logarithmically to the linear form, $\ln V = \ln T + A \ln L + B \ln K + \ln E$. This form describes the production relationship prevailing in the population of producers in the manufacturing industry and in turn is estimated from sample data applied to the form, $\ln V = \ln t + a \ln L + b \ln K + \ln E$. Hence, ln t, a, and b, are statistical estimates of the parameters ln T, A, and B, respectively.

The several problems associated with specifying the Cobb-Douglas function in linear form, which facilitates empirical analyses, and with selecting the appropriate units of measure on the pertinent variates are discussed below.

The Disturbance Term

A full discussion of the rationale for including the disturbance term, E, in the model is presented by Johnston (1960, p. 4). Briefly, a mathematical model omitting the disturbance term would specify an exact functional relationship between the dependent variate V, and the independent variates, L and K. The realities of economic life preclude the exact relationship from prevailing. However, central tendencies are expected to prevail around the hypothesized model. The model represents an average relationship among variates moving in an n-dimensional space. If the average relationship hypothesized is $TL^A K^B$, then individual observations on V are expected to equal $TL^A K^B$ plus or minus some amount of deviation or error, e. There are three ways for rationalizing the existence of an error, e, in each observation. Firstly, the moving average as hypothesized by the model may not include all the pertinent variates which are necessary to describe the production relationship. The omitted variates may be those which are not recognized as being pertinent, or those on which empirical measurements are not available. The error term is to compensate for this situation. Secondly, even if empirical information on all pertinent variates is included, production processes are subject to random human behavior. This behavior prevents an exact input-output relationship from prevailing in the process. The error term compensates for this situation. Thirdly, to be pragmatic, one must recognize that errors in observation and measurement exist over both input and output variates. The existence of the error term permits the assumption that the independent variates are truly independent and measured without error (Nerlove, 1965, p. 29). This is an important assumption when parameters are to be estimated using OLS techniques. It is also assumed that after logarithmic transformation, the individual error terms associated with each observation are distributed independently, normally, with equal variance, and have an expectation value of zero.

The Output Variate

Value added in manufacture is the most frequently used measure of output in aggregate production analyses (Klein, 1962, p. 85). This measure of output represents a departure from conventional production theory as applied to the firm. At the firm level, output is usually measured in physical units. However, because of either data limitations or the broad interests of analysts, most aggregate analyses focus on a group of related industries producing heterogeneous commodities. The most suitable common denominator for comparing and aggregating these heterogeneous commodity outputs is the dollar value. One dollar estimate of commodity output which is commonly available is the dollar value of shipments. However, the dollar value of shipments can be a misleading estimate of the value of production. Shipments may be larger than production when inventories are being depleted or, shipments may be less than production when inventories are being accumulated. The dollar estimate of output based on value added, while commonly used, has been criticized also. Klein (1962, p. 87) questions the validity of value added because it represents a revenue which is net of the costs of the intermediate goods and services used in the manufacturing process. It is interesting to note, however, that Klein continues his development of the subject of aggregate analysis using value added in manufacture as the measure of output. Kendrick (1956) argues that, as most aggregate analyses are concerned with the efficiency of the primary inputs, labor and capital, used in production, value added net of intermediate costs is the correct measure of output.

The Labor Variate

The measure most representative of labor services consumed in the production process is the number of man-hours worked by production workers (Klein, 1962, p. 85). These data are generally available for manufacturing industries. It must be recognized that this measure of labor services does not provide for real differences that may exist in labor quality (Nelson, 1967), nor does it indicate the level of labor capacity actually utilized in any given hour or average hour recorded as "worked". However, while these are real problems which must be recognized in labor data, they are not as serious within the context of most manufacturing efficiency studies as are those problems associated with the measure of capital.

The Capital Variate

The choice of which measure of capital to use for the capital input variate in aggregate production analyses is a complicated one. Economic theory states capital service is the appropriate measure. This is synonymous with economic depreciation or capital consumption in the production process (Heady, 1966). Global data for this measure are not available. Most depreciation data are developed on an accounting basis for taxation purposes and are not directly related to true capital consumption. Conceptually, net capital stocks or capital available for use in production is the next best alternative, where net capital stocks are equal to gross capital stocks minus consumption. However, as the elusive capital consumption estimate must be available for this calculation, the net capital stock concept is of little pragmatic value for empirical analyses. Consequently, gross capital stock measures are used (Ferguson, 1967, and Moroney, 1967) on the assumption that they are proportional to the flow of capital services consumed in production (Kendrick, 1956). This assumption is predicated on the additional assumption that capital is utilized at a constant rate over the period of the analysis (Klein, 1962). Walters (1963) argues that the constant rate of capital utilization assumption is realistic for cross-section studies based on annual data. Gort and Boddy (1967, p. 395) have summarized the attitudes of most contemporary researchers when they state,

> The role of capital stocks in empirical estimates of production relations is akin to that of a minor vice - we all know there is something wrong with it but persist in the practice for lack of a better substitute.

The Unit of Observation and the Level of Aggregation

Two associated problems which relate to the most appropriate method for developing existing data for use in aggregate analyses have received considerable attention in the economics literature. The first problem considers the selection of the most appropriate producing unit on which empirical observations are to be taken. Gort and Boddy (1967) believe the choice of the producing unit depends upon two criteria, (a) the homogeneity of the physical process under study and, (b) the degree of interdependency between capital goods used in the process. Using these criteria they propose that the plant is the most appropriate unit on which to make observations.

Most frequently, production data based on plant level observations are not available. Consequently, analysts resort to what is alleged to be firm level data (Moroney, 1967 and Ferguson, 1967). While these analysts purport to use firm level data in lieu of plant data, close inspection of the actual data used in these studies, data which are published by the U. S. Bureau of the Census, reveals that the establishment is the real unit of observation (U. S. B. C., C. M., 1966). The economic interpretation of the "establishment" was presented earlier. However, there is merit in reiterating that interpretation here. The establishment is just that part of an organization's manufacturing operation which is devoted to producing one commodity at one location. Consequently, the concept of the firm and the establishment are not synonymous. Additionally, the concept of the plant and the establishment are not synonymous. The establishment compares with the concept of the single location enterprise.

Considering the objectives of industrial production analysis, the establishment is not only a desirable unit of observation, but also it provides the best data base presently available on a national, regional, and local basis. However, Census does not disclose data on a per establishment basis but provides aggregated data over all establishments within county, state, and regional geographic areas. Therefore, even though individual establishments are the observation units for Census, geographic areas become the observation units for analysts using Census data. Hildebrand and Liu (1965) believe the correct adaptation of these data for aggregate analyses is to transform the published totals into averages per geographic area. This is tantamount to quantifying an "average establishment" for each area in which Census totals are available. Ferguson (1967, p. 210) says this transformation "is absolutely required for an analysis of returns to scale." Hildebrand and Liu, and Ferguson developed industrial production functions using the "average establishment per state" as the observation.

The second problem encountered in developing data for use in aggregate analyses focuses on which level of aggregation is most appropriate. The Census of Manufactures reports on a geographical basis, aggregated data for "all manufacturing industries" in the SIC system. These data represent the highest level of aggregation available. The SIC system provides for the disaggregation of this total into 21 very broad industrial groups, each of which is assigned a two-digit code. The two-digit industrial groups are then disaggregated further into 150 three-digit groups, and finally, into 425 four-digit industries. The system can be partially illustrated by the following example. One of the 21 two-digit industrial groups is coded as SIC 24 and classified as Lumber and Wood Products. This industrial group includes 5 three-digit sub-groups and the following 13 four-digit industries:

2411 - Logging camps and contractors
2421 - Sawmills and planning mills
2426 - Hardwood dimension and flooring
2429 - Special product sawmills, n. e. c.
2431 - Millwork plants
2432 - Veneer and plywood plants
2433 - Prefabricated wood products
2441 - Nailed wooden boxes and shook
2442 - Wirebound boxes and crates
2443 - Veneer and plywood
2445 - Cooperage
2491 - Wood preserving
2499 - Wood products, n. e. c.

The appropriate level of aggregation, that is, aggregation at the two-digit level versus aggregation at the four-digit level depends not only on the objectives of the research but also on the characteristics of the underlying production processes. Research objectives may require aggregation at a high level as for example has been done by Moroney (1967), Ferguson (1967), and Griliches (1967) where data aggregated at the two-digit industrial group level were used to estimate manufacturing functions for inter-industrial group comparisons. However, aggregation at this level does not permit the isolation and separate analysis of the rather unique production processes with specialized technologies and homogeneous inputs and outputs inherent within many four-digit industries.

For example, each of the studies cited above considered Lumber and Wood Products as one manufacturing process. An examination of the 13 four-digit industries included in this group reveals that several very diverse manufacturing processes are included. Most of these industries are comprised of establishments which operate from permanently located plants with stationary equipment. These establishments use as the major raw material input in their production process, sawn wood products which are transported to the plants for that purpose. Several others of these industries are also comprised of establishments operating from permanently located plants with stationary equipment but which use industrial roundwood that must be transported to the plant as their raw material input for manufacture into sawn, sliced, or peeled wood products. However, the logging industry, SIC 2411, is comprised of establishments which are not confined to permanently located plants. These establishments use labor and mobile equipment which travels through the woods to reach their raw material input, stumpage or standing timber, which is located in a fixed position. It is apparent that not only does this two-digit industrial group contain nearly all those industries necessary to transform standing timber into the many diverse producer's goods manufactured from solid wood but also, the raw material extraction process undertaken by the logging industry is quite different from the manufacturing processes of the other industries in the group. Consequently, the industries included in the Lumber and Wood Products group are characterized by different technologies, consumption of heterogeneous input services, and production of heterogeneous outputs. It is suggested that rash assumptions are necessary to justify aggregating the activities of these industries and inferring anything meaningful from the results. Practically no meaningful inferences respecting the logging industry can be drawn from studies of the Lumber and Wood Products group. As a result, a separate study of the logging industry based solely on SIC 2411 data is warranted.

Earlier discussion emphasized that the technology used by the logging industry is represented by many different logging systems. These systems are conditioned by the diverse ecological and socioeconomic characteristics encountered in the logging environment. Consequently, the criticisms levied above on empirical analysis based on the very diverse production processes included in Census two-digit level data apply also, though to a lesser degree, to this study based on Census four-digit level data. However, as Census data for Logging Camps and Contractors, SIC 2411, are the best data available, they are used with some reservations as the basis for empirical analyses in this study.

IV. THE NATIONAL ANALYSES

The discussion developed in the three preceding chapters has:

(a) emphasized the desirability for obtaining statistical estimates of aggregate resource efficiency in the logging industry and its two major sectors

(b) reviewed the theory underlying the aggregate production function and the use of this concept in deriving estimates of resource efficiency

(c) presented the rationale for using in this study both Census Bureau cross-section data on Logging Camps and Contractors, SIC 2411, and the single-equation model.

This chapter presents an application of the theory and methodology discussed earlier in a productivity analysis for the national logging industry and reports on the results of the analysis.

The Model

The model selected initially for describing the aggregate production function of the national logging industry was the unrestricted Cobb-Douglas function of the form

$$V_{11} = T_{11} \, K_{11}^{A_{11}} \, P_{11}^{B_{11}} \, S_{11}^{C_{11}} \, E_{11}$$

The subscripts used in the model are designed to facilitate understanding of the analyses to follow. The first digit in the subscript, cited above as 1, refers to the national analyses. In later discussion where the same model is used, the first digit of the subscript when cited as 2 refers to the analyses of the southern pine sector of the industry, and when cited as 3 refers to the analyses of the Douglas fir sector of the industry. Limitations of the data available for use in the study, as discussed later, prevented straightforward, logical solutions to the analyses. Therefore, several alternative approaches to the analyses had to be considered. Consequently, the second digit in the subscript, cited above as 1, refers to a specific approach under consideration. As five different approaches were considered, the second digit of the subscript ranges from 1 through 5.

The Variates in the Model

This model not only indicates that the dependent output variate V_{11} is a function of the independent factor input or resource variates K_{11}, P_{11}, and S_{11}, but also specifies the form of the functional relationship between these variates. The variates considered here as being relevant to the industrial roundwood production process are the value added output variate V_{11}, the capital, production worker, and supervisory worker input variates, K_{11}, P_{11}, and S_{11}, respectively, and the disturbance term E_{11}.

The Parameters in the Model

The parameters in the model specify explicitly the relationship between the output variate and the input variates. The parameters identified in this model are the intercept parameter T_{11}, and the elasticities of output or production A_{11}, B_{11}, and C_{11}, for the input variates capital, production workers, and supervisory workers, respectively. Each elasticity of production indicates the percentage response in output attributable to one percentage change in that input while all other inputs are held constant.

As indicated in Chapters I and III the elasticities of production are of fundamental importance to the determination of both resource productivity and returns to scale in the industry. However, these elasticities or parameters as presented in the model are characteristics of the population of all producing units in the industry. As observations on all producing units in the industry are not available, the parameters must be estimated from available observations over a sample of producing units from the industry. To facilitate the estimation of the parameters of the model, the Cobb-Douglas function is transformed logarithmically into the linear form

$$\ln V_{11} = \ln T_{11} + A_{11} \ln K_{11} + B_{11} \ln P_{11} + C_{11} \ln S_{11} + \ln E_{11}$$

This transformation permits the estimation of the parameters by OLS techniques.

The Data

The cross-section data used for the analyses in this study are from a Census Bureau survey of Logging Camps and Contractors, SIC 2411, undertaken in 1963 and published in 1966 (U. S. B. C., C. M., 1966). These data represent the most recent data available on the industry. While a more recent survey of the industry has been undertaken in 1967, the new data have not been published as yet in final form.

Census does not publish data on individual establishments but does publish data aggregated on a geographic basis. The smallest geographic units for which SIC 2411 data are available throughout the nation are individual states. Therefore, the production units observed for the national study are these states. However, Census does not provide data for every state. Consequently, the sample size for this study is limited to those states for which observations on variates included in the model are available from Census. As there are 35 of these states, the sample size for the national analyses is 35. The following states comprise the sample:

Alabama	Maine	Oregon
Arizona	Maryland	Pennsylvania
Arkansas	Michigan	South Carolina
California	Minnesota	Tennessee
Colorado	Mississippi	Texas
Delaware	Missouri	Vermont
Florida	Montana	Virginia
Georgia	New Hampshire	Washington
Idaho	New Mexico	West Virginia
Illinois	New York	Wisconsin
Kentucky	North Carolina	Wyoming
Louisiana	Ohio	

Output Data

The data on output are measured in terms of total value added in manufacture in thousands of dollars, for all establishments in each state. These data reflect the value added for just that output which has been produced during the year. That is, they do not include inventory carry overs from the preceding year but do include inventories resulting from production in the current year. Additionally, they include a component attributable to those commodities which have been partially produced but not completed to the point where these commodities can be either added to inventory or shipped. Within the context of the logging industry this adjustment would provide for inclusion of felled timber not yet bucked or yarded, or timber decked in the woods but not yet loaded or hauled. Total value added observations are available for all 35 states in the sample.

Capital Input Data

Problems associated with selection of the proper measure of capital to use in productivity studies have been discussed earlier. Most researchers have concluded that aggregate gross book value of depreciable assets is the best measure available. Census provides this measure of capital in the logging industry but only as a national total. Observations of aggregate gross book value of depreciable assets are not available for state level producing units. Therefore state estimates of this measure must be developed.

Census does publish for the logging industry, at both the national and state levels, data on total cost of materials used in manufacture. This cost includes a component cost for the fuel and energy required to operate capital equipment. Therefore, the national figure on the aggregate gross book value of depreciable assets in the logging industry is allocated among states in the same proportion as each state's total cost of materials in logging relates to the total national cost of materials in logging. This allocation is made on the assumption that capital assets are more closely correlated with cost of materials including fuel and energy purchases than they are with any other available data which could provide a basis for objective allocation. Derived aggregate gross book values of depreciable assets have been calculated on this basis for each of the 35 states in the sample and subsequently used as the capital resource observations in this study.

Production Workers Input Data

The flow concept of labor-services consumed in production processes is available in Census' data on total man-hours worked by production workers. Observations on this measure of labor consumption are available for the logging industry at the state level for each of the 35 states in the sample.

Supervisory Workers Input Data

As the roundwood production process is generally considered to be a labor intensive process, it was considered desirable in this study to consider the effectiveness of the supervisory workers employed in the industry. Presumably the use of supervisory workers should improve the effectiveness of production workers. Census' observations on the contribution of supervisory workers to the logging industry are provided separately from those for production workers. However, observed data for supervisory workers contain characteristics similar to those for capital data. These data indicate only the numbers of these workers who are employed during the year. Consequently, there is no information on what supervisory services were consumed in production during the year nor to what extent the available supervisory workers were utilized. Realizing the shortcomings of these data, one is confronted with the choice of ignoring the role of this kind of labor in production or accepting an inferior estimate of its contribution. The latter is considered to be the preferable choice (Moroney, 1967, p. 44). Therefore, the stock concept of numbers of supervisory workers is used in this study and the observations for each state in the sample as provided by Census are used.

The State as the Producing Unit

Observations on each of the variates in the model are provided by Census or derived from data provided by Census in the form of aggregates over the total number of establishments in operation. As was discussed in Chapter III, these observations, to be meaningful in the analyses, must be presented on the basis of the average establishment per producing unit or state. Therefore, total value added, total derived gross book value of depreciable assets, total number of manhours worked by production workers, and total number of supervisory workers observed in each state are divided by the number of establishments in each state. This calculation provides a set of observations for each state which represents the average establishment per state. The 35 sets of observations are used to estimate the parameters of the logarithmically transformed model.

Computed Results

The computations required to estimate the parameters of the industrial production function were undertaken on an IBM Series 360 computer, model 40. The 35 sets of observations were first transferred to punch cards which in turn became the input data deck for the programs used. The first program provided for the transformation of each observation into its natural logarithm. The second program, a standard stepwise regression program known as BMDO2R, Stepwise Regression, and published by the University of California, provided the OLS analysis. The details of the program are available in Dixon (1968, p. 233).

The details on the variates and units of measure on these variates which have been used to find an OLS solution to the function of the form

$$\ln V_{11} = \ln t_{11} + a_{11} \ln K_{11} + b_{11} \ln P_{11} + c_{11} \ln S_{11} + \ln E_{11}$$

were discussed earlier. The OLS solution to this function is

$$\ln V_{11} = 0.618 + \underset{(0.09682)}{0.55910} \ln K_{11} + \underset{(0.19449)}{0.84282} \ln P_{11} - \underset{(0.10877)}{0.31856} \ln S_{11}$$

where the standard error of each estimated coefficient appears in parentheses beneath the coefficient. This result when transformed into the form of the original Cobb-Douglas function appears as

$$V_{11} = 0.618\, K_{11}^{0.55910} P_{11}^{0.84282} S_{11}^{-0.31856}$$

Elasticities of Production

The coefficients of the industrial production function in logarithmic form or the exponents of the function in the original Cobb-Douglas form are the estimated elasticities of production for each input variate. As the estimated elasticities are derived from sample data, they are subject to variation from sample to sample that conceptually could have been selected. It is desirable to know whether, in the population of producing units, each input variate influences output as suggested by the sample estimates or whether these sample estimates represent an unacceptable chance occurrence. Therefore, each input variate is investigated to ascertain if it does influence output in the population. The test of hypothesis is that the true elasticity of production is equal to zero. If the probability that this should happen by pure chance is very small, less than 5 percent or 1 percent, the parameter in question is significant (Tintner, 1956, p. 127). The tests of hypotheses for each elasticity were conducted with the t test.

Capital. The estimated elasticity of production is +0.55910 which indicates that a 1 percent increase in capital input, while all other inputs are held constant, will on the average result in an increase in value added output of approximately 0.56 percent. As the elasticity is less than 1, diminishing returns to capital prevail.

The test hypothesis is that $A_{11} = 0$. Therefore,

$$t = \frac{a_{11} - 0}{(\text{standard error of } a_{11})}$$

$$= \frac{0.55910}{0.09682}$$

= 5.77463 with 31 degrees of freedom. On the basis of the computed t = 5.77463 with 31 degrees of freedom (d. f.), the hypothesis that $A_{11} = 0$ is rejected at both the 5 percent and 1 percent levels. Consequently, the elasticity of production for capital is considered to be significantly different from zero and therefore the capital variate does influence output.

Production workers. The estimated elasticity of production for production workers is 0.84282, or a 1 percent increase in this variate results in a 0.84 percent increase in the output variate. Again, as the elasticity is less than 1, there is diminishing returns to production workers.

The test hypothesis is that $B_{11} = 0$. Therefore,

$$t = \frac{b_{11} - 0}{(\text{standard error of } b_{11})}$$

$$= \frac{0.84282}{0.19449}$$

= 4.3333 with 31 d. f.

The hypothesis that $B_{11} = 0$ is rejected at both the 5 percent and 1 percent levels. Therefore, as this elasticity is significantly different from zero, production workers are considered to influence output.

Supervisory Workers. The estimated elasticity of production for this variate is -0.31856, or a 1 percent increase in supervisory workers results in approximately a 0.32 percent decrease in value added.

The test of hypothesis is that $C_{11} = 0$. Therefore,

$$t = \frac{c_{11} - 0}{(\text{standard error of } c_{11})}$$

$$= \frac{-0.31856}{0.10877}$$

$= -2.9287$ with 31 d. f. The hypothesis that $C_{11} = 0$ is rejected at the 5 percent and 1 percent levels. As the elasticity of production is significantly different from zero, this variate is considered to influence output.

Returns to Scale

The condition of returns to scale (RTS) prevailing in the industry is estimated from the sum of the elasticities of production. That is,

$$a_{11} + b_{11} + c_{11} = rts$$

$$\text{or } +0.55910 + 0.84282 - 0.31856 = +1.08336$$

As the estimated rts, +1.08336, is comprised of three sample estimates each having an associated standard error, the sum also has a standard error. The standard error of the sum of the regression coefficients, $[\mathrm{var}(a_{11} + b_{11} + c_{11})]^{1/2}$, is obtained as $\mathrm{var}(a_{11}) + \mathrm{var}(b_{11}) + \mathrm{var}(c_{11}) + 2\,\mathrm{cov}(a_{11}, b_{11}) + 2\,\mathrm{cov}(a_{11}, c_{11}) + 2\,\mathrm{cov}(b_{11}, c_{11})^{1/2}$. This calculation is performed directly from the output of the BMD regression analysis program as

$$(c_{11} + c_{22} + c_{33} + 2c_{12} + 2c_{13} + 2c_{23})\,(\mathrm{RMS})^{1/2}$$

where, in this one instance, the c_{ij} are the elements of the matrix of Gauss or c-multipliers. This matrix is the inverse of the matrix of sums, sums of squares, and sums of cross-products of the original observations on both input and output variates, and where RMS or residual mean square is equal to the (total sum of squares minus regression sum of squares) ÷ the degrees of freedom associated with the residual sum of squares (Freese, 1964).

As a result of these calculations, the sum of the elasticities of production equals + 1.08336 with a standard error of 0.11118.

The issue here is whether, in the real world population of producing units, decreasing, constant, or increasing returns to scale prevails. That is, does a 1 percent increase in all input variates together result in less than 1, 1, or more than 1 percent increase in output. As the only emprical evidence on this phenomena is derived from a sample of producing units, the hypothesis that

$$A_{11} + B_{11} + C_{11} = 1$$

is tested using the t test. That is,

$$t = \frac{(a_{11} + b_{11} + c_{11}) - 1}{(\text{standard error of } a_{11} + b_{11} + c_{11})}$$

$$= \frac{1.08336 - 1}{0.11118}$$

$$= \frac{0.08336}{0.11118}$$

$$= 0.74977 \text{ with 31 d. f.}$$

With this computed t value, the hypothesis that $A_{11} + B_{11} + C_{11} = 1$ is accepted at both the 5 percent and 1 percent levels because $(a_{11} + b_{11} + c_{11})$ is not significantly different from 1. Therefore, the empirical evidence from the sample suggests that constant returns to scale prevail in the industry.

Coefficient of Multiple Determination

The coefficient of multiple determination, or R^2, a measure of how well the regression fits the sample data, equals 0.89 for this analysis. That is, 89 percent of the variation in output is accounted for by the input variates considered in the regression.

Correlation Coefficients

An indication of the association between variates used in the regression is provided by the correlation coefficients. The values of this coefficient can range from -1 to +1. A coefficient approaching -1 indicates a highly negative correlation between two variates while a coefficient approaching +1 indicates a highly positive correlation between variates. A correlation coefficient of zero indicates there is no correlation between the variates.

The matrix of correlation coefficients for variates in this analysis is presented here.

	Value Added (V_{11})	Capital (K_{11})	Production workers (P_{11})	Supervisory workers (S_{11})
Value added (V_{11})	1.000	0.907	0.876	0.575
Capital (K_{11})	-	1.000	0.847	0.695
Production workers (P_{11})	-	-	1.000	0.740
Supervisory workers (S_{11})	-	-	-	1.000

Discussion

There are several aspects of this initial analysis of the national industry which are sufficiently disconcerting to justify considerable discussion.

Negative Elasticities

The first comment pertains to the supervisory worker input variate and its estimated negative elasticity of production. The negative sign on the coefficient suggests that an increase in the input variate results in a decrease in the output variate. Negative elasticities have been reported by several researchers.

Tintner and Brownlee (1944, p. 568) state,

> Negative elasticities, within the range of inputs on most farms, are meaningless. It seems unlikely that production should actually decrease if certain factors of production are increased.

However, in the Tintner and Brownlee study just cited, tests of hypotheses on the negative elasticities indicated that none of the negative estimates were significantly different from zero.

In another early study where negative coefficients were estimated, Heady (1946, p. 994) states,

> It is hardly conceivable that total production would decrease were more of any factor employed. None of the negative elasticities . . . are statistically significant at the 5 percent level of probability. Hence negative elasticities of the magnitude shown could have arisen with a probability of more than one in twenty even if the true population elasticities were zero.

In a more recent study, Moroney (1967, p. 45) provides the following comment on a negative elasticity of production estimated for non-production workers.

> This means, of course, that nonproduction workers were so excessively employed that the average establishment operated in an uneconomic region of the hypersurface. This is theoretically possible if the average establishment "overemployed" the service flows from its stock of nonproduction workers, but this is not a convincing explanation. For even if the plant had an excessive stock of nonproduction workers, it need not employ an uneconomical flow of services from that stock if such services are divisible . . . It is noted that Hildebrand and Liu . . . also obtain negative nonproduction worker coefficients in 6 different estimating models . . . , so they discard the production worker-nonproduction worker classification in this industry.

As a result of the negative coefficient obtained on the supervisory worker variate in the national logging industry analysis, the rejection of the hypothesis tested that the coefficient equalled zero, and the comments of those researchers who have confronted the negative coefficient problem, it appears desirable to investigate this variate more closely.

Census data transformed into average number of all employees and average number of supervisory workers per state producing unit are listed in Table 5. These data illustrate that supervisory workers are used very sparingly within the logging industry. Not only are there few supervisory workers employed in terms of absolute numbers but also, there are few supervisory workers employed in relation to the total number of all employees. On the basis of these data, it is very difficult to accept that, as economic theory suggests, the negative coefficient on the supervisory workers variate is attributable to over-use of this input.

Another aspect of this variate deserves comment. As discussed earlier, Census provides data on the total number of all employees together with a description of this statistic, and data on the total number of production workers together with a description of that statistic. In this study, prior to the analysis, it was assumed on the basis of Census' descriptions for these two statistics, that the part of the total number of all employees not accounted for by the total number of production workers was synonymous with total number of supervisory workers. It is now suggested that this assumption and interpretation of those employees within the residual group of employees remaining after production workers have been separated from all employees is erroneous.

More realistically, this group should be referred to as non-production workers or all other workers. Typically logging establishments are small producing organizations where the ownership provides any supervisory input that is made. Where logging establishments are formed as proprietorships or partnerships, any input performed by the principals is, by definition, not accounted for by Census in the all employees statistic and consequently any supervisory input by these principals cannot be accounted for in the non-production workers statistic. Supervisory input by this class of

Table 5. Number of employees by class per average state establishment, 1963.

State	All Employees	Class: Supervisory workers	Production workers
Alabama	4. 28	0. 47	3. 81
Arizona	5. 66	0. 54	5. 12
Arkansas	5. 19	0. 46	4. 73
California	7. 36	0. 80	6. 56
Colorado	5. 39	0. 53	4. 86
Delaware	5. 80	0. 40	5. 40
Florida	5. 32	0. 54	4. 78
Georgia	4. 47	0. 48	3. 98
Idaho	8. 60	0. 86	7. 74
Illinois	3. 40	0. 38	3. 05
Kentucky	3. 69	0. 46	3. 23
Louisiana	4. 60	0. 54	4. 05
Maine	4. 65	0. 44	4. 20
Maryland	2. 91	0. 19	2. 72
Michigan	3. 25	0. 30	2. 94
Minnesota	4. 65	0. 49	4. 18
Mississippi	4. 32	0. 48	3. 84
Missouri	3. 36	0. 13	3. 23
Montana	6. 80	0. 58	6. 22
New Hampshire	4. 69	0. 74	4. 01
New Mexico	7. 74	0. 41	7. 32
New York	3. 41	0. 32	3. 10
North Carolina	4. 30	0. 47	3. 82
Ohio	2. 20	0. 15	2. 05
Oregon	8. 52	0. 82	7. 70
Pennsylvania	2. 85	0. 27	2. 58
South Carolina	4. 51	0. 44	4. 07
Tennessee	3. 19	0. 35	2. 83
Texas	3. 25	0. 26	2. 99
Vermont	2. 52	0. 18	2. 34
Virginia	4. 68	0. 50	4. 18
Washington	8. 84	0. 83	8. 02
West Virginia	3. 39	0. 32	3. 07
Wisconsin	3. 86	0. 46	3. 40
Wyoming	3. 55	0. 32	3. 24

owners is lost from the statistics. Where logging establishments are formed as corporations, the input of corporate officers is accounted for in the all employee statistic and to the extent that these officers are not production workers, any supervisory input they contribute is also accounted for in the residual nonproduction worker statistic. However, these corporate officers probably perform duties other than supervisory to production. These duties are included in the non-production worker statistic.

It is recognized that no satisfactory explanation has been presented for the occurrence of the negative coefficient on the input variate which appears to be used sparingly rather than excessively in the production process. This writer has found no reasonable explanation for this result in any of the literature reviewed where negative elasticities have been estimated by other researchers. It is apparent that the input variate with the negative coefficient, originally referred to as the supervisory worker variate, not only does not account for all supervisory input that occurs in the industry but also does include some functions which are not directly related to the roundwood production process. This variate is more properly referred to as the nonproduction workers variate.

Multicollinearity

When some or all of the explanatory variates in a production relationship are highly correlated with each other the separate influence of any one of the variates is difficult to establish (Johnston, 1963, p. 201). The association between any two explanatory variates can be so strong that one of these variates may be expressed as a linear function of the other (Freese, 1964, p. 103). When this occurs, the use of both explanatory variates in a regression may not provide results on the predictive capability of the regression that are any better than those results obtained from a regression based on the one explanatory variate having the highest correlation with the dependent variate. In a structural analysis such as this logging study, use of highly correlated explanatory variates may result in coefficients estimated so imprecisely the separate influence of each variate becomes indeterminate (Leser, 1966, p. 27).

It is noteworthy that in most of the empirical production studies cited earlier, (Ferguson, 1967; Griliches, 1967, and 1968; Hildebrand and Liu, 1965; and Moroney, 1967), the authors refer only briefly to the phenomenon of multicollinearity and do not, as a matter of practice, present the matrices of correlation coefficients generated by their data. Readers of those studies must rely on a comparison of estimated coefficients with their standard errors for evidence as to the separable influence of each explanatory variate.

Klein (1962, p. 101), in a discussion of multicollinearity states

> Inter-correlation or multicollinearity is not necessarily a problem unless it is high relative to the over-all degree of multiple correlation among all variables simultaneously. Production functions with overall correlations much in excess of 0.95, as often occur in practice, can be well estimated with inter-correlations between labor and capital as high as 0.8 to 0.9. If these functions were not well estimated, we would tend to find high sampling errors of the estimated coefficients. By conventional criteria, the estimated parameters of Douglas and his co-workers in this field, are large relative to sampling error. The coefficients are generally high multiples of sampling errors (certainly more than twice, which is the customary critical value for the five percent level of significance). It does not appear that the Douglas type of research is open to the charge that the estimates are plagued by multicollinearity.

Critique of Initial Results

It is desirable to review the initial results of the national analysis within the context of the previous discussion.

The R^2 resulting from the analysis was not as large as was anticipated nor as large as deemed desirable by Klein. Moroney (1967, p. 46) developed aggregate production functions for each of 18 two-digit industrial groups. The R^2's which resulted ranged from 0.9509 to 0.9969. The lowest R^2 of 0.9509 was derived from SIC 24, the Lumber and Wood Products industrial group. The logging industry is a component of this group. Earlier discussion in this thesis emphasized the undesirable aspects of analysing aggregated production processes in this heterogeneous industrial group. However, it is apparent that on the basis of R^2, poorer results have been achieved on the more homogeneous production processes within the four-digit logging industry analysed in this study.

In the Moroney study cited above, the same 3 explanatory variates were used as are used in the initial analysis of this study. Of the 54 elasticities of production estimated by Moroney (3 in each of 18 industrial functions), only one resulted in a negative figure. That elasticity was on the nonproduction workers variate in the rubber industry and was significantly different from zero. This result is comparable to the result obtained here for the logging industry and may reasonably be referred to as a "nonsense" result (Ferguson, 1967, p. 213).

An examination of the matrix of correlation coefficients generated by the data reveals high correlation (0. 847) existing between the capital input variate and the production workers input variate. This multicollinearity appears excessive in view of the R^2 obtained and the remarks of Klein cited above. Additionally, the correlations between the supervisory workers input variate and each of the other input variates, while not excessive, are larger than the correlation between the supervisory workers input variate and the value added output variate. This situation casts additional doubt on the merit of including the supervisory or nonproduction workers variate in the industrial production function.

It should be emphasized that in spite of the diappointing results discussed above, on the basis of low standard errors on the coefficients, the elasticities of production appear to be well-estimated. That is, the separate influence of each input variate may be realistically presented.

In consideration of the several undesirable aspects of the initial analysis, it is considered desirable to specify other sets of input variates and undertake additional analyses. Four additional sets of input variates are specified and used to estimate four alternative production functions. Each analysis is identified by the second digit in the subscripts of the function.

Second Analysis

This section presents the details of the second analysis of the national logging industry.

The Model

The model selected for this analysis has the form

$$V_{12} = T_{12}\, K_{12}^{A_{12}} L_{12}^{B_{12}} F_{12}$$

In this model the variates and parameters are defined identically to those used in the initial analysis with two exceptions. In the initial analysis the contribution of labor to the production process was separated into two components, one component or variate represented the production workers input and one variate represented the nonproduction workers input. For the second analysis no distinction is made between kinds of labor input. One variate is used to represent all labor input into the production process. This variate, L_{12}, is defined as "all employees". Census publishes observations on this variate for each state in the sample. The observations represent only the stock concept of labor used by the industry. No inference from this variate may be made on the flow of labor services actually consumed by the industry.

The second exception in definition between the models of the first and second analyses derives directly from the definition of the labor input variate. That is, the parameter B_{12} indicates the elasticity of production for the all employees input variate.

To facilitate the analysis, the form of the model is transformed logarithmically into the form

$$\ln V_{12} = \ln T_{12} + A_{12} \ln K_{12} + B_{12} \ln L_{12} + \ln E_{12}$$

Estimated Parameters

The parameters of this function are estimated using OLS techniques and logarithms of sample observations on each variate applied to the function

$$\ln V_{12} = \ln t_{12} + a_{12} \ln K_{12} + b_{12} \ln L_{12} + \ln E_{12}$$

The solution to this analysis is

$$\ln V_{12} = \underset{}{2.06} + \underset{(0.10914)}{0.51067} \ln K_{12} + \underset{(0.21056)}{0.61572} \ln L_{12}$$

where the standard error of each estimated coefficient appears in parenthesis beneath the coefficient. The result when transformed into the form of the original function appears as

$$V_{12} = 2.06\, K_{12}^{0.51067}\, L_{12}^{0.61572}$$

The estimated elasticity of production for capital a_{12}, equals +0.51067 which suggests that a 1 percent increase in this variate will result in a 0.51 percent increase in output. Therefore, diminishing returns to capital prevails. The hypothesis that $A_{12} = 0$ is tested using the t test. On the basis of the computed t value, t = 4.6790 with 32 d.f., the hypothesis is rejected at both the 5 percent and 1 percent levels. Consequently, the elasticity of production for capital is considered to be significantly different from zero and the conclusion is that the capital variate does influence output as suggested by the estimated coefficient.

The estimated elasticity of production for all employees, b_{12}, equals +0.61572 which suggests that a 1 percent increase in this variate will result in approximately 0.62 percent increase in output. Therefore, diminishing returns to all employees prevails. The hypothesis that $B_{12} = 0$ is tested using the t test. On the basis of the computed t value, t = 2.9239 with 32 d.f., the hypothesis is rejected at both the 5 percent and 1 percent levels. Consequently, the elasticity of production for all employees is considered to be significantly different from zero and the conclusion is that the all employees input variate does influence output as suggested by the estimated coefficient.

On the basis of the comparison between estimated coefficients and their standard errors, it appears that each coefficient is well estimated.

Returns to Scale

The condition of returns to scale prevailing in the industry is indicated by the sum of the elasticities of production. That is, as $A_{12} + B_{12}$ equals less than 1, 1, or more than 1, decreasing, constant, or increasing returns to scale, respectively, prevail in the industry.

The sum of $A_{12} + B_{12}$ is estimated by $a_{12} + b_{12}$, or

$$+0.51067 + 0.61572 = +1.12639$$

As this estimate of returns to scale is comprised of two sample estimates each having an associated standard error, the sum also has a standard error. The standard error of the sum of the coefficients, $\text{var}\,(a_{12} + b_{12})^{1/2}$, is obtained as

$$[\text{var}\,(a_{12}) + \text{var}\,(b_{12}) + 2\,\text{cov}\,(a_{12}, b_{12})]^{1/2}$$

This operation is performed directly from the output of the BMD regression analysis program as

$$[(c_{11} + c_{22} + 2c_{12}) \text{ (RMS)}]^{1/2}$$

The meaning of the c_{ij} or Gauss multipliers and RMS or residual mean square were presented earlier (p. 70). As a result of these calculations, the standard error of the sum of the elasticities of production is found to equal 0.13058.

Using the sum of the estimated coefficients, the standard error on this sum, and the t test, the hypothesis that

$$A_{12} + B_{12} = 1$$

is tested. On the basis of the computed t value, t = 0.96791 with 32 d. f. the hypothesis is accepted. That is, at the 5 percent level, the estimated sum of the coefficients is not significantly different from 1. Therefore, on the basis of sample evidence, it can be stated that constant returns to scale prevails in the industry.

Coefficient of Determination

This analysis resulted in an R^2 of 0.86. That is, 86 percent of the variation in value added output is accounted for by the regression on the capital and all employees input variates as defined above.

Correlation Coefficients

The matrix of correlation coefficients generated by the analysis is presented below.

	Value Added (V_{12})	Capital (K_{12})	All Employees (L_{12})
Value added (V_{12})	1.000	0.907	0.875
Capital (K_{12})	-	1.000	0.853
All employees (L_{12})	-	-	1.000

These coefficients indicate that while there is a high correlation between each of the input variates and the output variate as is expected, there is almost as high a correlation between the two input variates. Thus the problem of multicollinearity has not been overcome by use of this set of input variates.

Third Analysis

The details of a national analysis based on a third set of legitimate variates is presented in this section.

The Model

The basic model used is unchanged. It has the form

$$V_{13} = T_{13} K_{13}^{A_{13}} P_{13}^{B_{13}} E_{13}$$

In this model the output variate, V_{13}, is defined identically to the output variates defined for the two previous analyses. Output is measured in terms of value added.

The capital input variate, K_{13}, is also defined the same as in the two previous analyses. That is, this variate represents a stock concept of capital and measures the estimated gross book value of depreciable assets in each producing unit or state. As a consequence of this definition, the parameter A_{13} represents the elasticity of production with respect to capital.

The labor input variate, P_{13}, used in this analysis is identical to that used in the initial analysis. That is, this variate represents the flow concept of labor services consumed in the production process and is measured in terms of man-hours worked by production workers. The parameter B_{13} represents the elasticity of production for this labor variate.

The intercept parameter T_{13}, and the error term E_{13} are defined in the same way as in the earlier analyses.

In summary, the third analysis differs from both the first and second analyses only on the basis of differences in the specification of labor in the production process. In the initial analysis the flow concept of labor services attributable to production workers was represented by one input variate and the stock concept of numbers of nonproduction workers used was represented by another input variate. In the second analysis the contributions of both production workers and nonproduction workers were aggregated and considered as one input variate which represented the stock concept of all employees used. In the third analysis only the flow concept of labor services consumed from production workers is included as a labor input variate. The role of the nonproduction workers is ignored.

The Results

The production function which resulted from this analysis is

$$\ln V_{13} = 1.52 + \underset{(0.23053)}{0.50472} \ln K_{13} + \underset{(0.23246)}{0.61735} \ln P_{13}$$

or in the original Cobb-Douglas form as

$$V_{13} = 1.52\, K_{13}^{0.50472} P_{13}^{0.61735}$$

The estimated elasticity of production for capital and its standard error were used in the t test to test the hypothesis that $A_{13} = 0$. On the basis of the computed t value, $t = 2.1894$ with 32 d. f., the hypothesis that $A_{13} = 0$ was rejected at the 5 percent level. However, the hypothesis was accepted at the 1 percent level.

The same procedure was used to test the hypothesis that $B_{13} = 0$.

With a computed t value of 2.6557 with 32 d.f., the hypothesis was rejected at the 5 percent level but accepted at the 1 percent level.

It is apparent from a comparison of the two estimated coefficients with their respective standard errors that the elasticities in this analysis are not as well-estimated as were those in the previous analyses.

The sum of the estimated coefficients, $a_{13} + b_{13} = 1.12207$, and the standard error of this estimated sum, 0.12277, were used in the test of hypothesis that $A_{13} + B_{13} = 1$. On the basis of the computed t value, $t = 1.6643$ with 32 d.f., the hypothesis that $A_{13} + B_{13} = 1$ was accepted at both the 5 percent and 1 percent levels. Therefore, the industry is considered to produce under constant returns to scale.

The coefficient of determination or R^2 which resulted from this analysis was 0.86. That is, 86 percent of the variation in value added output was accounted for in the regression by the two input variates as defined above. This result is identical to that obtained in the second analysis ($R^2 = 0.86$), and somewhat worse than that obtained in the initial analysis, ($R^2 = 0.89$).

The following matrix presents the correlation coefficients generated in this analysis (p. 90).

It is apparent from these coefficients that while there is high correlation between each of the input variates and the output variate, there also is almost as high a correlation between the two input variates. The problem of multicollinearity has not diminished with the specification of variates presented in this analysis.

	Value Added (V_{13})	Capital (K_{13})	Production workers (P_{13})
Value added (V_{13})	1.000	0.907	0.876
Capital (K_{13})	-	1.000	0.847
Production workers (P_{13})	-	-	1.000

Fourth Analysis

The details of the national analysis based on a fourth set of variates is presented in this section.

The Model

The form of the model used is unchanged. However, the model is expanded to include an additional input variate as was done in the initial analysis. The model appears as

$$V_{14} = T_{14}\, K_{14}^{A14} P_{14}^{B14}\, S_{14}^{C14}\, E_{14}$$

The output variate V_{14}, the intercept parameter T_{14}, and the error term E_{14} have the same interpretation in this analysis as they have had in previous analyses.

In this analysis the separate influences of the two kinds of labor input are considered individually as they were in the initial analysis. That is, the input variate P_{14} refers to the contribution of production workers. The observations on this variate are measured as the flow of man-hours worked by production workers. Consequently, the parameter B_{14} is the elasticity of production for man-hours worked.

The input variate S_{14} refers to the contribution of nonproduction workers and is measured as the stock concept of numbers of nonproduction workers used. The parameter C_{14} is the elasticity of production for the number of nonproduction workers used.

The difference between this analysis and all the previous analyses is based on the specification of the capital input variate. Earlier discussion emphasized the problems associated with selecting the proper measure of capital to use in aggregate production analyses. The rationale for using a stock concept of capital was presented. While the measure of capital used in the previous analyses, that is, gross book value of depreciable assets, has been used by several researchers, it was emphasized that for this study this measure of capital is not available in the form of aggregates for each state producing unit. Consequently, the national total was prorated over the sample states on the basis of costs of materials used. It is recognized that this method of proration, while it can be justified, does introduce a bias into the observations on capital for each state. This situation suggests that some other measure of capital be considered.

The measure of capital selected and used in this analysis is new capital expenditures. There are several good reasons for this choice and, unfortunately, some undesirable features. The first reason is a pragmatic one rather than a theoretical one. That is, Census publishes for Logging Camps and Contractors, SIC 2411, the total expenditure on new capital for each state producing unit. These data include, as stated by Census (U. S. B. C., C. M., MC 63(2) - 24A, 1966, p. 34)

> expenditures made during the year for permanent additions and major alterations to their plants, as well as for new machinery and equipment purchases, that were chargeable to fixed asset accounts of manufacturing establishments and were of a type for which depreciation accounts are ordinarily maintained. Expenditures for machinery and equipment were to include those made for replacement purposes, as well as for additions to plant capacity. Excluded from such expenditure totals are costs of maintenance and repairs charged as current operating expense; new facilities and equipment leased from non-manufacturing concerns . . .

As this measure of capital in use in the production process is reported by states no bias is introduced into the data from arbitrary prorating schemes.

Another reason for this choice is that new capital expenditures may be a reasonable proxy for real capital consumption in the production process. A full explanation for this reasoning would require a detailed discussion on the vintage effects of capital and technological change. This topic is beyond the scope of this thesis. However, Gort and Boddy (1967, p. 395) have suggested that of all the firm's or industry's capital assets, the newest assets are used the most in the production process. The older or partially worn assets represent outdated or antiquated technologies and frequently these are used only when operations reach the limits of capacity for the newest capital. Additionally, while new capital expenditures are allocated to purchases of new equipment embodying the latest technologies,

> It is recognized that a large portion of capital expenditures in the United States constitute outlays on "modernization".

(Gort and Boddy, 1967, p. 401). These expenditures for modernization are undertaken to incorporate into older machines as much new technology as is possible.

It is suggested that as new capital expenditures are undertaken to replace old technologies made obsolescent through use, these expenditures represent a measure of real capital consumption in the production process. It is recognized that some portion of new capital expenditures is invested in capital assets whose services are not consumed in current production but are postponed for consumption at a later date. For this reason, data on new capital expenditures may over estimate real capital consumption. At the same time, however, some capital services are being consumed from older assets purchased in earlier time periods. Data on new capital expenditures do not include those assets nor their capital services and therefore tend to under-estimate real capital consumption.

There is no empirical evidence to indicate to what extent the overestimate of real capital consumption incorporated into new capital expenditures data because of postponed use is compensated for by the underestimate attributable to capital services flowing from assets purchased in previous periods. However, in view of the generally accepted position that new assets are used most in the production process, the use of data on new capital investiments is used here, with some reservations, as a proxy for real capital consumption.

The capital input variate K_{14} has been defined above. The parameter A_{14} is the elasticity of production for new capital investment.

The Results

The production function which resulted from the analysis is

$$\ln V_{14} = 1.54 + \underset{(0.07763)}{0.77610} \ln K_{14} + \underset{(0.13538)}{0.69200} \ln P_{14} - \underset{(0.07485)}{0.18204} \ln S_{14}$$

which when transformed into the original Cobb-Douglas form appears as

$$V_{14} = 1.54\ K_{14}^{0.77610} P_{14}^{0.69200} S_{14}^{-0.18204}$$

The estimated elasticity of production for capital a_{14} and its standard error were used in the test of hypothesis that $A_{14} = 0$. On the basis of the computed t value, t = 9.9974 with 31 d.f., the hypothesis that $A_{14} = 0$ was rejected at the 5 percent level and the 1 percent level.

The estimated elasticity of production for production workers b_{14} and its standard error were used to test the hypothesis that $B_{14} = 0$. On the basis of the computed t value, t = 5.1115 with 31 d.f., the hypothesis that $B_{14} = 0$ was rejected at the 5 percent and the 1 percent levels.

The estimated elasticity of production for nonproduction workers c_{14} and its standard error were used to test the hypothesis that $c_{14} = 0$. On the basis of the computed t value, t = 2.4320 with 31 d.f., the hypothesis that $C_{14} = 0$ was rejected at the 5 percent level. However, this hypothesis was accepted at the 1 percent level.

It is apparent from a comparison of the estimated coefficients for capital and production workers with their respective standard errors that these coefficients are well-estimated. However, the coefficient for the nonproduction workers variate is not as well-estimated. This variate is suspect because of the negative sign attached to it. The reasons for questioning the validity of this result were presented in the initial analysis where a comparable result occurred on this same variate. However, if one is prepared to accept the test of hypothesis at the 1 percent level, then the conclusion is that the parameter C_{14} is not significantly different from zero and the negative sign on the estimate is irrelevant.

The sum of the estimated coefficients, $a_{14} + b_{14} + c_{14} = 1.28606$, and the standard error of this sum, 0.06789, were used in the test of hypothesis that $A_{14} + B_{14} + C_{14} = 1$, that is, that constant returns to scale prevail in the industry. On the basis of the computed t value, $t = 4.2142$ with 31 d. f., this hypothesis is rejected at the 5 percent level and the 1 percent level. The conclusion is that on the basis of sample evidence the sum of the coefficients is significantly greater than 1. Therefore, constant returns to scale do not prevail but rather, increasing returns to scale prevail.

The coefficient of determination or R^2 which resulted from this analysis was 0.947. Approximately 95 percent of the variation in the output variate was accounted for in the regression by the 3 input variates as defined above. This was the largest R^2 obtained from all the analyses on the national industry.

The correlation coefficients generated in the analysis are presented in the following matrix (p. 97).

It is apparent from these coefficients that high correlation exists between the output variate and both the capital and production workers input variates. This is anticipated. There is a considerably lower correlation between the output variate and the nonproduction workers input variate. This result was not anticipated a priori because it was believed this class of workers contributed to the production process. However, giving consideration to the negative coefficient on this variate and the fact that the coefficient was not well-estimated, this result is accepted.

The intercorrelation between the input variates, or multicollinearity, does not appear to be excessive in view of the high R^2 obtained.

	Value Added (V_{14})	Capital (K_{14})	Production workers (P_{14})	Non-production workers (S_{14})
Value added (V_{14})	1.000	0.950	0.876	0.575
Capital (K_{14})	-	1.000	0.806	0.588
Production workers (P_{14})	-	-	1.000	0.740
Nonproduction workers (S_{14})	-	-	-	1.000

Fifth Analysis

The details of the national analysis based on the fifth and last set of variates is presented in this section.

The Model

Again, the form of the model used is unchanged. However, the functional relationship is based on two input variates only. The model is

$$V_{15} = T_{15} K_{15}^{A_{15}} L_{15}^{B_{15}} E_{15}$$

In this model the output variate V_{15}, the intercept parameter T_{15}, and the error term E_{15} are defined no differently than in the four previous analyses.

The capital input variate K_{15} represents new capital expenditures as described in the fourth analysis. The parameter A_{15} is the elasticity of production with respect to new capital expenditures.

The labor input variate L_{15} represents all employees (production workers and nonproduction workers) as described in the second analysis. Following this, the parameter B_{15} is the elasticity of production with respect to all employees.

The Results

The production function estimated is

$$\ln V_{15} = 3.34 + \underset{(0.08525)}{0.78592} \ln K_{15} + \underset{(0.12687)}{0.51009} \ln L_{15}$$

or in original Cobb-Douglas form as

$$V_{15} = 3.34\, K_{15}^{0.78592}\, L_{15}^{0.51009}$$

Both coefficients and their standard errors were used in tests of hypotheses. The first hypothesis tested, that $A_{15} = 0$, resulted in a t value of 9.2190 with 32 d.f.. Consequently the hypothesis that $A_{15} = 0$ was rejected at the 5 percent and 1 percent levels. The second hypothesis tested, that $B_{15} = 0$, resulted in a t value of 4.02057 with 32 d.f.. Consequently the hypothesis that $B_{15} = 0$ was rejected at the 5 percent and 1 percent levels. It appears that A_{15} and B_{15} are both well-estimated by their respective statistics a_{15} and b_{15}.

The sum of the coefficients, $a_{15} + b_{15} = 1.29601$, and the standard error of the sum, 0.07661, were used to test the hypothesis that constant returns to scale prevails in the industry, that is, $A_{15} + B_{15} = 1$. As the computed t value equalled 3.4514 with 32 d.f., the hypothesis that $A_{15} + B_{15} = 1$ was rejected at the 5 percent and 1 percent levels. That is, $A_{15} + B_{15}$ is significantly greater than 1. Therefore constant returns to scale do not prevail in the industry but rather increasing returns to scale prevail.

The coefficient of determination or R^2 which resulted from this analysis was 0.935. Approximately 94 percent of the variation in the output variate was accounted for in the regression by the two input variates defined above. This was a superior result to all previous analyses excepting the fourth analysis.

The following matrix contains the correlation coefficients generated in the analysis.

	Value Added (V_{15})	Capital (K_{15})	All Employees (L_{15})
Value added (V_{15})	1.000	0.950	0.875
Capital (K_{15})	-	1.000	0.809
All employees (L_{15})	-	-	1.000

These correlation coefficients indicate that a high correlation exists between each of the input variates and the output variate. This result was anticipated. The problem of multicollinearity still exists. However, this high intercorrelation between the capital input variate and the all employees input variate does not appear to be excessive when considered in conjunction with the high R^2 obtained.

Evaluation of the Estimated Production Functions

The results obtained from the analysis based on the initial set of variates selected for this study were illogical in some respects. As a consequence, additional analyses were undertaken. Five sets of variates were defined and used in five separate analyses. These analyses produced considerable information which is consolidated and reviewed in this section. To facilitate this task, a summary of results is presented on page 102.

The summary shows the considerable difference in results that obtains from a standardized analysis when input variates are defined differently and when variates are added to or eliminated from the production function. Leser (1958, p. 40) illustrated this situation in his review of 45 Cobb-Douglas studies. His comment on these varying results is that

> This is not really surprising, for the statistical difficulties inherent in the nature of the problem are indeed great. For one thing, it is difficult to obtain satisfactory basic data, and in particular, the construction of an index of real capital presents a tricky problem. Furthermore, there is often multicollinearity between the variables, and the regression coefficients become unreliable.

It is noted that most of the Cobb-Douglas studies in the Leser publication are either time-series studies or those where *a priori* constant returns to scale have been specified in the model. Neither of these characteristics applies in this logging study. However, differences in results also appear in those few studies cited by Leser where cross-section analysis has been applied to the unrestricted Cobb-Douglas model.

The intent of this section is to evaluate the results of each of the five national analyses and eliminate those analyses which, on the

Summary of National Analyses

		Capital Coefficients			Labor Coefficients			
Analysis	Intercept	Assets	Expenditures	Man-hours	Nonproduction	All	Sum of Coefficients	R^2
1	0.618	+0.55910*	-	+0.84282*	-0.31856*	-	+1.08336	0.89
		(0.09682)		(0.19449)	(0.10877)		(0.10877)	
2	2.06	+0.51067*	-	-	-	+0.61572*	+1.12639	0.86
		(0.10914)				(0.21058)	(0.13058)	
3	1.52	+0.50472*	-	+0.61735*	-	-	+1.12207	0.86
		(0.23053)		(0.23246)			(0.12277)	
4	1.54	-	+0.77610*	+0.69200*	-0.18204*	-	+1.28606**	0.95
			(0.07763)	(0.13538)	(0.07485)		(0.06788)	
5	3.34	-	+0.78592*	-	-	+0.51009*	+1.29601**	0.94
			(0.08525)			(0.12687)	(0.07661)	

*Significantly different from zero at $P \leq 0.05$
**Significantly different from one at $P \leq 0.05$

Correlation matrices

	V_{11}	K_{11}	P_{11}	S_{11}
V_{11}	1.000	0.907	0.876	0.575
K_{11}	-	1.000	0.847	0.695
P_{11}	-	-	1.000	0.740
S_{11}	-	-	-	1.000

	V_{12}	K_{12}	L_{12}
V_{12}	1.000	0.907	0.875
K_{12}	-	1.000	0.853
L_{12}	-	-	1.000

	V_{13}	K_{13}	P_{13}
V_{13}	1.000	0.907	0.876
K_{13}	-	1.000	0.847
P_{13}	-	-	1.000

	V_{14}	K_{14}	P_{14}	S_{14}
V_{14}	1.000	0.950	0.876	0.575
K_{14}	-	1.000	0.806	0.588
P_{14}	-	-	1.000	0.740
S_{14}	-	-	-	1.000

	V_{15}	K_{15}	L_{15}
V_{15}	1.000	0.950	0.875
K_{15}	-	1.000	0.809
L_{15}	-	-	1.000

basis of evidence presented and this writer's reasoning, are dominated by those analyses which are more credible.

Elimination of the Initial Analysis

The manner in which the variates used in the initial analysis are defined has been presented earlier along with the results of that analysis. The undesirable aspects of the results were the occurrence of a negative coefficient on the nonproduction workers input variate and the evidence of multicollinearity. The negative coefficient presents serious implications for the productivity analyses to be presented later.

The desirability of retaining the nonproduction workers variate in the production function is now examined. Leser (1966, p. 27) states that

> Broadly speaking, a variable is considered as useful if its addition substantially increases the value of R^2. If it does not and its addition leaves the remaining regression coefficients largely unchanged, it is described as superfluous; generally the regression coefficient on a superfluous variable is small and insignificant. If the addition of the variable substantially changes all estimates of regression coefficients without noticeably improving the fit, it is taken to be detrimental . . . If the presence of multicollinearity has been established, it is not always easy to remedy this state of affairs. If a detrimental variable is omitted to obtain more reliable results for the other variables, this omission must be borne in mind when interpreting the results. It cannot be said that the omitted variable

> has no effect but merely that its effect is confounded with that of the other explanatory variables and cannot be isolated.

The decision as to retain or eliminate the third input variate in the function is the same decision as choosing between the initial analysis and the third analysis. The third analysis is in fact the initial analysis without, or prior to, adding the third variate.

The elimination of the nonproduction workers variate results in a reduction of the R^2 by only 3 percent, that is, from 0.89 to 0.86. While this action eliminates the troublesome negative coefficient, it also changes the magnitude of the coefficients on the two remaining input variates and changes the sign, from negative to positive, on the logarithm of the estimated intercept parameter.

Following Leser's position, the nonproduction workers input variate is considered to be detrimental and therefore is eliminated. The initial analysis is eliminated in favor of the third analysis as a consequence. This decision results in eliminating the production function having the highest R^2 among those functions which were based on capital input defined in terms of estimated gross book value of depreciable assets. Additionally, the estimated coefficients in the preferred third analysis are not as high multiples of their standard errors as are those in the initial analysis. This fact produced somewhat different conclusions between the two analyses to the tests of hypotheses on the coefficients. The conclusions drawn on the sum of the coefficients at both the 5 percent and 1 percent levels, and the conclusions drawn on the individual coefficients at the 5 percent level were identical in the two analyses. However, whereas in the initial analysis the conclusion was drawn at the 1 percent level that the individual coefficients were significantly different from zero, in the third analysis, because of the lower multiple of the coefficients with respect to their standard errors, the conclusion at the 1 percent level was that the individual coefficients equalled zero.

Having due consideration for these factors, the initial analysis is eliminated from the remaining study of the national logging industry.

Comparability of the Second and Third Analysis

While the third analysis is preferred over the first analysis for reasons presented above, some features of the third analysis deserve further comment. The first of these is the high multicollinearity existing between the two input variates. The second, while not overly serious, is the combination of stock and flow concepts of resource inputs within the same function. That is, capital is measured as a stock concept in terms of estimated gross book value of depreciable assets available for use while labor is measured as a flow concept in terms of man-hours of production workers' services consumed. The third and most questionable feature is that no consideration is given to the contribution of the non-production workers. It is recognized that when these workers were considered explicity by a separate input variate as was done in the initial analysis, very questionable results were obtained. However, the opportunity exists for combining the nonproduction workers' contribution with the production workers' contribution into one labor input variate. This input variate is the all employees variate which represents the stock concept of total number of production and nonproduction workers available for use in the production process.

The second analysis incorporates this change into the labor input variate P_{12} as an attempt to overcome the features of the third analysis questioned above. The results of the second analysis show that the use of the newly defined labor variate does not contribute to any substantial change over the third analysis with respect to either the R^2 obtained or the degree of multicollinearity between input variates. Additionally, there is little change in the numerical values of the coefficients, and no change in the signs on these coefficients. However, the coefficients obtained in the second analysis appear to be better parameter estimates than those obtained in the third analysis. Whereas in the third analysis tests of the null hypothesis on each elasticity of production were accepted at the 1 percent level, in the second analysis these same tests were rejected at the 1 percent level. No difference appeared in the condition of returns to scale estimated for the industry.

It is apparent from the foregoing discussion that the change in definition of the labor input variate does not substantially improve the results. Statistically speaking, the change does not produce any poorer results but does provide better estimated coefficients. Economically speaking, while the change forces sacrifice of the flow concept of capital services consumed in production which is approached in the measure of man-hours worked, it does achieve incorporation of the supervisory contribution to production included in the measure of nonproduction workers. As a consequence, both the second and third analyses are retained for further consideration in this study.

Elimination of the Fourth Analysis

Even though the fourth analysis includes the interesting capital input variate defined in terms of new capital expenditures, it also includes the nonproduction workers input variate having a negative estimated coefficient. As the negative coefficient is considered to be a nonsense result, the fourth analysis is eliminated from further consideration in this study for similar reasons as presented in the discussion above on elimination of the initial analysis. The decision to eliminate the fourth analysis results in discarding a function which has several desirable statistical features. First, this function has the highest R^2 obtained in all 5 analyses. Additionally, the coefficients in this function are well-estimated, and the multicollinearity is no more serious than that existing in the other functions. However, the economic implications of the negative coefficient are considered to be more undesirable than the statistical features are desirable.

Retention of the Fifth Analysis

The fifth analysis is retained for further consideration in this study because it represents a fairly successful attempt to incorporate as an input variate in the production function, the concept of new capital expenditures. The function developed does not contain any troublesome negative coefficients and the coefficients appear to be well estimated. The R^2 obtained is relatively high and only 1 percent less than the R^2 on the rejected function estimated in the fourth analysis. The multicollinearity is comparable to that resulting from previous analyses. This success is achieved by sacrificing the desirable flow concept of labor input services as measured by man-hours worked by production workers for the less desirable stock concept of labor input as measured by all employees. However, the undesirable features resulting from this analysis are considered to be of less importance than the desirable features achieved, particularly the achievement of positive signs on the estimated coefficients.

The plan for the development of this research study was predicated on the assumption that reasonable results would obtain from the set of variates as defined for use in the initial analysis. That assumption proved to be erroneous. Consequently, four alternative sets of variates were defined and used to estimate four alternative production functions. Results of the five analysis have been presented and compared. For the reasons discussed, two analyses have been rejected. Both analyses rejected included as a separate input variate the contribution to production of those workers classified as nonproduction workers. The three analyses retained, that is, the second, third, and fifth analyses, provide comparable statistical results but different economic interpretations. These economic interpretations have been discussed briefly but will be considered in more detail later in this chapter.

Resource Productivity

Resource productivity estimates provide considerable information on the conduct of an industry. As a necessary condition for achieving efficient resource use, production theory requires an industry operating in competitive markets and in a state of equilibrium to allocate dollar expenditures on a resource in such a manner as to equate the marginal cost of the resource with the marginal productivity of the resource. Another condition necessary for achieving efficient resource use is to allocate expenditures for resources in such a manner that equal marginal products are earned by the last dollar spent on each resource (Heady, 1952, p. 708).

The economics literature contains many theoretical references on the estimation of resource productivity from aggregate production functions. However, empirical studies on this topic are reported on infrequently in the literature. An exception to this generalized statement on productivity analysis occurs in the literature on the agricultural industry.

Klein (1962, p. 93) has presented a theoretical discussion on the productivity analysis based on the Cobb-Douglas function. Briefly, the contribution of any resource input to total production is measured by the marginal productivity of that input. The marginal productivity of the input may be visualized as the slope of the production function when graphed in the input-output dimensions as all other inputs are held constant. The slope of the Cobb-Douglas function changes as the application of input increases. However, this function has the desirable property of becoming linear when expressed in logarithmic units. After logarithmic transformation, the slope is constant and is identified by the estimated coefficient of the elasticity of production. The axes of the graph are in logarithmic units not arithmetic units. As a result, the marginal productivity of the input resource is estimated from the product of the elasticity of production and the average productivity of the resource.

This relationship between marginal productivity, elasticity of production, and average productivity can be illustrated by an example.

Let output = 0

Let input = I

and let the elasticity of production for I = a

Therefore, $$a = \frac{\%\text{ change in }0}{\%\text{ change in I}}$$

$$a = \frac{(\text{change in }0)/(0)}{(\text{change in I})/(\text{I})}$$

$$a = \frac{(\text{change in }0)}{(0)} \cdot \frac{(\text{I})}{(\text{change in I})}$$

$$a = \frac{(\text{change in }0)}{(\text{change in I})} \cdot \frac{(\text{I})}{(0)}$$

But, $\frac{(\text{change in }0)}{(\text{change in I})}$ is the marginal physical product (MPP) for I.

Therefore, $a = (\text{MPP}) \cdot \frac{(\text{I})}{(0)}$

or $\frac{(0)}{(\text{I})} \cdot (a) = \text{MPP}$

But, $\frac{(0)}{(\text{I})}$ is the average physical product (APP) for I.

Therefore, $\text{MPP} = (a) \cdot (\text{APP})$

or, the marginal physical product for input I equals the elasticity of production for I times the average physical product for I. This relationship indicates another important property of the Cobb-Douglas function. That is, marginal and average products are proportional, and the factor of proportionality is the elasticity of production

(Klein, 1962, p. 94).

As a result of this relationship, the estimated marginal productivity of each factor input can be derived with no difficulty after the production function has been estimated. However, as the productivity estimate is based on a sample of observed data, the estimate is subject to sample variation. Consequently, the standard error of each productivity estimate should be calculated also to permit testing hypotheses on both the reliability of the estimates and the comparability between estimates (Tintner, 1956, p. 126).

The methodology for calculating the standard error of the marginal productivity estimate has been the subject of some discussion in the theoretical literature. To facilitate a brief discussion of the controversy and to justify the approach used in this study, reference is made to the relationship between marginal physical product, average physical product and elasticity of production presented above where the equation $MPP = (a) \cdot \frac{(0)}{(I)}$ was developed. The approach used in the studies by Tintner and Brownlee (1944, p. 566), Heady (1946, p. 989), and Heady and Swanson (1952, p. 765), was to estimate marginal productivity first at the geometric mean of the factor input, which is mean marginal productivity, and second at the fiducial limits at the 5 percent level of probability. In these calculations, the variability in the productivity estimate (MPP) was determined only by the variability associated with the estimated elasticity of production (a). The average physical product $\frac{(0)}{(I)}$ was considered to be a constant.

Carter and Hartley (1958, p. 306) have suggested that the methodology used in the above cited studies is erroneous. They argue that when estimating the variance of productivity estimates in Cobb-Douglas analyses, one must recognize that not only is there variability associated with the estimated elasticity of production (a), but also, there is variability associated with the estimated average physical product $\frac{(0)}{(I)}$. The reason for this latter variability is that even though it is legitimate to consider (I) as being a constant, the output (0) is predicted at any (I) level from the estimated production function and therefore will have sample to sample variability. Carter and Hartley proceed to develop a more realistic variance formula for marginal productivity estimates and verify the merit of its use through some empirical comparisons. However, they state (Carter and Hartley, 1958, p. 309),

> The error committed using (the earlier approach) will usually be small if the estimate of the variance is made near the geometric mean of the independent variable. The error rapidly increases, however, as we make our estimate further away from the geometric mean quantities.

A more recent article by Fisk (1966, p. 162) has presented a third approach for estimating the variances of marginal productivity estimates. Fisk compared his approach with both that of Carter and

Hartley and the earlier authors who considere d only the variability associated with the estimated elasticity of production. His general conclusion was that the three approaches provide comparable results when marginal productivity estimates are derived for the geometric mean levels of factor inputs.

The marginal productivity estimates derived in this study are mean marginal productivities. That is, they are restricted to the geometric mean level of resources used. Consequently, the estimated standard errors on the marginal productivities are calculated by the same method used by Heady and Swanson (1952).

For reasons presented earlier, the initial and fourth analyses of the national industry were eliminated from further consideration in this study. As a consequence, marginal productivity estimates and tests of hypotheses on these estimates are undertaken for only those factor inputs used in the second, third, and fifth analyses.

Second Analysis

The data required for the productivity analyses are the mean level of output ($\bar{V}_{12}$), the mean level of capital input ($\bar{K}_{12}$), and the mean level of labor input ($\bar{L}_{12}$). These mean values are derived from the computer output as

$$\bar{V}_{12} = \$25,400.00$$
$$\bar{K}_{12} = \$22,700.00$$
$$\bar{L}_{12} = 4.4 \text{ employees}$$

The estimated coefficients and their standard errors for the capital and labor inputs have been presented previously.

Capital Productivity. The estimated mean marginal productivity of capital is

$$= \frac{\bar{V}_{12}}{\bar{K}_{12}} (a_{12})$$

$$= \frac{25,400}{22.700} (0.51067)$$

$$= 0.56684$$

The meaning of this estimate is that on the average, an additional dollar invested in gross book value of depreciable assets contributes an additional 57 cents, approximately, to value added output.

The standard error of the estimated mean marginal productivity for capital is

$$= \frac{\bar{V}_{12}}{\bar{K}_{12}} (\text{standard error of } a_{12})$$

$$= 1.11 (0.10914)$$

$$= 0.12114$$

or approximately $\pm$ 12 cents.

As this estimate considers only the variability associated with the coefficient a_{12}, there is no reason for testing the hypothesis that the marginal productivity of capital is equal to zero. The same hypothesis was tested previously when the test that $A_{12} = 0$ was performed (Fisk, 1966, p. 164). The hypothesis that $A_{12} = 0$ was rejected. Consequently, the marginal productivity for capital is considered to be significantly different from zero.

The information available on the use of capital by the logging industry is not as plentiful as desired. Consequently, it is difficult to draw meaningful inferences on the reationality of capital use in roundwood production. It is reiterated here that in this analysis capital is defined as estimated gross book value of depreciable assets. No precise relationship between this stock concept and the flow concept of capital consumption in production can be formulated with available data.

The empirical results of the analysis show the estimated mean marginal productivity per dollar of capital stock to be 57 cents. This is equivalent to a marginal rate of return of 57 percent. A rate of return of this magnitude to capital in logging appears to be excessive. However, Heady and Swanson (1952, p. 766) encountered very high mean marginal productivities for certain capital items used in Iowa farm production. They suggest capital is not being used in sufficiently large quantities to achieve efficiency. Their reasoning is that as the borrowing rate for investment credit is considerably less than the indicated marginal rate of return, funds should be borrowed for increased capital investment until the marginal rate of return on capital falls to equal the cost of capital. Data on the borrowing rates for credit to the logging industry are not available. It is doubtful the rates approached 57 percent in 1963. Consequently, this evidence suggests the logging industry was undercapitalized at that time.

Other evidence suggests the conclusion of an undercapitalized logging industry may be erroneous. Census publishes for this industry the national total value added in manufacture and the total payroll for all employees. These were \$520, 475, 000. 00 and \$281. 845, 000. 00 respectively. If one assumes, as does Maroney (1967, p. 45), that value added may be partitioned into two parts, one part representing payroll which is paid to employees for their contribution to production and one part representing quasi-rent which is paid to capital for its contribution to production, then the quasi-rent in this analysis amounts to \$238, 612, 000. 00. Census also reports a total gross book value of depreciable assets of \$529, 308, 000. 00 in the industry. If the quasi-rent of \$238, 612, 000. 00 represents a cost to the industry for use of the \$529, 308, 000. 00 of capital, the average rental payment per dollar of capital is approximately \$0. 45. Additionally, if one assumes average cost and marginal cost are equal, then the marginal cost of capital to the industry is \$0. 45 which is approximately equal to the statistically estimated marginal productivity of capital found earlier to be \$0. 57 $\pm$ 0. 12. Consequently, this evidence suggests the logging industry is using capital rationally and therefore the industry is not undercapitalized.

Further evidence on the use of capital by the industry can be developed by comparing the share of output returned to capital as suggested by Census data with the share that ought to be returned as suggested by production theory. Production theory states that where an industry operates under constant returns to scale, the estimated elasticities of production indicate the shares of total value product imputed to the input resources. In an earlier section the hypothesis that constant returns to scale prevails in this industrial analysis was accepted. Consequently, one would expect the share of value added returned to capital as quasi-rent would approximate the estimated elasticity of production on this variate. That statistic was estimated to be 0.51 ± 0.12. In the previous paragraph published Census data and the notion of quasi-rent were used to calculate capital's share of value added as 0.45. As the empirically estimated share from the regression analysis compares favorably with the actual share, the conclusion is made that capital is paid what it contributes to production.

<u>Labor Productivity.</u> The mean marginal productivity for labor is

$$= \frac{\bar{V}_{12}}{\bar{L}_{12}} \quad (b_{12})$$

$$= \frac{25,400}{4.44} \quad (0.61572)$$

$$= 3,3522.36$$

or approximately $3,522.00.

The meaning of this estimate is that on the average, when one additional employee is used in the production process, an additional output of approximately \$3,522.00 of value added results.

The standard error of this estimate is

$$= \frac{\bar{V}_{12}}{\bar{L}_{12}} \text{ (standard error of } b_{12})$$

$$= 5,720.72 \ (0.21058)$$

$$= 1,204.51$$

or approximately $\pm$ \$1,205.00.

As the hypothesis that $B_{12} = 0$ has been tested previously, there is no need here to test the hypothesis that the mean marginal productivity of labor equals zero. The hypothesis that $B_{12} = 0$ was rejected. Consequently, the mean marginal productivity of labor is considered to be significantly different from zero.

If one makes the assumption that employees are hired by the logging industry in competitive markets, then the marginal cost for an additional employee is equal to the average cost per employee. Census provides data on the total number of employees and the total payroll in this industry. These are 73,130 and \$281,845,000.00 respectively. Consequently, the average cost, and by assumption the marginal cost per employee is approximately \$3,854.00. The marginal cost and the marginal value product per employee are comparable when one considers the standard error on the estimated marginal productivity. As the marginal product is calculated at the geometric mean level of input, and as the geometric mean tends to underestimate the arithmetic mean, the marginal cost and marginal product per employee tend more to equality than the above figures indicate.

Additional evidence on the use of employees by the industry is gained from a comparison between the estimated share of value added returned to employees and the share calculated from published data. The estimated share derived from the estimated elasticity of production on this variate is approximately 0.62 ± 0.21. Census reports the logging industry produced $520, 457, 000. 00 of value added in 1963 and made payroll payments of $281, 845, 000. 00 to all employees. The payroll payment represents a factor share of value added approximating 0. 54. This factor share compares favorably with that estimated through the regression analysis.

The evidence presented by these results suggests the logging industry uses employees efficiently in roundwood production. On the average, employees are utilized to the level where their marginal cost to the industry equals their marginal productivity, and these employees receive payments equal to their contribution to value added in roundwood production.

Productivity Comparisons. It would be desirable to compare the mean marginal productivity of capital with the mean marginal productivity of labor to ascertain if the last dollar spent on each resource contributed an equal amount to value added. However, in this analysis, the mean marginal productivity of capital is estimated for capital input measured in dollars while the mean marginal productivity of labor is estimated for labor input measured in numbers of employees, not in dollars. As the bases on which the two marginal productivities are estimated are not comparable, there is no good reason for comparing the productivities.

Third Analysis

Following the methodology used in the previous section, the productivities of the resources used in the third analysis are estimated and analyzed. The data required are

$$\bar{V}_{13} = \$25,400.00$$

$$\bar{K}_{13} = \$22,700.00$$

$$\bar{P}_{13} = 7,490 \text{ man-hours}$$

and the estimated coefficients on the input variates along with their standard errors. The latter estimates were derived previously.

Capital Productivity. The estimated mean marginal productivity of capital is

$$= \frac{\bar{V}_{13}}{\bar{K}_{13}} (a_{13})$$

$$= \frac{\$25,400.00}{\$22,700.00} (0.50472)$$

$$= 0.56023$$

This estimate means on the average an additional dollar invested in gross book value of depreciable assets contributes an additional \$0.56, approximately, to value added output.

The standard error of this estimate is approximately \$0.26.

The hypothesis that $A_{13} = 0$ was tested previously and rejected. Consequently, the inference here is the mean marginal productivity of capital is significantly larger than zero.

The estimate of productivity derived here is comparable to the estimate on the same variate obtained in the second analysis. The two analyses are identical with respect to the capital input data used. However, because the labor variates are defined differently in the two analyses, the estimated coefficients on the variates differ. It is the difference in the estimated coefficients on capital which accounts for the small difference in the estimated marginal productivity of capital found in this analysis.

The discussion presented in the second analysis respecting the efficiency of capital use in the logging industry applies as well to capital use in this analysis because of the comparable results. Briefly, the mean marginal productivity of capital estimated as $\$0.56 \pm 0.26$ appears to be excessive. However, if the notion of quasi-rent is used then the marginal cost of capital calculated as \$0.45 approximates the return. Additionally, capital's share of value added as indicated by the estimated coefficient of 0.50 ± 23 compares well with the share of

0.45 calculated from quasi-rent. This crude evidence suggests capital is used rationally in the logging industry.

Labor Productivity. The mean marginal productivity for labor is

$$= \frac{\bar{V}_{13}}{\bar{P}_{13}} (b_{13})$$

$$= \frac{\$25,400}{7,490} (0.61735)$$

$$= \$2.09$$

which means when one additional man-hour of production worker services is used in the production process, on the average an additional output of $2.09 of value added results.

The standard error of this estimate is

$$= \frac{\bar{V}_{13}}{\bar{P}_{13}} (\text{standard error of } b_{13})$$

$$= 3.39\ (0.23246)$$

$$= 0.78803$$

or approximately $0.79.

The hypothesis that $B_{13} = 0$ was tested previously and rejected. Consequently, the inference here is the mean marginal productivity of labor is significantly larger than zero.

Census provides data on the total number of man hours worked by production workers and the total wages paid these workers in the logging. These are 122,505,000 and $254,122,000.00 respectively.

Consequently the average cost per man-hour to the industry is \$2.07. If one assumes the logging industry hires labor in competitive markets then the average cost per man-hour equals the marginal cost per man-hour. For all practical purposes the marginal productivity of one man-hour equals the marginal cost of one man-hour.

Additional evidence on man-hour use in the industry is gained from a comparison between the estimated share of value added returned to man-hours worked and the share calculated from published data. The estimated share derived from the coefficient on this variate in the production function is approximately 0.62 ± 0.23. Census reports the logging industry produced \$520, 457, 000.00 of value added in 1963 and made total payments of \$254, 122, 000.00 in wages for man-hours worked. The wage payment represents a factor share of value added approximating 0.49. This factor share compares favorably with that estimated from the production function.

The evidence presented by these results suggests the logging industry uses man-hours worked by production workers efficiently in the production process. On the average, man-hours are used to the level where their marginal cost to the industry equals their marginal productivity, and these man-hours worked receive a wage payment equal to their contribution to value added in roundwood production.

<u>Fifth Analysis</u>

The data required for estimating resource productivity in this analysis are

$$\bar{V}_{15} = \$25,400.00$$

$$\bar{K}_{15} = \$5,030.00$$

$$\bar{L}_{15} = 4.44 \text{ employees}$$

and the estimated coefficients on the input variates as well as their standard errors. The latter estimates were derived previously.

<u>Capital Productivity</u>. The estimated mean marginal productivity of capital is

$$= \frac{\bar{V}_{15}}{\bar{K}_{15}} \; (a_{15})$$

$$= \frac{\$25,400.00}{\$5,030.00} \; (0.78592)$$

$$= \$3.96866$$

or approximately \$3.97. This estimate means on the average, an additional dollar invested in new capital expenditures contributes an additional \$3.97, approximately to value added output.

The standard error of this estimate is approximately \$0.43.

The hypothesis that $A_{15} = 0$ was tested previously and rejected. Consequently, the inference here is the mean marginal productivity of new capital expenditures is significantly larger than zero.

The estimate for capital productivity derived here is not comparable to either of the two previous capital productivity estimates.

Whereas the two previous capital productivity estimates applied to a stock concept of capital, the estimate in this analysis applies to a proxy for the flow concept of capital consumption in roundwood production. The reasoning for this position was presented earlier.

The mean marginal productivity of new capital expenditures estimated at \$3.97 which is equivalent to a marginal rate of return of 397 percent, is exceptionally high. Following the argument of Heady and Swanson (1952, p. 766), a marginal productivity of this magnitude appears to be considerably in excess of the marginal cost of capital and therefore suggests the industry is undercapitalized. Consequently, the industry should continue investing in new capital facilities until the marginal productivity falls to equal the cost of capital.

Data on the cost of capital to the industry are not available. However, a crude approximation can be developed. From published Census data for 1963 it is known the industry generated \$520,457,000.00 in value added from which \$281,845,000.00 were paid to all employees as payroll costs. The residual \$238,612,000.00 could be considered as quasi-rent or the return to capital. Census also publishes the total expenditure for new capital. This expenditure amounted to \$95,602,000.00. If the quasi-rent payment is allocated to the total expenditure for new capital, the average payment to capital or cost to the industry for new capital results. This average cost is calculated to be \$2.50. If one assumes the industry borrows in competitive markets, the average cost of capital equals the marginal cost of capital. In these circumstances the evidence suggests the industry is not allocating sufficient funds to new capital investment because the marginal productivity of \$3.97 is considerably in excess of the marginal cost of \$2.50.

It is recognized the argument presented here is tenuous. New capital investment may be a poor proxy for real capital consumption. Some portion of new capital is not consumed in the current production period but is postponed for consumption in a later production period. Some consumption of capital in the current period is a result of capital investment in a previous period. Data are not available to indicate the extent to which current consumption from past investment compensates for future consumption from present investment. Should compensation not occur, the mean marginal productivity of capital obtained in the analysis is over-estimated and the marginal cost of capital calculated from Census totals is also over-estimated.

<u>Labor Productivity</u>. The mean marginal productivity for labor is

$$= \frac{\bar{V}_{15}}{\bar{L}_{15}} \quad (b_{15})$$

$$= \frac{25,400}{4.44} \; (0.51009)$$

$$= 2918.08$$

or approximately $2, 918. 00. On the average the addition of one employee to the production process results in an additional $2, 918. 00 of value added output.

The standard error of this estimate is $725. 79.

As the hypothesis that $B_{15} = 0$ has been tested previously and rejected, the conclusion here is the mean marginal productivity of all employees is significantly larger than zero.

An examination of Census data respecting the total number of employees in the industry and the total payroll payment to these employees reveals the average cost per employee to the industry to be $3, 854. 00. Assuming the market for employee services is competitive, the marginal cost per employee is also $3, 854. 00. As the marginal cost is considerably larger than the marginal productivity, the inference is the industry is employing more labor in roundwood production than can be justified and labor is receiving more than it contributes to value added.

Review of Results

Most results obtained in this chapter display considerable variability over the 5 approaches to the standardized analyses as the specification of input variates used is altered. However, the variability encountered is not inconsistent with findings of some other researchers (Leser, 1958, p. 60).

The only result which is consistent through the 5 approaches, irrespective of input variate specification, is the evidence of multicollinearity between the capital and labor variates. The multicollinearity does not appear excessive when considered in conjunction with the high R^2's obtained. Even though multicollinearity is a statistically undesirable feature, its present supports the concept of resource substitution in production. Previous discussion indicated roundwood production is a transportation or materials handling process comprised of distinct sequential operations. Each operation excepting the transportation of roundwood from the logging site to the conversion plant can be undertaken by highly capital intensive or highly labor intensive techniques, or techniques employing a wide range of capital-labor combinations. Examples of this diversity of resource combinations are common throughout the industry. As a roundwood production process evolves from low capital intensity to high capital intensity, the replacement of labor by capital occurs in a fashion more or less common throughout the industry. For example, a common development in the South is to replace hand loading techniques with machine loading techniques while in the Northwest, a common development on high-lead operations is to replace hand choker-setting with grapples. For these reasons, capital and labor are highly correlated in the roundwood production process. Consequently, it is not unreasonable to expect multicollinearity to occur in the analyses of this industry.

The most undesirable and disconcerting results occurred in the first and fourth analyses where supervisory or nonproduction workers were considered explicitly as a third input variate in the industrial production function. In both analyses negative coefficients were estimated on the nonproduction workers input variate. Economically this result means an increase in application of this kind of labor results in a decrease in output. Personal knowledge of the industry and a review of the basic data suggest the empirical results are unacceptable. Consequently, these two analyses were not considered for resource productivity estimates.

The variability in the remaining results appears to be predicated on the choice of specification for the capital input variate; that is, capital specified as estimated gross book value of depreciable assets (stock concept) as opposed to capital specified as new capital expenditures. The interesting differences in results are presented here.

Coefficient of Determination

Each of the production functions incorporating the stock concept of capital generated an R^2 of 0.86. This level of R^2 is considered to be low but considerably lower R^2's have been reported for aggregate production functions estimated in the agricultural industry. In those functions where the flow concept of capital was used, R^2's of 0.94 or more obtained. This range is consistent with the R^2's reported for aggregate production functions estimated in several manufacturing industries. Irrespective of the specification on the labor input variate, it is apparent the production functions incorporating the flow concept of capital account for more of the variability in output than do the functions using the stock concept of capital. This result tends to support the contention presented earlier that new capital investment is a reasonable proxy for capital consumption in the roundwood production process.

Elasticities of Production

Ignoring the production functions eliminated by reason of negative estimated coefficients, the functions incorporating the stock concept of capital provide approximately equal coefficients on both capital and labor input variates. However, in the function where the flow concept of capital input is used, the elasticity of production for capital is larger than the elasticity of production for labor.

These results have implications for policy makers, especially those who are anxious to increase the value added of roundwood production. The evidence provided by the results from the functions using the stock concept of capital suggest that a 1 percent increase in either labor or capital will increase output by the same amount;

that is, the percentage indicated by the comparable elasticities of production. However, the only way to increase the stock of capital input is to undertake new capital investment. The results of the regression using the latter concept indicate output is considerably more responsive to a 1 percent increase in new capital investment than it is to a comparable increase in labor input. Consequently, policy makers should exercise caution when interpreting the empirical results of production studies where the capital concept has not been discussed in detail.

Returns to Scale

Each of the production functions which incorporates the stock concept of capital input provides evidence to indicate constant returns to scale prevail in the industry. There is no advantage in terms of lower costs or higher returns accruing to producing units with large stocks of capital and large labor forces than to producing units with small capital stocks and small labor forces. This empirical result supports the assumption presented earlier indicating the logging industry approaches the conditions of pure competition presented in economic theory. Additional evidence supporting the empirical results derives from personal observations of the logging industry. One observes a viable coexistence among small roundwood producing units and large roundwood producing units.

Somewhat different results obtain from the production functions incorporating the flow concept of capital input. These functions indicate increasing returns to scale prevail in the industry. If true increasing returns do prevail in the industry the reasoning presented above respecting constant returns would be refuted. However, the two results may not be inconsistent. An attempt to rationalize the results is presented here. The reasoning is predicated on the difference in the two capital concepts under consideration.

It was suggested earlier that new capital is more productive than old capital because of the incorporation of new technology. Producing units which invest in new technology are also adding to their capital stock. Consequently, small producers become larger and large producers become even larger. At the same time small producers have a lesser amount of unproductive capital stock than do the large firms. Consequently, there can be increasing returns to new capital investment as well as constant returns to capital stock as long as the small producing units invest in capital at a comparable rate as the large producing units.

There were no comparable data available to indicate how the size distribution of producing units in the logging industry has changed over time.

Capital Productivity

Comparable estimates of mean marginal productivity of capital were obtained from the two production functions incorporating the stock concept of capital input. Diminishing mean marginal productivity was observed in both cases. The estimated productivities were high, approximating marginal rates of return of 57 and 56 percent. However, the marginal cost of capital calculated from aggregated data, and the share of value added returned to capital suggested by the estimated coefficient on capital provided evidence to suggest capital was used rationally in roundwood production. That is, capital was used to the point where its marginal cost equalled its marginal productivity and capital was reimbursed to the extent of its contribution to value added output.

A quite different result obtained from the production function incorporating the flow concept of capital input. The mean marginal productivity of capital was estimated to be $3. 97. This estimate was considerably higher than the calculated marginal cost of flow capital. Consequently the evidence indicates flow capital was not being used in sufficient quantities to achieve economic efficiency in roundwood production.

Labor Productivity

Results on estimated labor productivity in the industry are comparable to those for capital. Two production functions incorporated the stock concept of capital input. In one of these functions labor was specified as all employees used by the industry. In this case the mean marginal productivity of labor as estimated from the production function was approximately equal to the calculated marginal cost per employee to the industry. The conclusion here is the logging industry uses employees rationally in roundwood production. In the second capital stock function labor was specified as man-hours worked by production workers. In this case the estimated mean marginal productivity of labor was also equal to the calculated marginal cost per man-hour to the industry. Consequently, the conclusion is the logging industry uses man-hours worked by production workers rationally in roundwood production.

In the production function which incorporated the flow concept of capital input, labor input was specified as all employees used by the industry. In this case the estimated mean marginal productivity of labor was considerably less than the calculated marginal cost for labor. Consequently, it appears the industry is not using employees rationally in roundwood production. Labor was used to the extent its marginal productivity was less than its marginal cost and capital flow was used to the extent its marginal product exceeded its marginal cost. On the basis of these empirical results, new capital investment should be substituted for employees in roundwood production.

V. THE SOUTHERN PINE ANALYSES

The southern pine sector of the logging industry was described briefly in Chapter II. This sector of the industry is comprised of those roundwood producers operating in the following states.

Alabama	Georgia	North Carolina
Arkansas	Louisiana	South Carolina
Delaware	Maryland	Texas
Florida	Mississippi	Virginia

Chapter III presented the theory underlying the concept of an industrial production function, and a methodology for empirically analysing production relationships. That theory and methodology were used to analyze the national logging industry in Chapter IV and are used in this chapter to analyze the southern pine sector of the industry.

The analyses undertaken in this chapter are comparable to those undertaken in Chapter IV. The Cobb-Douglas function is used as the basic model to describe aggregate production relationships in the region. Five separate analyses are undertaken based on the five sets of variates defined and used in the national analyses. Consequently, the variates and parameters in each of the analyses have the same interpretation as the variates and parameters in the comparable national analyses.

To facilitate presentation of the results of the analyses, the system of subscripts on the variates and parameters, described earlier, is preserved. That is, the first digit of the subscript is designated as 2 to identify the southern pine sector while the second digit identifies the same set of variates as it identified in the national analyses.

The obvious difference between the southern pine and national analyses is in the producing units selected for observation. The southern pine analyses are restricted to observations on those 12 state producing units cited above. These observations are a subset of those used in the national analyses.

The Results

This section presents the results of the five analyses undertaken for the southern pine sector and a discussion on these results. The major results are summarized on page 153.

Initial Analysis

The production function selected for the initial analysis has the form

$$\ln V_{21} = \ln T_{21} + A_{21} \ln K_{21} + B_{21} \ln P_{21} + C_{21} \ln S_{21} + \ln E_{21}$$

In this function the variates are defined in the following manner.

V_{21} = output measured in terms of value added

K_{21} = capital input measured in terms of estimated gross book value of depreciable assets

P_{21} = labor input measured in terms of number of man-hours worked by production workers

S_{21} = labor input measured in terms of number of nonproduction workers used.

Statistical Results. The data were applied to the function

$$\ln V_{21} = \ln t_{21} + a_{21} \ln K_{21} + b_{21} \ln P_{21} + c_{21} \ln S_{21} + \ln E_{21}$$

and the OLS solution obtained was

$$\ln V_{21} = 0.313 + \underset{(0.16642)}{0.43712} \ln K_{21} + \underset{(0.40324)}{1.23064} \ln P_{21} - \underset{(0.18206)}{0.55383} \ln S_{21}$$

where the standard error of each coefficient is presented in parenthesis below the coefficient.

The following matrix contains the correlation coefficients generated by the analysis.

	Value Added (V_{21})	Capital (K_{21})	Man Hours (P_{21})	Non-Production workers (S_{21})
Value added (V_{21})	1.000	0.859	0.710	0.245
Capital (K_{21})		1.000	0.726	0.414
Man-hours (P_{21})			1.000	0.798
Nonproduction workers (S_{21})				1.000

Generally, the statistical features of this result are satisfactory. First, each of the coefficients is fairly well-estimated. The test of the null hypothesis on A_{21}, B_{21}, and C_{21} was rejected at the 5 percent level. That is, A_{21}, B_{21}, and C_{21} do not equal zero. Second, the R^2 of approximately 0.89 is considered adequate. Notwithstanding these favorable results, the correlation coefficients indicate the undesirable presence of high intercorrelation among the input variates.

Economic Interpretation. The economic implications of the results derive from the estimated coefficients or elasticities of production. As the elasticity of production for capital is positive and is less than unity, decreasing returns to this variate are indicated. This is a logical result.

The elasticity of production for man-hours worked is larger than unity which means that increasing returns prevail on this variate. Increasing returns implies that insufficient man-hours are being used to achieve production in the rational zone of the production function. Many casual observations of roundwood production operations in several areas of the South by this writer suggest the result obtained from this analysis is erroneous. Diminishing returns to labor is more plausible.

The negative sign obtained on the elasticity of production for nonproduction workers suggests this variate is being used to excess and in the irrational zone of production. A similar result was obtained on this variate in the initial analysis of the national industry. The negative sign on the coefficient is considered to be a nonsense result for reasons given previously.

The sum of the estimated coefficients is not significantly different from unity. Consequently, constant returns to scale are indicated for the industry. This is a plausible result.

However, the economic implications of the estimated elasticities of production for both man-hours worked and nonproduction workers, cited above, are such that the results of this analysis are considered unacceptable. This analysis is eliminated from further consideration in this study.

Second Analysis

The production function selected for this analysis has the form

$$\ln V_{22} = \ln T_{22} + A_{22} \ln K_{22} + B_{22} \ln L_{22} + \ln E_{22}$$

The variates used in this function are defined in the following manner.

V_{22} = output measured in terms of value added

K_{22} = capital input measured in terms of estimated gross book value of depreciable assets

L_{22} = labor input measured in terms of all employees used in production.

Statistical Results. The data were applied to the function

$$\ln V_{22} = \ln t_{22} + a_{22} \ln K_{22} + b_{22} \ln L_{22} + \ln E_{22}$$

and the OLS solution obtained was

$$\ln V_{22} = 2.22 + \underset{(0.20259)}{0.61926} \ln K_{22} + \underset{(0.31608)}{0.29806} \ln L_{22}$$

The following matrix presents the correlation coefficients generated by the data.

	Value Added (V_{22})	Capital (K_{22})	All Employees (L_{22})
Value added (V_{22})	1.000	0.859	0.717
Capital (K_{22})		1.000	0.718
All employees (L_{22})			1.000

Generally, this analysis provides poor statistical results. The coefficients obtained are not well-estimated. The test of the null hypothesis on A_{22} resulted in rejecting the hypothesis at the 5 percent level but accepting it at the 1 percent level. That is, at the 1 percent level, the hypothesis that $A_{22} = 0$ is accepted. The hypothesis that $B_{22} = 0$ was accepted at both the 1 percent and 5 percent levels. The latter result was anticipated considering the standard error obtained on the coefficient b_{22} is larger than the coefficient itself.

The R^2 of 0.76 is not as large as desired. Additionally, the addition of the second input variate, all employees, adds only 2 percent, approximately, to the R^2.

The problem of multicollinearity between input variates continues to exist.

Economic Interpretation. As the estimated elasticity of production for capital is positive and less than unity, additions to the capital input result in increases in output but at a less than proportionate rate. That is, decreasing returns to capital obtain, or capital is used in the rational zone of production.

A similar economic inference could be made with respect to the labor input variate except for the presence of certain statistical information. As a consequence of the poorly estimated coefficient on labor, the small contribution to R^2 from labor, and the high intercorrelation between labor and capital, such an inference cannot be made. Rather, the evidence suggests that labor enters the production process in some functional relationship to capital. Therefore, the separate influence or contribution of labor cannot be precisely determined.

The confusion as to the separate influence of labor does not affect the influence of labor and capital together. The sum of the estimated elasticities is not significantly different from unity. Consequently, constant returns to scale are indicated for the industry. This is a plausible result.

Third Analysis

The production function used in this analysis has the form

$$\ln V_{23} + \ln T_{23} + A_{23} \ln K_{23} + B_{23} \ln P_{23} + \ln E_{23}$$

where

V_{23} = output measured in terms of value added

K_{23} = capital input measured in terms of estimated gross book value of depreciable assets

P_{23} = labor input measured in terms of man-hours worked by production workers.

Statistical Results. Data on these variates applied to the function

$$\ln V_{23} = \ln t_{23} + a_{23} \ln K_{23} + b_{23} \ln P_{23} + \ln E_{23}$$

resulted in the following estimated production function

$$\ln V_{23} = 1.96 + \underset{(0.21137)}{0.63866} \ln K_{23} + \underset{(0.33908)}{0.25613} \ln P_{23}$$

The correlation coefficients generated in the analysis are presented in the following matrix (p. 145).

This analysis provides results which are comparable to those from the second analysis, and the results are questionable for similar reasons. The coefficients are not well-estimated. The test of the null hypothesis on A_{23} resulted in rejecting the hypothesis at the 5 percent level but accepting it at the 1 percent level. That is, at

	Value Added (V_{23})	Capital (K_{23})	Man Hours (P_{23})
Value added (V_{23})	1.000	0.859	0.710
Capital (K_{23})		1.000	0.726
Man-hours (P_{23})			1.000

the 1 percent level, the hypothesis that $A_{23} = 0$ is accepted. The hypothesis that $B_{23} = 0$ was accepted at both the 1 percent and 5 percent levels. The latter result was anticipated considering the standard error obtained on the coefficient b_{23} is larger than the coefficient itself.

The R^2 pf 0.75 is not as large as desired. Additionally, the addition of the second input variate, labor as measured by man-hours worked, adds less than 2 percent to the R^2.

The problem of high inter-correlation between the two input variates continues to exist.

Economic Interpretation. As the estimated elasticity of production for capital is positive and less than unity, additions to the capital input result in increases in output but at a less than proportionate rate. That is, decreasing returns to capital prevail, or capital is being used in the rational zone of production.

A similar economic inference could be made with respect to the labor variate except for the presence of statistical evidence. As a result of the poorly estimated coefficient on labor, the small contribution to R^2 from labor, and the high inter-correlation between labor and capital, such an inference cannot be made. The evidence suggests that labor enters the production process in some functional relationship to capital. Therefore the separate influence or contribution of labor cannot be precisely determined.

The sum of the estimated elasticities is not significantly different from unity. Consequently, constant returns to scale are indicated for the industry.

Fourth Analysis

The production function used in this analysis has the form

$$\ln V_{24} = \ln T_{24} + A_{24} \ln K_{24} + B_{24} \ln P_{24} + C_{24} \ln S_{24} + \ln E_{24}$$

where

V_{24} = output measured in terms of value added

K_{24} = capital input measured in terms of new capital expenditures

P_{24} = labor input measured in terms of man-hours worked by production workers

S_{24} = labor input measured in terms of number of nonproduction workers used.

Statistical Results. Data on these variates applied to the function

$$\ln V_{24} = \ln t_{24} + a_{24} \ln K_{24} + b_{24} \ln P_{24} + c_{24} \ln S_{24} + \ln E_{24}$$

resulted in the following estimated production function.

$$\ln V_{24} = 0.183 + \underset{(0.42321)}{0.81227} \ln K_{24} + \underset{(0.41005)}{1.49170} \ln P_{24} - \underset{(0.18881)}{0.72724} \ln S_{24}$$

The following matrix presents the correlation coefficients generated in the analysis.

	Value Added (V_{24})	Capital (K_{24})	Man Hours (P_{24})	Non-Production workers (S_{24})
Value added (V_{24})	1.000	0.736	0.710	0.245
Capital (K_{24})		1.000	0.795	0.618
Man-hours (P_{24})			1.000	0.798
Nonproduction workers (S_{24})				1.000

Generally, the statistical features of this result are unsatisfactory. While the coefficients B_{24} and C_{24} are well-estimated, the coefficient A_{24} is not well-estimated. The test of the null hypothesis on A_{24} resulted in accepting the hypothesis at the 5 percent level. That is, $A_{24} = 0$.

The R_2 of 0.85 is not as large as desired. Additionally, the labor input variate measured in terms of man-hours worked, which was the input variate having the most well-estimated coefficient, contributed only 0.07 to the R^2 after the other two input variates had entered the regression.

A problem of high multicollinearity between input variates continues to exist.

Economic Interpretation. As the estimated elasticity of production for new capital expenditures appears to be positive and less than unity, additions to this variate should result in increases in output but at a less than proportionate rate. That is, decreasing returns to new capital expenditures are suggested, or capital is being used in the rational zone of production. However, this inference cannot be made because of the statistical evidence that A_{24} equals zero.

The estimated elasticity of production for man-hours worked is larger than unity which means increasing returns obtained on this labor variate. Increasing returns implies that insufficient man-hours are being used to achieve production in the rational zone of production. This result does not appear to be plausible.

The negative sign obtained on the elasticity of production for nonproduction workers suggests this variate is being used excessively; that is, in an irrational zone of production. A similar result was obtained on this variate in the fourth analysis of the national industry. The negative sign on the coefficient is considered to be a nonsense result for reasons given previously.

The sum of the estimated coefficients is not significantly different from unity. Consequently constant returns to scale are indicated for the industry. This is a plausible result.

In consideration of the economic implications of the poorly-estimated elasticity of production for new capital expenditures, the increasing returns indicated for man-hours worked, and the negative sign on the estimated elasticity of production for nonproduction workers, the results of this analysis are considered unacceptable. This analysis is eliminated from any further consideration in this study.

Fifth Analysis

The production function used in this analysis has the form

$$\ln V_{25} = \ln T_{25} + A_{25} \ln K_{25} + B_{25} \ln L_{25} + \ln E_{25}$$

where

V_{25} = output measured in terms of value added

K_{25} = capital input measured in terms of new capital expenditures

L_{25} = labor input measured in terms of all employees available for use.

Statistical Results. Data on these variates were applied to the function

$$\ln V_{25} = \ln t_{25} + a_{25} \ln K_{25} + b_{25} \ln L_{25} + E_{25}$$

and the following OLS solution was obtained.

$$\ln V_{25} = 2.95 + \underset{(0.61865)}{0.86063} \ln K_{25} + \underset{(0.44667)}{0.50857} \ln L_{25}$$

The correlation coefficients generated in the analysis are presented in the following matrix.

	Value Added (V_{25})	Capital (K_{25})	Labor (L_{25})
Value added (V_{25})	1.000	0.736	0.717
Capital (K_{25})		1.000	0.762
Labor (L_{25})			1.000

Generally, this analysis provides poor statistical results. The coefficients are not well-estimated. The test of the null hypothesis on A_{25} resulted in accepting the hypothesis at the 1 percent level. That is, $A_{25} = 0$. The comparable test on B_{25} gave a comparable result. That is, at the 1 percent level, $B_{25} = 0$.

The R^2 of approximately 0.60 is considered to be excessively low, and high inter-correlation exists between the input variates.

Economic Interpretation. Considering the low multiple of each estimated coefficient in comparison with the respective standard error, and the results of the tests of the null hypothesis presented above, the separate influence of each input variate on production cannot be ascertained. However, the influence of both input variates together can be considered. The sum of the elasticities of production is not significantly different from unity. Therefore, constant returns to scale is indicated for the industry.

Review of Results

None of the analyses presented in this chapter have been successful in providing an acceptable estimate of a production function for the southern pine sector of the industry. In two of the analyses negative coefficients were estimated on input variates. This result is unacceptable on economic grounds for reasons discussed in Chapter IV where comparable results occurred. In the remaining three analyses coefficients were so poorly estimated no reasonable inferences could be drawn respecting the separate contribution to production by individual input variates.

There is sufficient evidence to suggest the southern pine sector operates under constant returns to scale. First, the empirical results in each of the analyses show the sum of the elasticities of production are not significantly different from unity. Second, personal observations emphasize the fact that small producing units coexist with large producing units in the region. This evidence supports the contention presented earlier that the logging industry in the south operates under conditions approximating those for pure competition posed by economic theory.

As a consequence of the poorly estimated coefficients on input variates, no attempt is made to estimate the marginal productivities of these resources. This decision represents a major departure from the original intent of this study. However, the empirical results dictate the decision.

Summary of Southern Pine Analyses

		Capital Coefficients		Labor Coefficients				
Analysis	Intercept	Assets	Expenditures	Man-hours	Nonproduction	All	Sum of Coeefficients	R^2
1	0.313	+0.43712*	-	+1.23064*	-0.55383*	-	+1.11393	0.89
		(0.16642)		(0.40324)	(0.18206)			
2	2.22	+0.61926*	-	-	-	+0.29806	+0.91732	0.76
		(0.20259)				(0.31608)	(0.22415)	
3	1.96	+0.63866*	-	+0.25613	-	-	+0.89479	0.75
		(0.21137)		(0.33908)			(0.23579)	
4	0.183	-	+0.81337	+1.49170*	-0.72724*	-	+1.57673	0.85
			(0.42321)	(0.41005)	(0.18881)		(0.26308)	
5	2.95	-	+0.86063	-	-	+0.50857	+1.36920	0.60
			(0.61865)			(0.44667)	(0.40106)	

*Significantly different from zero at $P \leq 0.05$
**Significantly different from one at $P \leq 0.05$

Correlation matrices

	V_{21}	K_{21}	P_{21}	S_{21}
V_{21}	1.000	0.859	0.710	0.245
K_{21}	-	1.000	0.726	0.414
P_{21}	-	-	1.000	0.798

	V_{22}	K_{22}	L_{22}
V_{22}	1.000	0.859	0.717
K_{22}	-	1.000	0.718
L_{22}	-	-	1.000

	V_{23}	K_{23}	P_{23}
V_{23}	1.000	0.859	0.710
K_{23}	-	1.000	0.726
P_{23}	-	-	1.000

	K_{24}	K_{24}	P_{24}	S_{24}
V_{24}	1.000	0.736	0.710	0.245
K_{24}	-	1.000	0.795	0.618
P_{24}	-	-	1.000	0.798
S_{24}	-	-	-	1.000

	V_{25}	K_{25}	L_{25}
V_{25}	1.000	0.736	0.717
K_{25}	-	1.000	0.762
L_{25}	-	-	1.000

VI. THE DOUGLAS FIR ANALYSES

A discussion of the Douglas fir sector of the logging industry was presented in Chapter II. This sector of the industry is comprised of the roundwood producers operating west of the summit of the Cascade mountains in Oregon and Washington. The aggregate industrial roundwood production process in the Douglas fir sector is analyzed in this chapter on a comparable basis as the analyses of the national industry and the southern pine sector presented in Chapters IV and V. Briefly, the Cobb-Douglas model is used as the basic model to describe aggregate production relationships in the region. Five separate analyses are undertaken based on five sets of variates which are considered appropriate to the problem. These variates have been described previously.

To facilitate presentation of the results of the analyses, the system of subscripts on the variates and parameters, described earlier, is preserved. That is, the first digit of the subscript is designated as 3 to identify the Douglas fir sector while the second digit identifies the same set of variates as it identified in both the national and southern pine analyses.

There are two aspects of the Douglas fir analyses which differ substantially from the methods used in the national and southern pine analyses. First, whereas in the two previous sets of analyses the state was selected as the producing unit under observation, in the Douglas fir sector which covers only a portion of two states, the county is selected as the producing unit under observation. There are 37 counties in this region, 18 in Oregon and 19 in Washington. These counties are

Oregon		Washington	
Benton	Lane	Clallam	Mason
Clackamas	Lincoln	Clark	Pacific
Clatsop	Linn	Cowlitz	Pierce
Columbia	Marion	Grays Harbor	San Juan
Coos	Multnomah	Island	Skagit
Curry	Polk	Jefferson	Skamania
Douglas	Tillamook	King	Snohomish
Jackson	Washington	Kitsap	Thurston
Josephine	Yamhill	Lewis	Wahkiakum
			Whatcom

However, observations on each variate in the five sets of variates used in the analyses are not available from Census for all 37 counties. The required observations are available for only 12 counties. These 12 counties which form the sample for the analyses are

Clackamas	Douglas	Clallam
Clatsop	Jackson	Grays Harbor
Coos	Lane	Lewis
Curry	Linn	Pierce

The second aspect of the Douglas fir analyses which differs from the previous analyses relates to the capital input variate as defined in terms of estimated gross book value of depreciable assets. As discussed earlier, in previous analyses this estimate of capital for each state was calculated by allocating the total gross book value of depreciable assets for the national industry over states in the same proportion as each state's total cost of materials for logging relates to the national industry's total cost of materials. As Census does not publish on a county basis the cost of materials to logging, another scheme for estimating gross book value of depreciable assets by county was devised.

Census does publish data on new capital expenditures in logging at both the county and state levels in Oregon and Washington. Consequently, each county's proportion of new capital expenditures in the state was calculated. This proportion was used to allocate the state's estimated gross book value of depreciable assets over the counties. This allocating scheme is predicated on the assumption that capital stocks in place by county are highly correlated with expenditures for new capital by county. The rationale behind this assumption is that the rate of capital consumption in any county is directly related to the stock of capital in place in that county. Further, the expenditures for new capital are directly related to the rate of capital consumption, and therefore are directly related to stocks of capital in place. This reasoning does not permit considerations respecting inter-county differences in proportions of capital in place actually consumed in production or inter-county differences in rates of replacement for capital consumed. These latter considerations are important when inter-county comparisons reveal different technologies prevail and different levels of capital utilization prevail. However, these differences are considered to be minimal among counties in the Douglas-fir region.

It is recognized that this system of allocation may result in estimated data on this capital variate which are not close proxies for the real gross book value of depreciable assets in place in any county. However, the scheme used appears to this author to be the best available considering the overall data limitations.

The Results

This section presents the results of the five analyses undertaken for the Douglas fir sector and a discussion on these results. The major results are summarized on page 153.

Initial Analysis

The production function selected for the initial analysis has the form

$$\ln V_{31} = \ln T_{31} + A_{31} \ln K_{31} + B_{31} \ln P_{31} + C_{31} \ln S_{31} + \ln E_{31}$$

In this function the variates are defined in the following manner

V_{31} = output measured in terms of value added

K_{31} = capital input measured in terms of estimated gross book value of depreciable assets

P_{31} = labor input measured in terms of number of man-hours worked by production workers

S_{31} = labor input measured in terms of number of nonproduction workers used.

Statistical Results. The data were applied to the function

$$\ln V_{31} = \ln t_{31} + a_{31} \ln K_{31} + b_{31} \ln P_{31} + c_{31} \ln S_{31} + \ln E_{31}$$

and the OLS solution obtained was

$$\ln V_{31} = 7.22 - \underset{(0.22021)}{0.11540} \ln K_{31} + \underset{(0.31516)}{1.11213} \ln P_{31} - \underset{(0.18905)}{0.26726} \ln S_{31}$$

The following matrix contains the correlation coefficients generated by the analysis.

	Value Added (V_{31})	Capital (K_{31})	Man Hours (P_{31})	Non-Production workers (S_{31})
Value added (V_{31})	1.000	0.069	0.703	0.226
Capital (K_{31})		1.000	0.369	0.441
Man-hours (P_{31})			1.000	0.684
Nonproduction workers (S_{31})				1.000

The statistical features of this analysis are not satisfactory. First, all the coefficients are not well estimated. The test of the null hypothesis on A_{31} and C_{31} was accepted at both the 5 percent and 1 percent levels. That is, neither A_{31} nor C_{31} are significantly different from zero. However, the test of the null hypothesis on B_{31}

was rejected at both the 5 percent and 1 percent levels. Second, the R^2 of approximately 0.63 is considered to be too low. Notwithstanding these results, the multicollinearity between input variates is considerably lower than has existed in the previous analyses.

Economic Interpretation. The major economic implications of the results derive from the estimated coefficients or elasticities of production. As the elasticity of production for capital appears with a negative sign, the initial interpretation is that capital is being used so intensively that additions to capital would result in decreases in output. This is considered to be a nonsense result for reasons presented in the initial analysis of the national industry. However, as the null hypothesis was accepted in the test on A_{31}, the conclusion is that capital input as estimated here does not influence output. This is not an acceptable result.

Conclusions similar to those on capital must be made on the nonproduction workers input because of the comparable results obtained on the elasticity of production for this input. This is not an acceptable set of conclusions.

The elasticity of production for man-hours worked is positive and greater than unity which means that increasing returns obtain on this variate. Increasing returns implies that insufficient man-hours are being used to achieve production in the rational zone. As diminishing returns to this variate are more plausible, this result is suspect.

The sum of the estimated coefficients is not significantly different from unity at the 1 percent level. Consequently, the evidence suggests that constant returns to scale prevails in the industry. This is a plausible result.

The desirable aspects of this analysis are considered to be of less importance than the undesirable aspects. Consequently, this analysis is eliminated from further consideration in this study.

Second Analysis

The production function used in this analysis has the form

$$\ln V_{32} = \ln T_{32} + A_{32} \ln K_{32} + B_{32} \ln L_{32} + \ln E_{32}$$

The variates of the function have the following definitions.

V_{32} = output measured in terms of value added

K_{32} = capital input measured in terms of estimated gross book value of depreciable assets

L_{32} = labor input measured in terms of all employees used in production.

Statistical Results. The data were applied to the function

$$\ln V_{32} = \ln t_{32} + a_{32} \ln K_{32} + b_{32} \ln L_{32} + \ln E_{32}$$

and the OLS solution obtained was

$$\ln V_{32} = 63.2 - \underset{(0.23224)}{0.28029} \ln K_{32} + \underset{(0.23257)}{0.75168} \ln L_{32}$$

The following matrix presents the correlation coefficients generated by the data

	Value Added (V_{32})	Capital (K_{32})	All Employees (L_{32})
Value added (V_{32})	1.000	0.069	0.682
Capital (K_{32})		1.000	0.457
All employees (L_{32})			1.000

Generally, poor statistical results obtained from this analysis. The coefficients obtained are not well-estimated. The test of the null hypothesis on A_{32} resulted in accepting the hypothesis at both the 5 percent and 1 percent levels. On the basis of the statistical evidence it is concluded that $A_{32} = 0$.

The coefficient B_{32} is somewhat better-estimated. The test of the null hypothesis on this coefficient resulted in rejecting the hypothesis at the 5 percent level but accepting it at the 1 percent level.

The R^2 of approximately 0.54 is considered to be excessively low.

Multicollinearity continues to exist between the input variates. However, in this analysis the multicollinearity is not as large as in the national and southern pine analyses but is somewhat more than in the initial Douglas fir analysis.

Economic Interpretation. As the elasticity of production on the capital input variate is so poorly estimated, it is not possible to determine the separate influence on output attributable to this input variate. The statistical evidence suggests capital does not influence output. This is an unacceptable result.

More realistic economic inferences can be made respecting the labor input variate. As the elasticity of production estimated is positive and less than unity, decreasing returns are indicated for labor input. Labor is being used rationally in production. However, these conclusions are predicated on the acceptance of statistical evidence at the 1 percent level only.

The sum of the estimated coefficients is not significantly different from unity at the 5 or 1 percent levels. Consequently, the hypothesis that constant returns to scale prevails in the industry is accepted.

As the undesirable features of this analysis are considerable and lead to unacceptable conclusions, this analysis is eliminated from further consideration in this study.

Third Analysis

The production function used in this analysis has the form

$$\ln V_{33} = \ln T_{33} + A_{33} \ln K_{33} + B_{33} \ln P_{33} + \ln E_{33}$$

where

V_{33} = output measured in terms of value added

K_{33} = capital input measured in terms of estimated gross book value of depreciable assets

P_{33} = labor input measured in terms of man-hours worked by production workers.

Statistical Results. Data on these variates applied to the function

$$\ln V_{33} = \ln t_{33} + a_{33} \ln K_{33} + b_{33} \ln P_{33} + \ln E_{33}$$

resulted in the following estimated production function

$$\ln V_{33} = 23.8 - \underset{(0.22295)}{0.20200} \ln K_{33} + \underset{(0.25937)}{0.83376} \ln P_{33}$$

The correlation coefficients generated in the analysis are presented in the following matrix.

	Value Added (V_{33})	Capital (K_{33})	Man Hours (P_{33})
Value added (V_{33})	1.000	0.069	0.703
Capital (K_{33})		1.000	0.369
Man-hours (P_{33})			1.000

This analysis provides results which are comparable to those obtained in the second analysis. Neither coefficient is well-estimated. As a result of the test of the null hypothesis, A_{33} is accepted as equalling zero at the 5 percent and 1 percent levels and B_{33} is also accepted as equalling zero at the 1 percent level. However, at the

5 percent level the hypothesis that $B_{33} = 0$ is rejected.

The R^2 of approximately 0.54 obtained in this analysis is considered to be excessively low.

While there is evidence that multicollinearity exists between the input variates, this evidence indicates the degree of multicollinearity is less than that prevailing in most of the earlier analyses.

Economic Interpretation. As the elasticity of production for the capital input variate is so poorly estimated, it is not possible to ascertain the influence this variate has on output. The statistical evidence suggests that capital does not influence output. This is an unacceptable result.

If the consequences of selecting the 5 percent level of probability over the 1 percent level are acceptable for tests of hypotheses, then more plausible economic inferences can be made respecting the labor input variate. That is, as the estimated elasticity of production on this variate is positive and less than unity, decreasing returns are indicated for labor. This is consistent with rational production decisions and therefore is an acceptable result.

The sum of the estimated coefficients is not significantly different from unity. Therefore, the hypothesis that constant returns to scale prevails in the industry is accepted.

Considering the undesirable features of this analysis and the unacceptable conclusions deriving therefrom, this analysis is eliminated from further consideration in this study.

Fourth Analysis

The production function used in this analysis has the form

$$\ln V_{34} = \ln T_{34} + A_{34} \ln K_{34} + B_{34} \ln P_{34} + C_{34} \ln S_{34} + \ln E_{34}$$

where

V_{34} = output measured in terms of value added

K_{34} = capital input measured in terms of new capital expenditures

P_{34} = labor input measured in terms of man-hours worked by production workers.

S_{34} = labor input measured in terms of number of nonproduction workers used.

Statistical Results. Data on these variates applied to the function

$$\ln V_{34} = \ln t_{34} + a_{34} \ln K_{34} + b_{34} \ln P_{34} + c_{34} \ln S_{34} + \ln E_{34}$$

resulted in the following estimated production function

$$\ln V_{34} = 6.59 - \underset{(0.24263)}{0.13531} \ln K_{34} + \underset{(0.41174)}{1.08702} \ln P_{34} - \underset{(0.29334)}{0.23285} \ln S_{34}$$

The following matrix presents the correlation coefficients generated in the analysis

	Value Added (V_{34})	Capital (K_{34})	Man Hours (P_{34})	Non-production workers (S_{34})
Value added (V_{34})	1.000	0.068	0.703	0.416
Capital (K_{34})		1.000	0.373	0.501
Man-hours (P_{34})			1.000	0.802
Nonproduction workers (S_{34})				1.000

The statistical features of this result are unsatisfactory. First, the coefficient on the capital input variate is very poorly estimated. At both the 5 percent and 1 percent levels of probability the null hypothesis that $A_{34} = 0$ is accepted. Second, the coefficient on the labor input variate described in terms of man-hours worked is not well estimated. When the 5 percent level of probability is chosen the hypothesis that $B_{34} = 0$ is rejected. However, at the 1 percent level this same hypothesis is accepted. Third, the coefficient on the labor input variate described in terms of nonproduction workers used is very poorly estimated also. At both the 5 percent and 1 percent levels of probability the null hypothesis that $C_{34} = 0$ is accepted.

The R^2 obtained of approximately 0.57 is considered to be excessively low.

The degree of multicollinearity existing between input variates does not appear to be excessive as compared with earlier analyses.

Economic Interpretation. As the elasticity of production for new capital expenditures is so poorly estimated it is not possible to ascertain the influence of this variate on output. The evidence suggests that this variate does not influence output. The economic implications of this conclusion are unacceptable.

While the elasticity of production for man-hours worked is somewhat better estimated than the elasticities on the other two input variates in the function as is indicated by the rejected null hypothesis at the 5 percent level, the economic implications of the estimated coefficient are still unacceptable. The estimated coefficient is positive and greater than unity. This implies that increasing returns prevail to man-hours worked, or that man-hours are used so sparingly that a rational production decision on their use has not been achieved.

The elasticity of production respecting nonproduction workers is poorly estimated. As the null hypothesis on this coefficient was accepted, the conclusion is that this variate does not influence production. This is an unacceptable conclusion.

The sum of the estimated coefficients is not significantly different from unity. Therefore, the hypothesis that constant returns to scale prevails in the industry is accepted.

Considering the undesirable features of this analysis and the unacceptable conclusions deriving therefrom, this analysis is eliminated from further consideration in this study.

Fifth Analysis

The production function used in this analysis has the form

$$\ln V_{35} = \ln T_{35} + A_{35} \ln K_{35} + B_{35} \ln L_{35} + \ln E_{35}$$

where

V_{35} = output measured in terms of value added

K_{35} = capital input measured in terms of new capital expenditures

L_{35} = labor input measured in terms of all employees available for use.

Statistical Results. Data on these variates were applied to the function

$$\ln V_{35} = \ln t_{35} + a_{35} \ln K_{35} + b_{35} \ln L_{35} + \ln E_{35}$$

and the following OLS solution was obtained

$$\ln V_{35} = 38.2 - \underset{(0.23053)}{0.28571} \ln K_{35} + \underset{(0.23246)}{0.75671} \ln L_{35}$$

The correlation coefficients generated in the analysis are presented in the following matrix, (p. 169).

Most of the statistical features of this analysis are unsatisfactory. The coefficient on the capital input variate is poorly estimated. The test of the null hypothesis on A_{35} resulted in accepting the hypothesis at both the 5 percent and 1 percent levels of

	Value Added (V_{35})	Capital (K_{35})	Labor (L_{35})
Value added (V_{35})	1.000	0.068	0.682
Capital (K_{35})		1.000	0.463
Labor (L_{35})			1.000

probability. The conclusion is that $A_{35} = 0$. Conversely, the coefficient on the labor input variate is well-estimated. At both the 5 percent and 1 percent levels of probability, the hypothesis that $B_{35} = 0$ is rejected.

The R^2 of approximately 0.54 is considered to be excessively low.

Intercorrelation exists between the input variates. However, it appears to be no more serious in this analysis than in previous analyses.

Economic Interpretation. As a consequence of the conclusion from the test of the null hypothesis on the elasticity of production for capital, the capital input variate is considered to have no influence on output. This is an unacceptable result.

The estimated elasticity of production for labor is positive, less than unity, and significantly different from zero. Consequently, labor does influence output and, as diminishing returns prevail to this input, labor is being used rationally in production.

The sum of the estimated elasticities of production is not significantly different from unity. Therefore, the hypothesis that constant returns to scale prevails in the industry is accepted.

As the undesirable features of this analysis lead to unacceptable conclusions, this analysis is eliminated from further consideration in this study.

Review of Results

It is apparent from the foregoing empirical analyses and interpretation of analyses that completely unsatisfactory results obtain on the estimated production functions for the Douglas fir sector of the logging industry. Consequently, no attempt is made here to estimate the marginal productivities of the input resources used by the industry. There are several possible reasons for the results obtained here. These reasons are presented in the final chapter of this study.

Summary of Douglas Fir Analyses

		Capital Coefficients		Labor Coefficients				
Analysis	Intercept	Assets	Expenditures	Production	Nonproduction	All	Sum of Coefficients	R^2
1	7.22	-0.11540	-	+1.11213*	-0.26726	-	0.72947	0.63
		(0.22021)		(0.31516)	(0.18905)	-	(0.26765)	
2	63.2	-0.28029	-	-	-	+0.75168*	0.47139	0.54
		(0.23224)				(0.23257)	(0.24223)	
3	23.8	-0.20200	-	+0.83376*	-	-	0.63176	0.54
		(0.22295)		(0.25937)			(0.27254)	
4	6.59	-	-0.13531	+1.08702*	-0.23285	-	0.71886	0.57
			(0.24263)	(0.41174)	(0.29334)		(0.29774)	
5	38.2	-	-0.28571	-	-	+0.75671*	0.47100	0.54
			(0.23053)			(0.23246)	(0.24002)	

*Significantly different from zero at $P \leq 0.05$
**Significantly different from one at $P \leq 0.05$

Correlation Matrices

	V_{31}	K_{31}	P_{31}	S_{31}
V_{31}	1.000	0.069	0.703	0.226
K_{31}		1.000	0.369	0.441
P_{31}			1.000	0.684
S_{31}				1.000

	V_{32}	K_{32}	L_{32}
V_{32}	1.000	0.069	0.682
K_{32}		1.000	0.457
L_{32}			1.000

	V_{33}	K_{33}	P_{33}
V_{33}	1.000	0.069	0.703
K_{33}		1.000	0.369
P_{33}			1.000

	V_{34}	K_{34}	P_{34}	S_{34}
V_{34}	1.000	0.068	0.703	0.416
K_{34}		1.000	0.373	0.501
P_{34}			1.000	0.802
S_{34}				1.000

	V_{35}	K_{35}	L_{35}
V_{35}	1.000	0.068	0.682
K_{35}		1.000	0.463
L_{35}			1.000

VII. SUMMARY

The major objective of this study was to evaluate the efficiency of resource use in the logging industry and in two sectors of the industry, the southern pine sector and the Douglas fir sector. A secondary objective was to undertake an inter-sector comparison of resource productivity. The purpose for defining and pursuing these objectives was to develop an information base on the roundwood production process to support decisions respecting the major identified policy issues confronting those concerned with the industry's performance. Evidence developed from a review of the forestry and economics literature indicated a study of aggregate resource productivity in logging as presented in this thesis had not been undertaken previously and subsequently published in the literature.

To achieve the objectives of the study, an analytical framework was developed based on the concept of the aggregate or industrial production function. The rationale was presented for selecting 1963 Census Bureau cross-section data aggregated at the SIC 2411, logging industry level, and fitting these data to the single-equation Cobb-Douglas model to estimate empirically an aggregate production function for the industry. Additionally, the analytical framework presented the methodology for deriving from the estimated production function three indicators of resource efficiency to be evaluated in the study. These three indicators were the estimated elasticity of production and mean marginal productivity of each resource input, and the estimated returns to scale of all resource inputs.

It was suggested the technologies used in roundwood production vary considerably across the nation as a result of conditions encountered by industry in the logging environment. A brief discussion of the range of ecological and socio-economic conditions confronting industry was presented. Apart from the obvious diversity of conditions confronting the national industry, it is apparent one more or less homogeneous set of conditions prevails in the southern pine sector while another more or less homogeneous set prevails in the Douglas fir sector. The characteristics of the conditions prevailing in the southern pine sector are markedly different from those in the Douglas fir sector. As a consequence, during the year for which the study applies, the southern pine sector tended to use labor intensive production techniques whereas the Douglas fir sector tended to use capital intensive production techniques.

To facilitate achieving the objectives of the study and to assure the separate investigation of resource efficiency attributable to regional differences in logging conditions, the study was designed around four major analyses. The first analysis provided for the estimation of an aggregate production function for the national industry and for estimates of production elasticities, marginal productivities, and returns to scale on resources used by the industry. The second and third analyses provided for the derivation of comparable estimates within the southern pine and Douglas fir sectors respectively. The fourth analysis proposed an investigation of inter-regional differences in resource productivity.

The empirical results obtained from the initial attempt to estimate aggregate production functions in each of the geographic areas under consideration were not considered acceptable. As a consequence, five alternative sets of input variates were defined and used to estimate five alternative production functions for each area. There were many undesirable features in the empirical results of these production analyses particularly within the two sectors of the industry. Consequently, it was not considered meaningful to investigate the inter-regional differences in productivity. This consequence represented a considerable departure from the original intent of the study. However, the empirical results dictated this decision.

The details of the empirical analyses undertaken have been presented in the three previous chapters. This chapter summarizes the major results and conclusions and presents recommendations for improvements that could be incorporated into future studies of the logging industry. The discussion is developed in three sections. The first section considers the issues respecting the industrial production functions. The second section considers the policy implications of the study, and the third section presents the conclusions.

The Industrial Production Functions

The Cobb-Douglas model appears to provide a good approximation of the aggregate production relationships in the logging industry. No strong evidence is generated in the study to refute the rationale for selecting this model as the appropriate model. Even in those cases where the production functions were poorly estimated, as was the general result of the analyses in the two sectors, it is difficult to criticize the selection of the basic model. The poorly estimated production functions probably resulted more from poor data than from an inappropriate model.

The data problems associated with this study were sufficiently serious to deter the development of the study as originally proposed and to suggest caution to those interpreting the results. A general comment respecting all data on the logging industry should be recorded. Bureau of the Census personnel have indicated to this writer their concern respecting the adequacy of SIC 2411 data as compared with data on other industries. Certain characteristics of logging establishments, that is, small size, remoteness of location, poor record keeping, and reluctance to divulge information, contribute to the questionable quality of the published data. However, as indicated earlier these data are the best available for the purposes of this study and therefore are accepted as given.

A more specific data problem occurs in conjunction with the input variate used unsuccessfully in the study to account for the contribution of supervisory workers in roundwood production. The data on nonproduction workers used as a proxy for supervisory workers generated unacceptable results in the estimated production functions. An evaluation of Census' description of the general statistic on nonproduction workers indicates the statistic includes some supervisory input. Additionally, the statistic includes functions other than those of a supervisory nature and ignores some supervisory input. Consequently, if the role of supervisory workers in roundwood production is to be empirically evaluated in the future, it is recommended that some effort be devoted to developing "clean" data on this input variate.

Another data problem associated with this study develops when an appropriate measure of the capital input to roundwood production is sought. Theoretical arguments for using the stock concept of capital, usually gross book value of depreciable assets, in lieu of a capital flow concept have been presented. However, Census does not publish data on stock capital for each state and county producing unit used as observations in this study. As a consequence, stock capital estimates for each state producing unit in the national and fir sample were derived through use of prorating schemes based on related data available for the producing units. The details of these prorating schemes were presented earlier. The use of the prorating schemes may introduce a bias into the derived capital stock input data for each producing unit. The extent of any such bias is undetermined. However, the correlation between capital input and output, as indicated by the correlation coefficients, is high in the national and southern pine analyses but unacceptably low in the Douglas fir analyses. The poor correlation between derived capital stock and output in the latter analyses may be a direct result of the prorating scheme used to derive the capital stock data. Any future attempt to estimate industrial production functions for the logging industry or its sectors should provide for a better method of deriving capital stock data than has been used in this study.

In the analyses of the national logging industry, it is apparent the production functions based on new capital expenditure data, purported to be proxy for capital flow or capital consumption data, were better estimated functions than those based on capital stock data. However, as it was not possible to develop an acceptable relationship between the new capital expenditure data used and the concept of real capital consumption in production, the meaning of the results derived is obscure. It is recommended that a detailed study of the relationships among capital stocks, new capital expenditures, and real capital consumption be undertaken for the logging industry.

High inter-correlation between input variates, or multicollinearity, was observed generally through the analyses of production functions in the study. This evidence suggests the industry is not characterized by producing units some of which have high capital-labor ratios while others have low capital-labor ratios as was expected but rather, is characterized by producing units which combine capital and labor in a more or less constant ratio. As a consequence, the production relationships cannot be envisioned as being continuous response surfaces in space but as concentrated ribbons or cylinders of response points suspended in space. The implications of this latter view of production relationships with respect to the estimation of production functions has been presented earlier.

It appears to this writer, however, the evidence of multicollinearity in the roundwood production process may be a result not of the real combinations of labor and capital prevailing in the industry but of the data used for each producing unit considered in the study. That is, in each geographical producing unit aggregate data for each resource input used formed the data base for the study. When these aggregates were divided by the number of establishments to determine the level of each resource input used by the average establishment per geographic producing unit, the more or less constant capital-labor ratio was forced into being. The argument is illustrated with a simple example. Consider a geographical producing unit containing only 2 roundwood producing establishments with equal output. One establishment uses 100 units of capital and 10 units of labor, and therefore has a high capital-labor ratio. The other establishment uses 10 units of capital and 100 units of labor, and therefore has a low capital-labor ratio. Capital and labor are not combined in a more or less constant ratio in the geographical unit. The average establishment, however, uses $\frac{100 + 10}{2}$, or 55 units of capital and $\frac{10 + 100}{2}$, or 55 units of labor. The result of this arithmetic calculation is to destroy the real spread of data over a production surface and to force the concentration of averaged observations. If the illustration is expanded for establishments with an equal but larger level of output, not only does concentration of averaged observations still occur, but also the observed increase in capital input is associated with a highly correlated increase in labor input. This phenomenon may have been an additional contributor to the poor results obtained in the study. Future studies of industrial production functions for logging might consider the use of data on individual establishments rather than data on geographic producing units. Such an approach would require development of a data source other than the Bureau of the Census.

The last comment respecting the adequacy of the data used in this study pertains to the sample sizes available. In the national analyses, production functions were estimated reasonably well on the basis of a sample comprised of 35 observations on state producing units. In the southern pine and Douglas fir sectors of the industry the unacceptable results may be attributable in part to the small sample size. In each sector the analyses were based on samples of only 12 observations. As the southern pine sector is comprised of few states, there is no opportunity to increase the number of state observations in the sample. However, any future study of aggregate production functions in this sector might consider the use of the county as the producing unit. The use of the county as a producing unit in the south would increase the sample size many fold. Presently, Census does not publish county data for logging in this region. However, these data may be obtained from Census by special request but they are both expensive and time consuming to acquire. Census personnel advised this writer these data would cost approximately $35, 000. 00 after a two year advance request. In the Douglas fir sector the county was used as the producing unit because Census publishes data on this basis in this region. However, published data were available for only 12 of the sector's 37 counties. It seems reasonable to assume if time and funds were available to develop an enlarged sample size for the sector, better estimated production functions would result.

The evidence presented in this section suggests the Cobb-

Douglas function is an appropriate model to use for estimating aggregate production functions for logging. The evidence also suggests the poorly estimated production functions were a result of inadequacies of the data available for use in the analyses.

Policy Implications

The objectives defined for this study were selected to provide for an empirical information base to aid in decision-making on major policy issues confronting those concerned with the performance of the logging industry and its two sectors. These policy issues, presented in the introduction to this study, were derived from normatively stated socially desirable goals to which it was suggested the logging industry ought to contribute. The empirical information base generated to facilitate policy decisions on the industry's production process consisted of estimated industrial production functions from which were derived estimated elasticities of production and marginal productivities for individual resources, and estimated returns to scale for all resources used in roundwood production.

The empirical results must be interpreted with caution not only for reasons of poor data discussed previously but also for reasons of the legitimately restrictive applicability of the aggregate production function. The concept of the aggregate production function as developed in this study represents the production relationships prevailing over a set of state or county producing units. The data used for each geographic producing unit are averages per representative establishment in the unit. As a consequence, the empirical results cannot be used for policy recommendations on individual establishments in the industry. Additionally, as roundwood production relationships may vary from timbershed to timbershed, results of the study may not apply specifically to any geographic producing unit. As the results do apply to an abstractly described industry comprised of an average establishment in each geographic producing unit under observation, policy decisions or recommendations developed from the empirical results should apply to only such an industry. For pragmatic purposes however, the results may be considered to be applicable to average inter-establishment production relationships, and policy recommendations may be developed accordingly.

Notwithstanding these precautionary comments, the degree of success achieved by this study can be examined by considering first, to what extent the empirical results contribute to a better understanding of the major policy issues confronting the logging industry and second, to what extent these results could support the decisions necessary to resolve the policy issues. This examination is presented separately for each of the geographic areas under consideration.

The National Industry

When the labor input variate used in the production analyses is defined in terms of either man-hours worked or all employees and the capital variate is defined in terms of gross book value of depreciable assets, the empirical evidence suggests the existing organization of resources in the industry approaches an optimal organization. The reason for this conclusion is that the industry uses both resources efficiently and constant returns to scale prevail in the production process. Consequently, no reallocations of resources are required.

The implication of this conclusion is that industrial roundwood is being produced at least-cost with the given level of technology, that resources are being compensated equitablyon the basis of their marginal productivities, and there is no reallocation of resources which would provide for larger returns to stumpage producers.

However, when the capital variate is redefined in terms of new capital expenditures, the empirical results change markedly and suggest different policy implications. These results suggest the existing organization of resources in the logging industry is not an optimal organization. The reason for this conclusion is that the industry uses both capital and labor resources inefficiently and increasing returns accrue to large scale resource use. Consequently a reallocation of resources is required.

The implication of this conclusion is that industrial roundwood is not being produced at least-cost, that resources are not being compensated according to their marginal productivities, and there are opportunities to provide for a larger return to stumpage producers. The policy recommendations suggested by the empirical evidence are for larger capital expenditures and less labor use in the production process.

It is apparent from these divergent conclusions that the study has generated results which only partially contribute to a better understanding of the national logging industry and consequently do not completely support any decisions to resolve the policy issues.

The Southern Pine and Douglas Fir Sectors

The only defensible empirical results generated in the analyses of production relationships in these two regions was the evidence suggesting that constant returns to scale prevail in both sectors.

Consequently, the study has not provided results which contribute very much to a better understanding of the regional production processes nor has it provided information to support any decisions necessary to resolve the major policy issues.

Conclusions

In an attempt to achieve the objectives of this study, 15 industrial production functions, five in each of the national, southern pine, and Douglas fir areas were estimated. Six of these production functions, two in each of the areas under examination, were rejected for reasons of nonsense results. Of the nine remaining functions, the three estimated for the national industry provided some information on the efficiency of roundwood production. The other six functions, three for the southern pine sector and three for the Douglas fir sector, were so poorly estimated no conclusion could be drawn respecting the contribution to production by individual resources, and only tenuous conclusions could be drawn respecting the combined contribution to production by all resources together.

It is suggested the results obtained may be attributable to several factors which deserve further consideration in any future attempt to empirically evaluate the efficiency of the logging industry. The first factor pertains to the quantity of data available for analysis. In this study, the two sectoral analyses were handicapped by the shortage of geographical producing units available for observation. It is recommended that consideration be given to acquiring either additional county data or data on individual producing establishments for further study of the Douglas fir and southern pine sectors.

The second factor pertains to the quality of the data available for analysis. In this study, the analyses were handicapped because of the inadequacies of the data on non-production workers and capital consumption. It is recommended that a separate investigation of both these resources be undertaken before they are used in any future analyses of production relationships in logging.

The third factor pertains to the choice of the model selected for describing the industrial production process. In this study, the Cobb-Douglas model was used. While this model did provide some acceptable results in the national analyses, it may not be the most appropriate model for describing the regional roundwood production relationships. It is recommended that consideration be given to evaluating the efficiency of resource use in the industry and its sectors using other kinds of econometric models.

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