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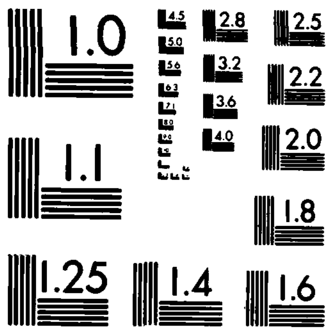

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A MODEL TO MEASURE THE RELATIVE
PRODUCTIVITY OF INDIVIDUAL
DOD CONTRACTORS

Edmund W. Berry, Lieutenant, USN
Paul M. Bland, Lieutenant, Supply Corps, USN

LSSR 40-82

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Useful measurement of defense contractor productivity is a primary concern within the Department of Defense. To improve the productivity of defense contractors, the need exists for a better understanding of what productivity is, and how it can be measured at the individual firm level. Based upon this need, this study develops and identifies a network, or family, of quantitative ratios for productivity measurement. These measures, when carefully monitored and analyzed, can be used to determine the relative productivity of individual defense contractors. In addition, this research identifies the data requirements and data sources, and presents an analytical framework for interpreting the data results. The study applies the analytical framework to two representative defense aerospace contractors. The approach is based upon graphical representation of the pertinent productivity measures identified. The data results and analysis indicate that the approach used is both feasible and effective in measuring productivity at the plant level. As shown in the final analysis, the methodology presented can be used in DOD source selection and contract management applications.

LSSR 40-82

A MODEL TO MEASURE THE RELATIVE PRODUCTIVITY OF INDIVIDUAL DOD CONTRACTS

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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September 1982

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has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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Robert F. Golden
COMMITTEE CHAIRMAN

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CHAPTER I

INTRODUCTION

Problem Statement

It has become increasingly apparent that the industrial revitalization of the United States and its related defense capability depend upon the effectiveness with which productivity improvement can be implemented in all related sectors of the economy. At present, however,

> . . . no Defense Department, or interagency organization continuously collects or analyzes the pertinent economic and financial data that can provide visibility into the long-term production efficiency trends of the U.S. Defense industry [7:6].

Without the tools for measuring productivity at the plant level, no significant progress toward productivity improvement is likely in the near future (30:ii).

Justification

In a report by the General Accounting Office, the problem of productivity measurement was analyzed. The report concluded that the exclusive use of labor data in highly aggregated form by the Bureau of Labor Statistics was a very poor measurement tool for measuring industry productivity trends and national productivity as a whole. In a reply to the GAO report, the BLS pointed out that there are no other reliable measurement techniques available due to the fact that only labor data is collected and reported by the various industries (30:50). The GAO also pointed out that for any productivity tool to be effective, the measurement technique necessary must be in a less aggregate form such as at the firm or plant level (30:9). The GAO investigation further discovered that few firms measure productivity, primarily because no simple, reliable method for measurement has been developed (30:ii).

The Defense Department has also recognized the need for enhancing the productivity of its contractors and has done a number of studies as well. As a result of one such study, Profit '76, greater emphasis was placed on DOD incentives for capital investment. Another study, Payoff '80, conducted by the Air Force Systems Command, also recognized that to improve the productivity of industry doing defense work,

> Significant credit for aggressive capital investment and implementation of advanced manufacturing technology can be given to contractors during source selection [17:IV].

Even more recently, the Deputy Secretary of Defense, Frank Carlucci, as part of his thirty-two Defense Acquisition Actions, has set improving productivity in the defense industry as one of his policies (4:54). This marks the first time that an administration has stated productivity improvement as a goal of the DOD acquisition process (4:59).

This commitment was reiterated by Mr. Vincent Puritano, Executive Assistant to the Deputy Secretary of Defense. In October of 1981, he stated eight management principles for acquisition managers, the main thrust of which was improving overall contractor productivity and strengthening the defense industrial base (4:58). Additionally a tri-service committee was formed to implement specific actions delineated in the "Action Plan for Improvement of Industrial Responsiveness" (4:67). One of the stated objectives of the committee is to, "Enable American industry to undertake a program of capital investment [4:68]."

It is apparent from the numerous initiatives aimed at improving the productivity of defense firms that the Defense Department considers productivity a very serious problem. There is a need, however, to be able to accurately measure productivity improvements in order to determine the effects of the numerous acquisition improvement strategies on contractor productivity. Also, since a good deal of emphasis on improving productivity has been placed on capital investment, any measurement tool should be able to adequately measure the contribution of capital to the overall productivity of a firm.

Purpose of Research

The purpose of this thesis is to develop a measurement tool which will enable a DOD contracting official to measure the relative productivity of a firm so as to compare that firm with other firms or industry averages and trends.

Research Objectives

The three objectives to this thesis effort were stated in the Acquisition Research Topics Catalogue, 1981, under the heading "Measuring Productivity of Defense Contractors:"

a. Identify and understand the quantitative measures of productivity.
b. Develop a relatively simple, valid, reliable, and inexpensive model to measure the relative productivity of the aerospace firm. The model should address the firm below the corporate level (division, segment, or plant level).
c. Identify productivity criteria and possible sources of data for use by contracting officials. This research should address the identifiable factors to be considered, the data sources available or necessary, and recommendations for using them in the process [2:8].

Scope of Research

This is a penetration study into the feasibility of measuring productivity based on past performance. The area investigated is limited to the aerospace industry which primarily receives negotiated DOD contracts. This is necessary to obtain data which is otherwise not available from other than negotiated contracts. The characteristics of the aerospace firms used in this study are: contractor owned, contractor operated plants, prime contractor, and airframe assembler. To aid in uniformity of data collection, only individual plants performing strictly military contracts are used. This narrowing of the scope is intended to minimize the problem of obtaining access to proprietary information. Additionally, since all profit in negotiated contracts is based on costs, the relevant raw cost data was available. This effort focuses on the elements of cost in developing a productivity measurement technique.

Assumptions and Limitations

The following is a list of the assumptions and limitations necessary to complete this penetration study on productivity measurement.

Assumptions

1. This is not a total factor productivity model. Materials volume is excluded in the productivity structure of the model.

2. Since this is a comparative study of two firms, inflation is assumed to be similar for both firms.

3. Quality of the firms' outputs is assumed to remain constant over time.

Limitations

1. Output measures sales volume only.

2. Only total direct production costs are included in the model.

3. A limited number of points are available from each reporting firm which constrains the method of analysis.

4. Only two firms reported data for use in this study.

CHAPTER II

LITERATURE REVIEW

Overview

This chapter reviews the different methods of measuring productivity. The first section discusses the general definition of productivity. The second section provides an overview of the evolutionary development of the various methods of measuring productivity. Finally, the chapter concludes with a brief summary of the Department of Defense instructions and studies on productivity and productivity measurement.

Productivity: General Definition

General agreement exists among economists that productivity is the ratio of some output to some input (3:38; 10:4; 16:2; 18:6; 20:35; 21;2; 22:2; 25:50; 27:1). However, there is general disagreement as to which outputs should be measured against which inputs. As Paul Mali states,

> The views of productivity for purposes of definition and understanding have not been consistent or uniform. In fact, the many views of productivity have contributed to confusion and obscurity about its nature. Years of seeking productivity growth should have yielded an acceptable meaning. This is not the case, probably due to different positions and emphasis in the degrees of skill in interpreting and looking at the productivity process and measurements [19:4].

Starting from the common ground of a ratio of some output to some input, the main differences lie in the answers to the questions: which outputs to which inputs are to be measured; which output-input comparisons are most relevant to the organization; and, after comparisons are made, how are the results to be interpreted (12:7)? These differences are mainly ones of perspective.

An excellent example of differing perspectives is described by Dr. Bela Gold. Figure 2-1 depicts Gold's concept of physical and financial flows within a firm (8:21). By segregating financial and physical flows within a firm, Dr. Gold makes the point that each group is concerned with different inputs and outputs. For instance, the investors and lenders of a firm are extremely interested in financial flows such as profit to total investment but have little interest in physical productivity. On the other hand, the perspective of the work center supervisor is focused on the physical inputs and outputs of his production process. Finally, a firm's management must integrate the physical and financial flows if it is to function optimally.

The Development of Productivity Measures

Single Factor Productivity Measurement

Productivity measurement began with the measurement of output per labor hour (20:39). Studies of output

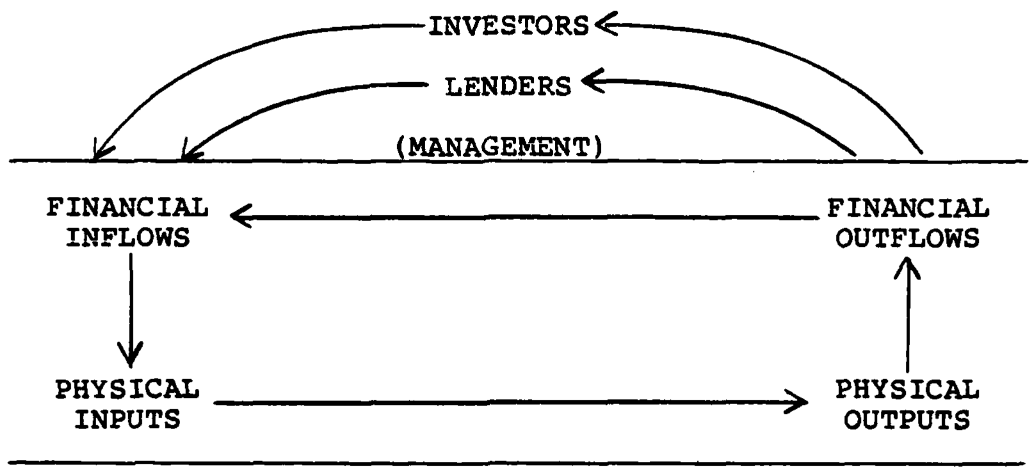

Fig. 2-1. Physical and Financial Flows Within a Firm

per unit of labor input were occasionally performed by the Bureau of Labor as early as the 1880s (20:39). Labor productivity studies began in earnest in the 1930s by both the National Bureau of Economic Research and the National Research Project of the Work Progress Administration (20:39). These studies laid the foundation for the estimates of labor productivity in sectors of the U.S. economy. These estimates by the Bureau of Labor Statistics began in 1940 (20:39). Today these government estimates of productivity are still confined to measures of output per labor hour (20:39).

Leon Greenburg, former Executive Director of the National Council on Productivity and member of the National Bureau of Economic Research, is a leading proponent of the use of labor productivity as a single factor productivity measure. His method uses labor hours as the sole input measurement because labor hours, "are the most appropriate unit for developing a measure of the physical output of the firm [16:19]."

To illustrate this point, Greenburg uses the example of a steel mill. The mill produces two products, carbon steel rods and alloy steel sheets. The labor measure is not affected by differences in the market value of products, by changes in prices, or by shifts in the proportion of goods manufactured (16:19). All measures are derived by equating all products in accordance with the number of labor hours required to make each product in a base year (16:19). This allows "one hour of carbon steel to equal one hour of alloy steel [16:19]." The many outputs of a single plant, several plants, or an entire sector of the economy can be measured and compared this way. The advantage of this method is that it also allows for productivity analysis between dissimilar sectors of the economy (20:39).

However, changes in labor productivity may not be directly attributable to increased effort on the part of labor. The National Research Council Panel to Review

Productivity Statistics points out,

> The Bureau of Labor Statistics (BLS), in the U.S. Department of Labor, often takes pains to warn its readers against possible misinterpretation of productivity measures [20:20].

Chapter 30 of the BLS Handbook on Methodology #1910 includes the following caution:

> Indexes of output per hour show changes in the ratio of output to hours of labor input; however, these indexes should not be interpreted as representing solely labor's contribution to production. Rather, they reflect the interaction of many factors working in cooperation with the hours of labor input, including technology, capital investment, human capital (education and skill), energy, and raw materials [6:221].

<u>Multifactor Productivity Measurement</u>

The development of multifactor productivity measures lagged behind labor productivity measures (20:42). There are three main reasons for this lag. First, the data base for estimates of labor productivity is much larger. This data base includes data from as far back as the mid-nineteenth century. Systematic estimates of capital did not begin until after World War II (20:42). Second, national economic accounting systems didn't appear until 1940 (20:42). Third, interest in the development of multifactor productivity measures didn't begin until the 1950s.

Smookler, Kendrick, Abromovitz, and Fabricant prepared estimates of multifactor productivity in the 1950s. The basic concept underlying their work is simple. They define multifactor productivity as:

$$\frac{Q}{aL+bK}$$

where Q is the real product of the sector (a price weighted quantity aggregate) of the economy being investigated; L is the labor input measured in labor hours; K is the capital input measured in dollars weighted by a base period; and a and b are the percentage shares of labor and capital originating in that sector (20:43). In this formulation, multifactor productivity is measured using macroeconomic principles (20:43).

In 1957, Robert M. Solow married the concept of multifactor productivity to parametric statistics by using the Cobb-Douglas production function (24:312). This production function was developed in 1927 but had never been used to derive productivity estimates (20:42). Solow's statistical approach is used by many economists. Variations of this method are produced as the statistical assumptions of the economists change (20:43). A more thorough discussion of Solow's approach is contained in Review of Economics and Statistics, August 1957.

There are also multifactor approaches based on a "family of ratios [22:25]." This method was also developed in the 1950s. Two noted proponents of this technique are Doctors Irving H. Siegal (1952) and Bela Gold (1955). The main differences between this method and the previous methods are in the focus and the objectives of measurement.

The family of ratios method usually focuses at the firm or corporate level. Most other multifactor methods try to include a spectrum from the firm to the national economy. This broad scope adds complexity to these methods. Due to its narrower focus, the family of ratios approach remains less complicated. Another advantage of this approach is that it allows the user to "seek and apply measures for a diversity of purposes and contexts [22:26]."

Dr. Gold's productivity model illustrates one method based on the family of ratios approach. This model attempts to define inputs and outputs on a number of levels to determine the productivity of a firm on a macro (work center) level. Gold is also very flexible in his approach to productivity studies and measurement.

Two of Dr. Gold's associates, Samuel Eilon and Judith Soesan, aided in developing the various productivity measurement approaches. They defined productivity measurement as falling into four categories: financial ratios, productivity costing, transfer pricing, and other empirically-oriented approaches. First, financial ratios compare financial outputs to financial input and include profit/investment (return on investment), profit/revenue (operating profitability), and revenue/investment (capital turnover). Each of these ratios may be further broken down into its component parts (8:7-8). These ratios are used

> . . . as a means of circumventing the problems rooted in the heterogeneity of physical inputs and in the difficulties of assessing the contributions of the different inputs of producing the products in question [8:7].

Second, the productivity costing approaches define the productivity of a product in terms of its ability to make a profit (8:8). This productivity is measured in terms of a rate of return on investment or a gross or net profit per product basis. Third, transfer pricing compares the cost of producing a product to the cost of obtaining the product from a competitor. This method is limited to organizations which transfer a product from one decision to another (8:10). Finally, the other empirically-oriented approaches include value added per product, unit cost, actual output to potential output, and percentage of output rejected (8:11). By using any of these four categories the user can choose that approach which best suits his organization and data requirement (8:11).

Figure 2-2 depicts the multifactor model developed by Professor Gold who calls his model the Productivity-Cost-Profitability (P-C-P) system. This model incorporates three levels of measurement and evaluation:

1. The bottom network which represents productivity relationships.

2. The center network which represents the cost structure.

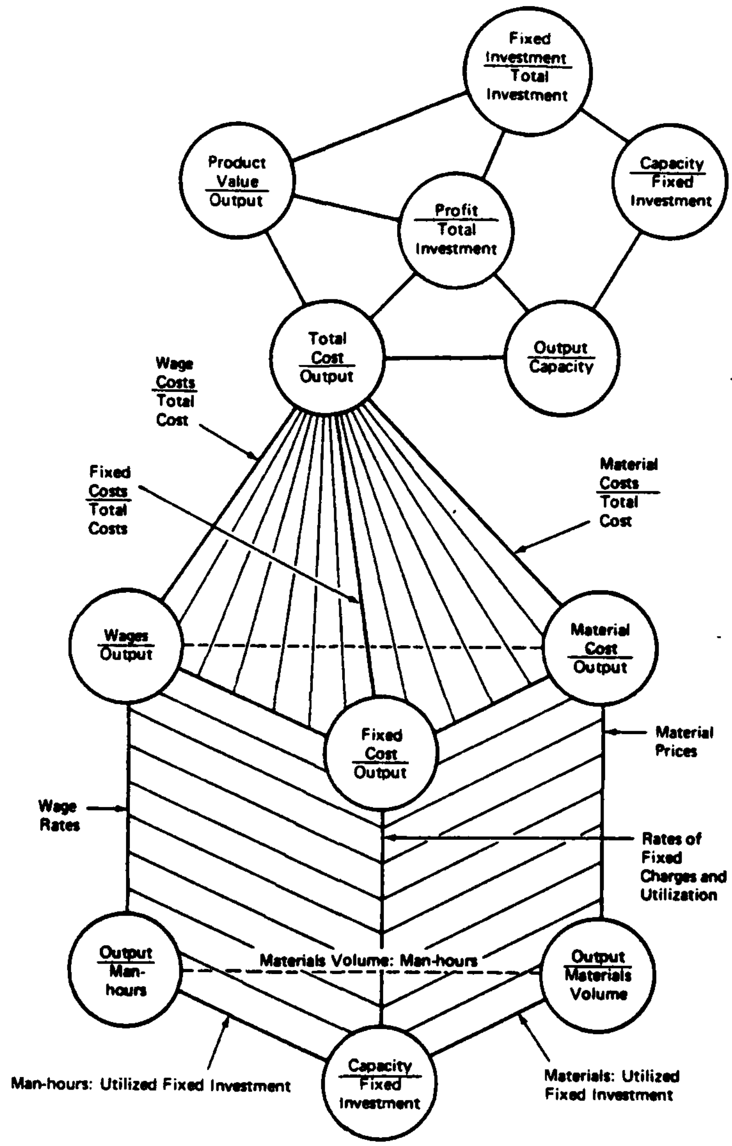

Fig. 2-2. P-C-P Model [14:51]

3. The top network of managerial control ratios which represent the other primary determinants of profitability (14:51).

The productivity network has six interacting links. Man-hours per unit of output, materials volume per unit of output, and fixed investment per unit of capacity represent the three direct input components per unit of output. The three remaining ratios describe any changes of the proportions in which the inputs are combined due to substitutions and utilization rates. These ratios are: man-hours to materials volume, actively utilized fixed investment to man-hours, and fixed investment to materials volume (14:51). This productivity network has three characteristics:

1. The results of changes in any of the six links can be traced through the entire system and integrated into it.

2. An observed change in any of the six links may not have originated in that component but "may represent a passive adjustment to a change elsewhere in the system [14:48]."

3. A change in any link affects the rest of the network and depends on simultaneous changes in output, capacity and the technological characteristics of the manufacturing process utilization in production (14:49).

However, Professor Gold points out that the productivity network does not stand alone. The cost structure must be integrated with changes in the productivity network in order to determine the economic desirability of those changes. First, the change in each unit input on its unit cost must be determined. Then, the effect of this unit change on total unit costs can be determined depending on the proportion of total cost accounted for by the change. For example, a 10 percent increase in output per man-hour accompanied by only a 5 percent increase in hourly wage rates would reduce unit wage costs by 5 percent. But if wages account for 20 percent of total costs, this could tend to reduce total unit costs by only 1 percent.

The top network, managerial ratios, covers the effects of productivity changes on product quality and other characteristics which affect the price of the product and the quantities which can be sold (14:51). It integrates the network of productivity with the structure of costs to provide a unified framework for the systematic exploration of the complex interactions between the productivity and cost networks (14:52). The objective of the managerial control ratios is to determine how to maximize the rate of profit on total investment (14:51).

Dr. Gold's model uses a family of ratios approach to measure not only productivity but the effects that changing costs and prices have on the overall profitability of a firm. It is flexible enough to provide meaningful information to all segments of a firm from corporate/plant management to the individual work center.

DOD Productivity

DOD Instruction 7041.3, Economic Analysis and Program Evaluation for Resource Management, defines productivity as: "The ratio of goods produced or services rendered (output) to resources expended (input) [27:1]." This instruction also defines Productivity Enhancement as: "Increasing that ratio of goods produced or services rendered (output) to resources expended (input) [27:1]." It goes on to define another important aspect of productivity, Productivity Measurement, as: "The determination and comparison of the change of output-input relationship for two or more periods of time [27:2]." Productivity Measurement is further defined as consisting of four parts: total factor productivity, labor productivity, capital equipment productivity, and real property productivity (27:2).

All productivity measurements are based on cost. Labor productivity measures costs related to labor per unit costs. Capital equipment productivity measures costs per unit related to productive investment. Real property productivity assigns costs to facilities. Total factor productivity encompasses the three parts listed above plus all costs for materials and overhead (27:2). Each of these productivity factors assigns some productivity cost to some resource; be it labor, machinery, facilities, or management. A true measurement of total productivity can be derived by aggregating all of the resource (input) costs. The output in goods or services is much easier to quantify. Standard guidelines for collecting cost data are contained in the Defense Acquisition Regulation. These definitions in DODI 7041.3 are as broad as possible since they must be applied to an equally broad spectrum of industries which comprise the defense industrial base.

Another instruction, DODI 5010.34, Productivity Enhancement, Measurement, and Evaluation--Operating Guidelines and Reporting Instructions, outlines the DOD productivity program. DOD uses labor productivity as its primary measurement technique for assessing the productivity of its varied components. The exact measurement technique for implementing this instruction is left to the reporting organization. The only requirement is that the reporting organization reduce its use of resources and comply with DOD Directive 5010.31.

DOD Directive 5010.31, Productivity Enhancement, Measurement, and Evaluation--Policies and Responsibilities, further defines how DOD would like to measure productivity. This directive states that where adequate cost information is available, the DOD prefers to measure productivity from a total factor or unit cost approach. This type of approach is similar to a successful program implemented by Kaiser Aluminum and Chemical Corporation. Kaiser Aluminum's productivity program is based on the corporate standard cost system. It compares one year's cost performance with that of the preceding year's performance. The improvement or regression noted is equated to productivity change (5:53).

In addition to these instructions, there are many recent studies conducted by the Department of Defense on productivity. These studies express serious concern about the low levels of long-term investment in technology and modern plant equipment by defense aerospace firms. The recent Payoff '80 study, conducted by Air Force Systems Command, revealed that investment in modern equipment, facilities and new technology is the most significant factor in productivity growth. Payoff '80 indicates that capital investment and new technology account for over 80 percent of productivity growth (17:III,IV).

Based on these studies and instructions the DOD perspective on productivity appears to be a total factor or unit cost approach with particular emphasis on labor and capital productivity.

Summary

In this chapter, the theory of productivity, what it is and how it is measured, was discussed. The Department of Defense instructions on productivity were also presented. While the theorists presented have very definite formulae for measuring productivity, the DOD does not. There are some good reasons for this ambiguity on the part of the Department of Defense. There are so many experts supporting so many theories that it is impossible to decide which theory is the right one to use. All of the theories and formulae for productivity and its measurement have some merit. The main point of this chapter is that productivity measurement will be different depending on the perspective of the user. This perspective will determine what is measured and how it is measured.

CHAPTER III

METHODOLOGY

Overview

The purpose of this research is to enable DOD contracting officials to measure the relative productivity of an individual defense firm against other defense firms, or against industry averages and trends. With this purpose in mind, the specific objective is to develop a productivity measurement model which can be used to describe, measure, and analyze the relative productivity of defense aerospace contractors. The methodology that was applied to achieve this objective will be outlined in this chapter. In the first section of this chapter, the general productivity measurement model used in this study is developed. The next section contains a discussion of the model itself and specifically addresses the data requirements and the model's analytical framework. Finally, the chapter concludes with a discussion of the procedures used in applying the model to representative defense aerospace firms.

Development of Productivity Measurement Model

Model Requirements

As stated in Chapter II, all productivity measurement studies are dependent upon the purposes for which they are to be used. Since this study examines the individual aerospace firm from the Department of Defense perspective, the essential model-building objective was to identify productivity measures that are of primary importance to the DOD. In this effort, the authors considered concepts originally noted in a 1981 study conducted by the Army Procurement Research Office (APRO).

APRO determined that the model should include as many input and output factors as needed to capture a firm's overall efficiency and effectiveness. Next, the factors should be quantifiable in order to facilitate tracking and comparisons over a period of time. Third, the model should be able to identify the contract which originally established the requirement. And finally, the model should be compatible with the data sources and measures presently in use by defense contractors (31:6-7).

In addition to these basic guidelines, it is essential that the original study objectives be considered. Specifically, the study's primary objective of devising a simple, valid, reliable, and inexpensive method of measuring the relative productivity of defense aerospace contractors must be addressed. To meet this objective, criteria to denote what is meant by simple, valid, reliable, and inexpensive have been established.

In developing a model, it is important that it be simple. To enhance the likelihood that the model will be applied by field contracting personnel, it must be readily understood. Common productivity measures such as output per man-hour, production capacity, and fixed investment must be used.

To ensure that the model is valid, it must "measure what it purports to measure [26:51]." In this study, the primary concern centers around content validity and face validity. Content validity refers to the extent that items making up a model comprise a representative sample of the population of items associated with the variable being measured (26:51). In other words, the model must use variables and ratios that are commonly associated with productivity measurement. Face validity refers to the extent that the model "appears to measure" productivity. This concept is important because in order for the model to be successfully employed in research and/or applied, it must be acceptable to both the user and the firm being measured (26:55).

In assessing the model's reliability, such factors as internal consistency, stability over time, and accuracy are of prime importance. Reliability means that regardless of the number of times data is applied to the model, the same outcome will occur. This sort of consistency and stability in replicating the model is essential. The extent to which the outcome is error-free, is the extent the model is reliable (26:44,51).

The final criterion for meeting the model-building objective is that it is inexpensive. The goal is to keep to a minimum, the effort, time, and cost that is required to collect the data. Within the DOD, most of the data are already accumulated in various reports. It is necessary to identify these reports so that the data can be extracted inexpensively.

Model Selection

In this study, the approach to productivity measurement is closely aligned to similar, but separate, methodologies espoused by Dr. Bela Gold of Case Western Reserve University, and Dr. Irving H. Siegal, a former member of the National Bureau of Economic Research. When measuring productivity from the overall plant level, both economists advocate the use of a "network," or "family," of ratios which link physical and financial input-output relationships. For more than twenty years, the two economists have successfully applied their methodologies and concepts in actual manufacturing firms (15:3; 22:xi).

To apply the methods of analysis of Doctors Gold and Siegal, it was necessary to reorient the perspective from which they had focused their studies. Dr. Gold's elaborate network of ratios, referred to as the Productivity-Cost-Profitability (P-C-P) system, measures productivity as viewed by management. The three-tiered model is based upon the assumption that management's overriding concern is to increase the firm's ultimate return on investment. He states that the primary criterion for performance evaluation is to increase revenue relative to costs, rather than reducing costs relative to output. And, even more important, is the motive for increasing profit relative to total investment (8:31). Thus, in essence, Gold's P-C-P model emphasizes the internal managerial control elements directed towards increasing profitability.

On the other hand, this study takes the more limited outsider's view of the firm by focusing on several key productivity ratios and their interaction with the direct input cost structure. Instead of measuring productivity from the profit-oriented management perspective, this study attempts to measure productivity from the cost-oriented Defense Department perspective. Gold states that his general approach to productivity measurement may be used from different points of view and at various levels of aggregation (8:16-17). The model is a modified version of Dr. Gold's original P-C-P system.

The Model

Introduction

This section will present a brief description of the model to be used, describe the data requirements necessary to implement the model, and conclude with a more detailed presentation of the analytical framework of the model.

Overview

As shown in Figure 3-1, the model is composed of two separate tiers--the network of productivity ratios and the structure of direct input costs. Based upon the ratios identified, this study looks at the network of productivity ratios in an effort to discern the nature of the changes which occur in the measures. Having identified the source of change, the analysis tries to interpret the interacting effects on each measure brought about by the observed change. By tracking and monitoring these changes, the network of productivity helps to identify the origin of the change instead of having to assume that it was derived within any particular measure registering an increase or decrease (8:27).

While the network of productivity ratios concentrates on the input-output relationships centering around labor and fixed capital, the primary emphasis of this study is to examine the economic changes that occur within the structure of costs as a result of changes in the productivity network. Regardless of the changes that occur in the input-output relationships, the final appraisal must

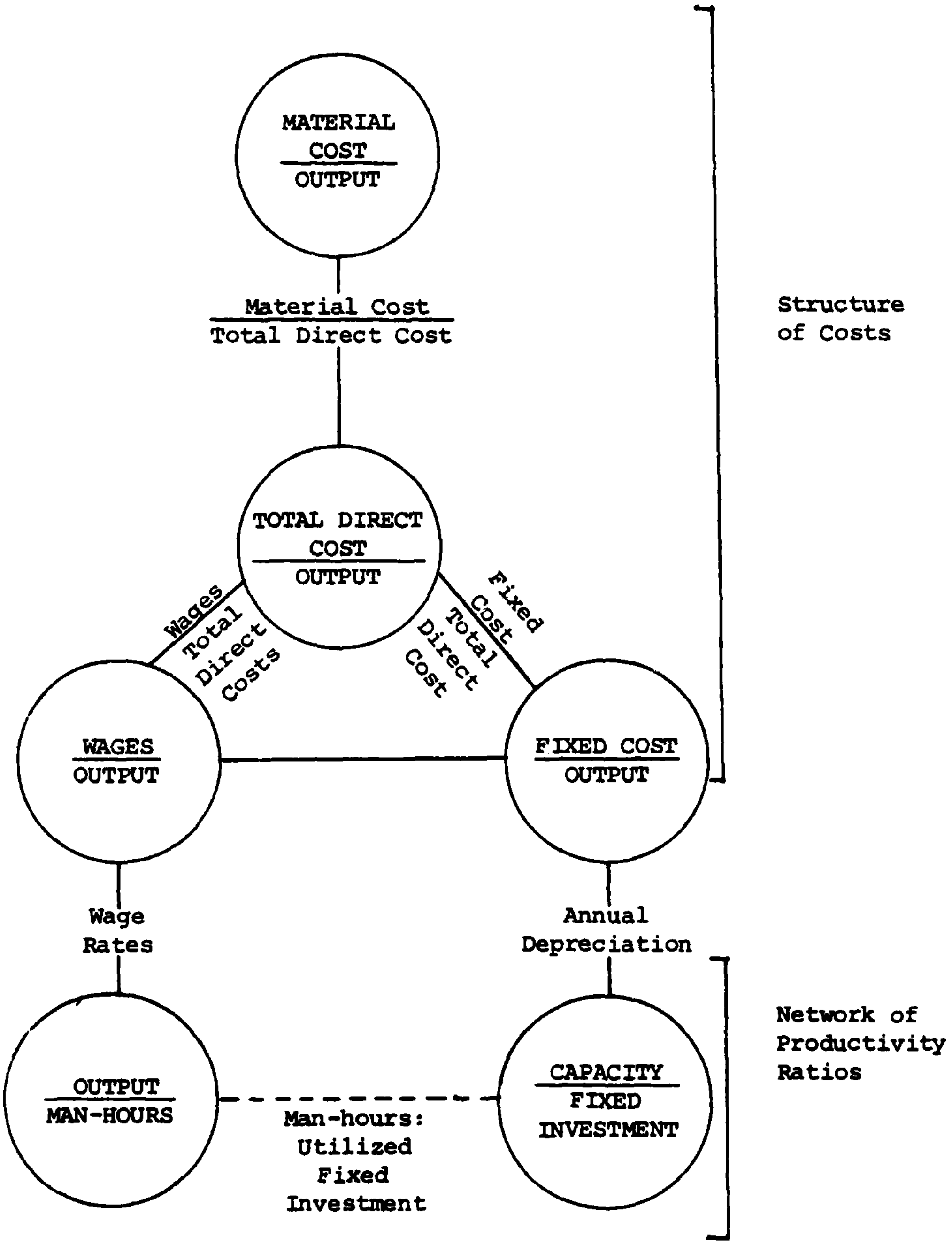

Fig. 3-1. Productivity and Cost Structure Ratios

be made from an economic point of view. This can only be done through a study of the structure of costs.

Within the structure of costs, this study will focus on two related aspects of the interactions among adjustments in the major components of total costs. The first is the relative weight of the various cost components--wages, fixed costs, and material costs. The second concerns the fact that changes in any one of these components will alter the proportion of the total outlay accounted for by the other components (11:71; 15:17). Thus, the primary concern is the cost interactions which deal with factor proportions and the changing balance among cost components which are competitive with and, to some extent, capable of subsititution for, one another (11:71).

Data Requirements

Before proceeding to a more detailed presentation of the model's analytical framework, it is necessary to outline the specific data requirements which were used in implementing the model. In collecting the data, the effort was to match existing sources to the model. With this in mind, a search was initiated that would attempt to link the productivity measurement requirements of the model with the data reporting requirements currently used in defense contracting.

Since this study focused specifically on aerospace firms whose production output was comprised almost entirely of DOD contracts, their present reporting requirements provided most of the necessary data. The specific reports used in this study included DD Form 1921-3, Plant Wide Data Report; Bureau of the Census, Survey of Plant Capacity Report (MQ-CI); and internal labor and overhead expense reports, production schedules, and sales reports.

To comply with present DOD reporting requirements, and simultaneously maintain sufficient conformity with standard economic definitions, only slight modifications in data format and definitions were necessary to meet the productivity measurement requirements for this study. The definitions and data requirements used are listed below:

1. Output (O). The change in total product value (value = price x quantity) between any two periods. (Dollars).

2. Man-hours (M-HRS). The total number of direct labor man-hours needed to produce the stated output.

3. Wages (W). Total wage cost attributed to direct labor man-hours. (Dollars)

4. Materials Cost (MATL). Total purchased materials cost and cost of supplies that go into the production process. (Raw materials, subcontracted purchased parts). (Dollars)

5. Fixed Investment (F.I.). Net book value of investment in fixed capital facilities and equipment. (Dollars)

6. Fixed Cost (F.C.). Allocated portion of fixed capital facilities and equipment needed to produce a stated output during a specified period. (Dollars) Categories included in this figure are the following:

I. Facilities--Building/Land

(a) Depreciation and Amortization

(b) Rentals

(c) Maintenance

(d) Insurance

(e) Utilities

(f) Property Taxes

(g) Plant Rearrangement

(h) Plant Security

(i) Other

II. Facilities--Furniture/Equipment

(a) Depreciation and Amortization

(b) Rentals

(c) Maintenance

(d) Data Processing Services

(e) Other

7. <u>Total Direct Cost</u> (TDC). The total wage costs, material costs, and fixed costs, as defined, which go into the production process. (Dollars)

8. <u>Capacity</u> (CAP). An estimate of the total output which could be produced of any given product, or mix of products, assuming some specified allocation of plant facilities and equipment was dedicated to such output. (Dollars)

Analytical Framework

To begin a more in-depth look at the model, Figure 3-2 shows that the network of productivity ratios is composed of three interacting ratios: (1) output per man-hour; (2) the ratio of productive capacity to net fixed investment; and (3) the ratio of actively utilized net fixed investment to labor man-hours. Within this network, there are three interacting links. Two cover the input requirements per unit of output for labor and capital. The remaining link covers the proportion in which these two inputs are combined.

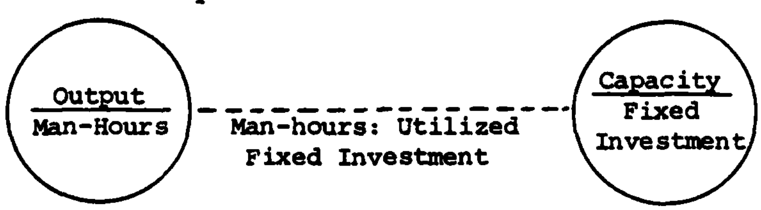

Fig. 3-2. Network of Productivity Ratios

By presenting productivity relationships as a network of interactions, the model emphasizes that a change in any component may merely be the passive result of changes initiated elsewhere in the network. For instance, the ratio, output per man-hour, may increase for a variety of reasons other than increased effort by labor. If additional machines were added, output per man-hour could increase even though labor's efforts continued unchanged. Another example of output per man-hour increasing through no extra effort of its own is when machine capacity is utilized more fully, or when machine capacity is increased through technical innovation. This study is primarily concerned with identifying the source of productivity changes and tracing their effect on the structure of costs (8:25-26; 13:65).

For the purpose of this study, output per man-hour will be examined to determine the percentage of changes that occur over a specified period of time. By measuring percentage changes that occur in this ratio, an estimate of the relative productivity of labor is determined. While labor is compared with a measure of output, net fixed investment is compared with productive capacity. Fixed investment is compared with capacity in order to differentiate between what the stock of capital goods can produce and the extent to which they are underutilized due to economic conditions (8:25). In this respect, the ratio, capacity to fixed investment, more closely approximates the true meaning of the concept, productivity of fixed capital. It reflects the technological efficiency of capital facilities when they are fully utilized (12:65).

The final component in the productivity network, the ratio of actively utilized fixed investment relative to man-hours, constitutes the proportion in which labor and capital are combined. Algebraically, this ratio is expressed as follows:

$$\frac{\text{FIXED INVESTMENT X } \frac{\text{OUTPUT}}{\text{CAPACITY}}}{\text{MAN-HOURS}}$$

By multiplying net fixed investment by the utilization ratio (output/capacity) the numerator is merely that proportion of net fixed investment which is actively employed in a firm's production process. Thus, the proportions in which man-hours are combined with a firm's total capital facilities is approximated by comparing man-hours not with fixed investment, but with that proportion of net fixed investment actually used (12:64-67).

As noted in Figure 3-2, the productivity of direct materials input has been omitted from the productivity network. Aside from the DOD's primary emphasis on labor and capital productivity, materials input was omitted because of the difficulty in measuring the many heterogeneous physical inputs involved in complex manufacturing firms. For example, each prime contractor may have thousands of subcontractors. To measure the materials volume which each subcontractor supplies to the prime contractor would be an extremely difficult task and would certainly not be cost effective. While it is acknowledged that productivity changes can occur due to increases in efficiency in the use of material inputs, this study is based upon the assumption that labor and capital account for the bulk of productivity growth. In support of this assumption, Solomon Fabricant, Director of the research staff at the National Bureau of Economic Research, along with the National Research Council, recently stated that total productivity and factor substitution between material, labor, and capital inputs can be reflected in the study of labor and capital alone (10:7; 20:13). Although not included in the network of productivity ratios, materials input is incorporated into the model in the structure of costs.

While the network of productivity ratios concentrates on the input-output relationships centering around labor and fixed investment, the structure of costs examines the economic effects that result from changes within the productivity network. To examine these changes and relationships, the structure of costs network must be analyzed in conjunction with the network of productivity ratios. However, to accurately analyze the effect of changes occurring between the two tiers, it is essential that the interactions between productivity adjustments and factor prices be considered. The effect of changes in output per man-hour on unit wage costs depends on the changes in wage rates. Likewise, the effect of changes in the productivity of fixed investment on fixed costs depends on the annual rate of fixed charges. It is not adequate to assume that factor prices remain unchanged (15:17).

To conduct a comprehensive study of the cost interactions, the approach used was the measurement of cost proportions. This entails measuring the percentage of total costs for each of the major cost components. Within the DOD and industry alike, very little use of this approach for either managerial decision making or economic analysis has been conducted. Thus, the potential for this type of analysis needs to be illustrated (11:71).

The benefit derived from measuring cost proportions is that it helps to analyze past adjustments in the structure of costs, and provides a guide to future developments (11:71). With emphasis in the DOD on cutting costs in procurement, a knowledge of the cost interactions once an innovation has been introduced, can provide essential insight into the possible cost ramifications before the fact. This insight could prove extremely beneficial in many budgetary decisions.

In this analysis of past adjustments in the structure of costs, there are four basic areas of concern that will be examined. These four areas are listed below (11:71-72):

1. Investigate the behavior of cost proportions on changes in total costs;

2. Trace the effects of changes in specific cost components on the other components;

3. Determine the trends and degree of stability exhibited by these proportions; and

4. Ascertain the stability of the overall pattern of cost proportions over short-term and long-term periods.

In the first area, when investigating the behavior of cost proportions on changes in total costs, one must be concerned not only with the relative change in each cost component, but also with the proportion of total costs accounted for by each. A knowledge of current cost proportions serves to indicate the components in which cost adjustments will have the greatest effect on total costs and aid in estimating the effect on total costs of planned adjustments (11:72).

The second area of concern involves tracing the effects of changes in specific cost components on the other components. This type of study may lead to the discovery of close relationships between major cost categories. For example, it may reveal that regular patterns occur between material costs and wages or, perhaps, between wages and overhead. Alternatively, investigation might reveal consistent patterns of adjustment in cost proportions during recessions, during periods of recovery, and during other periods characterized by special economic conditions (11:72-73). Findings of this nature would facilitate a more thorough analysis of the prospective effects of planned or anticipated innovations. It would concentrate attention not only on the narrowly localized effects of such innovations, but also their effects on other cost components (11:73).

The third area of cost proportion measurement centers around the determination of the trends and the degree of stability exhibited by the major cost components. In this type of analysis, the study of trends deals primarily with long-term effects, whereas the study of cost component stability deals with short-term effects. Through the recognition of trends, efforts can be made to identify their causes. The identification of various cost trends may lead to a method of proper adjustment to adopt policies which further their continuance, or take steps to prevent their recurrence. By examining the degree of stability in the cost proportions of the various components, contracting officials will have a method to analyze short-term changes in order to determine the effect on long-term goals. Briefly, a comparison of short-term stability with the long-term trends should help to indicate the relative influence of long-term and short-term factors in making the correct productivity adjustments (11:73-74).

The final area of study deals with the stability of the overall pattern of cost proportions. By determining the stability of the pattern of cost proportions, the relative strength of the forces tending to affect all cost components similarly and the forces tending to affect them differently can be ascertained. This knowledge can be useful in determining whether to introduce certain innovations in production, or the extent to which factor substitution can be initiated in the production process in order to enhance overall production efficiency (11:74).

By tracking and monitoring the cost proportion adjustments that occur as a result of changes within the network of productivity ratios, a more purposeful insight into the nature and causes of specific productivity innovations can be made. Through the effective evaluation of a firm's past performance, it will be possible to plan and appraise future improvements.

Model Application

General Methodology

The actual procedures used to extract information from the data are discussed in this final section. This study does not purport to identify one specific index which will identify the productivity of an individual firm. Rather, it is the tracking and monitoring of the many interacting relationships discussed in the previous section that must be analyzed and evaluated before a comparison between two or more firms can be made.

To apply the model, the data was collected and grouped into the variables/ratios of concern as outlined in the model framework. For the purposes of the analysis, the primary focus is on portraying the relationships among changes in the relative magnitudes of each of the variables. To do this, index numbers are used with all series having a common base year in any given application. Once the data is converted to a series of index numbers, the analysis concentrates primarily on graphical representation to make inferences concerning the relative changes occurring within an individual firm.

By graphically displaying the various ratios, positive or negative relationships are readily apparent. Although the absolute determinants of the various changes cannot be deduced from this type of analysis, it does provide legitimate guides to tracing the interacting effects between the network of productivity ratios and the structure of costs. Even though graphical representation is the primary method of analysis, the use of more reliable statistical measures, such as correlation analysis and linear regression, could be applied to the general analytical approach. This initial study was unable to apply these more sophisticated methods due to the small sample size of the data. As will be seen, however, the general methodology of this study will reveal the practical application and significance of the approach used.

Network of Productivity Ratios

Within the network of productivity ratios, the data analysis initially focuses on the relative changes that occur in the following productivity variables: capacity, output, man-hours, and net fixed investment. A brief exposition of the trends displayed by these key variables provides a general background for further analysis.

Following this exposition, the analysis focuses on the relative changes that occur in the following ratios:

Labor productivity: $\dfrac{\text{OUTPUT}}{\text{MAN-HOURS}}$

Capital productivity: $\dfrac{\text{CAPACITY}}{\text{FIXED INVESTMENT}}$

Ratio of actively utilized fixed investment: $\dfrac{\text{FIXED INVESTMENT} \times \dfrac{\text{OUTPUT}}{\text{CAPACITY}}}{\text{MAN-HOURS}}$

Looking at these ratios, the analysis specifically concentrates on the factors influencing the ratio, output per man-hour. The network of productivity ratios used in the model establishes that changes in the productivity of labor may not be solely attributable to changes in the efforts of labor alone. The network of ratios shows that changes may occur due to relative changes in the productivity of capital, or relative changes in the proportion of actively utilized capital to labor (8:101). As shown in the equation below, the relative changes in output per man-hour may be regarded as the product of relative changes in the ratio of actively utilized fixed investment to man-hours and the productivity of fixed investment:

$$\frac{\text{OUTPUT}}{\text{MAN-HOURS}} = \frac{\text{FIXED INVESTMENT} \times \dfrac{\text{OUTPUT}}{\text{CAPACITY}}}{\text{MAN-HOURS}} \times \frac{\text{CAPACITY}}{\text{FIXED INVESTMENT}}$$

This formulation seeks to distinguish between the relative contributions to changes in the ratio, output per man-hour. With this information, the changes which occur in the network of productivity ratios can be followed to examine their effect on the structure of costs.

Structure of Costs

Prior to examining the structure of costs, an analysis of the percentage changes in factor prices (wage rates and depreciation) will be conducted. Wage rates will be compared with percentage changes in the labor productivity ratio and depreciation costs will be compared with percentage changes in the capital productivity ratio. The interaction between the two tiers is based upon adjustments in factor productivities and the resulting adjustments in factor prices. This type of analysis is the first step in determining the effects of productivity changes on the structure of costs.

Within the structure of costs, the analysis focuses on the percentage changes which occur among the three direct input costs. The analysis examines the cost interactions among factor proportions and cost components. Specifically, the measures to be analyzed are the following unit cost ratios and total direct cost components:

Unit Cost Ratios

Wages/Output
Fixed Costs/Output
Material Costs/Output
Total Direct Costs/Output

Total Cost Components

Wages/Total Direct Costs
Fixed Costs/Total Direct Costs
Material Costs/Total Direct Costs

By identifying the economic changes within the above ratios, the model establishes a framework to evaluate the prospective effects on factor costs, total costs, and cost proportions of past, or anticipated changes in the network of productivity ratios (8:29).

Summary

This chapter discussed the methods used in building a DOD productivity measurement model. The model requirements, the model, the data sources and definitions, and the methods of analysis were identified. The approach was to structure a "network," or "family," of productivity and cost ratios which, when carefully monitored and evaluated, will provide DOD contracting officials with a framework to measure the relative productivity of defense aerospace contractors. The next chapter contains the results and analysis of the application of this methodology.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF RESULTS

Overview

This chapter describes the data collection, the data analysis, and the results of the data analysis.

Data Collection

To collect the data for this study, requests were sent to the DOD Plant Representative Offices at five major aerospace firms. The collection effort required the Plant Representative Office to compile most of the data with some assistance from the contractors themselves. The data include some proprietary information. Two of the Plant Representative Offices did not respond, one responded but failed to comply with the standard definitions enclosed in the solicitation letter, and two responded fully complying with all requirements. Due to the proprietary nature of the information in this study, the two firms are referred to as Company A and Company B. Both are large defense aerospace firms primarily involved in the manufacture of aircraft airframes.

Most of the data necessary were readily available due to standard reporting procedures required of all DOD prime contractors. Actual sources used included: Plant

Wide Data Report (DD Form 1921-3), internal labor and overhead expense reports, production schedules, sales reports, and Bureau of the Census, Survey of Plant Capacity Report (MQ-C1). Numerous telephone conversations followed receipt of the data to ensure that all standard definitions were fully understood and that all data were collected in a consistent manner. Additionally, the data represent the output for a single plant of each manufacturer which produces aircraft exclusively for the U.S. military.

Major Program Changes During Period of Study

The data covers a five-year period from 1 January 1977 through 31 December 1981. All data was compiled on a calendar year basis. During this period Company A underwent a dynamic change in its major program structure. Company A phased out two production aircraft and began production on another while beginning full-scale development on yet another aircraft program. Company B had a much greater degree of program stability during this same five-year period. Table 4-1 illustrates the major program changes which occurred during the period of this study. The reason these changes are important becomes evident later in this chapter.

Both Company A and Company B employed approximately equal numbers of direct production workers at their respective plants. Also, the average wage rates are comparable

TABLE 4-1

MAJOR PROGRAM CHANGES*

COMPANY A. MAJOR PROGRAMS BY YEAR			
Year	FSD	In Production	Program Termination
1	1	3	-
2	2	3	-
3	1	2	2
4	1	2	-
5	1	2	-
COMPANY B. MAJOR PROGRAMS BY YEAR			
Year	FSD	In Production	Program Termination
1	1	4	-
2	1	4	-
3	-	5	-
4	-	5	-
5	-	5	-

*Numbers in columns represent number of programs per year.

and the total number of man-hours worked each year is approximately equal. However, the total number of aircraft produced by Company A is approximately three times that of Company B. The significance of this factor will be brought out in the Data Results and Analysis section of this chapter.

Data Results and Analysis

In applying the data to the model, the analysis examines the network of productivity ratios and the structure of costs. Within the productivity network, the analysis initially focuses on the relative changes which occur in the individual productivity variables. The analysis then turns to an in-depth examination of the relative changes which occur in the productivity ratios. Within the structure of costs, the analysis initially focuses on a comparison of the relative changes in factor prices to factor productivities. Finally, the analysis concludes with an examination of the factor proportion and cost component changes which occur in unit costs and total costs.

Network of Productivity Ratios

Prior to showing the results of the data applied to the network of productivity ratios, a brief examination of the various individual productivity variables is warranted. The productivity variables of concern are capacity (CAP), output (O), man-hours (M-HRS), and net fixed investment (F.I.). All data for these variables are shown in Figures 4-1 and 4-2 and Tables 4-2 and 4-3.

Over the five-year period, total production capacity for Company A increased by 49 percent and output increased 53 percent. For Company B, production capacity also increased by 49 percent, while output increased by 38 percent. Man-hours fluctuated widely in Company A during the first three years, and then followed a steady upward trend. For the entire five-year period, man-hours increased by only 5 percent. With regards to Company B, man-hours dropped precipitously in year 2 (11 percent below the previous year), and then followed a steady upward trend. However, for the entire five-year period, man-hours decreased by only 3 percent. In Company A, the value of net fixed investment recorded a dramatic increase from year 3 to year 5. This large increase was primarily due to major expenditures for two aircraft programs which began full-scale production, one in year 3, and one in year 5. In years 3, 4, and 5, net fixed investment increased 31, 46, and 32 percent, respectively, from the preceding year. Through the entire five-year period, Company A experienced a 205 percent increase in net fixed investment. As for Company B, net fixed investment remained relatively stable until the fifth year, when it increased by 15 percent from year 4. For the entire

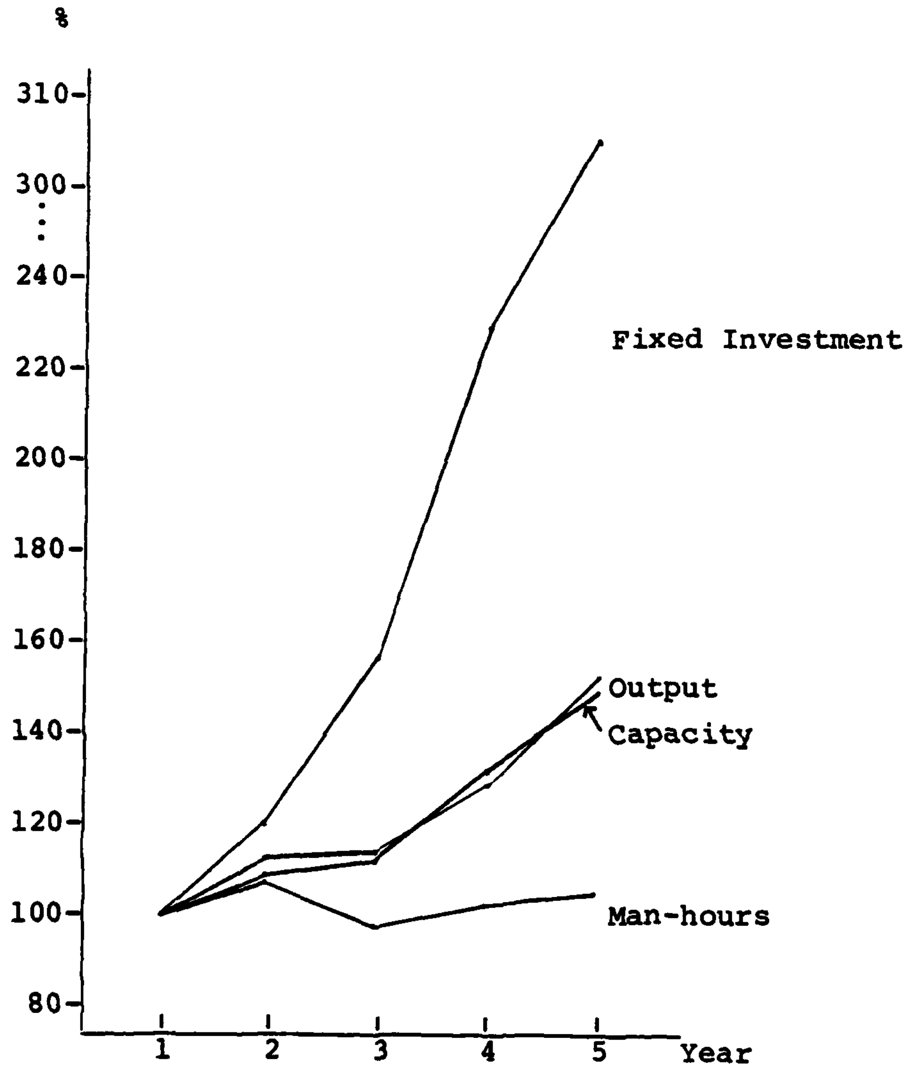

Fig. 4-1. Index of Productivity Variables--Company A

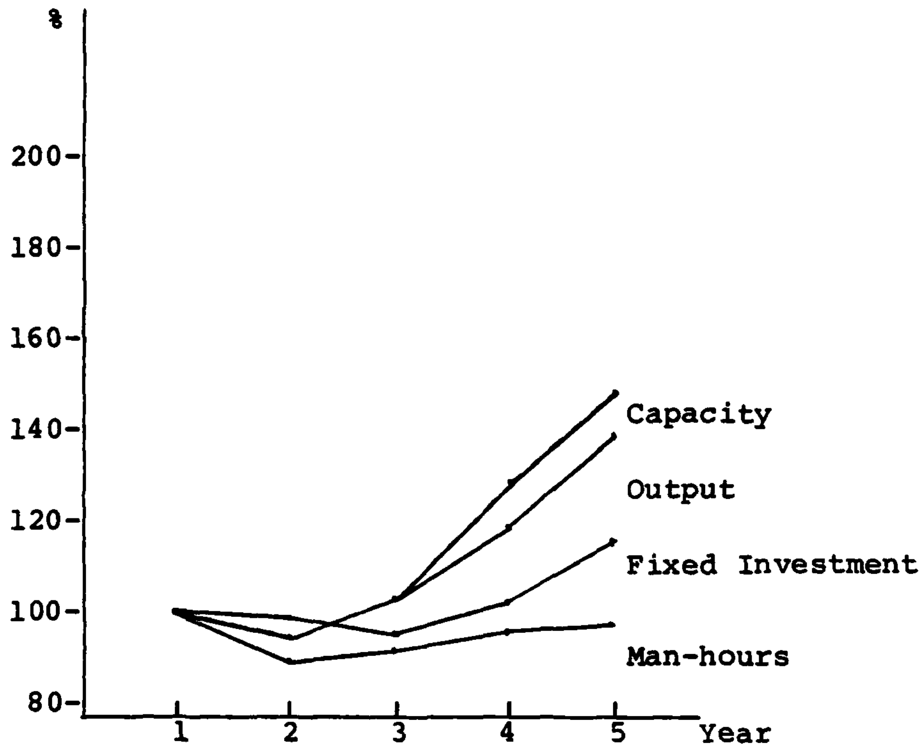

Fig. 4-2. Index of Productivity Variables--Company B

TABLE 4-2

PRODUCTIVITY VARIABLES--COMPANY A

ACTUAL DATA (HOURS AND DOLLARS IN 000'S)				
Year	Output	Capacity	Fixed Investment	Man-hours
1	$1,924,215	$2,960,330	$ 69,941	22,167
2	2,157,200	3,219,701	83,753	23,949
3	2,177,718	3,299,572	110,067	21,596
4	2,488,739	3,888,654	161,199	22,527
5	2,953,184	4,407,737	213,149	23,232
PERCENTAGE INCREASES/DECREASES (YEAR 1 = 100)				
Year	Output	Capacity	Fixed Investment	Man-hours
1	100	100	100	100
2	112	109	120	108
3	113	111	157	97
4	129	131	230	102
5	153	149	305	105

TABLE 4-3

PRODUCTIVITY VARIABLES--COMPANY B

ACTUAL DATA (HOURS AND DOLLARS IN 000'S)				
Year	Output	Capacity	Fixed Investment	Man-Hours
1	$1,113,385	$1,662,440	$ 71,136	26,965
2	1,042,944	1,556,633	70,455	23,981
3	1,146,814	1,711,663	67,930	24,465
4	1,328,491	2,142,727	71,492	25,522
5	1,535,072	2,475,923	82,488	26,038
PERCENTAGE INCREASES/DECREASES (YEAR 1 = 100)				
Year	Output	Capacity	Fixed Investment	Man-hours
1	100	100	100	100
2	94	94	99	89
3	103	103	95	91
4	119	129	101	95
5	138	149	116	97

period, Company B showed a 16 percent increase in net fixed investment.

In analyzing these data it is useful to start with an analysis of the factors associated with changes in output per man-hour (8:101). As mentioned in the previous chapter, the network of productivity ratios used in the model establishes that changes in the productivity of labor may not be solely attributable to changes in the efforts of labor alone. The network of ratios shows that changes may occur due to changes in the productivity of capital, or changes in the proportion of actively utilized capital to labor (8:101). For example, labor productivity may increase because new labor-saving equipment or facilities have been introduced even though labor's efforts and tasks remain unchanged (8:26). A decrease in labor's contribution, which would cause output per man-hour to rise, might be the result of the purchase of more highly fabricated components, the replacement of manual tasks by machinery, or the shifting of product-mix in favor of those requiring less manpower. Factors which might increase output without expanding labor's contribution, and thereby cause output per man-hour to rise, include utilizing machine capacity more fully, or increasing machine capacity through technical innovations (8:26).

Changes such as those mentioned above in the "apparent productivity" of direct labor, are reflected in the ratio of actively utilized fixed investment to labor (AUF.I.:M-HRS), and/or possibly, in the productivity of fixed investment (CAP/F.I.) (8:101-102). This relationship is shown below:

$$\frac{O}{\text{M-HR}} = \frac{\text{CAP}}{\text{F.I.}} \times \frac{\text{F.I. x O/CAP}}{\text{M-HR}}$$

Table 4-4 and Figure 4-3 indicate the productivity of labor increased by 46 percent in Company A. The relationships pictured in Figure 4-3 indicate that of the two primary factors influencing labor productivity, the ratio of actively utilized fixed investment to man-hours was the dominant factor. During the five-year period, AUF.I.:M-HRS increased by 200 percent. Throughout this same period, the ratio of capacity to fixed investment dropped to 49 percent of its original level. This sharp decline in the productivity of fixed investment significantly dampened the productivity improvements exhibited by labor. Table 4-5 is presented to illustrate this conclusion more readily. By dividing the five-year period into four subperiods, it can be seen that the increase in output per man-hour was primarily associated with increases in the ratio of actively utilized fixed investment to man-hours.

Turning to a more detailed look at the productivity of capital, it can be seen in Figures 4-1 and 4-3 that the decline in the productivity of capital was largely

TABLE 4-4

NETWORK OF PRODUCTIVITY RATIOS--COMPANY A

ACTUAL DATA			
Year	O/M-HRS	CAP:F.I.	AUF.I.:M-HRS
1	86.81	42.33	2.05
2	90.07	38.44	2.34
3	100.84	29.98	3.36
4	110.48	24.12	4.58
5	127.12	20.68	6.15
PERCENTAGE INCREASES/DECREASES (YEAR 1 = 100)			
Year	O/M-HRS	CAP:F.I.	AUF.I.:M-HRS
1	100	100	100
2	104	91	114
3	116	71	164
4	127	57	223
5	146	49	300

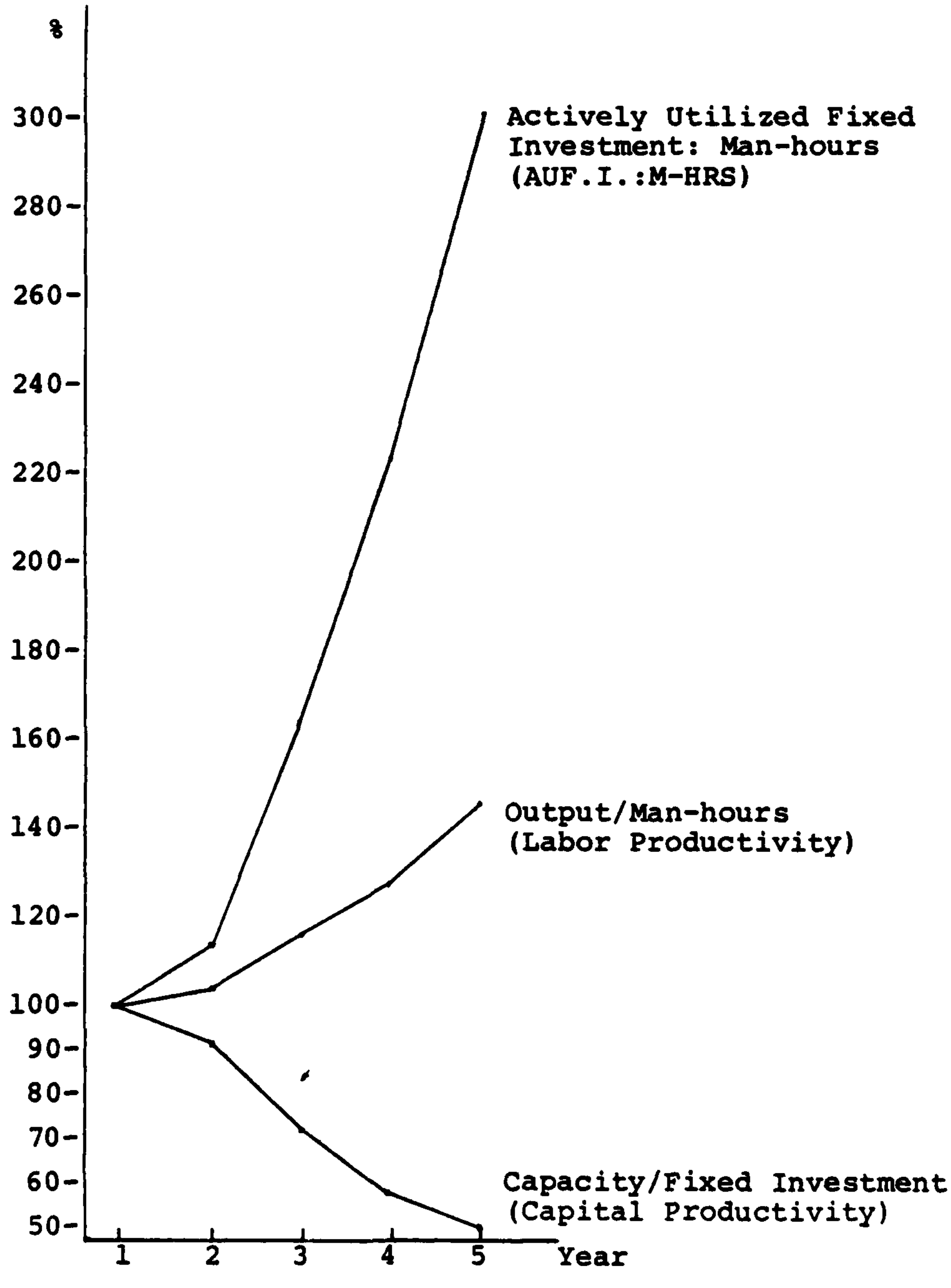

Fig. 4-3. Network of Productivity Ratios--Company A

TABLE 4-5

COMPANY A

Subperiod	O/M-HRS %	CAP/F.I. %	AUF.I.:M-HRS %
Yr 1-Yr 2	+ 3.8	- 9.2	+14
Yr 2-Yr 3	+11.7	-22.0	+44
Yr 3-Yr 4	+ 9.5	-19.5	+36
Yr 4-Yr 5	+15.0	-14.3	+35

attributable to increases in fixed investment. The very low productivity of capital during this period was caused by the large amount of investment to replace existing capital rather than to provide additional capacity. As the data shows, this was indeed the case. Company A had only one aircraft program which remained in steady production throughout the five years. One aircraft program ended production in year 3. A new program replaced it by going into production the same year, while still another program commenced in year 5. During this entire period, the productivity of capital decreased by 51 percent in Company A.

Progressing with a similar analysis for Company B, Table 4-6 and Figure 4-4 show that the productivity of labor increased by 43 percent. Unlike Company A, however, this increase was not primarily attributable to any one factor ratio. Aside from the possible contribution of

TABLE 4-6

NETWORK OF PRODUCTIVITY RATIOS--COMPANY B

ACTUAL DATA			
Year	O/M-HRS	CAP:F.I.	AUF.I.:M-HRS
1	41.29	23.37	1.77
2	43.49	22.09	1.97
3	46.87	25.20	1.86
4	52.05	29.97	1.74
5	58.96	30.02	1.96
PERCENTAGE INCREASES/DECREASES (YEAR 1 = 100)			
Year	O/M-HRS	CAP:F.I.	AUF.I.:M-HRS
1	100	100	100
2	105	95	111
3	114	108	105
4	126	128	98
5	143	128	111

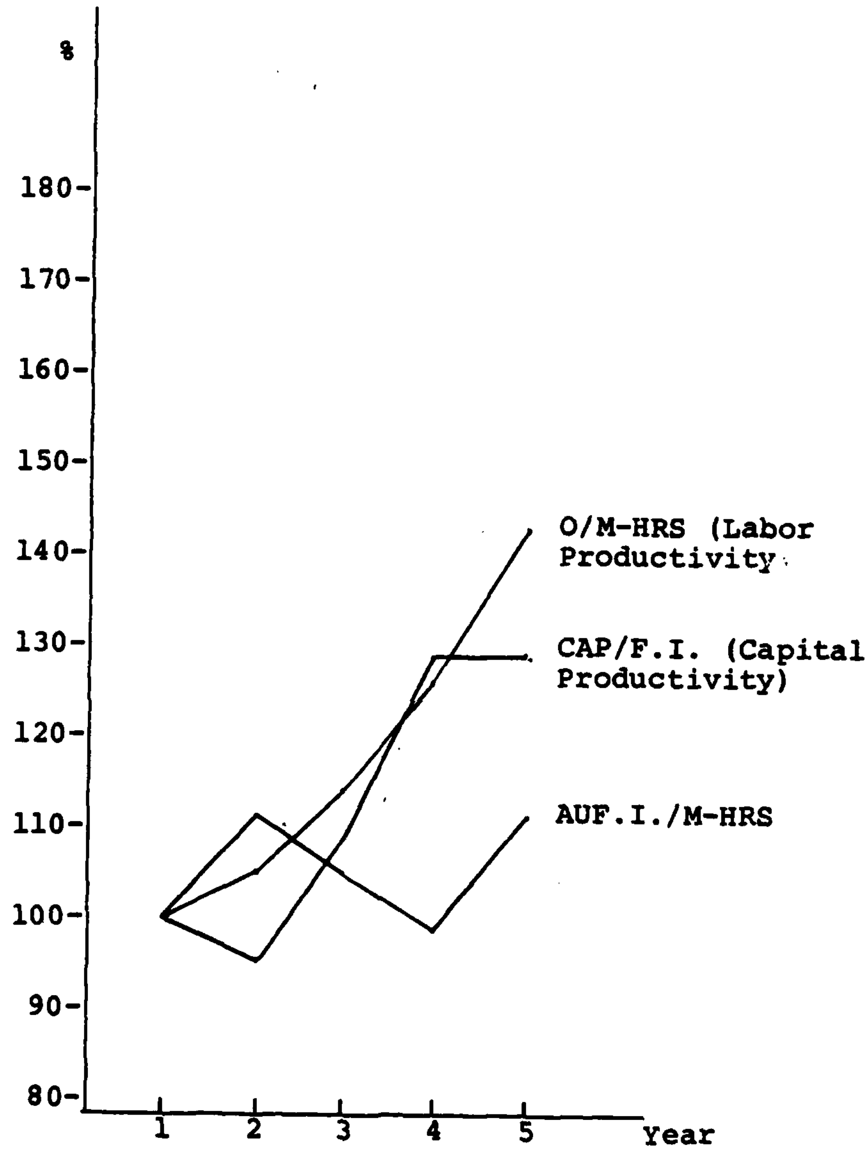

Fig. 4-4. Network of Productivity Ratios--Company B

labor's own intensified effort, both the ratio of actively utilized fixed investment to man-hours and capital productivity seem to have alternately exerted positive influence on output per man-hour. However, Figure 4-4 does show that between year 2 and year 4, capital productivity seems to have been the primary factor contributing to the increase in output per man-hour. During this two-year period, output per man-hour increased by 20 percent and the productivity of capital increased by 36 percent.

By referring to Figures 4-2 and 4-4, an investigation into the productivity of capital shows that the steady increase which occurred from year 2 through year 4 was largely attributable to changes in capacity, with some change in fixed investment in year 4. The large increase in fixed investment in year 5 was accompanied by a proportionate increase in capacity. By increasing capacity as well as fixed investment by proportionate amounts, the ratio shows that the expenditure added to the productivity of capital, rather than merely replacing existing capital. Over the entire five-year period, Company B's capital productivity registered a 28.5 percent increase.

Having discussed the changes which occurred in the network of productivity ratios during the five-year period, a brief clarification and interpretation of the findings is necessary. This discussion will highlight the effectiveness of the model in identifying productivity changes which occur within an individual firm. Company A will be discussed first, followed by a discussion of Company B. For convenience, the significant ratios and variables previously noted have been summarized in Tables 4-7 and 4-8.

<u>Company A</u>

Based upon annual reports and interviews with company representatives, Company A had three steady production aircraft programs in progress in year 1. Of these, production rates were declining in two and in the process of termination. In year 3, production was halted on both programs. At this point, Company A had machinery which was obsolete and no longer in use. During this same year, a new aircraft program was completing full-scale development and ready to move into production. In year 4, another new aircraft program began full-scale development. The tremendous increase in fixed investment shown by Company A represented the need for new equipment to support these programs.

During this five-year period, labor productivity increased by 46 percent. This increase was primarily the result of the rapid rise in the ratio of actively utilized fixed investment, which was due to the 205 percent increase in fixed investment. Thus, the increase in labor productivity was based upon the addition of a significant

TABLE 4-7

COMPANY A PRODUCTIVITY RATIOS

Ratio/Variables	(Year 1-5)	% Increase
Labor Productivity:	$\frac{O}{\text{M-HRS}}$	+ 46%
Capital Productivity:	$\frac{\text{CAP}}{\text{F.I.}}$	- 51.1%
Actively Utilized Fixed Investment to Man-hours:	$\frac{\text{F.I.} \times \frac{O}{\text{CAP}}}{\text{M-HRS}}$	+200%
Fixed Investment:	F.I.	+204.8%
Productive Capacity:	CAP	+ 85%

TABLE 4-8

COMPANY B PRODUCTIVITY RATIOS

Ratio/Variables	(Year 1-5)	$ Increase
Labor Productivity:	$\frac{O}{\text{M-HRS}}$	+ 42.8%
Capital Productivity:	$\frac{\text{CAP}}{\text{F.I.}}$	+ 28.5%
Actively Utilized Fixed Investment to Man-hours:	$\frac{\text{F.I.} \times \frac{O}{\text{CAP}}}{\text{M-HRS}}$	+ 10.7%
Fixed Investment:	F.I.	+ 16%
Productive Capacity:	CAP	+ 48.9%

amount of new machinery. However, while the new machinery added to labor's productivity, it did not add to the productivity of capital. As mentioned, the productivity of capital decreased by 51 percent during the five-year period. Even though fixed investment increased by 205 percent, capacity increased by only 49 percent. The new equipment primarily represented the replacement of existing machinery only; it did not signify an increase in the productivity of capital.

Company B

In comparison, during the five-year period under study, Company B had four relatively stable aircraft programs in production. In year 3, a fifth major program completed full-scale development and began production. In addition, in several years significant modifications to existing programs did occur.

During the five-year period, labor productivity in Company B increased by 43 percent. This increase was alternately influenced by labor's intensified effort, the ratio of actively utilized fixed investment to man-hours and the ratio of capacity to fixed investment. According to information received from the company, the early increases in labor productivity were due to efforts to control costs through closer management surveillance. Whereas in the latter years, the increase was primarily due to increases in fixed investment and capital productivity.

Although Company B's investment in capital equipment during this five-year period was relatively low, its capital productivity increased by 28.5 percent. This significant increase was due to the higher capacity utilization achieved from existing machinery.

Before continuing the analysis, one additional point concerning the data presented thus far needs to be addressed. This issue centers around the actual data for output per man-hour. As seen in Tables 4-4 and 4-6, output per man-hour for Company A registered an actual amount of \$127.12 in year 5; whereas, Company B registered \$58.96. This significant difference is primarily due to economic production quantities. For instance, in Company A, the major aircraft program throughout the five-year period experienced an average annual demand of over 100 units; whereas, the major program for Company B experienced an average annual demand of only one-third this amount. This factor is significant, and should be considered when interpreting the productivity of labor.

Having concluded the discussion of results and analyses surrounding the first level of the productivity measurement model, the structure of costs will be discussed next. The analysis up to this point has centered around the changes which occur within the network of productivity ratios, and the attempt to identify their source. By moving to the structure of costs, the model will determine how productivity changes interact and affect the cost structure.

Structure of Costs

Regardless of the insights revealed from the analysis thus far, a thorough evaluation requires an investigation into the economic implications of the productivity changes noted. Without taking into consideration the economic effects, it is difficult to accurately assess the benefit of specific changes that occur. In the model, factor prices form the link between changes in the productivity ratios and changes in the structure of costs. To examine the effect of these changes, the initial focus is a comparison of the changes in factor productivities with the accompanying adjustments in factor prices and unit costs.

The first comparative analysis centers around the interactions which occur between output per man-hour, hourly wage rates, and unit wage costs. For Company A, Table 4-9 and Figure 4-5 record the results. The results reveal that the 46 percent increase in output per man-hour was exactly offset by a 46 percent increase in hourly wage rates. Thus, no change occurred in unit wage costs. For Company B, the data results are listed in Table 4-10 and Figure 4-6. In this case, the 43 percent increase in output per man-hour was greater than the 41 percent increase

TABLE 4-9

OUTPUT PER MAN-HOUR, HOURLY WAGE RATES,
UNIT WAGE COSTS--COMPANY A

ACTUAL DATA			
Year	Output/Man-hour	Hourly Wage Rates	Unit Wage Costs
1	\$/M-Hr 86.81	\$ 8.42	\$ .097
2	90.07	9.15	.102
3	100.84	10.04	.100
4	110.48	11.31	.102
5	127.12	12.28	.097

PERCENTAGE INCREASES/DECREASES (YEAR 1= 100)			
Year	Output/Man-hour	Hourly Wage Rates	Unit Wage Costs
1	100	100	100
2	104	109	105
3	116	119	103
4	127	134	105
5	146	146	100

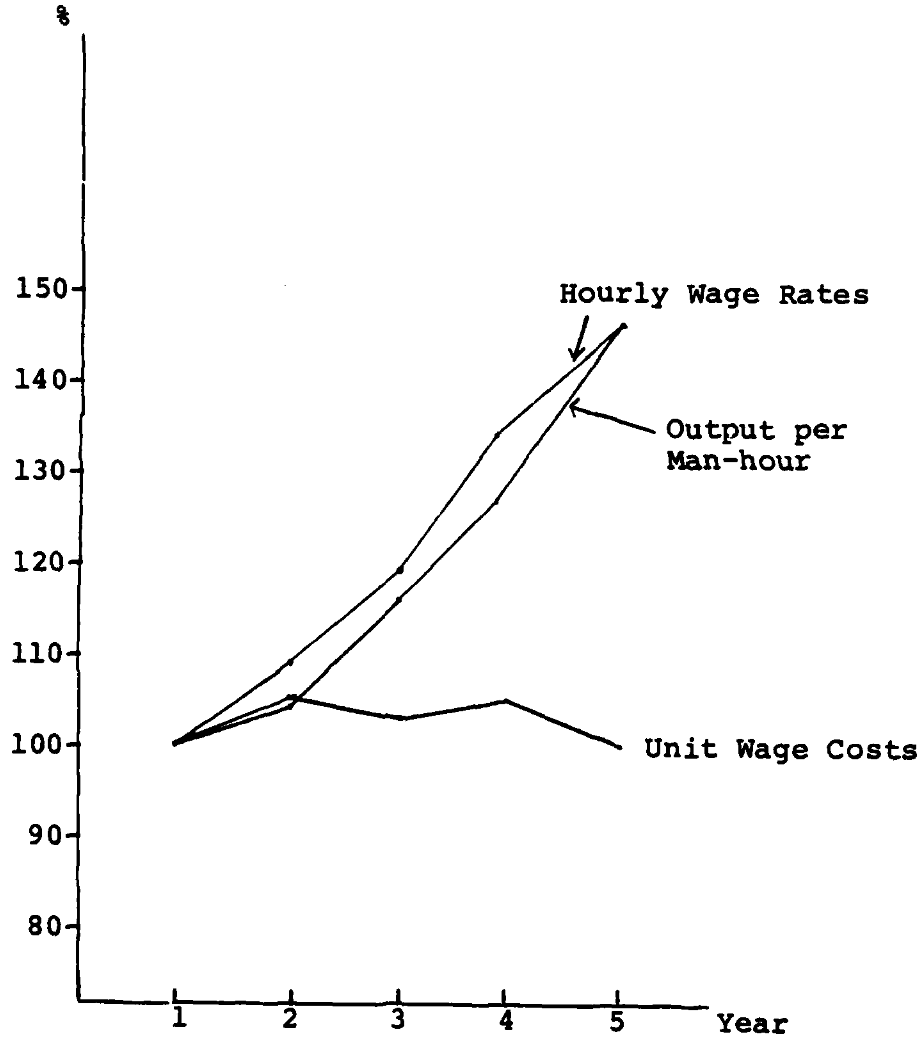

Fig. 4-5. Output per Man-Hour, Hourly Wage Rates, Unit Wage Costs--Company A

TABLE 4-10

OUTPUT PER MAN-HOUR, HOURLY WAGE RATES,
UNIT WAGE COSTS--COMPANY B

ACTUAL DATA			
Year	Output/Man-hour	Hourly Wage Rates	Unit Wage Costs
1	$/M-Hr 41.29	$ 8.53	$ .207
2	43.49	9.23	.212
3	46.87	10.11	.216
4	52.05	10.99	.211
5	58.96	12.04	.204
PERCENTAGE INCREASES/DECREASES (YEAR 1= 100)			
Year	Output/Man-hour	Hourly Wage Rates	Unit Wage Costs
1	100	100	100
2	105	108	102
3	114	119	104
4	126	129	102
5	143	141	99

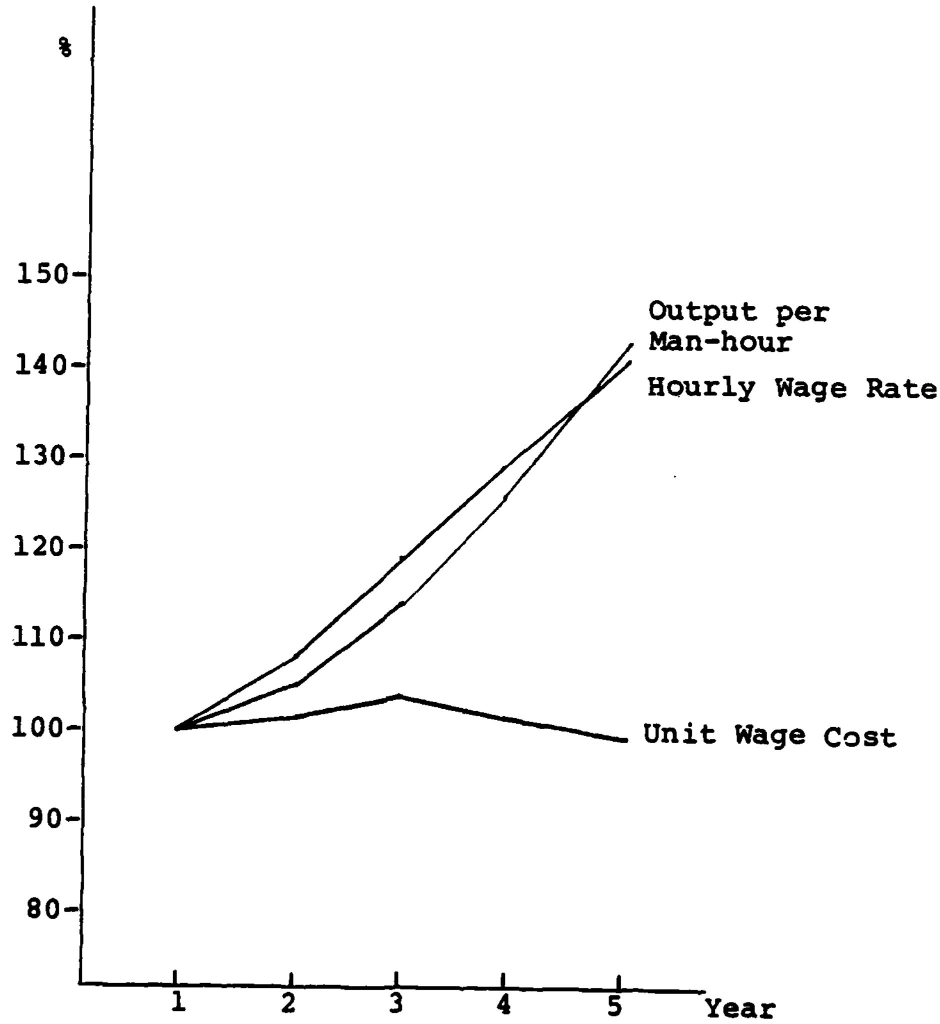

Fig. 4-6. Output per Man-Hour, Hourly Wage Rates, Unit Wage Costs--Company B

in hourly wage rates. As a result, unit wage costs decreased by 1 percent.

In analyzing these results, it is necessary to keep in mind the preceding analysis and the factors which originally brought about the apparent changes in output per man-hour. For Company A, the productivity analysis showed that the increases in labor's productivity was primarily influenced by the ratio of actively utilized fixed investment to man-hours. This influence, however, did not exert enough pressure on output per man-hour to cause any direct effect on unit wage costs. In analyzing the results of Company B, it is seen that the influences which increased output per man-hour did cause an effect on the structure of costs. Unit wage costs decreased. This general type of analysis highlights the fact that even though output per man-hour may increase, its effect on costs may be either minimal or nil.

The remaining comparative analysis concerning factor productivities and factor prices centers on the interactions which occur between the ratio, capacity to fixed investment, annual depreciation charges, and unit fixed costs. Table 4-11 and Figure 4-7 show the data results for Company A. The 51 percent decline in capital productivity (Capacity/Fixed Investment) resulted in a 36 percent increase in unit fixed costs. Due to the tremendous increase in net fixed investment during this five-year

TABLE 4-11

CAPACITY TO FIXED INVESTMENT, NET FIXED INVESTMENT, DEPRECIATION, UNIT FIXED COSTS--COMPANY A

ACTUAL DATA (NET F.I. AND DEPRECIATION DOLLARS IN 000'S)

Year	Capacity / Fixed Investment	Net Fixed Investment	Depreciation	Unit Fixed Costs
1	$42.33	$ 69,941	$13,287	$ .056
2	38.44	83,753	14,031	.060
3	29.88	110,067	16,547	.068
4	24.12	161,199	21,380	.071
5	20.68	213,149	28,076	.076

PERCENTAGE INCREASES/DECREASES (YEAR 1 = 100)

Year	Capacity / Fixed Investment	Net Fixed Investment	Depreciation	Unit Fixed Costs
1	100	100	100	100
2	91	120	106	107
3	71	157	125	121
4	57	230	161	127
5	49	305	211	136

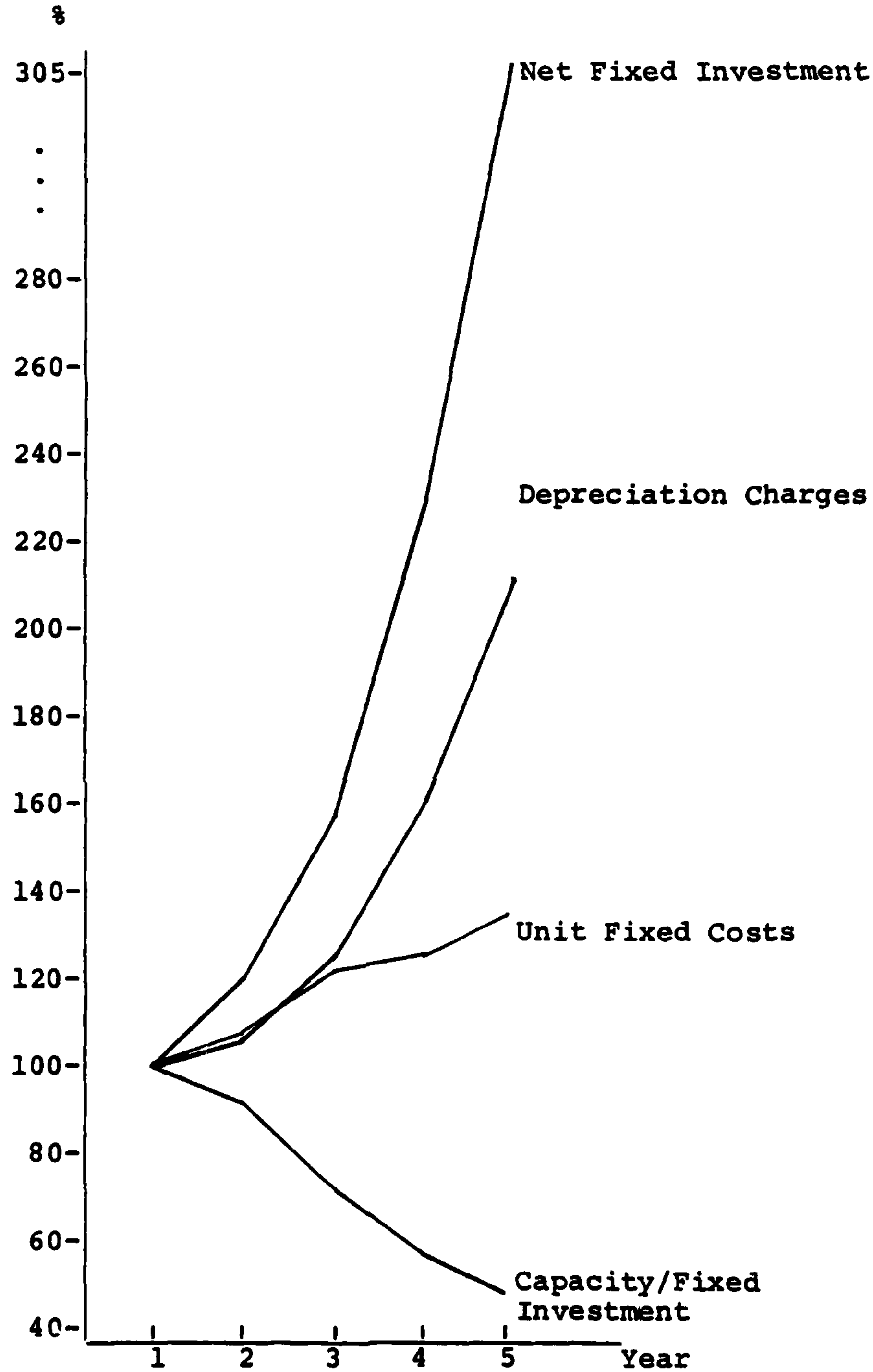

Fig. 4-7. Capacity to Fixed Investment, Net Fixed Investment, Depreciation, Unit Fixed Costs--Company A

period, annual depreciation charges increased by 111 percent. The data results for Company B are shown in Table 4-12 and Figure 4-8. In Company B, the 28 percent increase in capital productivity resulted in a 24 percent increase in unit fixed costs. The limited amount of new capital investment increased depreciation charges by only 18 percent.

In analyzing these results, there is not a direct cause and effect relationship in factor price to unit cost as displayed in the previous analysis with wages. The reason is that annual depreciation is not the only factor affecting fixed costs. Other factors such as utility costs, maintenance costs, and insurance costs are components of fixed costs as defined in this study. In fact, depreciation costs in Company A account for only 12.5 percent of total fixed costs. In Company B, depreciation accounts for 15.6 percent of total fixed costs. Thus, in analyzing the effects of the interactions between capital productivity and unit fixed costs, a study of the entire structure of costs is necessary.

Having briefly discussed the interactions between factor productivities and factor prices, the analysis turns to the structure of costs to determine what effects these interactions had on cost components and cost proportions. The first area to be analyzed is total direct costs and its components. Table 4-13 and Figure 4-9 show the data

TABLE 4-12

CAPACITY TO FIXED INVESTMENT, NET FIXED INVESTMENT, DEPRECIATION, UNIT FIXED COSTS--COMPANY B

ACTUAL DATA (NET F.I. AND DEPRECIATION DOLLARS IN 000'S)				
Year	Capacity / Fixed Investment	Net Fixed Investment	Depreciation	Unit Fixed Costs
1	$23.37	$71,136	$12,807	$ .051
2	22.09	70,455	13,009	.055
3	25.20	67.930	13,468	.061
4	29.97	71,492	12,895	.058
5	30.02	82,488	15,082	.063
PERCENTAGE INCREASES/DECREASES (YEAR 1 = 100)				
Year	Capacity / Fixed Investment	Net Fixed Investment	Depreciation	Unit Fixed Costs
1	100	100	100	100
2	95	99	102	108
3	108	95	105	120
4	128	101	101	114
5	128	116	118	124

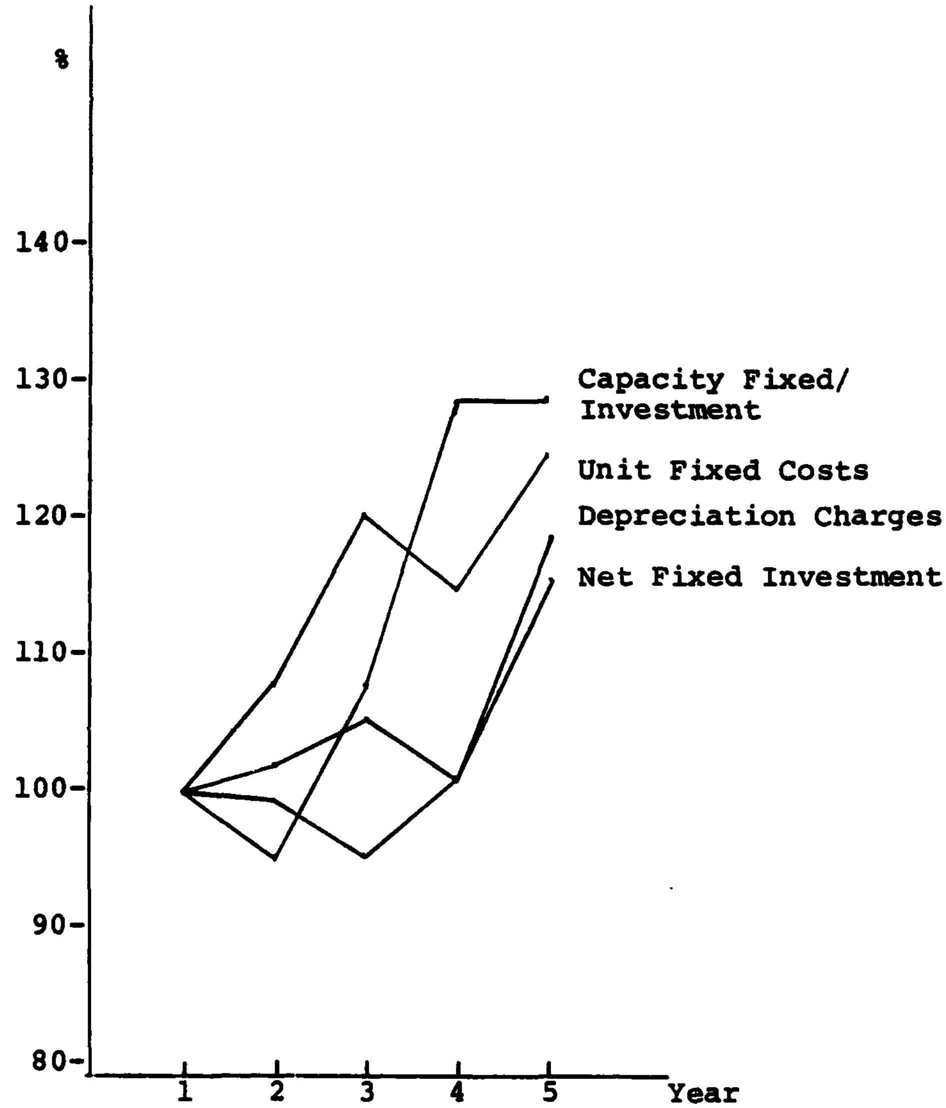

Fig. 4-8. Capacity to Fixed Investment, Net Fixed Investment, Depreciation, Unit Fixed Costs--Company B

TABLE 4-13

TOTAL DIRECT COSTS AND ITS COMPONENTS--COMPANY A

ACTUAL DATA (DOLLARS IN 000'S)					
Year	Total Direct Costs	Wages	Materials	Fixed Costs	Output
1	$1,421,761	$186,747	$1,126,809	$108,205	$1,924,215
2	1,573,267	219,165	1,225,275	128,827	2,157,200
3	1,549,895	216,929	1,185,538	147,428	2,177,718
4	1,810,266	254,817	1,378,764	176,685	2,488,739
5	2,144,151	285,294	1,633,378	225,479	2,953,184
PERCENTAGE INCREASES/DECREASES (YEAR 1= 100)					
Year	Total Direct Costs	Wages	Materials	Fixed Costs	Output
1	100	100	100	100	100
2	111	117	109	119	112
3	109	116	105	136	113
4	127	136	122	163	129
5	151	153	145	208	153

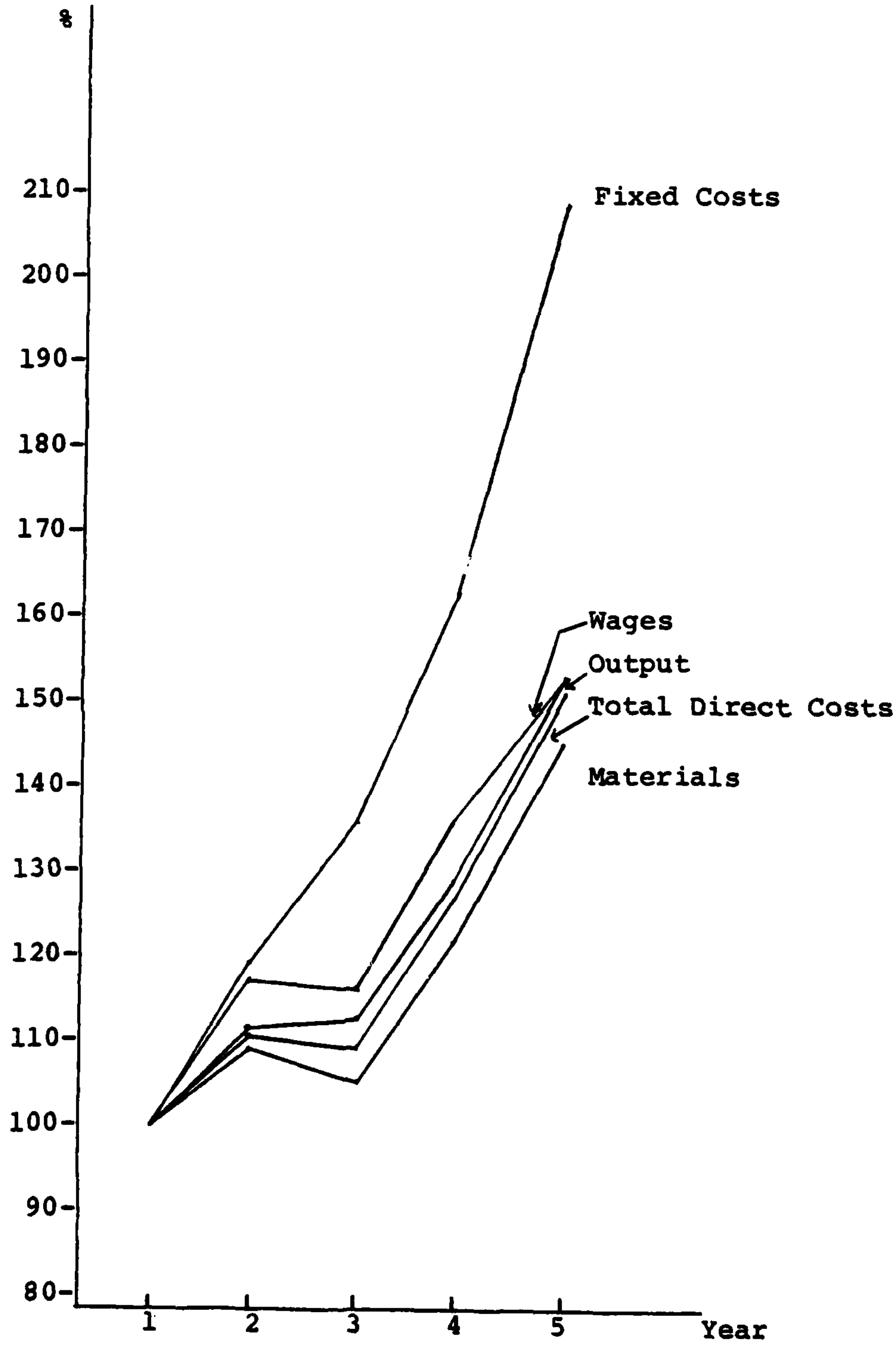

Fig. 4-9. Total Direct Costs and Its Components--Company A

results for Company A. Total costs and its components, with the exception of fixed costs, followed the same general trend as output. In year 3, when output increased by only 1 percent, total costs, wages, and material costs all declined. Recall that during year 3 two of the major aircraft programs were terminated in Company A. While fixed costs showed the greatest increase, it was material costs which had the smallest increase.

Figure 4-10 shows the effects that changes in direct cost components have on overall cost proportions within Company A. Figure 4-10 reveals that unit material costs decreased by 6 percent over the five-year period. Its unit proportion decreased from 58.6 percent to 55.3 percent. Unit wage costs remained unchanged, accounting for 9.7 percent of total costs. The largest increase (36 percent) occurred in unit fixed costs. Other costs (including profit) increased 5 percent. This analysis reveals that during the five-year period, the relative importance of material costs decreased while the relative importance of fixed costs and other costs increased. While changes did occur, the analysis also reveals that unit cost proportions remained relatively stable over the entire five-year period.

To conduct a parallel analysis of Company B's cost structure, attention is directed to Table 4-14 and Figure 4-11. As shown in Figure 4-11, total direct costs

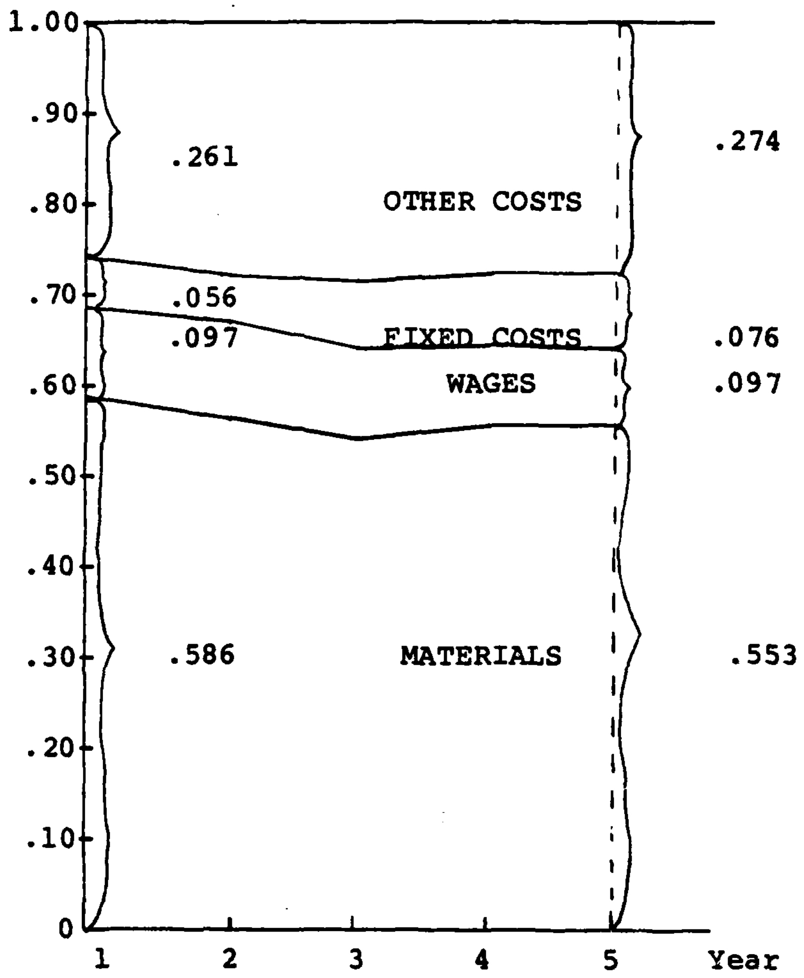

Fig. 4-10. Proportions of Total Costs--Company A

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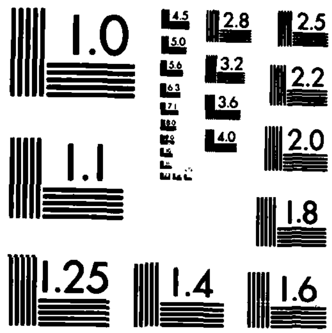

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TABLE 4-14

TOTAL DIRECT COSTS AND ITS COMPONENTS--COMPANY B

ACTUAL DATA (DOLLARS IN 000'S)					
Year	Total Direct Costs	Wages	Materials	Fixed Costs	Output
1	$740,813	$229,994	$454,477	$56,342	$1,113,385
2	654,457	221,252	375,984	57,221	1,042,944
3	709,667	247,412	392,029	70,226	1,146,814
4	817,949	280,422	459,914	77,613	1,328,491
5	948,727	313,523	538,817	96,387	1,535,072
PERCENTAGE INCREASES/DECREASES (YEAR 1 = 100)					
Year	Total Direct Costs	Wages	Materials	Fixed Costs	Output
1	100	100	100	100	100
2	88	96	83	102	94
3	96	108	86	125	103
4	110	122	101	138	119
5	128	136	119	171	138

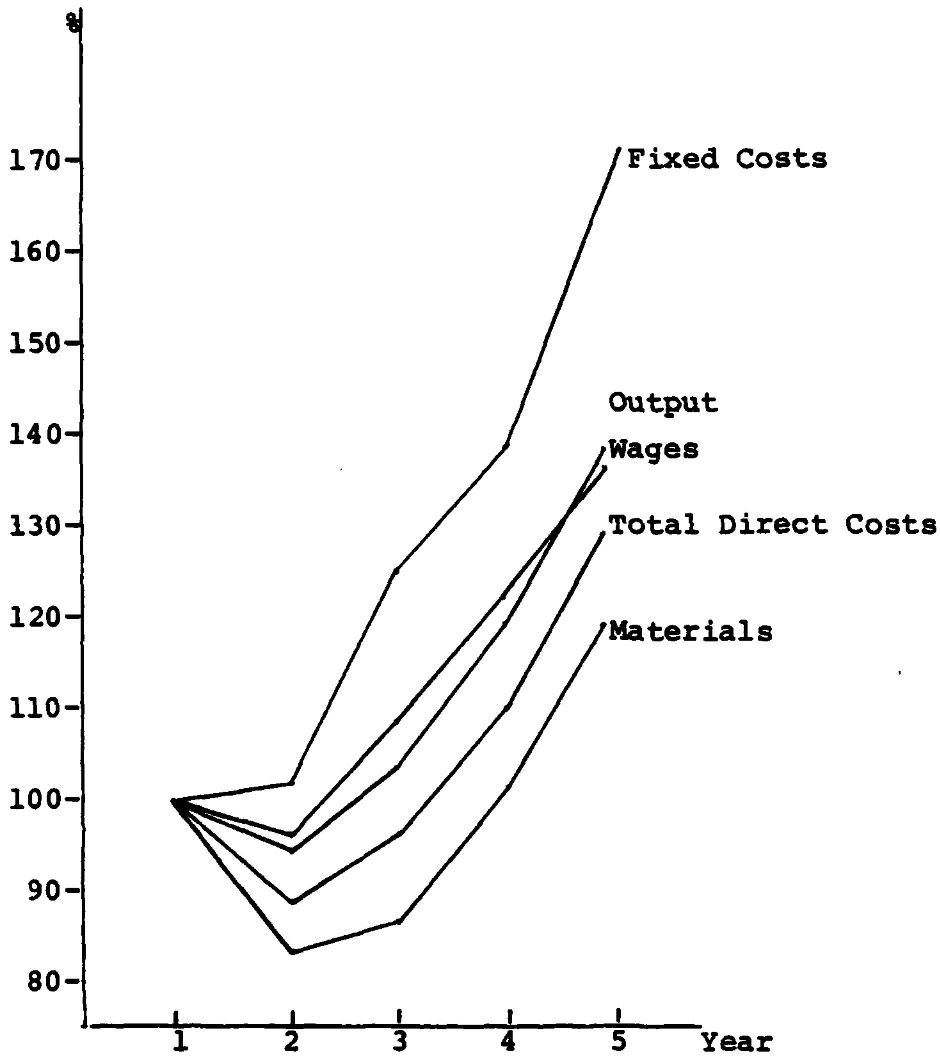

Fig. 4-11. Total Direct Costs and Its Components--Company B

and its components, with the exception of fixed costs, followed a similar pattern as output. However, over the entire five-year period, output increased by 38 percent, whereas total direct costs increased by only 28 percent. In fact, output increased by a greater percentage than all cost components, except fixed costs. In year 2, when output decreased by 6 percent, material costs were affected most. Material costs decreased by 17 percent in year 2.

Figure 4-12 examines the effect of these changes on overall cost proportions. As seen in this figure, the cost proportion structure for Company B changed dramatically. Unit material costs decreased by 14 percent while other costs increased by more than 14 percent. This significant reversal in cost proportions confirms information received from Company B that problems were encountered in controlling overhead costs. In year 5, more than 38 percent of unit costs were in other costs. This cost component primarily includes profit, indirect labor, and fringe benefits for direct and indirect labor. Referring back to the analysis of Company A, other costs accounted for only 27 percent of unit costs. Another significant factor highlighted in Figure 4-12 is the large unit proportion of wages. Wages account for over 20 percent of unit costs in Company B, whereas in Company A, wages account for less than 10 percent of unit costs.

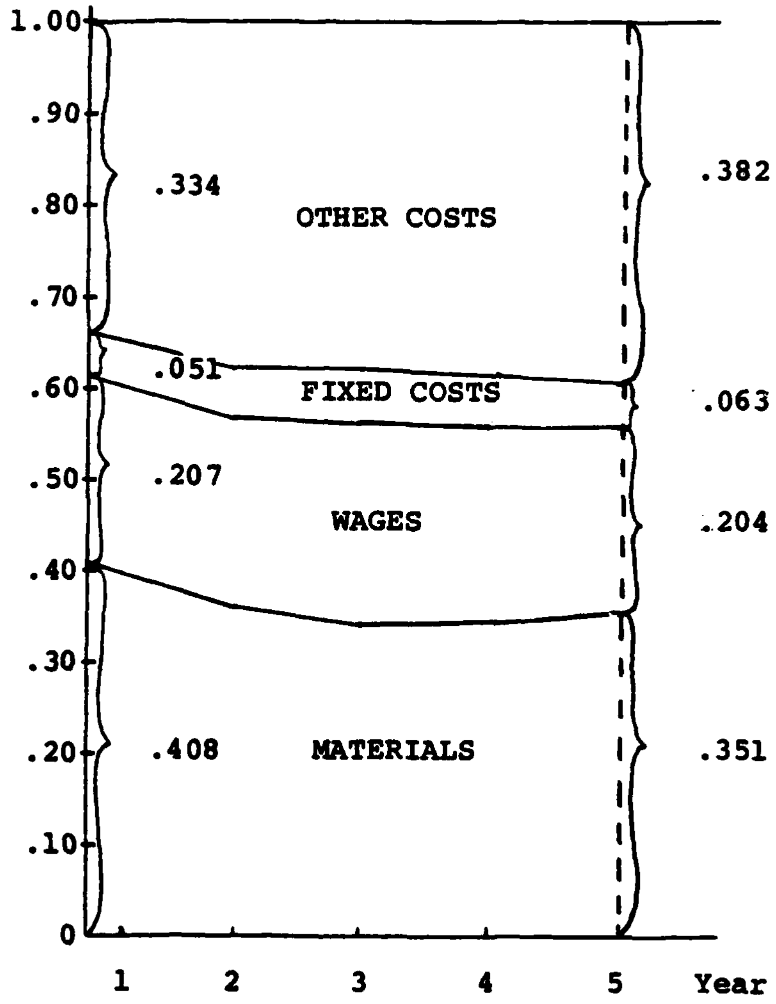

Fig. 4-12. Proportions of Total Costs--Company B

In concluding this section on data results and analysis, a brief summary of the significant findings is presented in Table 4-15. As seen in the table, significant differences between Company A and Company B occurred in many of the variables and ratios.

Summary

The analysis of the results of this research indicate that the proposed method of measuring the relative productivity of separate firms is feasible and effective. The analysis has shown that simple measures of labor productivity, or even capital productivity, cannot be accepted on face value. Further examination of the economic implications must be performed to determine their full ramifications.

The analysis of Chapter IV has shown how a specific analytical framework can be used to compare two firms. Chapter V contains a summary of the significant conclusions, and offers recommendations for using the selected model.

TABLE 4-15

SIGNIFICANT DATA FINDINGS

PERCENTAGE INCREASE/DECREASE FROM YEAR 1-5 (YEAR 1 = 100)		
Significant Factors	**Company A**	**Company B**
Labor Productivity $\frac{O}{M\text{-}HR}$	+ 46%	+ 43%
Capital Productivity $\frac{CAP}{F.I.}$	- 51%	+ 28%
Fixed Investment	+205%	+ 16%
Output	+ 53%	+ 38%
Total Direct Costs	+ 51%	+ 28%
Cost Proportion Changes:		
Materials	- 6%	- 14%
Wages	No change	- 1%
Fixed Costs	+ 36%	+ 24%
Other Costs	+ 5%	+ 14%

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Overview

The previous chapters addressed the subject of measuring the relative productivity of individual defense aerospace firms. Various methods of productivity measurement were identified and a specific methodology was chosen based on the DOD perspective. The results of the application of this methodology were presented and analyzed. This chapter summarizes the conclusions of this research and offers recommendations for its use and future study.

Conclusions

In the course of building and using this model the research objectives were accomplished. The quantitative measures of productivity were identified and an understanding of how they apply to productivity was gained. The model was kept relatively simple, the data requirements inexpensive and the issues of validity and reliability were addressed. This model measured productivity at the firm level. The family of ratios used in this model are the productivity criteria identified in this research and can be applied to any DOD contractor. The application of this model by a DOD contracting official will allow a comparison of a DOD contractor to other contractors or to industry averages and trends.

Recommendations

Further Research

An expansion of the yearly data used in this model to include a minimum of ten years is recommended. Additionally, a quarterly breakdown of each year is recommended. This type of breakdown will allow statistical analysis such as regression and correlation studies to be performed on this model. Statistical studies are a powerful method of gaining inferences about past performance and can be used to make valid short-term predictions. Correlation studies can aid in determining which ratios contribute the most to the main effects of the model. Examples of the application of these methods can be found in Chapter 7 of Applied Productivity Analysis for Industry by Samuel Eilon. Also, to increase the accuracy of such studies a more specific measure of output should be developed. The actual price and quantity of each product should be collected so as to develop a more accurate composite of actual output.

Finally, this model should be replicated incorporating the above recommendations. This can be done by using real-time tracking of existing programs at selected plants. The Plant Representative Office is the ideal place to collect the data and track contractor performance using this model. It is also at this level that regression and correlation studies on past performance can be validated.

Specific Recommendations for Use

This model has utility for both source selection and contract management. In the source selection process, the relative productivity measures can be used to make less subjective judgements. These judgements can later be applied to the Weighted Guidelines. General Slay, while Commander of Air Force Systems Command, required that a contractor's past performance be one factor in the contract award process. However, General Slay established no criteria for past performance measurement. This model can be used to more objectively measure the past productivity performance of defense contractors.

Perhaps the most powerful use of this model is in the area of contract management. The Administrative Contracting Officer (ACO) can use this model to more effectively monitor contractor performance. The ACO's access to the pertinent data will allow him to build a data base which, when applied to this model, can become a dynamic management tool. From the analysis supplied by this model, an ACO can gain the necessary insights to scientifically analyze contractor management decisions. The ACO can monitor past performance, analyze what happened and why it happened. This information can then be given to both the contractor's management to aid in future productivity planning and to the Procuring Contracting Officer to aid in source selection.

This model also can be used to monitor the performance of Air Force Technology Modernization (TECHMOD) programs in a number of ways. First, the model can aid in identifying candidate firms for TECHMOD programs by measuring present plant productivity. Then, when applied to a particular work center, the model can monitor the actual productivity gains resulting from TECHMOD implementation. Finally, this model can integrate TECHMOD work center productivity effects into the total production process to demonstrate the effects of a TECHMOD program on overall plant productivity. In this way, not only will labor hour savings be captured, but reductions in materials due to lower scrap and rework and increases in capacity will be captured as well. At present the Air Force relies solely on the contractor to provide this information.

General Recommendations for Use

Once this model is validated through the recommendations for further research, more general usage of this model will be possible. Universal use of this model by all ele ents of the DOD will establish a data base allowing ue : D to monitor the performance of all sectors of the defense industrial base. This expanded data base will also allow better analysis of defense industries from which a more cohesive DOD policy on productivity can be developed.

Summary

This research shows that the relative productivity of DOD contractors can be measured and that data is available for measurement. While the accuracy of these measures can be improved, the basic fact that a multifactor productivity measurement has been identified allows the Department of Defense the opportunity to establish a more meaningful productivity program.

SELECTED BIBLIOGRAPHY

A. REFERENCES CITED

1. Abramovitz, Moses. Inventories and Business Cycles, with Special Reference to Manufacturers' Inventories. New York: National Bureau of Economic Research, 1950.

2. Air Force Business Research Management Center. Acquisition Research Topics Catalog 1981. Dayton OH: Wright-Patterson AFB, 1981.

3. American Assembly of Columbia University. Wages, Prices, Profits and Productivity. New York: Columbia University, 1959.

4. Brabson, Colonel Dana G., USAF. "Department of Defense Acquisition Improvement Program," Concepts, Autumn 1981, pp. 54-75.

5. Buehler, Vernon M., and Y. Krishna Shetty, eds. Productivity Improvement: Case Studies of Proven Practice. New York: American Management Association, 1981.

6. Bureau of Labor Statistics. BLS Handbook of Methods. Bulletin 1910. Washington DC: U.S. Department of Labor, 1976.

7. Collins, Major Orville M., USAF. "Can the Pentagon Use Its Purchasing Power to Improve Industrial Responsiveness in the U.S. Aircraft Industry?" Unpublished research report No. 0545-81, Air Command and Staff College, Maxwell AFB AL, 1981.

8. Eilon, Samuel, Bela Gold, and Judith Soesan. Applied Productivity Analysis for Industry. Oxford ENG: Pergamon Press, LTD., 1976.

9. Fabricant, Solomon. Basic Facts on Productivity Changes. Occasional Paper 63. New York: National Bureau of Economic Research, 1959.

10. ________. A Primer on Productivity. New York: Random House, 1969.

11. Gold, Bela. Explorations in Managerial Economics. New York: Basic Books, Inc., 1971.

12. ________. *Foundations of Productivity Analysis*. Pittsburgh PA: University of Pittsburgh Press, 1955.

13. ________. "Productivity Analysis: Some New Analytical and Empirical Perspectives," *Business Economics*, May 1974, pp. 64-72.

14. ________. *Productivity, Technology, and Capital*. Lexington MA: D. C. Heath and Co., 1979.

15. ________, ed. *Technological Change: Economics, Management and Environment*. Oxford ENG: Pergamon Press, LTD., 1975.

16. Greenburg, Leon. *A Practical Guide to Productivity Measurement*. Washington DC: The Bureau of National Affairs, Inc., 1973.

17. Headquarters Air Force Systems Command. *Payoff 80: Manufacturing Technology Investment Strategy*. Dayton OH: Air Force Systems Command, 1 October 1980.

18. Kendricks, John W. *Productivity Trends in the United States*. Princeton NJ: Princeton University Press, 1961.

19. Mali, Paul. *Improving Total Productivity*. New York: John Wiley and Sons, Inc., 1978.

20. National Research Council. *Measurement and Interpretation of Productivity*. Washington DC: National Academy of Sciences, 1979.

21. Salter, Wilfred E. G. *Productivity and Technical Change*. New York: Cambridge University Press, 1966.

22. Siegal, Irving H. *Company Productivity: Measurement for Improvement*. Kalamazoo MI: W. E. Upjohn Institute for Employment Research, 1980.

23. Smookler, Jacob. "The Changing Efficiency of the American Economy, 1869-1938," *The Review of Economics and Statistics*, August 1952, pp. 210-232.

24. Solow, Robert M. "Technical Change and the Aggregate Production Function," *The Review of Economics and Statistics*, August 1957, pp. 312-330.

25. Stigler, George J. Trends in Output and Employment. New York: National Bureau of Economic Research, 1947.

26. Stone, Eugene F. Research Methods in Organizational Behavior. Santa Monica CA: Goodyear Publishing Co., Inc., 1978.

27. U.S. Department of Defense. Economic Analysis and Program Evaluation for Resource Management. DOD Instruction 7041.3. Washington: Government Printing Office, 18 October 1972.

28. ________. Productivity Enhancement, Measurement, and Evaluation--Operating Guidelines and Reporting Instructions. DOD Instruction 5010.34. Washington: Government Printing Office, 4 August 1975.

29. ________. Productivity Enhancement, Measurement, and Evaluation--Policies and Responsibilities. DOD Directive 5010.31. Washington: Government Printing Office, 27 April 1979.

30. U.S. General Accounting Office. Government Measures of Private-Sector Productivity: Users Recommend Changes. Washington: Government Printing Office, 1980.

31. Zabel, Wayne V., and Monte G. Norton. "Requisites for Contractor Productivity Improvement." Unpublished research report No. 81-03, U.S. Army Procurement Research Office, Fort Lee VA, 1981.

B. RELATED SOURCES

Aerospace Industries Association of America, Inc. Aerospace Facts and Figures 1977/78. New York: McGraw-Hill, 1977.

________. Aerospace Facts and Figures 1978/79. New York: McGraw-Hill, 1978.

________. Aerospace Facts and Figures 1979/80. New York: McGraw-Hill, 1979.

________. Aerospace Facts and Figures 1980/81. New York: McGraw-Hill, 1980.

________. Aerospace Facts and Figures 1981/82. New York: McGraw-Hill, 1981.

Babione, Dale R. "Contractor Investment in Defense Industry--Where Is It?" Defense Management Journal, April 1977, pp. 9-15.

Bertrand, Harold E., and others. "The Defense Industrial Base, Vol. I." Unpublished research report No. SD-321, Logistics Management Institute, Washington DC, 1977. AD 044799.

________. "The Defense Industrial Base, Vol. II." Unpublished research report, No. SD-321, Logistics Management Institute, Washington DC, 1977. AD 095054.

Gold, Bela. Productivity, Technology, and Capital. Lexington MA: D. C. Heath and Company, 1979.

________, ed. Research, Technological Change and Economic Analysis. Lexington MA: D. C. Heath and Company, 1977.

________, Gerhard Rosegger, and Myles G. Boylan, Jr. Evaluating Technological Innovations. Lexington MA: D. C. Heath and Company, 1980.

Gray, Harry D. "Industrial Capacity and Mobilization," U.S. Naval Institute Proceedings, September 1981, pp. 80-82.

Kendrick, John W. Productivity Trends: Capital and Labor. Occasional Paper 53. National Bureau of Economic Research, Inc., 1956.

National Bureau of Economic Research, Inc. Output, Input, and Productivity Measurement: Studies in Income and Wealth. Vol. 25. Princeton NJ: Princeton University, Press, 1961.

Patton, John A. Patton's Complete Guide to Productivity Improvement. New York: American Management Association, 1982.

Power, Richard J. "Productivity: A Defense Department Perspective," Defense Management Journal, April 1977, pp. 2-8.

Zabel, Wayne V., and Duane D. Knittle. "Improving Productivity and Reducing Cost Through Capital Investment Incentives." Unpublished research report No. 80-07, U.S. Army Procurement Research Office, Fort Lee VA, 1980.