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PRODUCTIVITY

IN THE

U.S. AEROSPACE INDUSTRY

1960-1978

RESEARCH REPORT

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U.S. AEROSPACE INDUSTRY

1960-1978

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The mission of the Aerospace Research Center is to engage in research, analyses and advanced studies designed to bring perspective to the issues, problems and policies which affect the industry and, due to its broad involvement in our society, affect the nation itself. The objectives of the Center's studies are to improve understanding of complex subject matter, to contribute to the search for more effective government-industry relationships and to expand knowledge of aerospace capabilities that contribute to the social, technological and economic well being of the nation.

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The definition and meaning of productivity have not been well understood, and the term is subject to widespread misuse. As a general concept, productivity is the relationship between the rate at which outputs of goods and services are produced and the rate at which inputs to the production process are consumed. A productivity measure is defined as the ratio of a measure of output (of a firm, industry, or group of industries) to the quantities of one or more of the resources (capital, labor, materials) utilized in production. Such measures are useful as indicators of changes over time in the structure and efficiency of the production process.

The most commonly used measure of productivity, output per manhour, is probably the measure that has been most subject to misinterpretation. An output per manhour, or labor productivity, index is derived by dividing an index of the quantity of production (often deflated annual dollar sales) by an index of labor inputs to production (e.g., total manhours for the year, or total employment, if manhour data is not available). Because this measure explicitly takes into account only one of the inputs to the production process, the use of the output per manhour index has sometimes obscured the role that capital formation and more efficient use of materials inputs play in productivity growth. Substitution of capital for labor in the production process in response, for example, to an increase in the price of labor relative to the price of capital, will be reflected by an increase in output per manhour. Such an increase in a productivity index stimulated solely by relative price changes does not represent a real gain in the efficiency of production.

The output per manhour index is not without its uses, however. Long-run growth in output per manhour is correlated to real gains in productive efficiency stimulated by technical advances, and in the U.S. economy as a whole, changes in real compensation per manhour have historically closely tracked the growth of output per manhour. The data necessary to estimate this index are usually more readily obtainable than data on capital and materials inputs necessary to calculate more complete productivity measures. Output per manhour is often the only measure available for comparisons of productivity change among different industries or countries.

Productivity Measures Used In This Study

In this study, two productivity measures which relate output to the total quantity of inputs consumed -- total productivity and total factor productivity -- have been derived, as well as the more common measure, labor productivity. <u>Labor productivity</u> is output per manhour. <u>Total productivity</u> is defined as total output divided by an aggregated index of all inputs -- labor, capital, and intermediate inputs (raw materials, fuels, parts,

EXECUTIVE SUMMARY

U.S. Aerospace Productivity

A study of productivity in the U.S. aerospace industry over the period 1960 through 1978 shows that all productivity measures -- input and output measures and indexes of output per manhour, total factor productivity and total productivity -- for the industry have shown significant increases (Table 1, page 18 and Figure 1, page 19). Output per manhour has had the greatest growth rate, at an average annual rate of 3.9 percent.

The growth of total productivity (the ratio of production to total inputs of capital, labor and purchased materials and services) has been much lower, an average of 1.2 percent per year. This slower growth is attributable to the decline in the ratio of output to capital over the period, and especially to the almost static (except for 1973-1975) ratio of outputs to materials inputs. Rising output per manhour has been related to increasing capital intensity in the industry (Figure 2, page 21). The 3.9 percent average growth in output per manhour has been accompanied by an average annual decline of 3.5 percent in output per unit of capital input.

A great deal of attention has been given recently to the slowdown in the rate of growth of labor productivity in the U.S. economy during the 1970s compared to the average rate since World War II.[1] Because of cyclical influences on the measures, it is difficult to determine whether the aerospace industry productivity experience of recent years reveals any significant departure from its long-term growth trend. The sharp productivity peak in the mid-1970s (1974 for total productivity, 1975 for total factor productivity and output per manhour) was apparently caused by the coincidence of

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[1] Typical figures show the annual rate of growth of labor productivity in manufacturing declining from 3.1 percent in 1948-1965 to 2.4 in 1965-1973, and 1.7 in 1973-1978. These figures are reported in "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors," Brookings Papers on Economic Activity, 2:1979 by J.R. Norsworthy, Michael J. Harper and Kent Kunze. This source shows an even greater slowing of productivity growth in the entire private business sector.

purchased services, and so on). Total factor productivity is defined as the ratio of value added (output net of inputs of purchased materials and services) to aggregate input of labor and capital.

The applicability of each of the measures can be summarized as follows. Production and employment data that permit calculating output per manhour, are more likely to be at hand than are the additional data on capital and materials inputs necessary for calculating total productivity. The output per manhour measure has valid uses in productivity analysis, as long as the limitations of the measure discussed above are recognized; it is an incomplete measure in the sense that it ignores capital and materials inputs. Total factor productivity has also seen frequent application in the literature on productivity but, in deriving this measure, the distinction made between the treatment of inputs of materials, and inputs of capital and labor is somewhat artificial. The total productivity measure best captures the concept of overall production efficiency, and is least likely to exhibit anomalous behavior. In fact, it is possible to construct examples in which total productivity is rising -- that is, total output per unit of input is increasing -- yet total factor productivity and output per manhour are declining.

Value of Productivity Measures

Productivity measures are closely related to the structure of the production process and to changes in that structure and their descriptive function -- as indicators of change for a firm, an industry, or the economy as a whole -- is perhaps their most significant value. Comparisons of productivity measures within an industry (the comparisons of the U.S. and European aerospace industries beginning on page 27, for example) can yield insights into the competitive positions of firms. Comparisons within or across industries may reveal whether opportunities for technical progress have been fully utilized. The productivity measures alone, however, never explain the changes in production efficiency that they reveal. In order to identify the causes of efficiency gains, the underlying processes of research, development, and innovation, as well as investment, factor prices and capacity utilization must be examined.

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the 1974 output recovery and the adjustment, over a period of several years, of employment and capital stocks to the new scale of the industry following the all-time high production level of the Vietnam period. The 1975-1977 decline in the productivity indexes was the sharpest of the entire 18-year period, but was primarily a cyclical fluctuation, tracking the production decline over the same period. Total productivity showed some recovery in 1978, although output per manhour continued to decline.

Comparison Of Aerospace With Other U.S. Industries

The only readily available data allowing comparison of productivity performance among industries are output per manhour series. Figure 3, page 25 plots output per manhour indexes for 1960 through 1976 for the aerospace industry, several other manufacturing sectors, and all manufacturing. The indexes for other industries are based on series of constant-dollar value of production and total manhours developed by the Bureau of Labor Statistics,[2] and the aerospace series is derived from the data developed for this study.

Based on the average annual rate of change of output per manhour over the period 1960 through 1976, the performance of the aerospace industry appears relatively good. Its growth rate of 3.9 percent is above the average for all manufacturing (2.6 percent) and the rates for the machinery manufacturing sectors, and is comparable to the rates for the electrical and electronic equipment sectors.

Comparisons Of Aerospace Productivity In The United States, The European Economic Community, Japan and Canada

Comparisons have been made of the productivity experience of the aerospace industries in the United States, the European Economic Community (EEC), Japan, and Canada, on the basis of estimates of output per employee for the period 1969 through 1977. Table 2, page 22 shows annual sales and number of

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2 U.S. Department of Labor, Bureau of Labor Statistics, Time Series Data for Input-Output Industries, Washington, D.C., March 1979.

employees, and Table 3, page 23 shows the ratios of sales per employee, and indexes of sales per employee, for each nation. Plots of sales per employee for the U.S., France, West Germany, and the total EEC are shown in Figure 4, page 30. The data show that the absolute level of output per employee in the aerospace industry has remained higher in the U.S. than in the other Western nations, and that the growth rate of this productivity measure in the U.S. has been somewhat slower than the rate for the EEC as a whole.

Despite the problems of assembling statistics which are comparable from country to country, the differences in the estimates of output per employee are large enough to conclude that the U.S. aerospace industry remains significantly more capital-intensive than its European counterpart. Only France appears to possess a current level of output per employee and an historic growth rate sufficient to approach the U.S. level within the foreseeable future.

The largest European national aerospace industry, that of the United Kingdom, appears to have the lowest level of labor productivity and British aerospace productivity has been a subject of criticism within the EEC. The Commission of the European Communities 1975 aerospace report implied that labor practices in the U.K. were at fault, stating that "The British industry has retained an excessively large labor force in relation to the fall in the value of its output."[3] The British industry association disputed this conclusion and produced its own assessment in which, by making adjustments to output and basing comparison on value added per employee rather than sales per employee, much of the difference between British and French productivity was removed.[4] This controversy illustrates the difficulties inherent in international comparisons.

The large differences in output per employee among the Western aerospace industries represent significant differences in the technology of production. However, since the data necessary to develop measures of total

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[3] Commission of the European Communities, The European Aerospace Industry: Trading Position and Figures, Brussels, February 1975 and July 1979.

[4] "British Aerospace," Interavia, September 1975.

factor productivity for each nation are not readily available, it is not possible to draw conclusions about the relative competitive positions of the national industries. Due to differences in wage rates among the industries, the variation in output per unit labor cost is smaller than differences in output per employee. Aerospace industry average annual wages and salaries per employee in 1972 were, in U.S. currency, $4900 in the U.K., $6200 in France and $12,200 in the U.S.[5]

In general, the nations with the greatest expansion of aerospace sales over the period experienced the greatest growth in labor productivity. The U.S. industry was exceptional in maintaining productivity growth during a period of declining real sales volume. The sales-per-employee growth rate for the total of all the EEC member nations was greater than the U.S. rate. This is not a surprising result; since the U.S. industry has historically been the leader in aerospace technology, research, and development, the potential exists for the European industry to continue its more rapid productivity growth by adopting U.S. developments.

Conditions And Public Policies That Affect Productivity Performance

Productivity is a measure of the efficiency with which resources are used to meet the nation's demand for goods and services. Efficiency is affected both by conditions within a business firm's control and by conditions that are external. Principally, a firm can control the efficiency with which it manages the resources it uses in production: labor, capital, technological know-how, and entrepreneurial talent. This control includes the combinations in which these resources are used in production, the scheduling of the use of these resources to minimize slack capacity, and the skill with which the resources are managed to gain larger production per unit of output.

Conditions external to the firm that affect productivity include:

1. Effect of overall economic conditions on product demand,
2. Availability and cost of investment capital,

5 "British Aerospace," Interavia, September 1975.

3. Labor union practices that may retard or enhance the introduction of new technology and production practices,
4. Tax laws that affect the rate of return on investments,
5. Efficiencies or inefficiencies that may arise from government regulation,
6. Uncertainty about future government policies,
7. The rate of general research and development,
8. National progress in improving the educational and skill levels of labor or human capital, and
9. Uncertainty arising from unstable world economic and social conditions.

The length of the above list may imply that most of the responsibility for productivity growth lies outside the firm, but this is not necessarily the case. Many of the external factors change only slowly over time and provide the economic and social conditions necessary for productivity and growth — conditions that provide opportunity for the entrepreneur to utilize the resources at his disposal to improve efficiencies in production. The external factors provide both impetus for and restriction on productivity growth but the inventor and the entrepreneur provide the ideas and ingenuity and take the risks prerequisite to progress and improved efficiency in the production and distribution of goods and services.

It is not possible to measure how much contribution has been made to productivity growth by internal entrepreneurship and management versus the external factors. These two sets of factors are complementary to each other and productivity advances depend upon both working in tandem. The entrepreneur, however, must take the initiative in making the countless decisions and taking the risks inherent in new technology and management practices that lead to improved efficiency. The entrepreneur must do what he can in spite of external policies that restrict maximum efficiency, and strive to influence improvement in the external factors through enlightened participation in the political processes that shape the external economic and social environment.

A number of factors that are especially important to productivity advance, and that could be improved by near-term changes either in industry practices or by public policy, include capacity utilization, investment and government regulations.

Capacity Utilization And Productivity

While the aerospace industry's long-run productivity performance compares favorably with that of other machinery industries and of manufacturing as a whole, it is subject to larger cyclical effects than most industries due to the volatility of demand for its products. As a result, average utilization of capacity has been substantially lower than for most other industries with consequently sharp fluctuations in aerospace productivity. Although the longer-term trend shows good performance in productivity, these cyclical fluctuations mean that a substantial amount of output is lost that is never recovered. The downward movement in productivity since 1974 is attributed largely to a cyclical downturn that is now reversing itself, with sharp increases in productivity expected over the next five to ten years.

The erratic movements in the productivity measures are closely related to capacity utilization: the degree of utilization of both plant and equipment and labor. Fixed capital in plant and equipment represents capacity which cannot be adjusted in the short-run in response to demand and industry production. Similarly, skilled labor represents an investment which can be adjusted downward in the short-run only at considerable cost: loss of investment in worker training and experience, termination pay, and lost output if demand rises sharply back to previous levels.

Figure 6, page 41 shows plots of the index of economic capacity utilization, the index of total factor productivity, and total factor productivity for the aerospace industry with the effect of the secular trend removed. The cyclical movements in the total factor productivity index, especially the positions of the peaks in 1963, 1967, and 1975, reflect the movements in the utilization index, but the increasing secular trend in the productivity index is unrelated to utilization rates.[6] Evidently the more effective use of resources of fixed capital and labor during peak production periods accounts for a large part of the cyclical movement in the productivity index.

Investment And Productivity

The net productivity of capital investment is accepted, although analysts may differ about the magnitude of its contribution to productivity advances vis-a-vis other factors, and its significance in productivity trends at various points in time.[7] Denison, for example, in his recent study[8] attempts to explain the sharp decline in productivity since 1973 and is unable to indentify changes in the rate of investment as a significant factor in this drop. On the other hand, Norsworthy et. al.[9] attributed much of the recent decline in productivity to a drop in the rate of investment. Regardless of such differences in the analysis, investment is unquestionably a large contributor to productivity, and greater investment is to be encouraged, subject to its payoff being greater than its cost (i.e., all investments are not necessarily economic and some, in fact, are wasteful of resources). Costs of investments include the time preference costs (interest) of the funds tied up, the amortization of the original capital, miscellaneous charges such as property taxes, and income and capital gains taxes on the

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6 The utilization index is significantly correlated to the detrended total factor productivity, $\frac{TFP_t}{(1+r)^t}$ where TFT_t is the total factor productivity in year t, and r is the average annual rate of growth of total factor productivity (3.6 percent).

7 In this context, productivity means total productivity or total factor productivity, not the partial measure of output per manhour.

8 Edward F. Denison, Accounting for Slower Economic Growth: The United States in the 1970s, Brookings Institution, Washington, D.C., 1979

9 J.R. Norsworthy, Michael J. Harper, Kent Kunze, "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors," Brookings Papers on Economic Activity, 2:1979.

before-tax return from the investments. If these costs are higher rather than lower, the result is to inhibit investment, especially investment with high risk, and to reduce the amount of resources allocated to building up capital stocks.

Government Regulation And Productivity

The impact on productivity of government regulation cannot be measured but can only be inferred by case study results projected to reflect the total economy. Much has been written on the paperwork costs of red tape and the administrative costs imposed by government regulation but the real costs lie in the inefficiencies resulting from the less than full utilization of resources, and the misallocations of resources that occur, when private sector innovation and decision-making are unnecessarily restricted. Case studies of transportation regulation impacts have estimated annual costs at several billions of dollars. The effects of regulation economy-wide can easily amount to over one hundred billion dollars annually.

OUTLOOK

Its productivity performance and technological leadership have placed the aerospace industry in a strong position today. Sales have rebounded since their downturn in the early 1970s and the forecasts are for exceptional growth over the next several years.[10] The improved utilization of capacity should in itself result in substantial increases in productivity. Opportunities for investment in improved technology and automation should result in further productivity improvements.

The prospects for general productivity gains in the economy are also good. Investment is expected to strengthen after its slow growth in recent years. The average composition of the labor force will become more mature after absorbing an abnormally high rate of new entrants in the past decade, resulting in a slower growing and more experienced, productive labor force.

With respect to public policy, increasing awareness of the costs of government regulations should bring pressures on Congress and public officials to revise statutes, where necessary, and to administer regulatory procedures in a more enlightened manner, working toward a gradual reduction of the adverse economic impact of these regulations. A similar awareness of the need to stimulate investment should result in reforms of tax policies that are currently dampening incentives for the risk-taking associated with investment. Finally, the awakening of the public and labor to the close link between productivity improvement and increases in living standards will, it is hoped, focus attention on the importance of improving production efficiency, promote cooperation in the introduction of new technology, and encourage the innovative labor-management relations necessary for progress in productivity.

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10 U.S. Department of Commerce, 1980 U.S. Industrial Outlook, January 1980.

THE CONCEPT OF PRODUCTIVITY

and

Definitions and Value of Productivity Measures

This study of productivity in the U.S. aerospace industry over the period 1960 through 1978 looked at three aspects of the problem: productivity concepts, methodological issues in productivity measurement, and the derivation of quantitative measures of productivity for the industry. The measurement methods developed were necessary to obtain meaningful quantitative results, and an understanding of productivity concepts is necessary to properly interpret those results.

Emphasis has also been placed on identifying the variety of factors that can influence the behavior of these measures, and on calling attention to possible sources of misinterpretation of their significance.

In the course of the study, it was necessary to resolve a number of difficult measurement problems. The principal areas of difficulty, including the aggregation of inputs and outputs and estimating inputs of capital services, are briefly discussed at the end of this section. The Appendix fully documents all methods and data sources.

Productivity: Concept And Measures

The definition and meaning of productivity have not been well understood, and the term is subject to widespread misuse. As a general concept, productivity is the relationship between the rate at which outputs of goods and services are produced and the rate at which inputs to the production process are consumed. A productivity measure is defined as the ratio of a measure of output (of a firm, industry, or group of industries) to the quantities of one or more of the resources (capital, labor, materials) utilized in production. Such measures are useful as indicators of changes over time in the structure and efficiency of the production process. However, since a productivity measure is a highly summary index of the behavior of a complex production process, some information about the process is inevitably lost in constructing the index. Therefore no single productivity measure is ideal, and the choice of a measure must depend on the information available and the application for which it is intended.

The most commonly used measure of productivity, output per manhour, is probably the measure that has been most subject to misinterpretation. An output per manhour, or labor productivity, index is derived by dividing an index of the quantity of production (often deflated annual dollar sales) by an index of labor inputs to production (e.g. total manhours for the year, or total employment, if manhour data is not available). Because this measure explicitly takes into account only one of the inputs to the production process, the use of the output per manhour index has sometimes obscured the role that capital formation and more efficient use of materials inputs play in productivity growth. Substitution of capital for labor in the production process, in response, for example, to an increase in the price of labor relative to the price of capital, will be reflected by an increase in output per manhour. Such an increase in a productivity index stimulated solely by relative price changes does not represent a real gain in the efficiency of production.

An increase in output per manhour over time is not an indication of an increase in the personal efficiency of workers; it is simply a measure of the difference between the rate of growth of output and the rate of growth of inputs of labor. In fact, none of the productivity measures derived in this report can be used, in themselves, to attribute productivity change to a change in the efficiency of any particular input. Additional information about the specific nature of the change in the production process is always necessary to determine the cause of productivity change.

The output per manhour index is not without its uses, however. Long-run growth in output per manhour is correlated to real gains in productive efficiency stimulated by technical advances, and in the U.S. economy as a whole, changes in real compensation per manhour have historically closely tracked the growth of output per manhour. The data necessary to estimate this index are usually more readily obtainable than data on capital and materials inputs necessary to calculate more complete productivity measures. Therefore, output per manhour is often the only measure available for comparisons of productivity change among different industries or countries. The aerospace output per manhour index is used in this report for comparisons of the U.S. aerospace industry to other U.S. manufacturing sectors and to foreign aerospace industries.

Measures Used In This Study

In this study two productivity measures which relate output to the total quantity of inputs (resources) consumed -- total productivity and total factor productivity -- have been derived, as well as the more common measure, labor productivity. Labor productivity is output per manhour. Total productivity is defined as total output divided by an aggregate index of all inputs -- labor, capital, and intermediate inputs (raw materials, fuels, parts, purchased services, and so on). Total factor productivity is defined as the ratio of value added (output net of inputs of purchased materials and services) to aggregate input of labor and capital.

The construction of the total productivity and total factor productivity measures compensates in part for the effects of price-induced shifts in the relative proportions of inputs in the production process which can cause misleading movements in the output per manhour index. These more complete measures are therefore more reliable indicators of real changes in the overall efficiency of the production process. However, they are also subject to movements which are purely artifacts of relative price changes and which can obscure the measurement of productivity gains resulting from true technical advances.

Total productivity relates gross output to the total of all inputs; total factor productivity relates value added to the aggregate of capital and labor inputs, since value added represents the returns to these factor inputs. Real productivity gains resulting from more efficient use of materials will be reflected by an increase in both measures (although the magnitudes of the movements of the two will differ). However, the total productivity measure perhaps focuses more clearly on the possibilities of productivity gains through more efficient use of materials.

The applicability of each of the measures can be summarized as follows. Production and employment data that permit calculating output per manhour are more likely to be at hand than are the additional data on capital and materials inputs necessary for calculating total productivity. The output per manhour measure has valid uses in productivity analysis, as long as the limitations of the measure discussed above are recognized; but it is an incomplete measure in the sense that it ignores capital and materials inputs. Total factor productivity has also seen frequent application in the literature on productivity but, in deriving this measure, the distinction made between the treatment of inputs of materials and inputs of capital and labor is somewhat artificial. The total productivity measure best captures the concept of overall production efficiency, and is least likely to exhibit anomalous behavior. In fact, it is possible to construct examples in which total productivity is rising -- that is, total output per unit of input is increasing -- yet total factor productivity and output per manhour are declining.

The discussion above of some possible misconceptions concerning the output per manhour measure suggests interpretation of productivity measures is complicated by the variety of factors that can influence any index. The major factors are:

o Technical Change -- Improvements in the design of machines, increases in the skills of the labor force, gains in the effectiveness with which management organizes production, and so on; in general, any change which permits the same level of real output to be produced with fewer units of inputs. The definition of productivity change is usually confined to apply only to technical change; however, all the commonly used productivity indexes may also be affected by other factors.

o Substitution Among The Factors of Production -- There is some flexibility as to the degree of capital intensity in almost all production processes, and firms will choose that combination of inputs that minimizes their production costs. If the relative prices of inputs of capital, labor, and materials change, the least-cost proportions of inputs will change, even in the absence of any technological advance.

In the aerospace industry, the cost of labor has been rising somewhat more rapidly than the cost of capital over the past 20 years, and part of the increasing capital intensity of the industry is attributable to these price changes, although this effect has probably been small compared to the impact of technical advances. Substitution of capital or labor for materials is also often possible and in recent years rising costs of metals, fuels, and other materials have been a stimulus for more conservative production practices.

Output per manhour is the productivity measure most subject to movements which are purely artifacts of relative price changes. Since the total productivity and total factor productivity measures are constructed from indexes of all the inputs, they are less sensitive to price-induced shifts in input proportions. However, the cumulative effects of price changes may distort these measures, when inputs and outputs are evaluated using base year prices.

o Business Cycle Effects -- The stock of fixed capital of a firm or industry, as well as the employment of skilled workers, cannot be adjusted in the short run to fully respond to cyclical fluctuations in demand. Retention of excess capacity during periods of slack demand is in the firm's long-run best interests, but in the short run leads to increased capital and labor costs per unit of output. The close relationship between cyclical fluctuations in capacity utilization and productivity in the aerospace industry is examined in the section beginning on page . Because of this relationship, it is not possible to infer a significant trend in aerospace productivity from the movement of the productivity measures over just a few years. A trend will emerge only from data over a period of several cycles.

Increased capital investment is often cited as a primary source of productivity growth. Note that both shifts in relative factor prices and technical change may stimulate capital spending. A firm investing in response to rising labor costs relative to the cost of capital will be just keeping even, rather than making any real productivity gains. Increased investment is the means of taking advantage of technical advances that increase the productivity of equipment and plant. Obviously, expansion of capital assets is efficient only up to the optimum level at which production costs are minimized. This level may be altered by technical change, by price changes, or changes in government tax policy which affect the cost of capital to business.

Value of Productivity Measures

Productivity measures, then, are closely related to the structure of the production process and to changes in that structure. Their descriptive function -- as indicators of change for a firm, an industry, or the economy as a whole -- is perhaps their most significant value. Comparisons of productivity measures within an industry (for example, the comparisons of the U.S. and European aerospace industries beginning on page 27) can yield insights into the competitive positions of firms. Comparisons within or across industries may reveal whether opportunities for technical progress have been fully utilized. The productivity measures alone, however, never explain the changes in production efficiency that they reveal. In order to identify the causes of efficiency gains, the underlying processes of research, development and innovation--as well as investment, factor prices, and capacity utilization--must be examined.

Problems of Measurement

Productivity analysis presents problems of measurement which are closely related to the conceptual difficulties discussed above. Two principal issues concern the aggregation of input and output quantities, and the measurement of the flow of inputs of capital services. In this study, considerable effort has been devoted to dealing with these measurement problems in a manner that is theoretically well-founded and fully utilizes the available data.

The concept of productivity is the measurement of changes in the relation between quantity of output and the quantity of inputs. Since each of these quantities is a heterogeneous grouping, involving diverse products or different types of labor, materials and capital inputs, the quantities must be aggregated into a common unit of measure. This is usually accomplished by weighting the output and input quantities by their respective prices in a base year or by deflating dollar values of output or input to a common vintage of prices. The development of suitable deflators for this purpose, especially for industries with highly complex and custom-designed products, is a major problem in the measurement of productivity.

Another problem concerns the measurement of the capital input. Whereas the inputs of labor and materials have prices which are recorded in transactions data, analogous rental prices for the use of capital are not generally available. This is due to the fact that most capital equipment is owned by the companies which use it and the implicit rental costs must be calculated. These costs consist of the economic depreciation of the assets involved and the financial or interest cost of the funds tied up in the capital. These costs should be measured in base year prices to be symmetrical with the weighting of other inputs. To do so requires that capital assets be valued in the prices of a common year rather than the values carried on the books. Economic depreciation is then calculated consistent with these base year values. Economic depreciation reflects the annual loss in the value of an asset due to wear and tear, obsolescence, and loss of remaining life, and is generally different from most accounting depreciation measures. The concept of the measurement of capital input has been followed in this study.

The methods used in this study for aggregating inputs and outputs, and estimating the annual input of capital services, are described in the Appendix.

U.S. AEROSPACE PRODUCTIVITY

Input and output measures and indexes of output per manhour, total factor productivity and total productivity for the U.S. aerospace industry from 1960 through 1978 are shown in Table 1. Figure 1 shows plots of the productivity and output indexes versus time. The data sources and methods used in deriving the measures are described in the Appendix.[1] The series for labor, capital, materials, and production are expressed in dollar terms, but should be interpreted as measures of the physical quantities of inputs employed and outputs produced. That is, the starting point in the derivation of the labor input series, for example, was total hours worked by production workers and total number of nonproduction employees. These two distinct components of labor input were then aggregated to a single series by weighting them according to the compensation paid per production worker-hour and per salaried employee, respectively, in 1972. The derivation of the other input and output series is conceptually similar: physical units of distinct components have been summed using base year prices as weights.

All the productivity measures have shown significant increases over the period. Output per manhour has had the greatest growth rate, at an average annual rate of 3.9 percent.[2] The growth of total productivity (the ratio of production to total inputs of capital, labor and purchased materials and services) has been much lower, an average of 1.2 percent per year. This slower growth of total productivity is attributable to the decline in the ratio of output to capital over the period, and especially to the almost static (except for 1973-1975) ratio of outputs to materials inputs.

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[1] Note the definition, given in the Appendix, of the aerospace industry used for this study. This definition is more restrictive than that used for statistical tabulations by the Aerospace Industries Association. The industry definition used herein was dictated by the availability of data from the U.S. Census on production, employment, purchased materials, and capital investment at a sufficient level of disaggregation to permit computation of the productivity measures.

[2] All growth rates herein are average annual percentage change, compounded annually, based on the least-squares trend of the logarithms of the index numbers.

TABLE 1

U.S. AEROSPACE INDUSTRY INPUT AND OUTPUT MEASURES AND PRODUCTIVITY INDEXES

1960-1978

(Millions of 1972 Dollars)

	INPUT					OUTPUT		Productivity Indexes 1972=100		
Year	Labor	Capital	Total Capital and Labor	Materials and Services	Total, all Inputs	Production	Value Added	Output per Manhour	Total Factor Productivity	Total Productivity
1960	8136.5	487.8	8624.3	9185.3	17809.6	16476.8	7291.5	68.1	66.6	82.8
1961	8343.1	486.9	8830.0	10499.4	19329.4	17918.5	7419.1	72.2	66.2	82.9
1962	8761.9	506.7	9268.6	10438.1	19706.7	18144.7	7706.6	69.6	65.5	82.4
1963	8328.9	542.4	8871.3	9928.4	18799.7	18174.3	8245.9	73.3	73.2	86.5
1964	8078.9	557.0	8635.9	9848.8	18484.7	17179.0	7330.2	71.5	66.9	83.2
1965	7749.5	588.1	8337.6	10339.9	18677.5	18385.0	8045.1	79.7	76.0	88.1
1966	8963.2	717.9	9681.1	12110.2	21791.3	22561.9	10451.7	84.6	85.1	92.6
1967	9751.5	889.2	10640.7	14607.1	25247.8	27047.9	12440.8	93.2	92.1	95.9
1968	9718.3	983.5	10701.8	15910.0	26611.8	28066.5	12156.5	97.1	89.5	94.4
1969	9301.5	1023.4	10324.9	13853.4	24178.3	24663.1	10809.7	89.1	82.5	91.3
1970	7927.5	1054.4	8981.9	11708.1	20690.0	22334.9	10626.8	94.7	93.2	96.6
1971	6282.0	987.2	7269.2	9703.9	16973.1	17590.6	7886.7	94.1	85.5	92.7
1972	5847.2	955.2	6802.4	8765.8	15568.2	17398.7	8632.9	100.0	100.0	100.0
1973	6013.5	939.7	6953.2	9395.3	16348.5	19565.6	10170.3	109.3	115.3	107.1
1974	5973.4	939.8	6913.2	9409.5	16322.7	20965.1	11555.6	118.0	131.7	114.9
1975	5744.5	912.4	6656.9	9586.4	16243.3	20733.6	11147.2	121.3	131.9	114.2
1976	5373.2	857.8	6231.0	9275.8	15506.8	18810.2	9534.4	117.6	120.6	108.5
1977	5580.8	843.2	6424.0	9853.4	16277.4	17833.3	7979.9	107.4	97.9	98.0
1978	6128.2	872.2	7000.4	9692.4	16692.8	18880.8	9188.4	103.5	103.4	101.2
Average annual percentage rate of change:								3.87	3.63	1.21

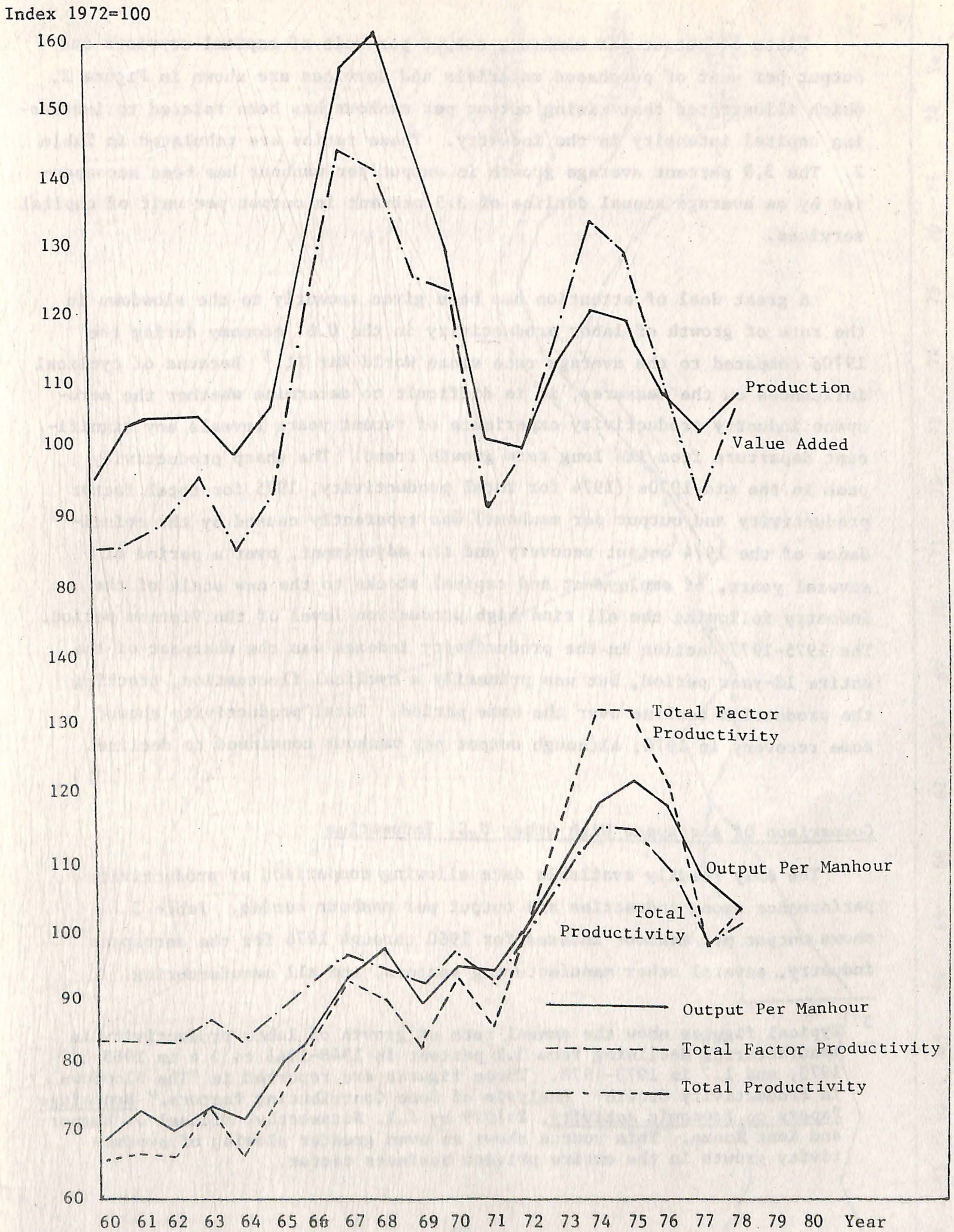

FIGURE 1--U.S. AEROSPACE INDUSTRY OUTPUT AND PRODUCTIVITY INDEXES, 1960-1978

Plots of output per manhour, output per unit of capital services and output per unit of purchased materials and services are shown in Figure 2, which illustrates that rising output per manhour has been related to increasing capital intensity in the industry. These ratios are tabulated in Table 2. The 3.9 percent average growth in output per manhour has been accompanied by an average annual decline of 3.5 percent in output per unit of capital services.

A great deal of attention has been given recently to the slowdown in the rate of growth of labor productivity in the U.S. economy during the 1970s compared to the average rate since World War II.[3] Because of cyclical influences on the measures, it is difficult to determine whether the aerospace industry productivity experience of recent years reveals any significant departure from its long term growth trend. The sharp productivity peak in the mid-1970s (1974 for total productivity, 1975 for total factor productivity and output per manhour) was apparently caused by the coincidence of the 1974 output recovery and the adjustment, over a period of several years, of employment and capital stocks to the new scale of the industry following the all time high production level of the Vietnam period. The 1975-1977 decline in the productivity indexes was the sharpest of the entire 18-year period, but was primarily a cyclical fluctuation, tracking the production decline over the same period. Total productivity showed some recovery in 1978, although output per manhour continued to decline.

Comparison Of Aerospace With Other U.S. Industries

The only readily available data allowing comparison of productivity performance among industries are output per manhour series. Table 3 shows output per manhour indexes for 1960 through 1976 for the aerospace industry, several other manufacturing sectors, and all manufacturing.

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3 Typical figures show the annual rate of growth of labor productivity in manufacturing declining from 3.1 percent in 1948-1965 to 2.4 in 1965-1973, and 1.7 in 1973-1978. These figures are reported in "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors," Brookings Papers on Economic Activity, 2:1979 by J.R. Norsworthy, Michael J. Harper and Kent Kunze. This source shows an even greater slowing of productivity growth in the entire private business sector.

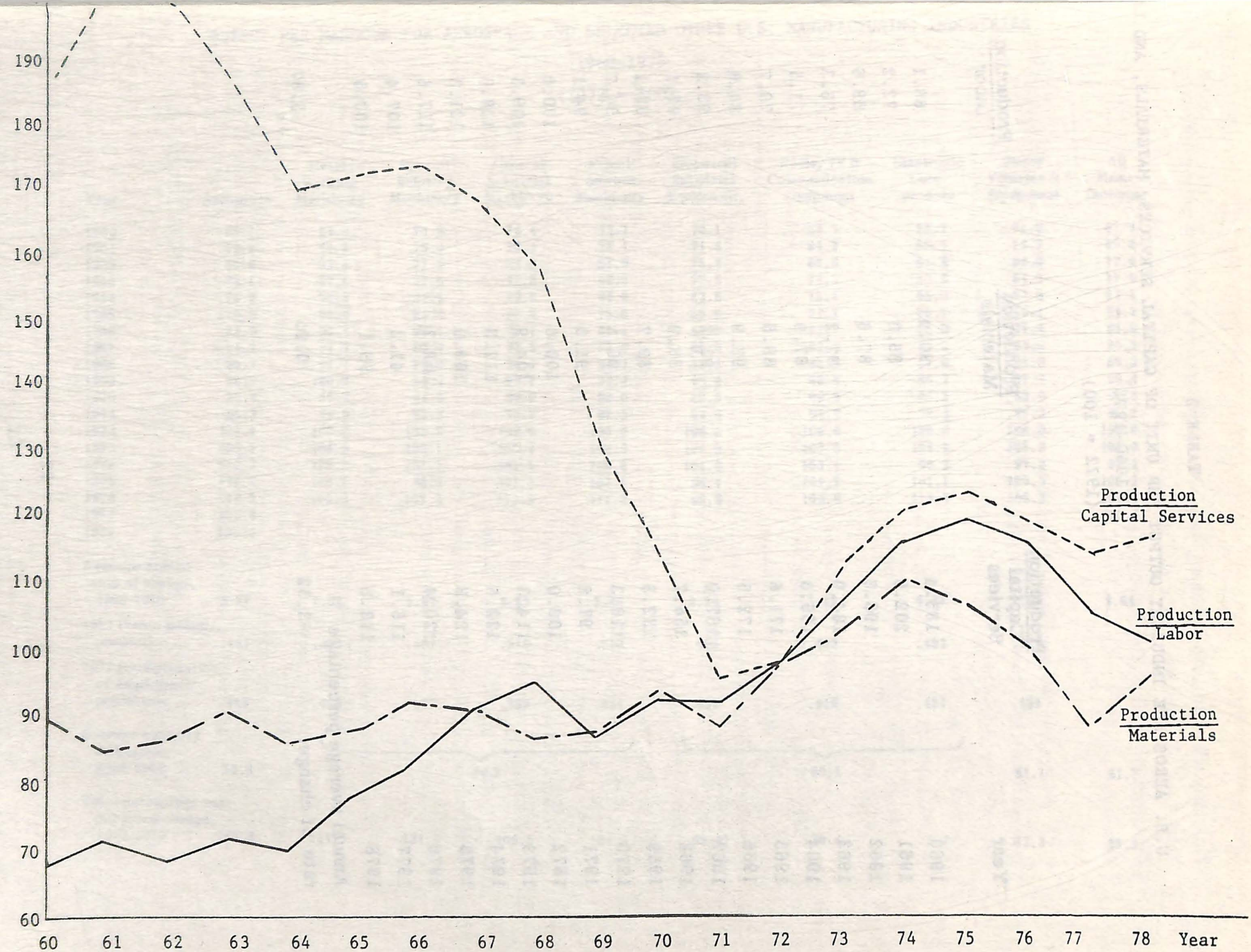

FIGURE 2--U.S. AEROSPACE INDUSTRY OUTPUT PER UNIT OF CAPITAL SERVICES, MATERIALS AND LABOR, 1960-1978

TABLE 2

U.S. AEROSPACE INDUSTRY OUTPUT PER UNIT OF CAPITAL SERVICES, MATERIALS, AND LABOR

1960-1978

(1972 = 100)

Year	Production / Capital Services	Production / Materials	Production / Labor
1960	185.4	90.4	68.1
1961	202.0	86.0	72.2
1962	196.6	87.6	69.6
1963	184.0	92.2	73.3
1964	169.3	87.9	71.5
1965	171.6	89.6	79.7
1966	172.5	93.9	84.6
1967	167.0	93.3	93.2
1968	156.7	88.9	97.1
1969	132.3	89.7	89.1
1970	116.3	96.1	94.7
1971	97.8	91.3	94.1
1972	100.0	100.0	100.0
1973	114.3	104.9	109.3
1974	122.5	112.3	118.0
1975	124.8	109.0	121.3
1976	120.4	102.2	117.6
1977	116.1	41.2	107.4
1978	118.8	98.1	103.5
Annual average percentage rate of change:	-3.52	0.95	3.87

TABLE 3

OUTPUT PER MANHOUR FOR AEROSPACE AND SELECTED OTHER U.S. MANUFACTURING INDUSTRIES

1960-1978

(1972 = 100)

Year	Aerospace	Metal-working Machinery	Special Industry Machinery	General Industrial Machinery	Miscel-laneous Machinery	Electrical Industrial Equipment	Radio, TV & Communication Equipment	Electronic Com-ponents	Motor Vehicles & Equipment	All Manu-facturing
1960	67.1	84.9	76.0	76.4	72.1	70.1	53.7	58.2	71.6	67.9
1961	72.2	86.2	79.9	78.3	76.1	71.6	64.2	55.4	72.7	69.6
1962	69.9	93.4	77.5	82.0	81.9	75.2	69.6	61.4	80.9	72.8
1963	73.1	92.1	77.0	87.8	80.2	77.5	74.5	63.5	84.3	77.9
1964	70.9	96.2	82.5	92.6	82.9	83.6	75.2	66.0	83.8	82.1
1965	79.0	98.8	84.4	96.8	75.8	88.8	81.7	75.7	89.1	84.7
1966	82.9	99.4	89.1	95.4	81.5	89.9	82.7	76.0	87.4	85.9
1967	91.2	97.7	86.0	91.5	98.0	88.6	82.1	84.2	83.6	86.2
1968	95.7	97.7	89.2	90.0	94.7	89.2	88.5	81.6	88.8	89.3
1969	88.9	100.3	86.7	93.7	93.4	90.8	88.6	85.2	87.7	90.4
1970	95.4	89.2	84.2	92.9	99.0	88.9	89.0	86.3	83.0	90.1
1971	95.3	98.8	86.2	94.7	97.3	94.0	94.2	92.4	99.3	95.2
1972	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1973	109.1	104.5	102.1	105.4	100.9	104.3	103.0	104.1	102.9	102.9
1974	117.3	104.3	101.3	105.5	100.8	101.9	103.4	99.2	97.8	97.2
1975	121.7	100.1	98.2	102.0	101.1	96.1	101.2	101.1	100.3	100.3
1976	118.3	105.3	107.3	110.9	111.2	99.9	103.6	113.7	105.3	107.1
1977	109.0									109.4
1978	104.6									
Average Annual rate of change, 1960-1976	3.87	1.04	1.97	1.85	2.40	2.25	3.55	4.37	2.09	2.64
1972 (Value added)/ production	.461	.601	.507	.510	.559	.496	.463	.493	.329	
1972 (Compensation of employees)/ production	.445	.486	.382	.399	.434	.401	.416	.434	.191	
Average capacity utilizaiton, 1968-1976	72.8			80.2			80.1		81.1	81.7
Total percentage output price change, 1960-1976	108.8	124.5	131.6	109.5	101.0	69.6	38.4	5.7	63.3	88.8

The indexes for other industries are based on series of constant-dollar value of production and total manhours developed by the Bureau of Labor Statistics,[4] and the aerospace series is derived from the data developed for this study.[5]

Based on the average annual rate of change of output per manhour over the period 1960 through 1976, the performance of the aerospace industry appears relatively good. Its growth rate of 3.9 percent is above the average for all manufacturing (2.6 percent) and the rates for the machinery manufacturing sectors shown in the table, and is comparable to the rates shown for the electrical and electronic equipment sectors.

Figure 3 shows plots of output per manhour for aerospace, all manufacturing, and the two industries in Table 3 with the highest and lowest output per manhour growth rates. Explanation of these differences in output per manhour growth in terms of broad industry characteristics is difficult. Sectors were chosen for comparison that had ratios of compensation of employees to production and value added to production in 1972 that were similar to these ratios for the aerospace industry.[6] If productivity growth in individual industries depended primarily on economy-wide changes in the skills of the labor force, production technology, or relative prices, one might expect industries with similar degrees of labor intensity to have similar opportunities for productivity growth. The productivity performance varies greatly among these industries, however, and there is no significant correlation between either the labor/output or the value added/output ratios and the output per manhour growth rates.

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[4] U.S. Department of Labor, Bureau of Labor Statistics, Time Series Data for Input-Output Industries, Washington, D.C., March 1979.

[5] The aerospace output per manhour index in Table 3 is derived from production divided by total production worker and non-production worker hours, for the sake of consistency with the other industry indexes. This index therefore differs slightly from the output per manhour index in Table 1, which is based on a compensation-weighted aggregate of manhours.

[6] U.S. Department of Commerce, Bureau of Economic Analysis, The Input-Output Structure of the U.S. Economy, 1972, 1979.

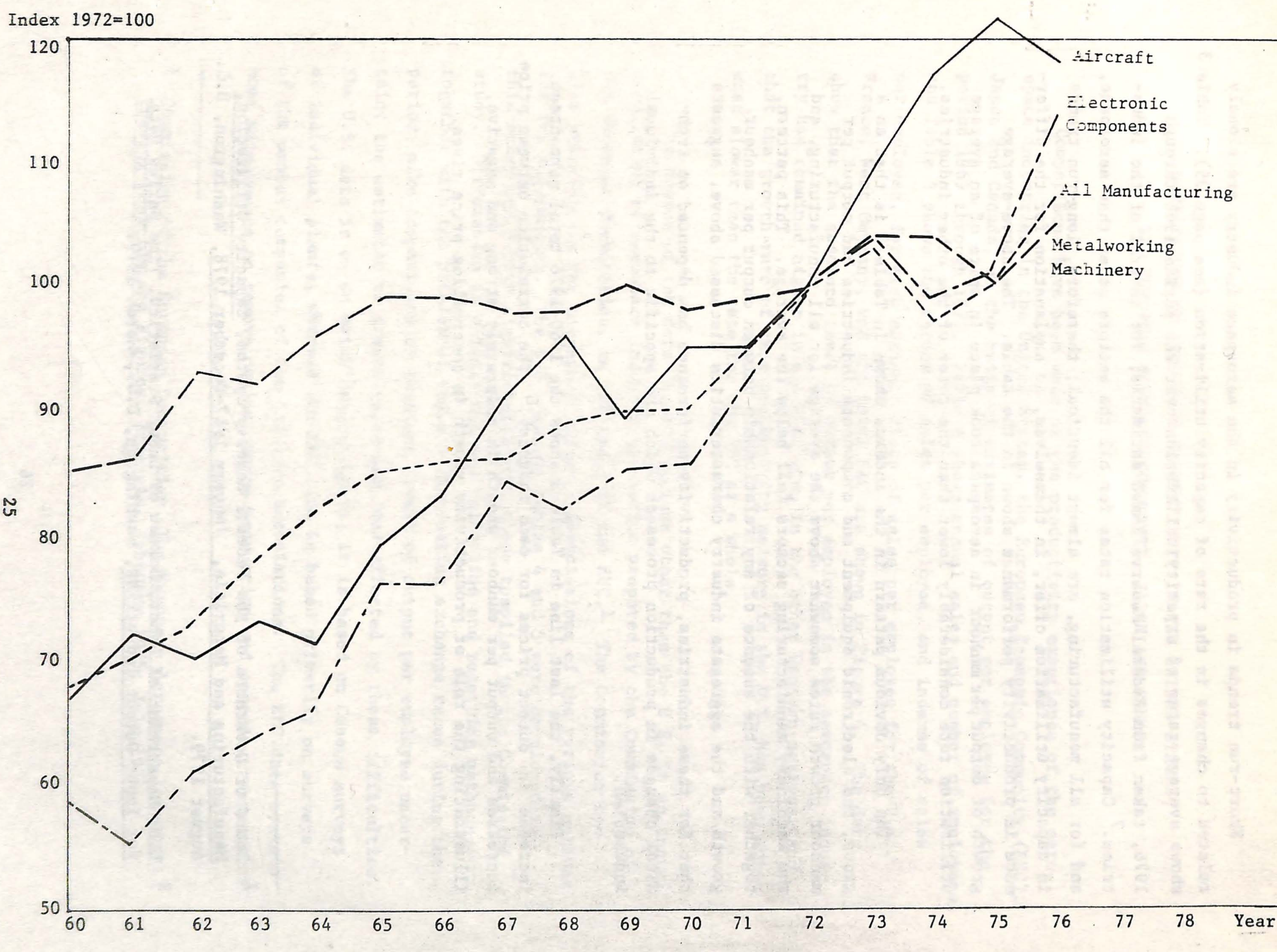

FIGURE 3--OUTPUT PER MANHOUR FOR AEROSPACE AND SELECTED OTHER U.S. MANUFACTURING INDUSTRIES, 1960-1978

Short-run trends in productivity in the aerospace industry are closely related to changes in the rate of capacity utilization (see page 35). Table 3 shows average rates of capacity utilization over the period 1968 through 1976, taken from Federal Reserve Board estimates, for several of the industries.[7] Capacity utilization rates for all the sectors other than aerospace, and for all manufacturing, are almost identical; therefore, long-run trends in capacity utilization offer, in themselves, no explanation for the difference in productivity performance shown in the table. The above-average growth of output per manhour in aerospace took place in spite of an average utilization rate considerably lower than the rates of the other industries.

The only obvious pattern in the indexes shown in Table 3 is that as a group, the electronic equipment and components industries had output per manhour growth rates somewhat above the average for all manufacturing, and the machinery manufacturing sectors fell below the average. This pattern, together with the absence of any relationship between output per manhour growth and the aggregate industry characteristics discussed above, suggests that for these industries, productivity performance has depended on technical changes in production processes which are specific to the individual industries.

Finally, the last line in Table 3 shows the 1960-1976 total percentage increase in output prices for each industry.[8] The correlation between price increases and output per manhour growth is moderately strong and negative, illustrating the role of productivity growth in controlling price rises.

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7 Board of Governors of the Federal Reserve System, <u>Capacity Utilization, Manufacturing and Materials, January 1967-December 1978</u>, Washington, D.C. August 1979.

8 U.S. Department of Labor, Bureau of Labor Statistics, <u>Time Series Data for Input-Output Industries</u>, Washington, D.C., March 1979.

COMPARISONS OF AEROSPACE PRODUCTIVITY IN THE UNITED STATES, THE EUROPEAN ECONOMIC COMMUNITY, JAPAN AND CANADA

Comparisons have been made of the productivity experience of the aerospace industries in the United States, the European Economic Community (EEC), Japan and Canada, on the basis of estimates of output per employee for the period 1969 through 1977. Table 4 shows annual sales and number of employees, and Table 5 shows the ratios of sales per employee, and indexes of sales per employee, for each nation. Plots of sales per employee for the U.S., France, West Germany, and the total EEC are shown in Figure 4. The data show that the absolute level of output per employee in the aerospace industry has remained higher in the U.S. than in the other Western nations, and that the growth rate of this productivity measure in the U.S. has been somewhat slower than the rate for the EEC as a whole.

The source of the data for all nations other than the U.S. is an annual compilation of aerospace industry statistics prepared by the Commission of the European Communities, an affiliate of the EEC.[1] The Commission relies primarily on the aerospace industry associations of the various nations for its information. The U.S. data in Tables 4 and 5 were developed in this study and differ significantly from those compiled in the Commission study. Differences in definitions and collection and reporting methods, together with the problem of rapidly fluctuating exchange rates during the period, make comparisons of absolute levels of output per employee uncertain; the estimates of growth rates are less affected by these difficulties. The U.S. data is on an establishment basis; it is based on Census surveys of individual plants, whereas the EEC data is based primarily on surveys of the member companies of the industry associations. The EEC data contain some adjustments to remove non-aerospace production and certain transactions

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1 Commission of the European Communities, The European Aerospace Industry: Trading Position and Figures, Brussels, February 1975; July 1979.

TABLE 4

ANNUAL SALES AND EMPLOYMENT IN THE U.S. AND FOREIGN AEROSPACE INDUSTRIES

1969-1977

Year	U.S.	West Germany	France	U.K.	Belgium	Netherlands	Italy	Total EEC	Japan	Canada
					Sales (constant prices; millions of 1972 EUA[a]'s)					
1969	22360	802	1353	2042	48	137	244	4626	296	698
1970	19480	819	1474	1765	44	137	256	4595	318	658
1971	16813	912	1474	1656	56	134	231	4463	326	573
1972	15126	908	1529	2125	65	169	359	5155	396	562
1973	17570	982	1778	2226	54	140	352	5532	321	601
1974	18859	920	1901	2330	56	107	332	5646	350	476
1975	18612	890	2002	2319	66	152	403	5832	390	375
1976	17872	964	2435	2376	65	163	389	6392	400	449
1977	16144	822	2396	2442	59	153	408	6280		
					Number of Employees (thousands)					
1969	773	52	97	248	4	7	27	435	23	44
1970	648	56	103	237	5	8	30	430	26	36
1971	516	55	109	218	5	8	28	423	26	29
1972	480	52	109	208	5	7	28	409	26	29
1973	501	53	106	202	4	7	30	402	26	32
1974	500	53	107	210	4	7	30	411	28	28
1975	475	52	109	234	4	8	31	438	27	27
1976	443	51	107	227	5	8	32	430	26	25
1977	458	52	103	219	5	7	32	418	24	27

[a]EUA: European Unit of Account. 1 EUA = $1.12 U.S. in 1972.

Source: Commission of the European Communities, The European Aerospace Industry: Trading Position and Figures, Brussels, February 1975; July 1979.

TABLE 5

OUTPUT PER EMPLOYEE FOR THE U.S. AND FOREIGN AEROSPACE INDUSTRIES

1969-1977

(Thousands of Constant 1972 EUAs[c])

	U.S.		West Germany		France		U.K.		Belgium		Netherlands		Italy		Total EEC		Japan		Canada	
Year		Index		Index		Index		Index		Index		Index		Index		Index		Index		Index
1969	28.9	91.9	15.4	89.0	14.0	99.0	8.2	80.4	10.7	81.5	19.6	76.7	9.0	71.6	10.6	84.4	12.8	84.1	15.86	81.8
1970	30.1	95.4	16.3	94.4	14.3	99.4	7.4	72.7	9.3	70.6	17.2	67.1	8.7	68.7	10.5	83.1	12.4	81.7	18.28	94.3
1971	32.6	103.6	16.5	95.5	13.6	96.3	7.6	74.2	12.5	94.9	16.7	65.3	8.2	69.1	10.6	83.7	12.3	80.8	19.76	102.0
1972	31.5	100.0	17.3	100.0	14.1	100.0	10.2	100.0	13.2	100.0	25.6	100.0	12.6	100.0	12.6	100.0	15.2	100.0	19.38	100.0
1973	35.0	111.3	18.5	107.1	16.7	118.9	11.0	107.8	12.3	93.3	20.0	78.0	11.7	93.2	13.8	109.2	12.3	81.0	18.78	96.9
1974	37.7	119.9	17.4	100.3	17.8	126.4	11.1	108.3	12.7	96.4	16.3	63.7	11.1	87.8	13.7	109.0	13.7	89.9	17.00	87.7
1975	39.2	124.5	17.1	99.1	18.4	130.4	9.9	96.8	16.4	124.7	19.8	77.3	13.1	103.9	13.3	105.7	14.6	95.7	13.89	71.7
1976	40.3	128.0	18.8	108.4	22.7	160.8	10.4	102.0	13.0	98.5	20.7	80.9	12.2	96.6	14.9	118.0	15.4	101.0	16.63	85.8
1977	35.2	112.0	15.7	90.6	23.2	164.7	11.1	108.8	12.1	92.2	20.9	81.7	12.7	101.1	15.0	119.2				
Average annual percentage rate of change, 1969-1977:		3.8		0.9 [a]		7.5		4.8		3.4[a]		1.2		5.3		5.1		2.6[b]		-1.8[a]
Percentage change in annual sales, 1969-77:		-28		3		82		20		23		11		68		36		35 [b]		-36 [b]

[a] *Trend is not statistically significant.*

[b] *1969 through 1976.*

[c] EUA: European unit of account. 1 EUA = $1.12 U.S. in 1972.

Source: Commission of the European Communities, The European Aerospace Industry: Trading Position and Figures, Brussels, February 1975; July 1979.

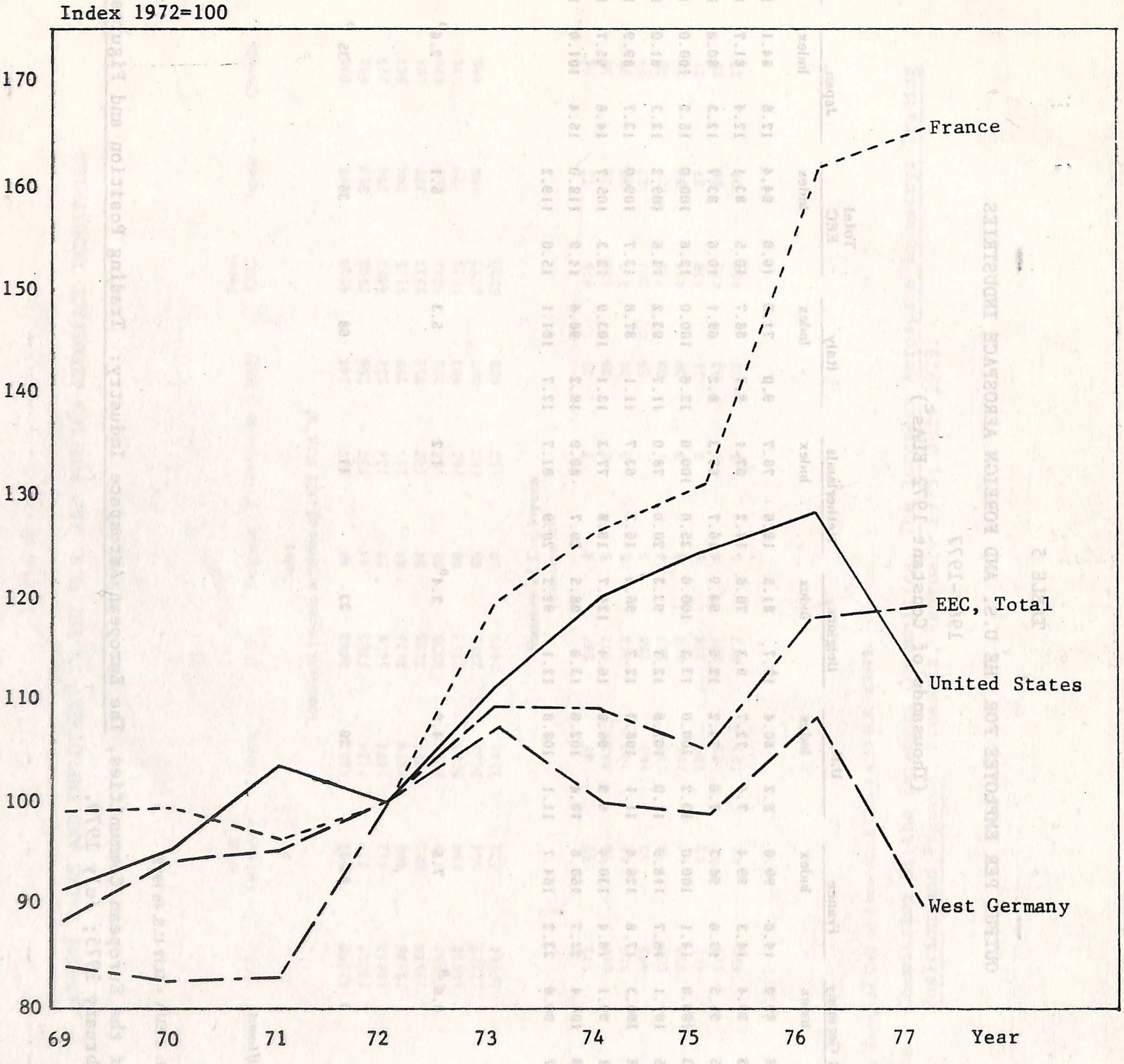

FIGURE 4--CHANGE IN OUTPUT PER EMPLOYEE IN THE U.S. AND EUROPEAN ECONOMIC COMMUNITY AEROSPACE INDUSTRIES, 1969-1977

within the industry, although these adjustments are not documented in the Commission reports.[2]

The units used in the tables for sales and sales per employee are constant 1972 European Units of Account (EUA), a unit employed by the EEC for international accounting purposes. One EUA was equal to $1.12 U.S. in 1972. The constant EUA sales figures were developed by first deflating annual sales in local currencies to sales in constant 1972 local currencies, using gross domestic product or producers' prices deflators for each country, then converting constant-local-currency sales to 1972 EUAs using 1972 exchange rates. This method removes any effect of changes in exchange rates from the calculated output per employee growth rates.[3]

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2 The U.S. data are gross sales, including sales by aerospace firms to other U.S. aerospace firms. Intra-industry sales amounted to 17 percent of gross U.S. aerospace sales in 1972. Therefore the individual nations' net sales appear biased downward in a comparison to U.S. gross sales. However the difference between gross and net is probably much smaller for most European countries than is the difference for the U.S. The "Total EEC" figures in Tables 4 and 5 are simple sums of the sales figures for the individual member nations, with no adjustments for international transactions among EEC aerospace firms. The total EEC figures are therefore more directly comparable to U.S. gross sales.

3 A previous study of comparative productivity in the U.S. and other Western nations by Donald W. Huffmire found much higher rates of productivity growth in some of the European industries than those reported in Table 5. In that study, as reported in "Productivity of Aerospace Industry Employees--The U.S. and Eight Other Countries," Business Economics, May 1976, annual sales were converted to a common currency using the exchange rates for each year, and the large European growth rates primarily reflect the changing terms of trade over the period. Growth rates calculated in this manner are not the rates that would be perceived by internal observers of the domestic aerospace industries.

The difference between the levels of labor productivity in the U.S. and Europe would appear smaller due to changes in exchange rates, if a base year later than 1972 were used, although the growth rates would not be affected. 1977 sales per employee, in 1977 prices and exchange rates, were as follows (in EUAs).

U.S.	West Germany	France	U.K.	Belgium	Netherlands	Italy
48,100	27,300	38,100	15,600	23,200	41,100	17,700

Despite the problems of assembling statistics which are comparable from country to country, the differences in the estimates of output per employee are large enough to conclude that the U.S. aerospace industry remains significantly more capital-intensive than its European counterpart. Only the French industry appears to possess a current level of output per employee, and an historic growth rate sufficient to approach the U.S. level within the foreseeable future.

The largest European national aerospace industry, the United Kingdom's, appears in these data to have the lowest level of labor productivity. British aerospace productivity has been a subject of criticism within the EEC. The Commission of the European Communities 1975 aerospace report implied that labor paractices in the U.K. were at fault, stating that "The British industry has retained an excessively large labor force in relation to the fall in the value of its output."[4] The British industry association disputed this conclusion and produced its own assessment in which, by making adjustments to output and basing comparison on value added per employee rather than sales per employee, much of the difference between British and French productivity was removed.[5] This controversy illustrates the difficulties inherent in international comparisons.

The large differences in output per employee among the Western aerospace industries represent significant differences in the technology of production. However, since the data necessary to develop measures of total factor productivity for each nation are not readily available, it is not possible to draw conclusions about the relative competitive positions of the national industries. Due to differences in wage rates among the industries, the variation in output per unit labor cost is smaller than differences in output per employee. Aerospace industry average annual wages and salaries per employee in 1972 were, in U.S. currency, $4900 in the U.K., $6200 in France and $12,200 in the U.S.[6]

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4 Commission of the European Communities, <u>The European Aerospace Industry: Trading Position and Figures</u>, Brussels, February 1975; July 1979.

5 "British Aerospace," <u>Interavia</u>, September 1975.

6 <u>Ibid</u>.

The growth rates for sales per employee shown in Table 5 vary over a wide range. In general, the nations with the greatest expansion of aerospace sales over the period experienced the greatest growth in labor productivity. The U.S. industry was exceptional in maintaining productivity growth during a period of declining real sales volume. The sales-per-employee growth rate for the total of all the EEC member nations was greater than the U.S. rate. This is not a surprising result; since the U.S. industry has historically been the leader in aerospace technology, research, and development, the potential exists for the European industry to continue its more rapid productivity growth by adopting U.S. developments.

CONDITIONS AND PUBLIC POLICIES THAT AFFECT PRODUCTIVITY PERFORMANCE

Productivity is a measure of the efficiency with which resources are used to meet the nation's demand for goods and services. Efficiency is affected both by conditions within a business firm's control and by conditions that are external. Principally, a firm can control the efficiency with which it manages the resources it uses in production: labor, capital, technological know-how, and entrepreneurial talent. This control includes the combinations in which these resources are used in production, the scheduling of the use of these resources to minimize slack capacity, and the skill with which the resources are managed to gain larger production per unit of output.

Conditions external to the firm that affect productivity include:

1. Effect of overall economic conditions and product demand,
2. Availability and cost of investment capital,
3. Labor union practices that may retard or enhance the introduction of new technology and production practices,
4. Tax laws that affect the rate of return on investments,
5. Efficiencies or inefficiencies that may arise from government regulation,
6. Uncertainty about future government policies,
7. The rate of general research and development,
8. National progress in improving the educational and skill levels of labor or human capital, and
9. Uncertainty arising from unstable world economic and social conditions.

The length of the above list may imply that most of the responsibility for productivity growth lies outside the firm, but this is not necessarily the case. Many of the external factors change only slowly over time and provide the economic and social conditions necessary for productivity and growth--conditions that provide opportunity for the entrepreneur to utilize the resources at his disposal to improve efficiencies in production. The external factors provide both impetus for and restriction on productivity growth but the inventor and the entrepreneur provide the ideas and ingenuity and take the risks prerequisite to progress and improved efficiency in the production and distribution of goods and services.

It is not possible to measure how much contribution has been made to productivity growth by internal entrepreneurship and management versus the external factors. These two sets of factors are complementary to each other and productivity advances depend upon both working in tandem. The entrepreneur, however, must take the initiative in making the countless decisions and taking the risks inherent in new technology and management practices that lead to improved efficiency. The entrepreneur must do what he can in spite of external policies that restrict maximum efficiency, and strive to influence improvement in the external factors through enlightened participation in the political processes that shape the external economic and social environment.

A number of factors that are especially important to productivity advance and that could be improved by near-term changes either in industry practices or by public policy include capacity utilization, investment and government regulations. These are discussed below. Other important factors that contribute to productivity growth gradually over a longer time period are not discussed. These include educational levels, research and development, and international economic and social stability.

Capacity Utilization and Productivity

The aerospace industry's long-run performance in productivity advances compares favorably with that for other machinery industries and for manufacturing as a whole. However, it is subject to cyclical effects larger than that for most industries due to the volatility of the demand for its products. As a result, its average utilization of capacity has been substantially lower than for most other industries with consequently sharp fluctuations in productivity performance. Although the longer-term trend shows good performance in productivity, these cyclical fluctuations mean that a substantial amount of output is lost that is never recovered. The downward movement in productivity since 1974 is largely attributed to a cyclical downturn that is now reversing itself, with sharp increases in productivity expected over the next five to ten years.

The erratic movements in the productivity measures are closely related to capacity utilization in the industry. Capacity utilization involves the degree of utilization of both plant and equipment and labor. Fixed capital in plant and equipment represents capacity which cannot be adjusted in the short-run in response to demand and industry production. Similarly, skilled labor represents an investment which can be adjusted downward in the short-run only at considerable cost: loss of investment in worker training and experience, termination pay, and lost output if demand rises sharply back to previous levels.

Some analysts have argued that an adjustment should be made to measures of productivity to remove the effects of capacity utilization. The flow of services from stocks of capital and labor depends not only on the size of the stocks, but also on their rate of utilization. The adjustment would consist of defining the input measures to be proportional to stocks multiplied by utilization rates. The adjusted output/input ratios would be the same as the unadjusted ratios calculated in a world where producers could change the levels of their stocks of capital and labor instantly in response to shifts in demand.

There are, however, at least two difficulties which would make any adjustment to the capital and labor inputs to reflect capacity utilization inappropriate in this report. First, the measurement of capacity utilization must involve assumptions about productivity change. The estimate of the maximum output attainable from a given stock of inputs at any time requires an assumption about the technologically-determined relationship between output and inputs. However, the measurement of changes in this relationship over time is exactly the objective of productivity studies. Adjustment of the productivity measures to reflect capacity utilization would therefore involve a circular argument. Second, managers plan their use of capital and labor, and their long-run investment and employment practices to minimize the sum of the costs of carrying excess capacity in slack periods and the costs of having insufficient capacity during peak demand periods. Productivity measures should reflect the efficiency with which this management function is carried out.

A broad indicator of capacity utilization has been calculated in Table 6, and the method illustrated in Figure 5. In the figure, the ratio of value added to the stock of capital goods (VA/K)[1] has been plotted for each year, and a trend (the line labeled "maximum efficient VA/K") estimated representing the ratio of value added to capital stock that would obtain in each year if output were at the maximum efficient level. The slope of the trend line represents a crude estimate of the combined effects over time of changes in technology and prices on efficient production practice.[2] The Economic Capacity Utilization index in Table 6 is the ratio of actual VA/K to maximum efficient VA/K.

In surveys of plant capacity, managers often report the existence of some slack capacity even at times of the greatest peaks in production. This buffer capacity probably corresponds to a production level that would be technically, but not economically, feasible. A single estimate (about 6 percent) of the value of the buffer capacity for the aerospace industry was made based on the estimate of capacity utilization in the industry in 1967, the greatest production peak in the period, contained in an earlier study of capacity utilization.[3] The Peak Normal Capacity index in Table 6 is capacity utilization adjusted downward to allow for the buffer capacity.

These utilization indexes focus solely on the availability of capital equipment and structures as the binding constraint on production during peak periods. They are also to some extent indicative of labor utilization during the one or two-year period around peak utilization years. However, since the labor force can be adjusted more rapidly than capital stock, the index

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1 The capital stock series in Table 6 is gross stocks adjusted for decline in productive efficiency with age, and so represents an index of the total physical quantity of stocks. This series differs from the "value of plant and equipment" series in Table A-3, which is total stocks adjusted for the loss in market value due to both decline in efficiency and decline in expected remaining life as the stock ages. The two series were constructed using the same method, as described in the Appendix, except the final adjustment for loss in value due to declining remaining lifetime was not applied to the series of Table 6.

2 Estimation of the maximum VA/K trend line is described in the Appendix.

3 Jack Faucett Associates, Inc., Disaggregate Measurement of Emergency Industrial Capacity for Demand Impact Transformation Sectors, prepared for the Federal Preparedness Agency, September 1979.

TABLE 6

CAPACITY UTILIZATION IN THE U.S. AEROSPACE INDUSTRY

1960–1978

Year	Capital Stock (millions of 1972 dollars)	Value Added (millions of 1972 dollars)	Value Added / Stocks $(\frac{VA}{K})$	Full Capacity $\frac{VA}{K}$ Ratio	Economic Capacity Utilization Index	Peak Normal Capacity Utilization Index
1960	3246.1	7291.5	2.246	2.503	89.7	84.4
1961	3305.8	7419.1	2.244	2.474	90.7	85.4
1962	3428.0	7706.6	2.248	2.445	91.9	86.5
1963	3643.9	8245.9	2.263	2.416	93.7	88.2
1964	3851.6	7330.2	1.903	2.387	79.7	75.0
1965	4074.9	8045.1	1.974	2.358	83.7	78.8
1966	4708.3	10451.7	2.220	2.329	95.3	89.7
1967	5408.3	12440.8	2.300	2.300	100.0	94.1
1968	5762.9	12156.5	2.109	2.271	92.9	87.5
1969	6295.9	10809.7	1.717	2.242	76.6	72.1
1970	6419.6	10626.8	1.655	2.213	74.8	70.4
1971	6303.3	7886.7	1.251	2.184	57.3	53.9
1972	5890.9	8632.9	1.465	2.155	68.0	64.0
1973	5773.6	10170.3	1.762	2.126	82.9	78.0
1974	5748.5	11555.6	2.010	2.097	95.9	90.3
1975	5527.4	11147.2	2.017	2.068	97.5	91.8
1976	5498.9	9534.4	1.734	2.039	85.0	80.0
1977	5450.9	7979.9	1.464	2.011	72.8	68.5
1978	5532.3	9188.4	1.661	1.982	83.8	78.9

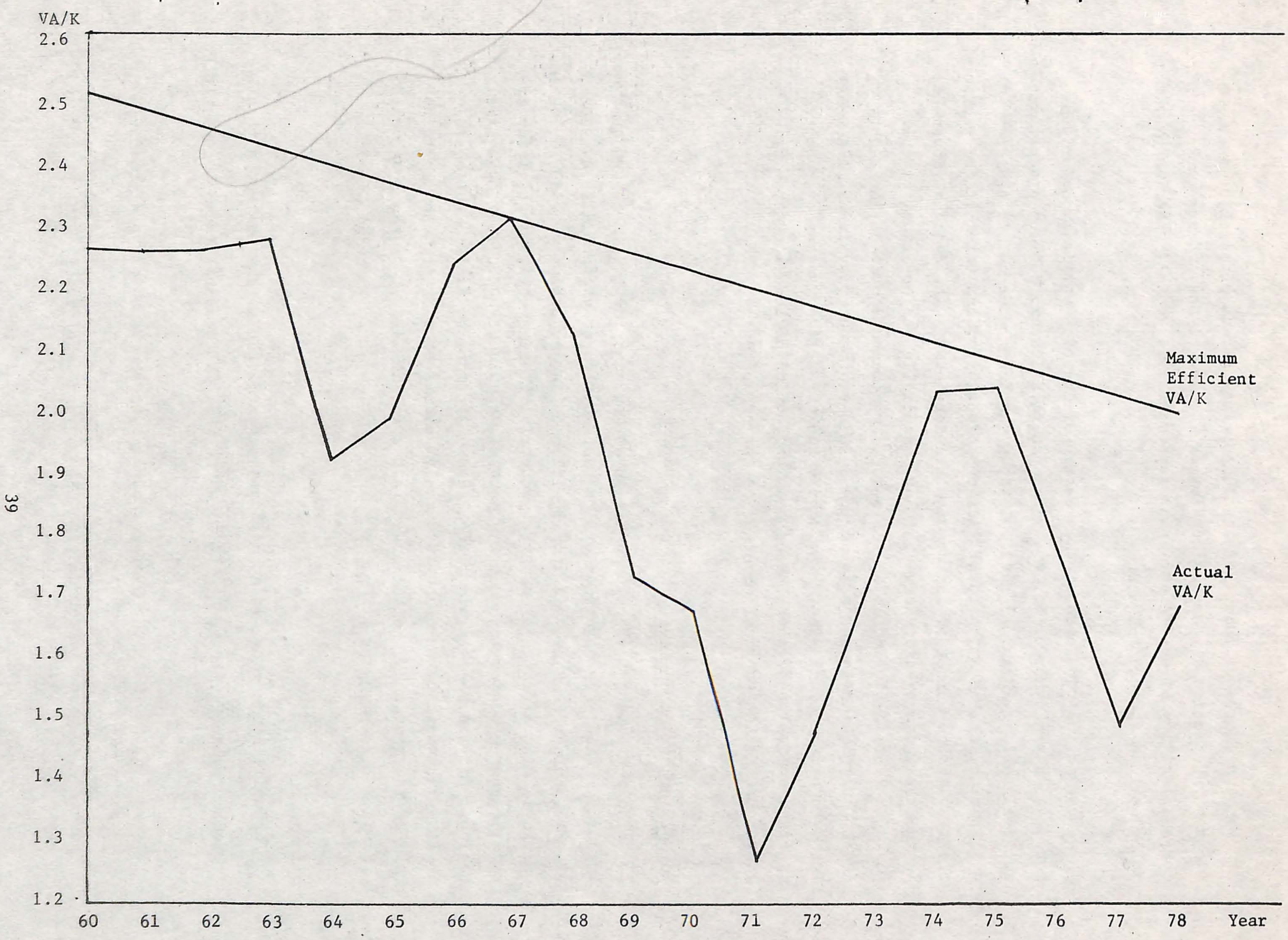

FIGURE 5--CAPACITY UTILIZATION IN THE U.S. AEROSPACE INDUSTRY, 1960-1978

is less indicative of labor utilization during periods of slack demand. Obviously, production at the maximum levels implied by the indexes would require the availability of sufficient labor (and materials and all other inputs) to fully utilize the capital stock.

Despite the crudeness of the measure of capacity utilization derived here, it is still useful for analyzing the relationship between productivity and utilization. Figure 6 shows plots of the index of economic capacity utilization, the index of total factor productivity, and total factor productivity with the effect of the secular trend removed. The cyclical movements in the total factor productivity index, especially the positions of the peaks in 1963, 1967, and 1975, reflect the movements in the utilization index, but the increasing secular trend in the productivity index is unrelated to utilization rates.[4] Evidently the more effective use of resources of fixed capital and labor during peak production periods accounts for a large part of the cyclical movement in the productivity index.

Investment and Productivity

The net productivity of capital investment is accepted, although analysts may differ about the magnitude of its contribution to productivity advances vis-a-vis other factors, and its significance in productivity trends at various points in time. (In this context, productivity means total productivity or total factor productivity, not the partial measure of output per manhour.) Denison, for example, in his recent study[5] attempts to explain the sharp decline in productivity since 1973 and is unable to identify changes in the rate of investment as a significant factor in this drop. On the other hand,

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4 The utilization index is significantly correlated to the detrended total factor productivity, $\frac{TFP_t}{(1+r)^t}$ where TFT_t is the total factor productivity in year t, and r is the average annual rate of growth of total factor productivity (3.6 percent).

5 Edward F. Denison, Accounting for Slower Economic Growth: The United States in the 1970s, Brookings Institution, Washington, D.C., 1979.

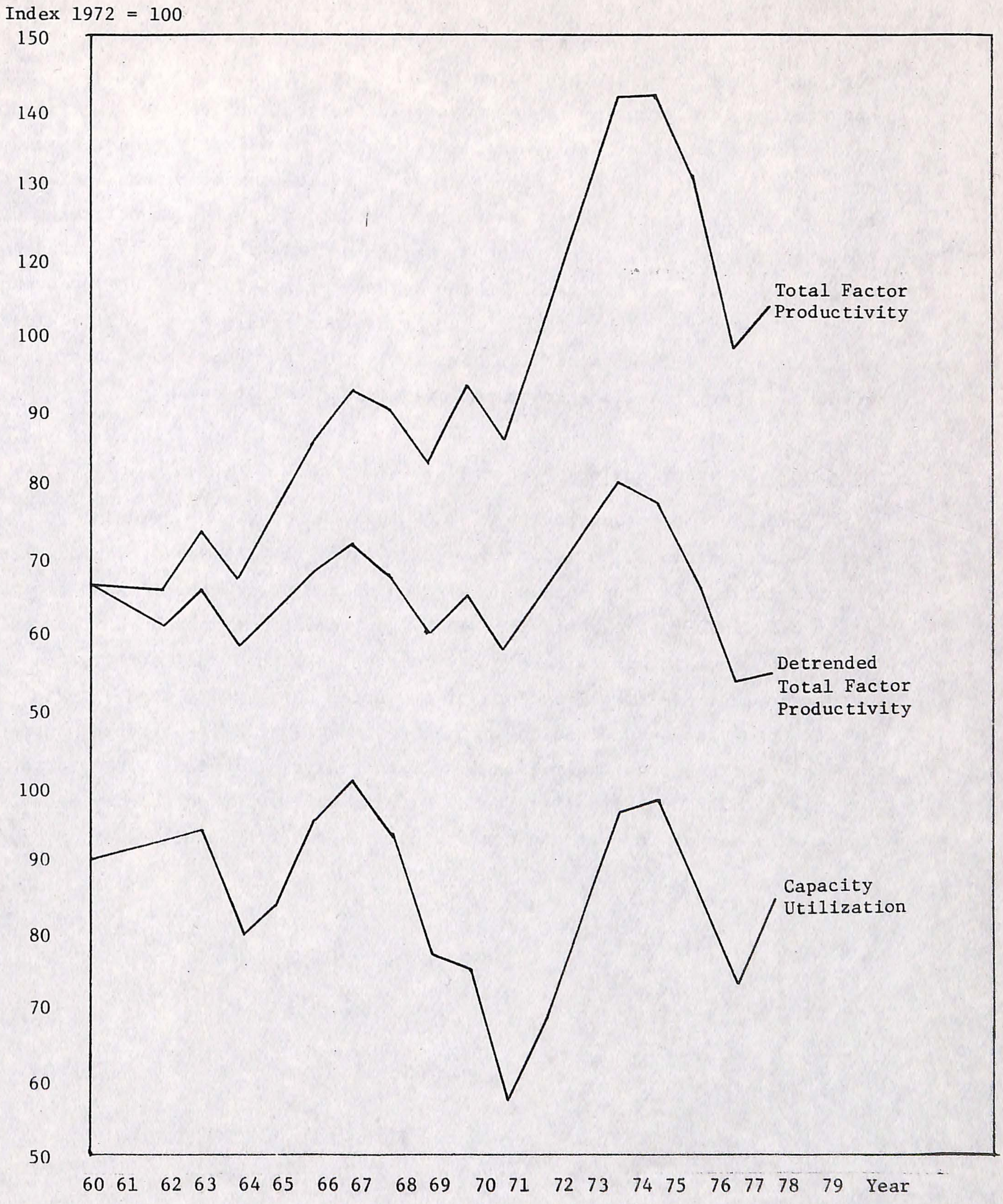

FIGURE 6--CAPACITY UTILIZATION AND PRODUCTIVITY IN THE U.S. AEROSPACE INDUSTRY, 1960-1978

Norsworthy et. al.[6] attributed much of the recent decline in productivity to a drop in the rate of investment. Regardless of such differences in the analysis, investment is unquestionably a large contributor to productivity, and greater investment is to be encouraged, subject to its payoff being greater than its cost (i.e., all investments are not necessarily economic and some, in fact, are wasteful of resources). Costs of investments include the time preference costs (interest) of the funds tied up, the amortization of the original capital, miscellaneous charges such as property taxes, and income and capital gains taxes on the before-tax return from the investments. If these costs are higher rather than lower, the result is to inhibit investment, especially investment with high risk, and to reduce the amount of resources that are allocated to building up capital stocks.

Government Regulations and Productivity

The impact on productivity of government regulation cannot be measured and can only be inferred by case study results projected to reflect the total economy. Much has been written on the paperwork costs of red tape and the administrative costs imposed by government regulation but the real costs lie in the inefficiencies resulting from the less than full utilization of resources, and the misallocations of resources that occur, when private sector innovation and decision-making are unnecessarily restricted. Case studies of transportation regulation impacts have estimated annual costs at several billions of dollars. The effects of regulation economy-wide can easily amount to over one hundred billion dollars annually.

6 J.R. Norsworthy, Michael J. Harper, Kent Kunze, "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors, "Brookings Papers on Economic Activity, 2:1979.

APPENDIX

METHODOLOGY AND DATA SOURCES

Industry Definition

All data on inputs and production are for establishemnts classified as SIC 372, SIC 3764, and SIC 3769, according to the SIC definitions used by the U.S. Bureau of the Census from 1972 to the present. This industry group is equivalent to that included in SIC 372 prior to 1972.

The titles of the SIC industries included are:

3721 - Aircraft

3724 - Aircraft engines and engine parts

3728 - Aircraft parts and auxiliary equipment, not elsewhere classified

3764 - Guided missile and space vehicle propulsion unit parts

3769 - Guided missile and space vehicle parts and auxiliary equipment, not elsewhere classified

Establishments classified as SIC 3761 -- guided missiles and space vehicles -- have been excluded. Adequate data for the development of productivity measures for this SIC industry, especially the data necessary for the capital inputs series, are not available from the Census.

Output

Industry production is value of shipments adjusted for change in the level of inventories of finished goods and work in process. Shipments and inventory are reported annually in the Annual Survey of Manufactures[1] or the Census of Manufactures.[2] Table A-1 shows shipments and inventories in

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1 U.S. Department of Commerce, Bureau of the Census, Annual Survey of Manufactures, 1962-1976, Washington, D.C.

2 U.S. Department of Commerce, Bureau of the Census, Census of Manufactures, 1963, 1967, 1972, 1977, Washington, D.C.

TABLE A-1

U.S. AEROSPACE INDUSTRY SHIPMENTS AND INVENTORIES IN CURRENT PRICES

AND

SHIPMENTS, INVENTORIES AND VALUE ADDED IN 1972 DOLLARS

1959-1978

(Millions of Dollars)

Year	Current Prices Shipments	Current Prices Inventory	Output Deflator 1972=100	1972 Prices Shipments	1972 Prices Inventory	1972 Prices Inventory Change	Production	Production Index 1972=100	Materials & Services Inputs, 1972 dollars	Value Added, 1972 dollars	Value Added Index 1972=100
1959		2913.1	73.0		3990.5						
1960	12360.3	2601.3	73.1	16908.8	3558.5	-432.0	16476.8	94.7	9185.3	7291.5	84.5
1961	13373.7	2519.5	74.0	18072.6	3404.7	-154.1	17918.5	103.0	10499.4	7419.1	85.9
1962	13723.3	2697.3	76.2	18009.6	3539.8	135.1	18144.7	104.3	10438.1	7706.6	89.3
1963	13700.8	2932.2	76.6	17886.2	3827.9	228.1	18174.3	104.5	9928.4	8245.9	95.5
1964	13559.5	2867.9	78.2	17339.5	3667.4	-160.5	17179.0	98.7	9848.8	7330.2	84.9
1965	14315.6	3039.6	78.7	18190.1	3862.3	194.9	18385.0	105.7	10339.9	8045.1	93.2
1966	17417.0	4145.1	81.6	21344.4	5079.8	1217.5	22561.9	129.7	12110.2	10451.7	121.1
1967	21063.9	5859.1	83.8	25135.9	6991.8	1912.0	27047.9	155.5	14607.1	12440.8	144.1
1968	22721.4	7253.5	85.5	26574.7	8483.6	1491.8	28066.5	161.3	15910.0	12156.5	140.8
1969	22233.9	7167.2	88.7	25066.4	8080.3	-403.3	24663.1	141.8	13853.4	10809.7	125.2
1970	20526.6	8063.7	94.0	21836.8	8578.4	498.1	22334.9	128.4	11708.1	10626.8	123.1
1971	18432.8	7160.5	97.8	18847.4	7321.6	-1256.8	17590.6	101.1	9703.9	7886.7	91.4
1972	16955.9	7764.4	100.0	16955.9	7764.4	442.8	17398.7	100.0	8765.8	8632.9	100.0
1973	20247.4	7847.9	102.8	19695.9	7634.1	-130.3	19565.6	112.5	9395.3	10170.3	117.8
1974	21923.1	7734.3	103.7	21140.9	7458.3	-175.8	20965.1	120.5	9409.5	11555.6	133.9
1975	23702.0	8324.0	113.6	20864.4	7327.5	-130.8	20733.6	119.2	9586.4	11147.2	129.1
1976	25083.2	7641.2	125.2	20034.5	6103.2	-1224.3	18810.2	108.1	9275.8	9534.4	110.4
1977	25119.3	8104.6	138.8	18097.5	5839.0	-264.2	17833.3	102.5	9853.4	7979.9	92.4
1978	28280.9	9392.1	152.4	18557.0	6162.8	323.8	18880.8	108.5	9692.4	9188.4	106.4

current prices, and shipments, inventories, production, and value added in 1972 dollars.

The data on shipments in 1978 and inventories in 1959, 1960, 1977 and 1978 are estimates. Shipments for 1978 were estimated based on Census Bureau data summarized in Aerospace Facts and Figures 1979/1980.[3] The Census has reported only total inventories, including materials, for 1959, 1960 and 1977. The level of inventories of completed goods and work in process for these years was estimated based on percentage movements in total inventories reported by the Census. Inventories for 1978 were estimated based on the 1977 to 1978 percentage change in total inventories.[4]

The deflated industry production is an estimate of the production in each year evaluated according to the prices of industry products prevailing in the base year, 1972. Suppose in year t the industry produces n different products in quantities $q_1,\ldots,q_n$; and prices are $p_1,\ldots,p_n$ in year t and $p_1^o,\ldots,p_n^o$ in the base year. Then the deflated output in year t is:

$$Q = \sum_{i=1}^{n} q_i p_i^o;$$

and the output deflator for year t is:

$$d = \frac{\sum_i q_i p_i}{\sum_i q_i p_i^o}$$

3 Aerospace Industries Association of America, Inc., Aerospace Facts and Figures, 1979/80, New York, McGraw-Hill, July 1979.

4 U.S. Federal Trade Commission, Quarterly Financial Report for Manufacturing, Mining, and Trade Corporations, various issues.

The output deflator derived was based on three sources:

- o A price deflator series for U.S. government purchases of military aircraft developed by the Bureau of Economic Analysis (BEA). This series is available for 1972 through 1978 and is published for 1972-1977.[5]
- o A price deflator series for purchases of civil aviation transport aircraft, developed by the Civil Aeronautics Board (CAB) and published by the BEA. The price and sales data for this series are from a survey of purchases of new aircraft by U.S. commercial air carriers, conducted periodically by the CAB.
- o A general aviation price deflator developed for this study. This series is derived from data on prices, sales, and specifications for a representative sample of general aviation aircraft models, as reported in various issues of Aviation Week and Space Technology.[6]

The industry-wide deflator is a composite of these three series weighted according to the value of industry shipments in each of the three aerospace categories -- military, commercial transport, and general aviation aircraft -- in each year. Industry products not falling clearly in one of these three categories were assigned to the category to which they seemed most related, or were deflated using the composite deflator. Prior to 1972, the deflator is based on the commercial and general aviation series only. The three deflator series and the composite are shown in Table A-2.

The development of a consistent measure of output over time for the aerospace industry is a difficult task. Industry output comprises a large number of very different products and services. Significant changes in the quality, or performance characteristics, of products are frequent, and entirely new products -- space vehicles, for example -- are introduced. It is impossible to fully express the many dimensions of output as a single-valued index. The best that can be done is to construct an index with the

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5 U.S. Department of Commerce, Bureau of Economic Analysis, Price Changes of Defense Purchases of the United States, Washington, D.C., March 1979.

6 "Aerospace Forecast and Inventory," Aviation Week and Space Technology, (various issues), 1960-1979.

TABLE A-2

U.S. AEROSPACE INDUSTRY OUTPUT DEFLATORS
1959-1978
(1972 = 100)

Year	Military Aircraft	General Aviation Aircraft	Commercial Transport Aircraft	Composite
1959		71.7	73.2	73.0
1960		72.5	73.2	73.1
1961		74.4	73.9	74.0
1962		76.0	76.3	76.2
1963		77.2	76.4	76.6
1964		80.7	77.5	78.2
1965		77.8	78.9	78.7
1966		81.9	81.5	81.6
1967		84.0	83.8	83.8
1968		83.8	85.7	85.5
1969		90.0	88.4	88.7
1970		94.0	94.0	94.0
1971		95.5	98.1	97.8
1972	100.0	100.0	100.0	100.0
1973	101.9	102.1	103.6	102.8
1974	98.0	103.5	108.5	103.7
1975	108.3	118.3	118.4	113.6
1976	118.1	133.0	133.2	125.2
1977	133.0	144.2	146.0	138.8
1978	146.9	156.6	156.9	152.4

Sources: U.S. Department of Commerce, Bureau of Economic Analysis (military, commercial); Jack Faucett Associates (general aviation, composite).

fewest undesirable properties for its specific intended application, in this case the study of productivity changes.

Some earlier studies of aerospace industry production, including a 1974 study for the Aerospace Industries Association,[7] have constructed an output measure by deflating current dollar volume of output by a deflator derived from price changes of the inputs to production. This method obviously avoids the problems presented by the complexity of aerospace outputs. However, the use of an input price index to deflate output must involve some assumptions about how input price changes affect production costs. Changes in the relative prices of inputs may stimulate changes in the proportions of the inputs utilized in the production process, changing the average productivity of the inputs. Also, a change in productivity, through a change in technology, for example, may itself lead to a change in the market price of output, independent of any input price change. Therefore, the use of an input price deflator in measuring production is not very suitable for the purpose of studying productivity.

The output deflator used for this study is the best available deflator based on output prices for the aerospace industry, although considerable room for refinement still exists. The constant dollar output series is an estimate of the physical volume of output in each year. The addition of different types of output products is accomplished by converting the physical output units to dollars sales value evaluated in base year prices.

In constructing the general aviation deflator, a base year price for new aircraft models, or models having undergone changes in performance specifications, was inferred based on the ratios of the price of the new model to prices of models that were produced in the base year, during an overlap period in which both old and new models were produced. A similar method was used by BEA for the military aircraft deflator. This method of evaluating performance changes by means of price changes is not ideal. A major performance improvement might conceivably be accomplished by only a minor price increase, or even by a price decrease.

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7 Jack Faucett Associates, Inc., Productivity and Capacity Utilization in the Aerospace Industry, prepared for the Aerospace Industries Association, Washington, D.C. December 1974.

The only means of evaluating quality change more precisely would be to measure physical output each year in units directly related to performance characteristics -- for example, aircraft speed, capacity, operating economy, safety and so on -- and inferring a set of base year prices for these performance characteristics. Attempts have been made to develop output indexes of this type, so-called hedonic price indexes, for a few industries. However, the method used for this study is satisfactory, and more practical than the hedonic price method.

Several areas for improvement of the output deflator in future work exits:

- o The method used by the CAB in deriving the commercial transport deflator is not consistent with the method used for the general aviation and military aircraft deflators. A corrected commercial transport deflator could be constructed using the original CAB price and sales data.
- o Work is currently in progress at BEA on extending the military aircraft deflator to years prior to 1972.
- o An attempt could be made to identify existing price indexes, or develop new indexes, specifically applicable to some of the components of aerospace industry output other than military, general aviation, and commercial transport aircraft: modification and other services on aircraft, research and development, and space vehicles, for example.

Capital Input

Just as the physical quantity of annual output may be evaluated in dollar terms by means of base period prices of the outputs, and units of labor input evaluated by base period wage and salary rates (see p. 53), the annual input of services derived from the industry's stock of capital assets may be evaluated as the annual cost implicit in holding these assets. This cost is the sum of depreciation and the implicit interest cost on the value of stocks of plant and equipment. The proper measure of depreciation for computing the implicit cost of capital is economic depreciation, that is, the annual loss in the present discounted value of the future flow of services from the capital assets. Economic depreciation is equivalent to the annual loss in market value of the stock of capital in a (hypothetical) market for used capital assets.

If an active market for the sale or rental of used assets existed, the annual cost of capital services could be observed directly from the prices in this market. However, transactions in used capital assets are not common, so in this study economic depreciation and the value of stocks of assets have been computed using the perpetual inventory method. In this procedure annual investments in plant and equipment, measured in constant 1972 dollars, are cumulated over time and discarded at the end of their useful lives to derive a measure of the annual levels of capital stocks, disaggregated by plant and equipment.

Depreciation is calculated in each year by discounting to present value the annual loss in the value of the flow of services from the assets over their remaining expected lifetimes. The value of services per dollar of initial investment is adjusted downward in each year of the life of an asset by a factor reflecting the decline in productive efficiency of the asset with age. Capital services units are normalized so that the present value of lifetime services from one dollar's-worth of investment in new assets equals one dollar. Finally, the net value of stocks is computed for each year by cumulating investment and subtracting depreciation for the year.

The annual investment series, estimates of average lifetimes and rates of efficiency decline, and the deflators for converting annual purchases of new plant and equipment to 1972 prices were developed in previous studies by Jack Faucett Associates for the Bureau of Labor Statistics.[8] The major sources of investment data were the Annual Survey of Manufactures and Census of Manufactures with supplementary sources for the earlier years in the series. Service lives were derived from Internal Revenue Service sources. Deflators for individual types of equipment and structures derived by BEA were combined into two composite deflator series, one for structures and one for equipment,

8 U.S. Department of Labor, Bureau of Labor Statistics, Capital Stocks Estimates for Input-Output Industries, Washington, D.C., September 1979.

using weights depending on the composition of purchases of new plant and equipment estimated by BEA in the 1963 and 1967 "Interindustry Transactions in New Structures and Equipment" tables.[9]

The depreciation and net value of stocks series derived by the perpetual inventory method were not used directly in calculating the annual cost of capital for this study. The gross book value of assets reported for the aerospace industry in the Annual Survey of Manufactures does not agree with the historic gross stocks series (annual investment less annual discards in current prices) calculated by the perpetual inventory method. The difference in the two series for equipment stocks does not appear too significant but, in the case of structures, the Census stocks are consistently less than the perpetual inventory stocks by 15 to 27 percent during the period 1960 to 1978. This discrepancy presumably reflects either different service lives for structures in actuality than those assumed in the perpetual inventory calculations, or transfers of assets into and out of the industry, including transfers of government owned-contractor operated stocks to the private sector. In order to take this difference into account, the final depreciation and net value series were derived by multiplying the perpetual inventory series by the ratio of Census book value to perpetual inventory historic gross value in each year. Depreciation in year "t" in these adjusted series, is no longer equal to net value of stocks at the end of year "t-1", plus investment in year t, less stocks at the end of t. The difference between depreciation and change in value of stocks is taken to represent transfers of stocks into or out of the industry, other than purchase of new assets and discards of fully depreciated ones.

The final series for depreciation, net value of capital stocks, and implicit interest cost are shown in Table A-3. Business inventories are also an investment good, and the interest cost of holding them has been included in total capital input. An interest rate of four percent was chosen to represent the real, or "inflation-free," cost of money.

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9 U.S. Department of Commerce, Bureau of Economic Analysis, "Interindustry Transactions in New Structures and Equipment, 1967," Survey of Current Business, September 1975.

TABLE A-3

U.S. AEROSPACE INDUSTRY CAPITAL INPUT

1960-1978

(Millions of 1972 Dollars)

Year	Depreciation			Value of:			Interest Cost (@ 4%)	Total Capital Input	
	Plant	Equipment	Total	Plant and Equipment	Inventories	Total		Depreciation plus Interest	Index 1972=100
1960	88.1	138.9	227.0	2162.1	4359.0	6521.1	260.8	487.8	51.1
1961	90.0	142.6	232.6	2179.8	4178.4	6358.2	254.3	486.9	51.0
1962	92.6	149.6	242.2	2258.4	4354.4	6612.8	264.5	506.7	53.0
1963	97.9	160.6	258.5	2395.6	4702.9	7098.5	283.9	542.4	56.8
1964	102.1	174.6	276.7	2474.0	4534.7	7008.7	280.3	557.0	58.3
1965	106.5	188.5	295.0	2648.3	4680.1	7328.4	293.1	588.1	61.6
1966	118.8	220.1	338.9	3169.6	6306.0	9475.6	379.0	717.9	75.2
1967	129.8	261.9	391.7	3736.9	8699.9	12436.8	497.5	889.2	93.1
1968	130.2	296.8	427.0	3979.5	9932.8	13912.3	556.5	983.5	103.0
1969	137.9	334.2	472.1	4334.4	9449.3	13783.7	551.3	1023.4	119.7
1970	137.4	352.6	490.0	4317.8	9792.7	14110.5	564.4	1054.4	110.4
1971	136.8	349.5	486.3	4100.3	8421.4	12521.7	500.9	987.2	103.4
1972	129.3	330.3	459.6	3703.2	8686.0	12389.2	495.6	955.2	100.0
1973	129.2	323.2	452.4	3502.7	8680.1	12182.8	487.3	939.7	98.4
1974	127.9	327.9	455.8	3455.5	8645.4	12100.9	484.0	939.8	98.4
1975	120.9	322.7	443.6	3272.3	8448.2	11720.5	468.8	912.4	95.5
1976	120.2	323.1	443.3	3230.8	7131.7	10362.5	414.5	857.8	89.8
1977	119.3	321.5	440.8	3192.1	6867.5	10059.6	402.4	843.2	88.3
1978	117.9	331.7	449.6	3271.9	7293.7	10565.6	422.6	872.2	91.3

In addition to those estimates documented in previous studies,[10] investments in new plant and equipment for 1977 and 1978, and the ratios of book value to perpetual inventory gross value for some of the earlier years and 1977 and 1978 had to be estimated because complete Census data is not available for these years. The book value ratios were estimated based on trends in the historic ratios for the available years, and the investments were estimated from more aggregate investment data reported by BEA.[11]

Labor Input

Wages paid to production workers, and salaries paid and number of salaried employees (all employees other than production workers), are shown in Table A-4. Total labor input in year "t" has been defined as:

(total hours worked by production workers in year t) x (1972 hourly wage) + (total number of salaried employees in year t) x (1972 average annual salary).

The labor input series therefore represents total physical units of labor input, with the contributions of production workers and salaried employees summed by weighting them according to their relative compensation rates in the base year.

The data on wages, salaries, and number of salaried employees through 1977 are from the Annual Survey of Manufactures and Census of Manufactures. Wages and number of salaried employees for 1978 are estimated based on aerospace industry employment data reported by the Bureau of Labor Statistics (BLS).[12] The wage deflator is the ratio of production worker average hourly earnings in each year to 1972 average hourly earnings, as reported by BLS [13].

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10 U.S. Department of Labor, Bureau of Labor Statistics, Capital Stocks Estimates for Input-Output Industries, Washington, D.C., September 1979.

11 John T. Woodward, "Plant and Equipment Expenditures, The Four Quarters of 1979," Survey of Current Business, U.S. Department of Commerce Bureau of Economic Analysis, September 1979.

12 U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings, United States, 1909-1978, Washington, D.C., 1979.

13 U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings, United States, 1909-1978, Washington, D.C., 1979.

TABLE A-4

U.S. AEROSPACE INDUSTRY LABOR INPUT

1960-1978

(Millions of 1972 Dollars)

	Production Workers			Salaried Workers			Total Labor Input	
Year	Wages	Deflator 1972=100	Wages in 1972 Dollars	Salaries	Deflator 1972=100	Salaries in 1972 Dollars	Wages and Salaries in 1972 Dollars	Index, 1972=100
1960	2399.2	58.4	4108.2	2217.0	55.0	4028.3	8136.5	139.2
1961	2383.4	60.2	3959.1	2530.9	57.7	4384.0	8343.1	142.7
1962	2530.2	62.1	4074.4	2803.9	59.8	4687.5	8761.9	149.8
1963	2562.8	63.9	4010.6	2665.5	61.7	4318.3	8328.9	142.4
1964	2592.4	65.4	3963.9	2549.4	62.0	4115.0	8078.9	138.2
1965	2608.7	68.0	3836.3	2729.6	69.8	3913.2	7749.5	132.5
1966	3329.0	71.6	4649.4	3165.7	73.4	4313.8	8963.2	153.3
1967	3792.9	74.7	5077.5	3416.5	73.1	4674.0	9751.5	166.8
1968	3842.2	78.4	4900.8	3628.2	75.3	4817.5	9718.3	166.2
1969	3734.1	83.5	4472.0	3915.9	81.1	4829.5	9301.5	159.1
1970	3234.8	89.0	3634.6	3530.5	82.2	4292.9	7927.5	135.6
1971	2646.7	93.5	2830.7	3120.0	90.4	3451.3	6282.0	107.4
1972	2784.5	100.0	2784.5	3062.7	100.0	3062.7	5847.2	100.0
1973	3114.4	108.0	2883.7	3264.4	104.3	3129.8	6013.5	102.8
1974	3413.9	117.3	2910.4	3433.4	121.3	3062.7	5973.4	102.2
1975	3493.8	129.9	2689.6	3714.8	121.6	3054.9	5744.5	98.2
1976	3479.2	139.4	2495.8	3815.5	132.6	2877.4	5373.2	91.9
1977	3718.4	149.8	2482.2	4398.0	141.9	3098.6	5580.8	95.4
1978	4546.8	163.2	2786.0			3342.2	6128.2	104.8

Materials and Other Input

Materials and other input includes raw materials, supplies, components, fuels and purchased services. It includes all inputs other than labor and inputs associated with capital. The costs of purchased materials, supplies, components and fuels, and inventories of materials, have been tabulated from the Annual Survey of Manufactures and Census of Manufactures through 1977. An estimate for purchased services, not included in the Census data, was made based on the ratio of the total of intermediate inputs (including purchased services) to Census cost of materials, from the national input-output tables (Sector No. 60-Aircraft and Parts) for selected years (1958, 1963, 1967, 1972); the ratio is interpolated and extrapolated to the other years. The materials input series is adjusted for changes in the level of materials inventories.

A deflator series was specially constructed reflecting changes in product prices of some 70 sectors providing inputs to the aircraft and parts industry, weighted by the relative importance of these inputs to the industry in 1967 as tabulated in the 1967 national input-output table. The total series was deflated to 1972 dollars using this deflator series. The deflators for the individual product inputs through 1976 were compiled by the BLS.[14] The 1977 and 1978 deflators are based on the movements in the BEA deflator for manufacturing industry product.[15]

Since data on cost of materials, etc. for the industry for 1978 are not yet available from the Census survey, the 1978 figure was estimated based on the trend in the ratio of materials and services input to production.

The relevant data are tabulated in Table A-5.

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14 U.S. Department of Labor, Bureau of Labor Statistics, Time Series Data for Input-Output Industries, Washington, D.C., March 1979.

15 U.S. Department of Commerce, Bureau of Economic Analysis, "National Income and Product Tables," Survey of Current Business, July 1979.

TABLE A-5

U.S. AEROSPACE INDUSTRY MATERIALS AND OTHER INPUTS

1959-1978

(Millions of 1972 Dollars)

Year	Purchased Materials, Supplies & Fuels	Adjustment For Purchased Services	Adjusted Purchases	Materials Inventory	Deflator 1972=100	Materials Purchased 1972 dollars	Materials Inventory 1972 dollars	Inventory Change 1972 dollars	Materials Input 1972 dollars	Index 1972=100
1959				627.1	76.2		823.0			
1960	5840.6	1.197	6991.2	610.8	76.3	9162.8	800.5	22.5	9185.3	104.8
1961	6483.9	1.234	8001.1	591.1	76.4	10472.6	773.7	26.8	10499.4	119.8
1962	6315.4	1.271	8026.9	624.0	76.6	10479.0	814.6	-40.9	10438.1	119.1
1963	5848.4	1.310	7661.4	671.1	76.7	9988.8	875.0	-60.4	9928.4	113.3
1964	5913.7	1.303	7705.6	679.1	78.3	9841.1	867.3	7.7	9848.8	112.4
1965	6307.6	1.295	8168.3	647.0	79.4	10287.5	814.9	52.4	10339.9	118.0
1966	7913.4	1.288	10192.5	998.2	81.4	12521.5	1226.2	-411.3	12110.2	138.2
1967	9784.3	1.280	12523.9	1417.6	83.0	15089.0	1708.1	-481.9	14607.1	166.6
1968	10637.3	1.258	13381.7	1239.1	85.5	15651.1	1449.2	258.9	15910.0	181.5
1969	9902.0	1.236	12238.9	1223.9	88.8	13782.5	1378.3	70.4	13853.4	158.0
1970	8919.6	1.214	10828.4	1139.0	93.8	11544.1	1214.3	164.0	11708.1	133.6
1971	7820.6	1.194	9322.2	1069.0	97.4	9587.1	1097.5	116.8	9703.9	110.7
1972	7341.8	1.170	8589.9	921.6	100.0	8589.9	921.6	175.9	8765.8	100.0
1973	8505.3	1.170	9951.0	1096.2	104.5	9522.7	1049.0	-127.4	9395.3	107.2
1974	9334.2	1.170	10921.0	1398.4	113.9	9588.2	1227.7	-178.7	9409.5	107.3
1975	10343.4	1.170	12101.8	1519.7	126.6	9559.1	1200.4	27.3	9586.4	109.4
1976	10568.5	1.170	12365.1	1455.3	135.1	9152.6	1077.2	123.2	9275.8	105.8
1977	11992.5	1.170	14031.2		142.4	9853.4			9853.4	112.4
1978					151.6				9692.4	110.6

Capacity Utilization

Estimation of the maximum (value added/capital stock) trend line in Figure 5, labeled "maximum efficient VA/K," was based on the judgment that capacity utilization was near 100 percent in the peak production year of 1967 but that capacity was not fully utilized during the 1963 and 1975 production peaks. Therefore, the actual VA/K ratio for 1967, the highest peak in the period, was chosen as the maximum efficient VA/K for that year. The actual VA/K in 1975, the second highest peak, was estimated at 97.5 percent of the maximum efficient VA/K for that year, based on the ratio of utilization rates for the aerospace industry during the two peaks estimated in an earlier study of industrial capacity.[16] The trend line was drawn through these two points.

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16 Jack Faucett Associates, Inc., Disaggregate Measurement of Emergency Industrial Capacity for Demand Impact Transformation Sectors, for the Federal Preparedness Agency, September 1979.