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REPORT OF THE COMPTROLLER GENERAL OF THE UNITED STATES

NASA Report May Overstate The Economic Benefits Of Research And Development Spending

The National Aeronautics and Space Administration commissioned Chase Econometrics, Inc., to evaluate how spending on NASA research and development affects the U.S. economy. Chase's report concluded that many benefits resulted from such spending between 1960 and 1974.

GAO assessed the Chase study to determine whether it successfully estimated the benefits of NASA spending. The study does not prove convincingly that the benefits are as large as stated.

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OCTOBER 18, 1977

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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-164912

The Honorable William Proxmire
Chairman, Subcommittee on
HUD-Independent Agencies
Committee on Appropriations
United States Senate

Dear Mr. Chairman:

Pursuant to your request of September 15, 1976, we have prepared an independent assessment of the NASA-commissioned report entitled "The Economic Impact of NASA R&D Spending," issued by Chase Econometrics, Inc. In May 1977, we sent you a draft copy of our report to assist you in your appropriations hearings. Our final report presents the same assessment along with NASA's and Chase's comments. In general, both agreed with our conclusions.

As agreed with your office, we expect to release the report to the public in about 7 days.

Sincerely yours,

Elmer B. Staats

Comptroller General
of the United States

REPORT OF THE
COMPTROLLER GENERAL
OF THE UNITED STATES

NASA REPORT MAY OVERSTATE THE ECONOMIC BENEFITS OF RESEARCH AND DEVELOPMENT SPENDING

D I G E S T

The National Aeronautics and Space Administration (NASA) contracted with Chase Econometrics Associates, Inc., to evaluate how Government research and development spending, particularly NASA's, affects the U.S. economy.

Chase's report "The Economic Impact of NASA R&D Spending" concluded that this spending produced many benefits between 1960 and 1974. The study did not try to evaluate how effectively NASA carried out its primary objectives, such as space exploration and satellite communication. NASA cited the Chase study in its 1976 appropriations hearings as evidence of certain beneficial effects of research and development.

The Chase study does not prove convincingly that the benefits are as large as stated. The study is useful as exploratory research, but other types of studies are necessary to provide a complete evaluation of NASA research and development.

The most significant conclusion of the Chase study is that "* * * a $1 billion sustained increase in NASA R&D spending will raise real GNP $23 billion by 1984 * * *." Of this estimated increase, $21 billion would result from improved technology and productivity, and the rest would result from increased Government spending, which stimulates spending in different parts of the economy.

Since similar increases would result from Government spending on other projects, such as welfare programs, the "multiplier effects" alone do not justify more NASA research and development spending. For this reason, GAO focused on projected technological improvements.

The Chase conclusions are questionable from three points of view:

--The results, even if accepted as accurate, do not provide the type of information needed to determine whether NASA's spending should increase or decrease. The estimates are of average, rather than incremental, effects. Therefore they do not show whether more spending for research and development would result in as many benefits as before. Within NASA's budget, the most productive or unproductive projects or types of spending have not been spelled out.

--Even if the Chase approach is accepted, the techniques used had certain shortcomings. Plausible and seemingly minor changes in the study's assumptions lead to major changes in the results. Under some of these alternatives, NASA research and development seemed to have no great effect on productivity. Such sensitivity to small changes in methodology indicates considerable uncertainty in Chase's results.

--Basically, the results depend upon statistical correlation between NASA research and development spending and changes in a measure of gross productivity in the U.S. economy. No information on specific NASA projects or on the adoption of new techniques by private business is used in the study. Because of problems in measuring total productivity in the economy and because other possible causes of technological progress were ignored, the correlations may not indicate a true cause-and-effect relationship.

Although the methodology of a particular study may be questioned, the importance of evaluating NASA's programs is undiminished. NASA has clearly been an important source of technical progress in recent years.

RECOMMENDATION TO THE ADMINISTRATOR OF NASA

Future evaluation studies should look at specific innovations, their effect on specific industries, and the process by which NASA expenditures for research and development improve productivity in the economy. In other words, some of the more important innovations, rather than the total budget, could be examined, and individual technological improvements in individual industries, rather than gross national product figures, could be studied. GAO believes that such studies would give the Congress a more accurate picture of what taxpayers are getting for their money.

MATTER FOR CONSIDERATION BY THE CONGRESS

Technical studies are frequently presented to the Congress in support of agency budgets and as evidence for or against proposed legislation. When important questions are at stake, such studies should be subjected to independent examination and appraisal.

AGENCY COMMENTS

In general, NASA as well as Chase Econometrics, Inc., agreed with our assessment of the Chase report. (See ch. 5.)

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Contents

ABBREVIATIONS

GAO	General Accounting Office
GNP	gross national product
NASA	National Aeronautics and Space Administration
R&D	research and development

CHAPTER 1

INTRODUCTION

The National Aeronautics and Space Administration (NASA) spent about $40 billion on research and development (R&D) between 1961 and 1974. This represented 12 percent of total R&D spending in the United States during that period. Realizing that NASA's research findings could have wide application throughout the economy, the Congress directed NASA to "* * * provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

NASA's findings have had countless applications--in cardiac pacemakers, insulation materials, integrated circuits, gas turbines, and many more. Little is known, however, of the magnitude of these "spinoff" benefits to the economy. Chase Econometrics, Inc., prepared a report "The Economic Impact of NASA R&D Spending" for NASA evaluating these effects. The report concluded that NASA has a very favorable impact on the economy.

We were requested to "* * * evaluate the appropriateness of the study's assumptions, its analytical techniques, and the validity of its conclusions."

SCOPE OF REVIEW

In making this review, we

--analyzed the Chase report and, for background, some other NASA studies of R&D spillovers;

--replicated some of the statistical analysis of the Chase report to obtain certain measures of statistical significance and to see how sensitive the conclusions would be to changes in the basic assumptions; and

--discussed the report with NASA and Chase officials, and several other experts on the economics of R&D.

CHAPTER 2

THE PROBLEM OF R&D EVALUATION AND HOW THE CHASE REPORT TRIES TO SOLVE IT

THE PROBLEM OF EVALUATING GOVERNMENT-SPONSORED R&D

The Federal Government finances research and development in addition to that carried out by the private sector. The usual reasons for private R&D spending are future sales and profitability. Private firms tend to ignore benefits that would accrue to other firms (unless they can receive royalties) or to society as a whole. These are known as "spillover" benefits. Also, private firms may emphasize projects with short-term payoffs. Additional R&D spending by NASA or other government agencies, it is argued, could provide benefits to the Nation in excess of costs and thereby in some sense increase total benefits to society.

This analysis is similar to that supporting government regulation of pollution--an individual firm may fail to consider the harmful results of its activities if it does not have to bear the costs. Society may benefit by inducing the firm to reduce the pollution it causes. The R&D argument is the other side of the coin--that the government can increase benefits to society by inducing the firm to carry out more R&D or by doing the R&D itself.

The above argument for government involvement is valid, but it leaves the practical problem of deciding how much and what type of R&D to sponsor. First, the benefits that can be expected from the R&D must be estimated. There are many types of benefits--new products, greater productivity, lower costs--all of which are difficult to measure. Similarly, there are many types of R&D--such as medical, aerospace, and electronic--and analysis of aggregate R&D may not be very helpful to government decisions in specific sectors. In any case, predicting the results of any particular research activity is difficult. Examining the results of past programs may suggest productive new R&D ventures, but it will not provide exact measurements of future benefits.

WHAT THE CHASE REPORT SAYS

The Chase study has three main parts corresponding to the types of economic impact of R&D spending.

Section 2: Short-term economic impact. The NASA spending is directed toward certain high-technology industries and naturally affects them more than other parts of the economy. There are also short-term "multiplier" effects of the spending. Chase reports that keeping the Federal budget constant, while shifting more dollars to NASA, would cause the gross national product (GNP) to increase slightly as the dollars spent move through the economy.

Section 3: Long-run economic impact. The Chase study says that NASA R&D spending affects technological progress and results in higher productivity in the economy.

Section 4: Macroeconomic impacts. Here, the estimated improvements in productivity plus the multiplier effects of hypothetical higher NASA spending are analyzed together, using the Chase Econometrics Ma[illegible] model to estimate effects on GNP, inflation, unem[illegible]ent, etc. The study concludes that "* * * a $1 bill[illegible] sustained increase in NASA R&D spending will raise real GNP $23 billion by 1984 * * *." Of this estimated increase, $21 billion comes from technological progress and $2 billion comes from multiplier effects of increased government spending.

The results in section 2 are, in our judgment, reasonable estimates, in accord with widely accepted economic analysis. These effects are small, however, and they are not "benefits" in the strictest sense. Rather, they are measures of induced increases in the level of economic activity. As such, they are not crucial to deciding whether more or less money should be spent on NASA R&D, because similar effects could be obtained by other forms of government spending--such as defense procurement or energy R&D. Tax cuts are, of course, a comparable alternative, although the size of their impact may differ. Because the results in section 2 are not particularly controversial or critical to budgetary decisions, we do not discuss them further in this report.

The results in section 4 depend upon section 3, but they are basically elaborations of the macroeconomic effects of section 2.

Section 3 is the heart of the Chase report because it estimates economic benefits (in the form of increased productivity) as opposed to impacts on the economy (which may be neutral rather than beneficial). Government spending for certain goods causes some industries to grow in relation to other industries. Policymakers should be aware of such impacts, but such impacts are not necessarily a worthy goal of government policy. On the other hand, increased productivity in the economy is clearly beneficial. Therefore, the remainder of our report deals with this important topic.

HOW THE CHASE REPORT REACHED THESE CONCLUSIONS

Chase Econometrics attempted to test the theory that NASA R&D (among other factors) affects the rate of technological progress in the U.S. economy. Testing this theory requires a measure of technological change, a subject on which considerable research has been done. The Chase study uses a productivity measure based on a data series for "potential" GNP developed by the Council of Economic Advisors. Potential GNP is that which could be achieved if all labor and capital were fully employed. Potential GNP has grown steadily over the years, partly because of increases in the available quantities of labor and capital. The rest of the growth of potential GNP is the result of improvements in productivity; that is, growth in the level of output per unit of input. The statistical measure of productivity growth is a residual factor--it represents increases in potential GNP not due to increases in the available quantities of labor and capital.

The next part of the theory is that increases in productivity result from several explanatory variables:

--NASA R&D expenditure as a percentage of GNP.

--Other R&D expenditures as a percentage of GNP.

--An index of "industry mix" to measure the effect of different rates of technological growth in different industries.

--An index of labor quality (for which no significant statistical effect could be identified).

--An index of capacity utilization.

The Chase hypothesis is that if this theory is true (that these variables affect technological progress), then an empirical test of the theory would yield statistically significant results. That is, there will be a statistical pattern of correlation between the "causes" and the "effect."

It is logical to assume that R&D will not affect technological progress as soon as the R&D money is spent, but will have a delayed effect spread over several years. Chase uses statistical methods intended to allow for this delayed effect.

Within this theoretical framework, there are many possible variations in statistical testing. For example, variables can be measured in different ways, data from different time periods can be used, and variables can be added, left out, or combined in different ways. Chase experimented with many of these variations, finally selecting a statistically estimated equation that Chase believed best expressed the underlying theoretical considerations. Chase's "preferred" equation supported the theory that NASA R&D has had a significant effect on technological progress.

CHAPTER 3

CRITIQUE OF THE STUDY'S STATISTICAL FINDINGS

Even if the Chase Econometrics approach is accepted, certain statistical problems cast doubt on the results. In replicating the statistical analysis, we found that plausible and seemingly minor changes in the study's assumptions led to significant changes in the results. (See app. II for details.) Under some of these alternative assumptions, NASA R&D apparently had no significant effect on productivity. Here, as throughout this report, we take no position on the actual magnitude of NASA's impact. The point is that the great sensitivity of the Chase report results to small changes in methodology indicates considerable uncertainty in the Chase conclusions. We believe that the findings should be insensitive to slight changes in the methodology.

The key number in the Chase conclusions is the estimated coefficient of NASA R&D spending--the "NASA effect." In Chase's "preferred equation," this figure is estimated to be 0.426. Chase's interpretation is that a $1 billion increase in NASA R&D spending would eventually increase the total capacity of the U.S. economy by $4.26 billion. Another interpretation by Chase is that this represents a 43-percent rate of return on investment in NASA R&D.

This conclusion, if accepted, would indicate an enormous impact on the economy. The literal interpretation is that, if NASA had spent nothing on R&D, productivity would have declined in the United States between 1965 and 1974. That is, NASA R&D is given credit for all of the Nation's productivity growth, and more besides.

Minor alterations in the Chase techniques, however, lead to lower estimated values for the NASA effect. In some cases, the estimated value of the key coefficient is not much above zero, which would indicate no discernible impact.

To investigate the sensitivity of the Chase results to changes in some of the statistical assumptions, we replicated the Chase statistical analysis. Using the same data and the same basic statistical techniques, we estimated several different regression equations that we believed to be as plausible as or more plausible than Chase's preferred equation. (See app. II.)

Our results are summarized as follows:

1. Chase's preferred equation uses data from 1960 to 1974. If data from 1956 to 1974 were used, the estimate of the effect of NASA R&D drops 25 percent to 0.318.

In general, using the longer period is preferable because the larger the sample, the smaller the likelihood of spurious correlation. The Chase report prefers the shorter period because NASA R&D spending was negligible from 1956 to 1959.

We believe that including a period in which NASA spending was negligible is advantageous because this gives a wider range of values to NASA R&D spending. To see why this is worthwhile, consider the opposite case: If NASA R&D had been exactly, say, $2 billion each year for 10 years, an examination of data for that period would yield no information on the effect of changes in NASA R&D, for no changes would have occurred. Only by including a variety of values in the sample can the cause-and-effect relationship be observed and measured.

2. The Chase report makes certain adjustments for the level of capacity utilization in the economy. Alternative adjustments, which we consider superior, cause significant changes in the main results.

3. Chase's preferred equation does not include changes in labor quality as a possible influence on productivity. The Chase report noted that variables representing labor quality did not significantly affect productivity. We believe that labor quality should be considered in the statistical estimation procedures. If it had, the estimate of the "NASA effect" would have been about 33 percent lower for 1960-74 and 16 percent lower for 1956-74.

4. When we incorporate all of the changes we believe to be improvements, the estimated value of the NASA R&D coefficient drops to 0.136--a figure less than a third as large as Chase's estimate. Furthermore, the statistical measure of significance falls to a level that can be interpreted as "insignificant." That is, in our equation the observed relation between NASA R&D and productivity growth is indistinguishable from a relation that might be observed by chance between two unrelated data series.

We emphasize that this is not "proof" that NASA R&D has no effect on productivity. But such findings cast doubt on the Chase methodology.

5. Finally, the Chase results may be questioned because of a statistical problem called "multicollinearity." This problem occurs when two variables that are supposed to affect the dependent variable (in this case "productivity") are closely correlated. In such a case, distinguishing between the separate effects of the two variables is difficult. In fact, NASA R&D is highly correlated with other R&D expenditures between 1960 and 1974. This correlation casts doubt on the accuracy of the estimate of the NASA effect; it is also largely responsible for the sensitivity of the estimates to slight changes in the assumptions.

In statistical work of this type, there are many possible alternative assumptions. We reestimated the Chase equation making certain changes that we considered improvements to the Chase approach. Our estimate of the "NASA effect" was considerably lower than that of the Chase study. Such results do not, in any sense, prove that the NASA effect is zero; they merely fail to identify such an effect.

At this stage, it is well to repeat that we believe that NASA has had certain beneficial effects on the economy, but that such effects are not well measured by the Chase method.

CONCLUSION

The results of the Chase study are sensitive to plausible and minor changes in the methodology. Under some assumptions, it could be concluded that NASA R&D had no significant effect. We, therefore, conclude that the Chase study does not sufficiently substantiate its findings on the effect of NASA R&D on productivity.

CHAPTER 4

CRITIQUE OF THE STUDY'S BASIC APPROACH

PROBLEMS WITH THE STUDY'S METHODS

The basic findings of the Chase Econometrics study depend upon statistical correlation between NASA R&D spending and changes in a measure of productivity for the entire economy. The data on these two variables shows that NASA R&D reached its highest levels in 1966-68 and that the highest rates of productivity change occurred in 1970-72. Since (in the Chase preferred equation) the data studied covers only 1960 to 1974, these two changes dominate the analysis and are responsible for the correlation discovered. Indeed, extending the analysis to include data from earlier years weakens the findings. Although this correlation may suggest a cause-and-effect relationship, it should not be interpreted as a precise measure of the NASA effect.

Figure 1 shows the basic data series that Chase worked with. (Other variables were also used in the analysis.) Productivity growth is explained mainly by NASA R&D and by other R&D, expressed as a percentage of GNP. As the graph shows, productivity growth has varied during the period illustrated. A main conclusion of the Chase study is the statistical correlation between NASA R&D and productivity growth. The two data series are virtually uncorrelated with each other, but this is plausible; it would probably take several years for R&D spending to affect productivity. Thus, Chase determined that the peak in productivity growth (1971) was caused by the peak in NASA R&D (around 1967).

The series on productivity growth has fluctuated irregularly for as long as the data has been available--over 60 years. In this broader context, how reasonable is it to ascribe the latest upsurge in productivity almost entirely to an increase in NASA R&D? As mentioned in chapter 3, including only 4 more years of data in the analysis reduced the estimated impact of NASA R&D by 25 percent.

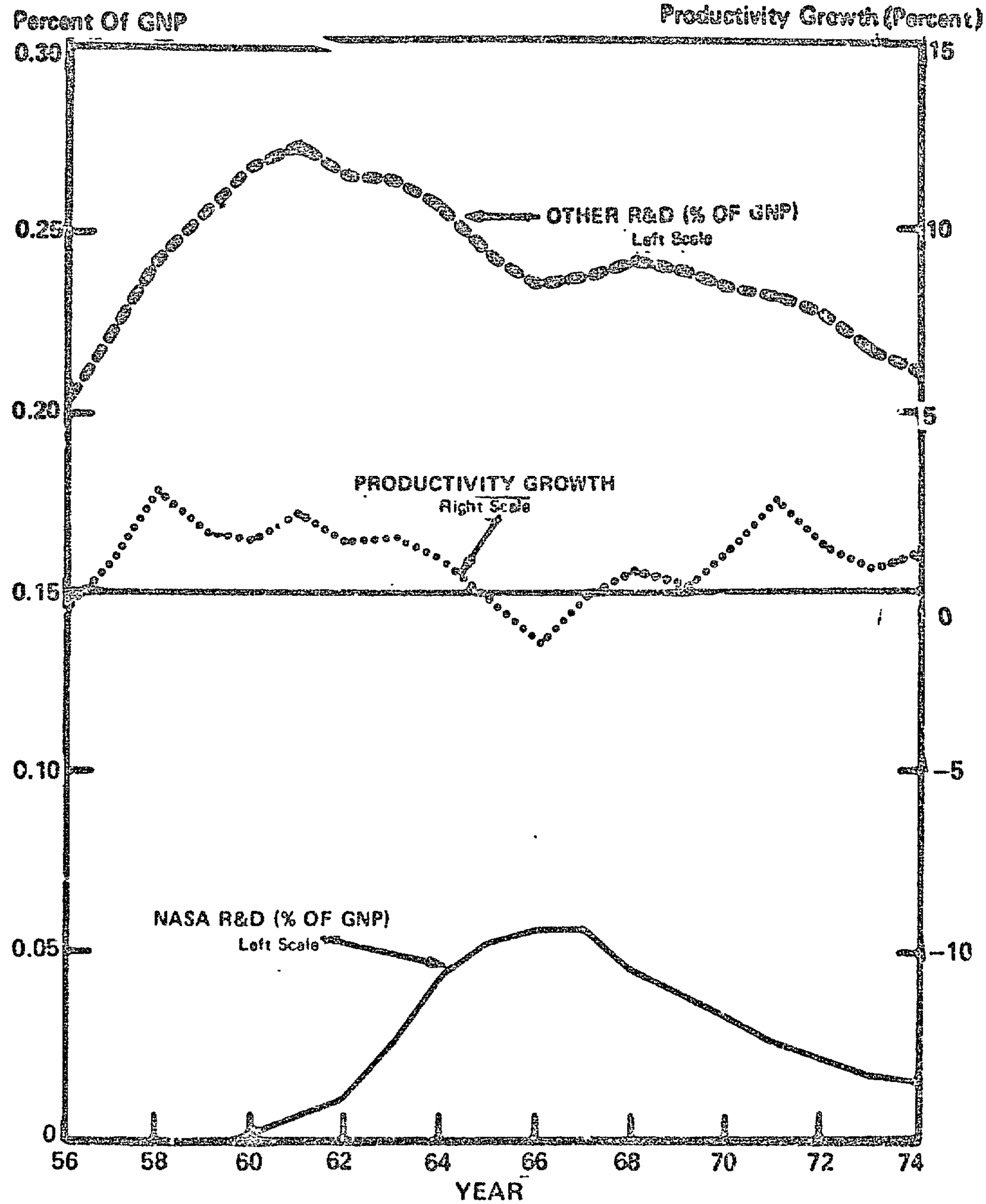
Figure 1 illustrates two more aspects of the basic data:

--NASA R&D is a small portion of total R&D--about 12 percent between 1961 and 1974. Yet this portion is held responsible for all of the productivity growth.

--Other R&D declined at about the same time that NASA R&D increased. This creates the statistical problem,

Figure 1

PRODUCTIVITY GROWTH
NASA R&D AND OTHER R&D
(AS DEFINED BY CHASE ECONOMETRICS)



mentioned in chapter 3, that makes it difficult to separate the effects of the two types of R&D.

In the Chase study, the main effect of NASA R&D is assumed to be raising the level of productivity in the economy; that is, increasing the total product (measured in dollars) that could be produced with available labor and capital. This does not directly measure the benefits resulting from improvements in products, except insofar as consumers demand fewer of the improved products and thereby release capital and labor to produce more of other products. Similarly, the value of new products is not well accounted for. If a new and better product replaces an old product that cost the same amount to produce, the GNP figures will not show the benefit. These criticisms of the Chase methodology point up inherent problems in using GNP as a measure of welfare.

The study does not use data on specific NASA projects or on the adoption of new techniques by the private sector. Rather, the data are on such an aggregate level that nothing about NASA is measured directly except its budget. More information, we believe, could have been used to advantage. As it is, the empirical work rests upon a theory--that more NASA R&D will cause more growth in productivity--which has little analytical support. Economists who have reviewed the study have asserted that the process of technological change is considerably more complex than the Chase study implicitly assumes.

USEFULNESS OF THE STUDY'S RESULTS

Granted that the Chase study has merit as exploratory economic research, how useful are its results to the budget process? Do the study's results, even if accepted as accurate, provide the information needed to determine whether NASA's budget should increase or decrease?

Any government program that produces a 43-percent rate of return would certainly be worth continuing. This greatly exceeds the average rate of return in the private sector. Still, the occurrence of past spinoffs does not insure that future spinoffs will occur at the same rate as new and different R&D projects are sponsored. New projects would still have to be justified on their own merits.

Two aspects of the Chase approach should be noted. First, the estimates of NASA's effect are average, rather than incremental, amounts. Even if it is granted that NASA's spending in 1965, for example, produced certain benefits, it does not follow that increasing that year's budget by, say 20 percent, would have increased the benefits by 20 percent. More likely, the increase in benefits would have been less than 20 percent.

In any year, NASA considers many possible R&D projects. If NASA pursues those it judges to be the most productive, then increasing its budget would allow it to pursue one or more of those projects that it had previously rejected as below average in prospective payoff. To state the same principle of "diminishing returns" somewhat differently, it is likewise possible that, even in a year when NASA's projects produced great benefits, a few unproductive projects could have been eliminated, thereby reducing the budget without reducing benefits.

In any case, efficient budget management requires project-by-project evaluation. Whatever the merits of an overview of the impact of the entire agency budget, such an approach misses this necessary detail.

Second, when discussing the usefulness of this approach, one should keep in mind that much of the Chase report was devoted to macroeconomic and interindustry impacts of NASA R&D spending. Any form of government spending produces some such effects, and the differences among these effects are not crucial to allocating public funds to a particular agency.

IN DEFENSE OF THE CHASE METHOD

The merits of the Chase approach stand out more clearly when the alternatives are considered. Studying the effect of NASA R&D on a totally disaggregate basis involves many problems:

--Assessing the impact of every NASA R&D contribution would be prohibitively expensive, but choosing just a few would not necessarily give an accurate picture.

--Major technical innovations are spread through many segments of the economy and their effects are not felt for several years. It is doubtful that all of the effects could be accounted for in studies of individual projects.

The Chase approach at least attempts to measure the diffuse effects, although not with total success. The Chase study is not a definitive budget justification, but it is a worthwhile exploratory approach to a difficult problem in economics.

We believe that some compromise is possible between the Chase approach and the project-by-project approach. This would involve studying technical progress in the industries for which NASA R&D has been particularly important. NASA officials said some such studies are being considered.

RECOMMENDATION TO THE ADMINISTRATOR OF NASA

We recom that the Administrator see that future evaluation st. ies take a less highly aggregated approach. That is, the researchers should

--analyze the process by which NASA R&D expenditures improve productivity in the economy;

--study some of the more important innovations, rather than the total R&D budget; and

--study individual technological improvements in particular industries, rather than GNP figures.

This kind of research would not produce a single measure of the total impact of all NASA R&D, like the $23 billion figure given by Chase. Indeed, accurate and meaningful aggregations of this kind may not even be feasible. But we believe that the results of a number of disaggregated studies would give the Congress a more accurate and informative picture of what taxpayers are receiving in return for their money.

MATTER FOR CONSIDERATION BY THE CONGRESS

Technical studies are frequently presented to Congress in support of agency budgets and as evidence for or against proposed legislation. We believe that, when important questions are at stake, such studies should be subjected to independent examination and appraisal.

CHAPTER 5

NASA AND CHASE COMMENTS

AND OUR RESPONSE

We asked both NASA and Chase Econometrics to comment on our report. In general, both agreed with our conclusions. (See apps. III and IV.)

Some NASA comments leave the impression that our objection was merely over which of the alternative estimates is the most acceptable and that the estimate we chose still shows a high rate of return to NASA R&D spending. This is, however, not our point.

The logic of our analysis is as follows:

--In chapter 4, we argue that the approach taken by Chase will not answer the basic questions. Productivity is a complicated function of so many variables, current and lagged, that explaining it by a few variables will not provide meaningful information on cause-and-effect relationships. We doubt whether statistical investigations of time series data on GNP will ever measure the relation between R&D spending and productivity with the precision sought by the Chase study.

--In chapter 3, we assume, for the sake of argument, that the approach taken by Chase is acceptable. We conclude that minor respecification of Chase's preferred equation to produce a more plausible model results in a lower rate of return for NASA R&D on the one hand, and the possibility of no NASA productivity effect on the other. In NASA's words, "the variables selected may statistically interact to cloud the validity of the results." With the Chase result (a 43-percent rate of return), this is clearly the case. Though the validity of our result (a 28-percent rate of return) does not suffer from this particular statistical deficiency, it should not be taken at face value either, for reasons cited in this report.

United States Senate
COMMITTEE ON APPROPRIATIONS
WASHINGTON, D.C. 20510

September 15, 1976

Honorable Elmer Staats
Comptroller General of the United States
General Accounting Office
441 G Street, N. W.
Washington, D. C. 20548

Dear Elmer:

At the Appropriation hearings for fiscal 1977, before the Subcommittee on Housing and Urban Development and Independent Agencies of the Committee on Appropriations, NASA presented to the Subcommittee, in support of its budget request, a study entitled: "The Economic Impact of NASA R&D Spending." This study, commissioned by NASA and performed by Chase Econometrics, Inc., concluded that NASA R&D spending has a substantial beneficial impact on the economy.

Although we find this study a useful input to our hearings, we would like the GAO to make a careful assessment of that study. This would give the members of the Subcommittee an independent view of the impact of NASA functions on the economy.

In your assessment of the study, we would like the GAO to evaluate the appropriateness of the study's assumptions, its analytical techniques, and the validity of its conclusions.

For your report to be timely, we would like to have it available to the Subcommittee before its Appropriations hearings that will be held in February or March of 1977. While NASA comments might be useful, the process of obtaining them should not delay the completion of the report beyond the time that it is needed. If you have any questions concerning this request, please contact Mr. Thomas van der Voort of my staff.

Sincerely yours,

William Proxmire, Chairman
HUD-Independent Agencies Subcommittee
Senate Appropriations Committee

WP:tvk

TECHNICAL APPENDIX TO CHAPTER 3

The Chase Econometrics "preferred equation" was one of many equations which were devised to determine the contribution of NASA R&D expenditures to the rate of technological change. The coefficient estimates which Chase produced from these equations may be found in table 3.13 on pages 87 and 88 of their report. Chase did not, however, present summary statistics of the range of error associated with coefficient estimates in alternative equation forms. These statistics describe the range of variability of the coefficient estimates and measure the range within which the true measure of the effect probably lies. The range of error associated with the Chase estimates of NASA R&D productivity effects in alternative equation forms is particularly important in view of the report's conclusions. We reproduced Chase's methodology in order to determine the range of error associated with coefficient estimates for NASA R&D in alternative equation forms that we believe are more plausible on both economic and statistical grounds.

Our reproduction of the Chase methodology should not be construed as an endorsement of a macroeconomic approach to measuring NASA-induced productivity changes. We are simply examining the following problem: If a macroeconomic approach is acceptable, how reliable are the estimates of the NASA contribution to the rate of technological change and how sensitive are these estimates to minor respecification of equations or variables that produce a more plausible model.

VARIABLES USED BY CHASE ECONOMETRICS

Chase used the following variables as proxies for the rate of technological change and for theoretical influences.

Dependent variable

Gamma - Council of Economic Advisors rate of technological change based on trend, adjusted for full employment of labor and capital resources.

Independent variables

NRDA - Almon weighted ratio of NASA R&D expenditures to GNP.

ORDA - Almon weighted ratio of other R&D expenditures to GNP.

ORDC - Almon weighted ratio of other R&D expenditures to GNP, weighted by a standardized measure of capacity underutilization.

$IM-\overline{IM}$ - Deviations of a Chase-designed industry mix variable from its mean. This variable is intended to account for resource shifts from low-technology to high-technology industries and vice versa.

$CP-\overline{CP}$ - Deviations of the Chase index of capacity utilization from its mean.

ΔIE - First differences in an index of labor quality as affected by education.

ΔIAS - First differences in an index of labor quality as affected by age-sex mix of the labor force.

Chase measured these variables over a period from 1956 to 1974. They were intended to measure five categories of influences on the rate of technological change, including (1) labor quality, (2) utilization of productive factors, (3) resource transfers which, when incorporated in high-technology industries, may be expected to increase the rate of technological change, (4) R&D expenditures, and (5) a dynamic or lagged response of the rate of technological change to increases in R&D expenditures. These determinants seem sound on theoretical grounds and may include all possible determinants.

RESULTS

Chase's preferred equation estimates the contribution of NASA R&D expenditures to the rate of technological change, includes the capacity weighted other R&D variable (ORDC), omits labor quality proxies (ΔIE and ΔIAS), and includes only observations for 1960 to 1974.

We believe that a more theoretically justifiable equation for measuring NASA-induced productivity changes would include labor quality proxies, an unweighted measure of other R&D expenditures (ORDA), since the capacity transformation of this variable (ORDC) is questionable and leads to very complex interpretation of results. Also, we used observations for 1956 to 1974.

Our results are presented in table 2. The Chase results for the Chase preferred equation and for our preferred equation are presented as equations 1 through 4. These results are followed by our estimates of those same four equations (equations 5 through 9). Comparison of our results with Chase's results shows that we have very closely reproduced its methodolcgy for both sample periods.

Choice of sampling period

Correlation matrices for the variables we used in each sample period are presented in table 1. The correlation coefficient between the R&D variables that Chase employs in its preferred equation for 1960 to 1974 is very high (0.917). When collinearity is this high between two variables, sorting out the separate effects of each is impossible. Because of this, the coefficient estimates that Chase presents in table 3.13 of its report are very sensitive to minor alterations in variable or equation form. The correlation coefficient between NRDA and ORDC is, however, only 0.267 for 1956-74, well within the range of acceptability. In comparisons of the matrices for each sampling period, the correlation coefficients between the critical pairings of R&D variables and between R&D variables and other included variables are more often lower over the longer sample period. The correlation coefficient for NRDA and ORDA is higher during 1956 to 1974 than during 1960 to 1974, but it is within an acceptable range. For these reasons, the longer sample period is preferred, particularly for estimating Chase's preferred equation.

Labor quality and other influences

In our preferred equation, NASA R&D enters without statistical significance for either sampling period. The coefficient on the other R&D variable is statistically significant for our preferred sampling period. When the Chase preferred equation for 1960-74 is altered only by substitution of a noncapacity weighted other R&D variable for the one Chase prefers, the coefficient on NASA R&D drops from 0.428 to 0.259 for 1960-74 and from 0.318 to 0.227 for the longer sampling period. The NASA coefficient remains statistically significant for both periods, however (equations 9 and 11). But the introduction of labor quality into these equations, though itself insignificant, causes the NASA coefficient to become statistically insignificant (equations 7 and 8).

Table 1

Correlation Matrices

1956-74

	GAMMA	NRDA	ORDC	ORDA	IMD	CPD	Δ IE	Δ IAS
GAMMA	1.000							
NRDA	-.0085	1.000						
ORDC	-.2745	-.2670	1.000					
ORDA	-.3259	.5272	.6487	1.000				
IMD	.6810	-.6646	-.0185	-.5988	1.000			
CPD	-.7964	.1537	.6187	.6771	-.6220	1.000		
Δ IE	-.0972	.2046	.0736	-.0560	-.1678	.2704	1.000	
Δ IAS	.4110	.1517	-.0452	.0237	.1718	-.1528	-.1052	1.000

1960-74

	GAMMA	NRDA	ORDC	ORDA	IMD	CPD	Δ IE	Δ IAS
GAMMA	1.000							
NRDA	.0819	1.000						
ORDC	-.3445	-.8170	1.000					
ORDA	-.6285	.2959	.2270	1.000				
IMD	.6588	-.6259	.2706	-.7506	1.000			
CPD	-.8388	-.1219	.5284	.6997	-.5119	1.000		
Δ IE	-.0963	.1769	.0093	-.0855	-.1449	.2814	1.000	
Δ IAS	.6192	.1876	-.1018	.0024	.2540	-.3873	-.1207	1.000

APPENDIX II

When labor quality proxies are introduced into an equation which is in all other respects similar to the Chase preferred equation, the coefficient on the NASA R&D variable becomes insignificant for 1960-74 (equation 10) but remains significant during the longer sampling period (equation 12). The result for 1960-74 is caused by the instability of the NASA R&D coefficient which results from the high intercorrelation between the preferred NASA and other R&D variables during that period.

We reemphasize that our preferred equation is equation 8. Labor quality is included and, thus, the equation contains all Chase proxies for theoretical influences. Capacity utilization enters "on its own" and not combined with an obscure transformation of the other R&D variable. In this equation, the NASA effect is insignificant.

CONCLUSION

The Chase results are sensitive to both the manner in which the estimating equations are specified, the sample periods, and the manner in which R&D variables are measured. If NASA R&D spending has as strong an effect as the Chase study claims, then that effect should not be greatly altered in a more fully specified and more theoretically defensible equation.

Table 2

Coefficient Estimates and Summary Statistics

Chase results	Const.	NRDA	ORDA	ORDC	$IM-\overline{IM}$	$CP-\overline{CP}$	ΔIE	ΔIAS	$\bar{R}^2$	D.W.	S_e	Eq. No.
Chase Pref	-1.81	(.426)		.074	.031	-.157			.883	1.95	?	1
1960-74	(?)	(3.9)		(2.0)	(4.5)	(3.1)						
Chase Pref	-.94	.318		.046	.029	-.158			.883	1.94	?	2
1956-74	(?)	(5.4)		(2.4)	(4.3)	(3.7)						
GAO Pref	?	.179	.080		.029	-.140	.072	2.09	.88	?	?	3
1960-74	(?)	(?)	(?)		(?)	(?)	(?)	(?)				
GAO Pref	?	.135	.087		.026	-.177	.096	1.97	.90	?	?	4
1956-74	(?)	(?)	(?)		(?)	(?)	(?)	(?)	(?)			

GAO results

GAO results	Const.	NRDA	ORDA	ORDC	$IM-\overline{IM}$	$CP-\overline{CP}$	ΔIE	ΔIAS	$\bar{R}^2$	D.W.	S_e	Eq. No.
Chase Pref	-1.74	.428		.074	.031	-.157			.885	1.96	.34	5
1960-74	(1.52)	(3.96)		(2.04)	(4.52)	(3.18)						
Chase Pref	-.60	.318		.046	.029	-.158			.884	1.95	.36	6
1956-74	(1.33)	(5.45)		(2.40)	(4.36)	(3.77)						
GAO Pref	-1.46	.178	.081		.029	-.140	.072	2.09	.877	1.80	.35	7
1960-74	(.52)	(2.03)	(.67)		(2.95)	(2.05)	(.90)	(1.18)				
GAO Pref	-1.48	.136	.087		.026	-.177	.096	1.97	.897	1.72	.34	8
1956-74	(2.21)	(1.73)	(2.73)		(3.97)	(4.24)	(1.57)	(1.82)				
ALT	-1.83	.259	.102		.037	-.124			.862	1.75	.38	9
1960-74	(1.00)	(3.26)	(1.32)		(4.43)	(2.58)						
ALT	- .71	.287		.037	.027	-.134	.029	2.04	.879	1.83	.35	10
1960-74	(.49)	(1.79)		(.78)	(3.26)	(2.32)	(.47)	(1.21)				
ALT	- .89	.227	.067		.033	-.139			.876	1.83	.37	11
1956-74	(1.38)	(3.14)	(2.11)		(5.13)	(3.53)						
ALT	- .79	.269		.047	.024	-.173	.048	1.77	.891	1.70	.35	12
1956-74	(1.71)	(4.20)		(2.53)	(3.44)	(4.02)	(.83)	(1.59)				

APPENDIX II

National Aeronautics and
Space Administration

Washington, D C
20546

July 11, 1977

Reply to Attn of: W

Mr. R. W. Gutmann
Director
Procurement and Systems
Acquisition Division
U.S. General Accounting Office
Washington, DC 20548

Dear Mr. Gutmann:

Thank you for the opportunity to comment on the draft report entitled, "Review of 'The Economic Impact of NASA R&D Spending'," which was prepared by GAO's Program Analysis Division pursuant to a request of the Chairman, Subcommittee on HUD-Independent Agencies, Senate Committee on Appropriations.

NASA finds that the GAO analysis is well done and does not take issue with the results. The enclosure discusses the most important differences between the GAO analysis of the data used in this study and the Chase Econometrics analysis, which are based on the art of interpreting the statistical results.

Sincerely,

Kenneth R. Chapman
Assistant Administrator for
DOD and Interagency Affairs

Enclosure

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
COMMENTS ON THE GAO DRAFT REPORT
ENTITLED "REVIEW OF 'THE ECONOMIC
IMPACT OF NASA R&D SPENDING'"

The GAO finds that the Chase study does not:

- Provide information useful to budget makers which indicates the economic impacts of incremental changes in NASA R&D funding
- Present statistical results that are stable and accurate within acceptable levels of confidence
- Reveal a true cause and effect relationship between NASA funding and changes in total productivity

But the GAO recognizes and believes that:

- NASA has contributed significantly to the economic productivity of the nation
- The Chase study was valuable exploratory research into a difficult (and as yet) unsolved problem
- It would be valuable for NASA to continue doing economic evaluations of its programs, particularly at a more detailed industry and specific innovation level

The major methodological problem that the GAO had with the Chase study was the sensitivity of the results to relatively minor changes in the variables used for the regression analysis. With this in mind, they re-created the data base Chase used and re-ran the equations, testing for statistical significance.

The most important differences between the GAO analysis of the data used in this study and the Chase Econometrics analysis rest in the art of interpreting the statistical results. Chase chose a regression equation which when analysed showed a 43 percent rate of return to NASA R&D funding. In their preferred equation the "NASA R&D" variable was statistically significant. The GAO chose an equation that included the greatest number of explanatory variables at the expense of the statistical reliability of the "NASA R&D" variable. They also used a longer time span which included a period without NASA spending as well as the period of heavy NASA funding which Chase had mainly emphasized. Interpreting the regression equation that the GAO prefers (which was one of the many equations Chase had analysed and rejected) yields a 28 percent rate of return to NASA R&D. This result is still well within a range of economic returns that can be considered very good investment of government R&D funds.

NASA accepts the GAO critique and its conclusions as being constructive, accurate, and objective. We agree that the data contain some inherent measurement problems and that the variables selected may statistically interact to cloud the validity of the results.

NASA recognizes that empirical measurement in economics is an inexact science and that the specific magnitude of the results of the Chase study is not as important a finding as the direction and the approximate range of returns. The GAO analysis does not change the basic conclusions of the Chase study. Their discussion tends to reinforce those conclusions since their data indicate that between 1966 and 1974 NASA has (when NASA funding was having its full effect) contributed to productivity about 26 percent as much as all other R&D combined. This can favorably be compared to the fact that NASA in those same years was funding only 12 percent of all of the R&D investment in the nation.

NASA agrees that the macroeconomic approach to economic evaluations of impacts has limitations. The GAO points these out, but also recognizes that the alternatives to providing similar policy conclusions are not feasible. They are also aware that the Chase approach is based on standard and supportable economic theory.

NASA finds that the GAO analysis is well done and does not take issue with their results. Their suggestions for further analysis have helped in the planning already underway within NASA for doing more detailed microeconomic and macroeconomic studies, which will improve on the past analyses.

Nathaniel B. Cohen
Director, Office of Policy Analysis

7/7/77
Date

 APPENDIX IV

Chase Econometric Associates, Inc.

a Subsidiary of The Chase Manhattan Bank, N.A.

555 City Line Avenue, Bala Cynwyd, Pennsylvania 19004 (215) 667-7350 Telex: 831609

June 14, 1977

Mr. Harry S. Havens
Director
Program Analysis Division
United States General Accounting Office
Washington, DC 20548

Dear Mr. Havens:

Thank you for your letter of June 1 and the accompanying draft of your report entitled "Review of 'The Economic Impact of NASA R&D Spending.'"

I have read your review and must say that I find it to be fair to all sides concerned. We did experiment with some 60 different regression equations and found that the critical coefficient of NASA R&D spending did not vary as much as you have indicated. However, I would certainly not rule out the fact that it is possible to choose other combinations of variables in that regression, although you did not list these specifically.

I appreciate your giving me the opportunity to review this draft.

Sincerely yours,

Michael K. Evans

Michael K. Evans

MKE:mhr

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