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Summary

In this study Chase Econometric Associates, Inc., has undertaken an evaluation of the economic impact of R & D spending, particularly NASA R & D spending, on the U. S. economy. The crux of the methodology and hence the results revolve around the fact that we need to consider both the demand effects of increased spending and the supply effects of a higher rate of technological growth and a larger total productive capacity. The demand effects are primarily short-run in nature, while the supply effects do not begin to have a significant effect on aggregate economic activity until the fifth year after increased expenditures have taken place.

This report is divided into two principal sections. In the first part we examine the short-term economic impact of alternative levels of NASA expenditures for 1975. The methodology used in this section is as follows:

1) We prepared macroeconomic forecasts for alternative levels of NASA spending. In these runs the level of total Federal government expenditures remained the same. Thus the improvements result solely from a shift among different types of expenditures.

2) We used INFORUM, an inter-industry forecasting model which utilizes an updated input/output table, to determine the effects of employment and output at the industry level.

3) The shifts in industry output caused by an increase in the level of NASA spending redistribute demand from low productivity industries to higher productivity industries, thereby increasing total productivity in the economy.

The principal conclusions reached in this part of the study show that a $1 billion increase in NASA spending in 1975, coupled with a $1 billion reduction of other Federal expenditures, would have the following effects:

1) A higher level of NASA expenditures would not have an inflationary impact on the U. S. economy during 1975 and would probably reduce the inflationary pressures in the economy.

2) A shift of $1.0 billion in 1971 dollars, or $1.4 billion in 1975 estimated prices, from other Federal non-defense expenditures to NASA expenditures will reduce the inflationary pressures in several key basic materials industries.

3) A shift to increase NASA expenditures will increase employment by 25,000 in the missile and ordnance and aircraft industries. While it will reduce employment in ten other industries, the net increase in the manufacturing sector will be 20,000 jobs.

4) Output will be stimulated in twenty-one industries. The principal industries which will be affected currently have considerable excess capacity and are producing at levels well below their peak years and in most cases below the average of the past five years.

5) A shift toward higher NASA spending within the framework of a constant level of total Federal expenditures creates jobs without raising the rate of inflation, and hence is more stabilizing in a recovery period than general government spending.

The second major section of the report deals with the long-term economic impact of increased levels of NASA R & D spending over a sustained period. The methodology used in this section is as follows:

We first developed estimates of historical series for the rate of aggregate technological progress for the postwar period.

2) We next estimated multiple regression equations relating this series to a number of variables, including NASA R & D spending, other R & D spending, gross national product, the index of capacity utilization, an industry mix variable, and an index of labor quality.

3) We calculated the increase in GNP per unit increase in NASA R & D spending which would occur taking into consideration only the "pure" productivity effects. These increments represent the expansion of the aggregate production possibility function due to a more rapid rate of technological advancement.

4) We simulated the macro model to determine how the multiplier effects of increases in NASA spending and in the rate of technological progress would affect aggregate demand and the overall economy.

The principal conclusions reached in this part of the study show that a sustained increase in NASA spending of $1 billion in 1958 dollars for the 1975-1984 decade would have the following effects:

1) Constant-dollar GNP would be $23 billion higher by 1984, a 2% increase over the "baseline", or no-additional-expenditure projections.

2) The rate of increase in the Consumer Price Index would be reduced to the extent that by 1984 it would be a full 2% lower than indicated in the baseline projection.

3) The unemployment rate would be reduced by 0.4% by 1984, and the size of the labor force would be increased through greater job opportunities so that the total number of jobs would increase by an additional 0.8 million.

4) By 1984 productivity in the private non-farm sector would be 2.0% higher than indicated in the baseline projection.

5) Other simulations which were calculated indicated that these results would be proportional for increases of $500 million or $100 million in NASA R & D spending.

The reason for the unique combination -- for a government spending program -- of increased real GNP and a lower inflation rate is to be found in the growth of labor productivity. A growth in productivity means that less labor is needed per unit of output. The key to the growth of labor productivity is the higher rate of technological growth spurred by the increase in research and development expenditures.

Thus in this study we have found that an increase in NASA R & D spending increases the rate of technological change and reduces the rate of inflation for two reasons. First, in the short run it redistributes demand in the direction of the high-technology industries, thus improving aggregate productivity in the economy. As a result, NASA R & D spending tends to be more stabilizing than general government spending during a period of recovery. Second, in the long run, increased NASA R & D spending expands the production possibility frontier of the economy by increasing the rate of technological progress. This improves labor productivity at a faster rate, which results in lower unit labor costs and hence lower prices. A slower rate of inflation leads in turn to a more rapid rise in real disposable income, which provides consumers with the additional purchasing power to buy the additional goods and services which are being produced.

I. INTRODUCTION

The question of whether the U. S. economy can experience full employment and price stability at the same time has been one of the most thoroughly debated issues in the postwar period. Yet in spite of the great amount of resources and expertise devoted to this question, the uneducated citizen could be pardoned for observing that we seem to have accomplished just the opposite -- rapidly rising prices with unacceptably high unemployment. Repeated doses of fiscal and monetary policy have apparently resulted in long-term secular increases in both the rate of unemployment and the rate of inflation.

A complete discourse on the recent illness of the economy would have to include at a minimum chapters on the Arab oil embargo and cartel, the unexpected doubling of many food prices, worldwide shortages of many basic industrial raw materials, and the distortions caused by wage and price controls. Yet we would not do violence to the facts of the past decade if we were to summarize the causes of the current disequilibrium in the economy by stating that government policy has worked to increase aggregate demand without increasing aggregate supply. The vast majority of fiscal stimulus in the past decade has been directed toward increasing consumption, while the burden of restrictive monetary policy has fallen on reducing investment. Thus the economy has gradually been edged into a situation where shortages have developed, productivity has declined, and inflation has mushroomed. The economic "discomfort index", calculated as the sum of the rate of unemployment and the rate of inflation, reached an all-time high in 1974 and will remain at near-record levels in 1975.

We offer no simple cures for the present condition of the economy, and note that even if the optimal fiscal and monetary policies were to be followed in the future, it would take three to five years to return the economy to an equilibrium situation. Yet this relatively long adjustment time means it is even more imperative to move quickly, rather than wait until the next economic crisis is upon us. It is necessary to implement policies which increase productivity and lower the rate of inflation as well as stimulate the overall level of demand. Fiscal policy which increases aggregate demand without raising aggregate supply will not cause noticeably higher inflation this year or next, but will eventually lead to supply shortages when the economy does regain full momentum.

In general, any increase in investment spending will generate a higher level of productivity, since new capital goods will replace older ones. However, the improvement in productivity will be confined to those industries in which the additional investment is taking place. The goals of the economy would be better met if increased spending leads not only to a decline in the average age of capital but also produces increases in the level of technology which are then applicable to other industries. These spillover effects then raise the overall level of productivity even further.

It is often claimed that spending for research and development accomplishes these aims. A number of studies have shown that the rate of return on research and development is greater than is the case for other types of investment, both because technology is advanced more rapidly in the originating industry and because of the spillover effects. Not all R & D spending would be expected to have the same effect on the rate of technological growth; in particular we might expect that general-purpose R & D spending in high-technology areas would have greater spillover effects than that aimed at the development and marketing of a specific product.

The vast majority of economists who have worked in the area of productivity growth agree that R & D spending is a major contributory factor to technological progress. In the pioneering work of Abramovitz (1), Fabricant (25), Kendrick (32), and Denison (14), advances in knowledge has always been prominently identified as one of the major factors, if not the major factor, contributing to the growth in output per unit of input. Denison, for example, found that of the 1.8% growth in output per unit of input for the period 1948-1969, 1.2% was due to advances in knowledge above and beyond those increases in labor input due to improved education (p. 127).

Similarly, important work done at the micro level by Mansfield (41, 42), Minasian (48), Schmookler (60), and Nelson, Peck and Kalachek (54), has indicated high returns to R & D spending on an individual firm or industry basis. In addition, Griliches (28) has shown that the marginal social product of R & D expenditures is more than twice its private marginal return.

A number of other studies have addressed themselves directly to the question of the specific effect of R & D spending on the growth in productivity. In one such paper, Raines (59) estimated production functions for 24 two- and three-digit industries; the functions include applied R & D spending as one of the independent variables in addition to labor and capital. He found that of the average annual gain in labor productivity of 4.5% per year for those industries studied, 29% was due to R & D spending by the originating industry and another 24% was due to R & D spending by other industries (p. 40). However, the Raines work, while highly instructive, contains only a rudimentary lag structure and does not allow for time lags of greater than four years, which is almost certainly an underestimate.

In a more recent study done by Midwest Research Institute (47), an attempt was made to introduce longer lags into the relationship between R & D spending and gains in productivity. Lags of up to 18 years were used but the lag distribution was not determined empirically. Furthermore, the report states that 60% of the advance in technological progress was due to R & D spending. However, this finding was determined through a residual method and hence no direct estimation of this parameter estimate was attempted. In a very recent study, Mathematica, Inc. estimated the benefits to the national economy from applications of NASA technology (43). Here again, however, a statistical approach is not used.

Thus the methodology in this study represents a major departure from previous work designed to measure the effects and benefits of R & D spending. In generating the results in this study, we have relied heavily on the econometric and statistical approach. First, we have estimated an annual series for changes in productivity; previous work has dealt with these changes only on a decade-by-decade basis. Second, we have used a variant of Lagrangian interpolation polynomials to estimate the lag between R & D spending and changes in productivity. Third, we have used multiple regression techniques to determine the parameter estimates of the various factors influencing the rate of technological progress. Fourth, we have used large-scale macroeconomic and input-output models to determine the effects of R & D spending on the overall economy and individual industries after the interactive and dynamic multiplier effects have been taken into account.

In breaking as much new ground as is the case in this study, we admit that some of the results may be controversial. However, we have attempted to document all of the data and methodology carefully so that similar results may be obtained by other researchers. We believe that the overall results given in this study are consistent in broad form with earlier results, while introducing further elements of precision and dynamic interpretation.

2. SHORT-TERM ECONOMIC IMPACT OF ALTERNATIVE LEVELS OF NASA EXPENDITURES FOR 1975

A. Introduction

The question which we explore in this part of the study is concerned with whether a higher level of NASA expenditures is more beneficial to the U. S. economy than a lower level of NASA expenditures during the year that the expenditures are made, holding the level of total Federal government budget constant in each case. This analysis is useful in examining the effects of altering the level of NASA expenditures as part of an overall economic stabilization policy. Thus we address the effects on several potential targets, including those of higher employment and reduced inflationary pressures.

In this regard the term "beneficial" used above is defined as having several characteristics.

1) A reduction in the direct demand pressures on industries which might be operating at high levels of capacity utilization or with tight labor markets, thereby reducing the inflationary pressures on that industry. This problem is somewhat less germane in 1975 than would ordinarily be the case, but cannot be ignored completely.

2) An increase in the demand for those industries which are currently operating with idle capacity, thereby increasing employment and output.

3) A reduction in the derived demand pressures on basic material producing industries which currently have shortages in supply, rely on imported raw materials, and are operating at high capacity utilization rates. This would

then reduce the inflationary pressures in these basic industries and the industries which they supply.

4) An increase in the demand for labor in those industries which are presently operating at levels below those of recent years.

5) The direction of expenditure away from those industries which have full utilization toward underutilized industries. This will increase employment, whereas the converse will tend to increase prices but not employment.

B. NASA Expenditure Assumptions

Two forecasts of the U. S. economy for 1975 were developed using alternative levels of NASA expenditures. These forecasts were termed NASAHI and NASALO. No assumption of the model used other than the level of NASA expenditure was altered between the NASAHI and the NASALO forecasts.

The NASALO forecast assumes an expenditure by NASA of $1.35 billion for goods and services (excluding NASA employee wages) during calendar 1975. These expenditures and all other data in this section of the study are expressed in terms of constant 1971 prices, except as specifically noted, because our initial focus is to examine the effect on real economic activity, i.e., adjusted to eliminate the effects of price changes. We then examine the effects on prices separately.

The NASAHI forecast assumes an expenditure by NASA of $2.35 billion during calendar 1975. The $1.0 billion addition to NASAHI is obtained by reducing general Federal non-defense expenditures by $1.0 billion, leaving the level of total Federal government expenditures unaltered. NASAHI may be described as involving a redistribution of $1.0 billion of government expenditures to NASA from other Federal government programs.

The $1.0 billion shift in Federal government expenditures is equivalent approximately to a $1.4 billion shift in Federal government expenditures in estimated 1975 prices. The exact price index to be used depends, of course, on whether the funds are spent in NASA programs or other Federal programs.

Because the level of total Federal government expenditure was not altered between NASAHI and NASALO, the amount of the shift in expenditure was only $1.4 billion in estimated 1975 prices, and only the first-year impacts are being measured, the aggregate economic impact shown for this shift will necessarily be small. It is desirable, however, to analyze the microeconomic impact across a broad range of industries to determine whether this shift affects the differential performance and employment in particular industries. Of greatest concern is whether the inter-industry effects are beneficial as described above.

In order to measure the differential industrial effect of the NASAHI and NASALO expenditure levels, we utilized the INFORUM Inter-Industry Forecasting Model. This model, which was developed by the Interindustry Forecasting Project of the University of Maryland has been expanded and modified by Chase Econometrics and has been linked to the Chase Econometrics Macroeconomic Forecasting Model to provide consistent economic forecasts for the industries included in the model. This method links the techniques of input-output analysis with the regression techniques utilized in constructing a macroeconomic model. While regression techniques provide the behavioristic equations required for macroeconomic forecasting, inter-industry shifts are best examined in a more deterministic framework, such as an input-output model, providing that the input-output model includes a degree of flexibility in its structure.

C. Input-Output Economics

Basic Elements

Aggregate econometric models seldom account for production in any way other than as aggregates of final output. All of the consumption goods sold to consumers are added up under the heading of consumer durables, nondurables and services; all of the products sold to companies for plant and equipment are added up and classified accordingly. Most of these models tend to obscure the existence of a very large number of transactions between companies throughout the economy. The production of products which are to be used in the making of other products is a major part of economic activity. When we are considering the production of such large complex pieces of machinery as a launch vehicle, or a space shuttle, we must explicitly recognize that there are a large number of products that are inputs to these products, and moreover, these inputs originate in a very large number of industries. One major aspect of all of this is the methods of production that are to be used; in other words, how various inputs are combined to produce outputs.

Input-output analysis is a method of accounting for these industry-to-industry transactions. The salient feature of input-output analysis is the industry-by-industry specification of the dollar's worth of specific inputs that are required to produce a dollar's worth of different outputs. In some respects, an input-output table is an existing technology map. It provides a starting point for diagnosis and for examination.

Another major feature of input-output analysis is that the table of transactions among industries -- usually termed intermediate transactions to distinguish them from final transactions that cover the sales to final users -- is integrated with the National Income Accounts. Consequently, one can still maintain consistency with the data for consumption, investment, government expenditure, etc.

For purposes of illustration, Table 2.1 contains a highly condensed example of an input-output flow table. In this illustration, there are four producing sectors (whereas in the model that we have used for analysis purposes in this report, there are 185 industries). The units in Table 2.1 may be read as millions of constant dollars -- flows of dollars in the period of a year. The magnitudes used here are purely illustrative.

Reading across the first row of Table 2.1 we find that Agriculture sells 15 units to itself. This can be simply enough explained by noting that it is necessary to plant wheat to grow wheat. Consequently, in any one year, a certain amount of the output of Agriculture must be retained by Agriculture for the purpose of generating next year's crop.

The second column of the first row shows the sale of 100 units by Agriculture to Manufacturing I. Similarly, sales by Agriculture to Manufacturing II of 75 units and sales of 40 units to Services are shown. There is no entry in the Imports column. This is because a sale of agricultural products to other countries would result in an export, and exports are included in Final Demand. The Total Intermediate column is simply the sum of the sales by Agricultural to itself, both Manufacturing sectors and Services.

The next column is Final Demand. This column contains sales to consumers, sales of plant and equipment products to investors, sales to government, and sales to exports.

The Total Output column is again simply the sum of the Total Intermediate plus Total Final Demand. Consequently, although Agricultural is shown to produce a total output of 450 units, only 220 are sold into final demand and the balance is sold into other industries to become a part of the products that they manufacture.

Each of the three following rows in Table 2.1 -- Manufacturing I, Manufacturing II, and Services -- may be interpreted in the same fashion. The import row requires a slightly different interpretation. Sales of imports into agricultural, manufacturing and services may be interpreted in the same fashion as the earlier rows. On the other hand, imports are treated as a negative in final demand. Consequently, the sum of the total intermediate plus the total final demand results in a zero total output.

The next row is termed Value Added. This is a catchall term for the payments by each column industry for non-material inputs. In other words, Value Added includes the payments by each industry to labor, capital (depreciation), profits, rents, net interest, etc. Another way of expressing value added is in terms of income; value added payments are those payments generally treated as income in the National Income Accounts: wages, salaries, profits, rents, net interest, etc. A similar interpretation of value added is valid for each of the column industries.

The last row, Total Inputs, is simply the sum over the column. It should be noted that the figure in the Total Inputs row must equal the figure in the total output column for each industry. Another way of looking at this is in the standard accounting income statement format. The elements in each row, for instance, the figures in the row for Agriculture refer to the sales by, or revenues accruing to agriculture. These total 450 units. Those 450 units are in turn disbursed amongst a number of uses. That disbursement is shown in the Agriculture column where 15 units are paid to other firms in the Agricultural industry, five units are paid to manufacturing -- for example, for inputs of fertilizer and agricultural chemicals; 20 units are paid for the purchase of services -- and these are explicitly non-labor services (one example would be the rental of aircraft for spraying of pesticides and herbicides).

The figure in the imports row indicates that agriculture is paying out 10 units for imported products. Similarly, the 400-unit entry in the value added is the total of wages, salaries, profits, depreciation, rents, etc. that are paid out. Since the column contains all disbursements and the row contains all revenues for the year then the totals must equal. A similar interpretation applies to each of the industries listed.

Moving now to the right hand side of the table, the sum down the column of Total Intermediate transactions simply provides an adding-up of all of the dollar's worth of exchanges between industries.

The sum over the Final Demand column provides an adding-up of all of the dollar values of products and services that are sold as consumers goods, plant and equipment, and products sold to government. This is equivalent to Gross National Product. Gross National Product can, of course, be defined in two ways: as the dollar value of all goods and services purchased in the economy, or the dollar value of all income spent in the economy. It is therefore not surprising to note that the sum across the row labeled "value added" also adds up to the same value as the sum over the column of final demand.

Consequently, in the lower right hand corner of Table 2.1, we find that the total of intermediate transactions within this sample economy is 1220 units, the total GNP is 1080 units, and the sum of these two -- generally termed Total Gross Output -- is 2300 units.

Table 2.1: SAMPLE OF A COMPRESSED INPUT-OUTPUT TABLE

PURCHASES BY:

SALES BY:

	Agriculture	Manufacturing I	Manufacturing II	Services	Imports	Total Intermediate	Final Demand	Total Output
Agriculture	15	100	75	40	-	230	220	450
Manufacturing I	-	50	200	100	-	350	400	750
Manufacturing II	5	170	35	140	-	350	250	600
Services	20	30	40	20	-	110	390	500
Imports	10	100	50	20	-	180	-180	-
Value Added	400	300	200	180	-			
Total Inputs	450	750	600	500	-	1220	1080	2300

Table 2.2 shows the direct input relationships that are derived from this input-output table shown in Table 2.1. The method of deriving this table is simply to divide every element in each column by the total output of the industry represented by that column. Consequently, one would divide the first column in Table 2.1 by 450. The resulting coefficients are termed the direct, or technical coefficients of production. To produce one unit of output, the Agricultural sector must purchase .0333 units from itself. Similarly, to produce a unit of output, Agricultural must purchase .0111 units of the output of Manufacturing II and .0444 units of the output of Services. Similarly, it requires .0222 units of imports. Addition of .8889 units' worth of labor, management, financial services, etc. rounds out the ability of the Agricultural sector to produce one unit of output.

While these tables tend to appear most complex when presented in their full detail, they are in fact relatively simply in concept. Their primary purpose is to allow one to get into the nuts and bolts of production. When these tables are integrated into forecasting models they allow one to explore the effects of changing the distribution of demand. They also allow the analyst to explore the impact of explicit changes in the ways the products are made -- regardless of whether these changes originate in technological changes or in a simple substitution caused by change in relative prices. In some instances, these methods allow us to explore the impact on the economy of the construction of new products. In the past we have analyzed the impact on the U. S. economy of the B-1 bomber production program (10). A similar analysis could be undertaken of the production program for the space shuttle vehicle, or the introduction of any major new product line; be it government sponsored or a strictly private business development.

Table 2.2: MATRIX OF DIRECT REQUIREMENTS COEFFICIENTS

	Agriculture	Manufacturing I	Manufacturing II	Services	Imports	Total Intermediate	Final Demand	Total Output
Agriculture	.0333	.1333	.1250	.0800				
Manufacturing I	-	.0667	.3333	.2000				
Manufacturing II	.0111	.2267	.0583	.2800				
Services	.0444	.0400	.0667	.0400				
Imports	.0222	.1333	.0833	.0400				
Value Added	.8889	.4000	.3333	.3600				
Total Inputs	1.000	1.000	1.000	1.000				

Input-Output Models

Input-output, or interindustry analysis, is a method of determining detailed industry outputs which is much more powerful than pure regression techniques. An equation relating electronic components to GNP may have worked well enough in the past; coupled with a projection of potential GNP, it may produce a forecast which time will prove to be more accurate -- or more lucky -- than one made with input-output. But it remains basically an inscrutable forecast. When we want to take a "long, hard look at it", there is nothing to look at but a graph of how well it has done in the past. A major advance would be to utilize our knowledge about the myriad products incorporating electronic components -- instruments, home entertainment goods, biomedical equipment, military hardware, etc. But then we need forecasts of instrument output, radio-TV output, defense spending, and investment by the medical and health care industries. The last item depends, in turn, upon a varied set of federal and regional government policies and a host of other variables. When faced with a problem of such rapidly increasing complexity it is no wonder that business forecasters have turned to various short-cut methods. Input-output, however, provides both a means of coping with this complexity, and a method of incorporating a wide variety of specific information.

The input-output framework contains a complete set of relationships between any industry and all of the markets for its product (the provision of a service is also called a "product"). The portion of output sold to other industries for further processing is called intermediate product, for it is used by the purchasers as a current input in their production processes. The remainder of output is by definition sold to final demand. These final demand customers fall into the familiar Gross National Product (GNP) Accounts categories, that is, personal consumption, investment in plant, equipment and inventory, government and foreign trade.

The entire I-O accounting framework can be expressed as a simple set of equations, one for each industry:

(1) Output = Consumption
+ Investment
+ Government
+ Net Foreign Trade
+ Intermediate Sales

"Intermediate Sales" is the only category normally omitted from GNP, since it would lead to many instances of double counting. A calculation of GNP does not count the value of wheat in flour if it has already accounted for wheat production elsewhere.

The most important contribution of I-O is the method of computing these intermediate sales. We have 185 industries in our system, leading to an astonishing 34,225 (=185^2) possible intermediate sales to other industries, including sales made completely within one industry. Presently, 14,000 contain non-zero entries. This matrix has actually been estimated for the United States economy by the Bureau of Economic Analysis (BEA) for the years 1958, 1963, and 1967. Presently, through a process of updating, our matrix is based on 1971 data.

With this matrix of transactions, we then have a shopping list of inputs for each industry, and we can derive a set of direct or technical coefficients (a_{ij}) giving us the weight of the i^{th} item in the list for the j^{th} industry. More precisely, a_{ij} is the value of the i^{th} product used as input to produce one dollar's worth of product j. For example, in 1967 the Motor Vehicle industry required \$0.0206 worth of rubber, \$0.071 worth of iron and steel, and \$0.0571 worth of metal stampings as direct input to each dollar of motor vehicle output. If we assume that the j^{th} industry's demand for each item on the list is proportional to its own output, then we can solve equation (1) simultaneously with similar equations for every other industry.* In this way we obtain industry outputs that are in balance with current input requirements and with final demands.

The system outlined above is a good one for evaluating such problems as the current period impact upon all industries of a change in automobile sales. We can easily trace the resulting changes in the purchases of steel, rubber, glass, plastic, and other items on the auto industry's shopping list. But this is only a <u>static</u> application of the input-output <u>table</u>. It does not, for example, evaluate the income effects of this change in auto demand, nor does it tell us anything about resulting changes in investment plans by the auto and steel industries, which in turn would each have further effects on the steel industry.

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*For those a bit familiar with matrix algebra, let A be the matrix of all the a_{ij}'s, and F be the vector of total final demands for each product. If Q is the vector of total output, then:

$$Q = F + AQ, \text{ the solution for which is:}$$

$$Q = (I-A)^{-1}F$$

where I is the identity matrix, and $(I-A)^{-1}$ is called the "Leontief Inverse" or the matrix of direct and indirect requirements per dollar of delivery to final demand.

D. INFORUM: Beyond Input-Output Tables

INFORUM, on the other hand, is a consistent dynamic forecasting model. This means that industry outputs are determined year by year on the basis of forecasts for all product markets, the building of sufficient capacity to produce those outputs, and the availability of labor. Thus no industry is allowed to grow faster than the sum of all its markets. While the I-O matrix plays quite an important role in this model, it should be clear now that it helps us to forecast only one of the several types of markets to which any product is sold. Hundreds of forecasting equations using various regression techniques are used to forecast final demands, productivity and other series in INFORUM.

An integral part of this procedure is the estimation of coefficient change, since few, if any, production processes will remain exactly the same over the medium to long term.

1) The Input-Output Table in INFORUM

The basic structure of the input-output coefficient matrix in INFORUM is, at present, derived from the detailed 480 industry 1963 input-output matrix produced by BEA. Work on implementing the 1967 BEA table, including comparing the estimated 1967 table with the actual, is now underway. The reader should note that the complete BEA tables are much more detailed than the aggregated versions published in the Survey of Current Business and in Scientific American.

Two major differences exist between the most recent published table and the one actually used in INFORUM. The first comes about because the published BEA matrix is defined in terms of sales by establishments and purchases by product; this matrix is definitionally hybrid -- an "establishment-product" matrix. The INFORUM matrix, on the other hand, has been "purified". This means that the secondary products of an establishment are reassigned from the industry where it was produced to the industry where its production is primary. For example, lumber produced in a plant whose primary product is furniture is transferred back to the lumber industry. Along with this reassignment of outputs, it is necessary to reassign those inputs necessary for the production of that secondary output. The basic assumption used for reassigning inputs to secondary production is that a given product is made by the same process, no matter what kind of establishment makes it.

The result of this "purification" is to transform the input-output matrix from an "establishment-product" hybrid to a "product-product" purified matrix. Consequently, INFORUM's input-output data are defined in terms of products. This is in direct contrast to other I-O models that produce output data in terms of outputs by establishments, and allows INFORUM to incorporate meaningful coefficient change procedures.

The second alteration made to the BEA matrix is to update it to the most recent complete set of data available. Currently we are using a matrix which has been "balanced" to 1971 row controls (outputs) and column controls (total inputs). Soon we will be using the 1967 BEA matrix, purified and then updated to 1972 controls largely derived from the 1972 Census of Manufacturers.

2) Coefficient Change

The problem of coefficient change has been approached by analysts from many different directions. We avoid the approach made in many models, where coefficient change is treated as a residual to be explained away. These models make no attempt to determine exactly what individual coefficient changes are implied or whether they are reasonable. More important, they are incapable of producing the consistent details of INFORUM's unique Matrix Listing during forecast years.

In INFORUM, and particularly in the Chase Econometrics version, we take the more direct approach. In those industries where coefficient change is expected, we have undertaken to examine the actual paths of the coefficient over time. Reasons for this change may be the introduction of new technologies, or changes in laws (witness changes due to environmental regulations), preferences, or relative prices. The time-series data that are used for this analysis do not come from the I-O tables. As is well known, the government produces the tables once every five years or so, and then usually with a five to six year lag. Consequently we use data from other parts of government, from a host of industry associations, and from various trade publications.

We use three basic methods to project the value of input-output coefficients into the future.

1) Assumption of a constant coefficient. We might think at first that all very small coefficients should be randomly tossed into this category. But even these must be examined. An example may suffice to show why. During the last decade the coefficient for sales of integrated circuits to electronics would have been very small -- a minor input to electronics, but to project such a coefficient into the future at a constant level would be absurd. All told, less than 10% of our coefficients remain constant.

2) Ex Ante forecasting. Ex ante forecasting is essentially a process of (a) taking estimates, usually from engineers, of the technical input structure for some product in a future year, (b) translating this structure into a numeric framework compatible with input-output analysis, and (c) depending

upon assumptions about the timing of introduction of this new technology, incorporate the new column of technical coefficients in the I-O structure.

3) Determine the historical pattern of movement in a coefficient, and fit that pattern to an S-shaped logistic curve. The method then gives a non-linear extrapolation of the historical path of the coefficient. This method is an improvement over both the assumption of constant coefficients and of linear extrapolation. Using logistic curves we can more realistically forecast the use of new technologies whose rate of growth will inevitably level off after several years. In many cases, these logistic paths have been shown to approximate closely the likely path of the coefficient derived from ex ante forecasts and engineering information. We are in the process of improving the procedure by including other relevant variables, such as relative prices, into the logistic formulation. Among other things, this will greatly facilitate Chase Econometrics' ongoing research into the direct and indirect effects of commodity inflation and the energy crisis.

E. Macroeconomic Impacts

Before analyzing the inter-industry impacts of the NASAHI and NASALO expenditure levels, it is necessary to prepare a macroeconomic forecast using each of these alternatives. The results of these alternatives on the aggregate economy are shown in Table 2.3. While the results are not dramatic, they do indicate that the direction of change in economic activity from an increase in the level of NASA expenditure is positive and beneficial. The magnitudes are small because the total Federal expenditure has not been altered and these improvements result solely from a shift within total Federal expenditures. Nonetheless, these results do indicate that NASA expenditures are less inflationary than other Federal government expenditures, and that a shift toward higher NASA spending with a constant Federal expenditure is not inflationary in the present economy. Conversely, it would follow that a shift away from NASA to other Federal programs could be relatively inflationary in the present economy. Further, the employment effect of NASA expenditures is beneficial, although not large for this small change, and thus both goals of higher employment and lower rates of inflation would be hindered by a lower level of NASA expenditure.

TABLE 2.3

MACROECONOMIC IMPACT OF NASAHI AND NASALO EXPENDITURES

	NASALO 1975	NASAHI 1975
Gross National Product	1529.9	1530.1
Gross National Product (1958$)	820.7	820.8
Consumer Price Index (% change)	10.5	10.5
Disposable Personal Income	1084.9	1085.0
Wholesale Price Index (% change)	15.5	15.6
Federal Government Deficit	17.0	16.9

All figures are in billions of dollars except where indicated otherwise.

NASAHI = NASA expenditures during 1975 of $2.35 billion in 1971 dollars.

NASALO = NASA expenditures during 1975 of $1.35 billion in 1971 dollars.

The changes that are presented between the NASALO and NASAHI expenditure levels are not large, all being in the last digit or changes of $0.1 billion, except for GNP where the change is $0.2 billion. Since these gross aggregates are inadequate to examine the full impact of this small change, we now turn to the microeconomic results of utilizing the INFORUM model.

F. Industry Impacts

1) Employment

We first examine the manufacturing sector. As shown in Table 2.4, employment is increased by 20,000 jobs in total manufacturing. While the statistical significance of the magnitude of this change is questionable, it is nonetheless evident that NASAHI creates jobs rather than destroying jobs. This is particularly important for 1975 when the U. S. economy will be attempting to recover from the longest recession in the post-World War II period.

Aggregate U. S. employment as estimated in the INFORUM model increases by 7,000 jobs in 1975 under the NASAHI assumption as compared with the NASALO assumption. This change also confirms that NASA spending creates rather than destroys jobs.

2) Output

Manufacturing output in 1975 (measured in 1971 constant-dollar terms) is 0.1% higher under NASAHI than under NASALO. This increase of $847 million in output results only from a redistribution of government spending from other Federal government expenditures to NASA expenditures. It is also important to note that the manufacturing sector will be slowest to recover during 1975 because of the secondary effects of the severe recession in the automobile industry, and that again the effect of this shift will be stabilizing.

3) Productivity

The shifts in industry output caused by an increase in NASA spending redistribute some demand in addition to creating new demands. This redistribution of demand tends to shift spending from traditionally low productivity industries to higher productivity industries, thereby increasing the aggregate productivity in the economy. While the change, as with employment, is once again rather small, it adds to the preponderance of evidence that NASA spending tends to be more stabilizing in a recovery period than general government spending. The increase in productivity, which is measured in thousands of dollars of output per man-year, is shown in Table 2.4.

TABLE 2.4

TOTAL MANUFACTURING OUTPUT, EMPLOYMENT, AND PRODUCTIVITY FOR 1975

	NASAHI	NASALO	Ratio
Output (billions 1971 dollars)	$ 789.340	$ 788.493	1.001
Employment (millions of jobs)	20.061	20.041	1.001
Productivity (thousands of dollars per man-year)	39.347	39.344	1.0001

G. Inter-Industry Effects

1) Employment

In the 94 industry disaggregation of the U. S. economy for which the INFORUM model computes employment forecasts, the NASAHI assumption results in higher employment than the NASALO during 1975 in four industries and in lower employment in six industries. The remaining industries were unchanged by varying this assumption. While only four industries were aided, this resulted in an aggregate increase of 28,000 jobs, primarily in the aircraft and ordnance industries. The aggregate loss of jobs in the six manufacturing industries affected totaled 7,000 jobs, with no individual industry showing a large change. Table 2.5 presents the employment results for the affected industries.

TABLE 2.5

EMPLOYMENT BY INDUSTRIES AFFECTED BY A NASA SPENDING SHIFT

EMPLOYMENT BY SELECTED INDUSTRIES			HI (thousands)	LO	DIFF
Industry Number	Industry	SIC Code			
5	Missiles and Ordnance	19	154	142	+12
59	Machine Shop Products	359	191	190	+ 1
67	Communication Equip.	366	404	402	+ 2
71	Aircraft		501	488	+13
	Total				+28
22	Logging and Lumber	241, 242	307	308	- 1
25	Furniture	25	543	544	- 1
27	Paper and Products	26 (ex 265)	501	502	- 1
30	Printing & Publishing	27	688	689	- 1
31	Industrial Chemicals		295	296	- 1
72	Shipbuilding	373	169	171	- 2
	Total				- 7
	Net gain in Manufacturing Employment (thousands of jobs)				+20 *

2) Output

Of 185 industries of the U. S. economy for which the INFORUM model prepares total shipments forecasts, the NASAHI assumptions increase demand for 21 industries, reduce demand for 130 industries, and have no output effect on 34 industries. As was shown in Table 2.4, the aggregate manufacturing output was increased, but it is particularly important to examine the major

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* Round-off error

industries affected, particularly in areas where supply conditions have persistently caused bottlenecks, and in which these constrained supply conditions have caused severe inflationary pressures.

We first examine the basic materials industries in Table 2.6. The demand for all of these materials, excepting aluminum, is decreased slightly by the shift in spending from NASALO to NASAHI. Of course, NASA expenditures will continue to utilize all of these materials, but the net change as compared with the average of other Federal government programs results in reductions in demand in these industries. This result is due to the large equipment component of NASA expenditures and probably results from the significant intermediate demands placed on these industries by other government programs.

These small reductions in demand pressure would, at the margin, contribute to relief in terms of inflationary pressures on these industries. It is also important to note that several of these industries depend heavily on imported raw materials and should therefore benefit the U. S. balance of payments position slightly.

TABLE 2.6

SHIPMENTS OF BASIC INDUSTRIES

	NASAHI	NASALO	DIFF
Copper	6260	6267	- 7
Industrial chemicals	20662	20682	- 20
Steel	34931	34933	- 2
Zinc	515	515	0
Lead	546	547	- 1
Aluminum	8010	7985	+ 25
Structural metal products	14391	14399	- 8
Computers	11302	11323	- 21
Petroleum refining	30658	30685	- 27

All figures are in millions of 1971 dollars.

The effect on NASA's major supplying industries is even more dramatic than the effects on basic materials industries. Table 2.7 indicates the change in shipments by each of NASA's major supplying industries. It is noted that the aggregate change in shipments by these industries is greater than the $1.0 billion change in expenditure between NASAHI and NASALO assumptions. This additional increase occurs because the redistribution in government spending has some feedback effects in the economy during the first year of expenditure and these multiplier effects themselves increase demand in these industries.

TABLE 2.7

SHIPMENTS BY MAJOR NASA SUPPLYING INDUSTRIES

	I-O Category	NASAHI	NASALO	DIFF
20	Guided Missiles	2890	2324	+566
127	Communications Equipment	13576	13500	+ 76
134	Aircraft	8019	7880	+ 39
135	Engine	3198	3080	+ 18
136	Aircraft Parts, etc.	5097	4768	+329
			Total	1028

All figures are in millions of 1971 dollars.

Considering the possible inflationary effects of a demand increase in these industries, we must first attempt to get an estimate of capacity in these industries. Because no accurate measure of physical capacity exists for these industries, we have used employment data as a proxy. Both production worker and total employment was examined for peak years and for an average of pre-Vietnam and post-Vietnam years to conclude whether resources should be available in the economy to permit an increase in output in these industries without increasing factor costs significantly. Table 2.8 indicates that employment in three of these industries has declined substantially both from peak years of 1966 for Electronic Components and Guided Missiles and 1968 for Aircraft. Additionally, each of these three categories has declined on average during the post-peak Vietnam period, indicating a substantial margin of slack capacity in these industries. Only Instruments has seen a growth in employment from 1968 to 1973. There should not be any resultant supply difficulties in these industries which account for virtually all of NASA spending, and it is therefore unlikely that this demand increase will affect the overall rate of inflation in the U. S. economy.

TABLE 2.8

EMPLOYMENT IN MAJOR NASA SUPPLYING INDUSTRIES

	1966	1968	1973	1969-1973 average	1960-1964 average
Aircraft	417	489	275	333	328
Guided Missiles	159	150	95	99	157
Instruments	431	462	495	466	359
Communication Equipment	468	523	438	468	415

(thousands of jobs)

It should be noted in particular that in addition to only one industry, instruments, having employment above its prior peak year, only instruments has a level of employment above its 1969-1973 average, showing a secular trend which must leave substantial idle capacity in these industries.

3) Productivity

Just as in total manufacturing there was no statistically significant change in productivity during 1975 as the result of a higher level of NASA spending for individual industries, there are also few productivity changes. Of 87 industries for which output per man-year is calculated, increases were shown in only two industries, ordnance and aircraft, both of which would be expected. In neither case was the increase significant. Only one industry showed a reduction in productivity as a result of the NASAHI assumption; this change was insignificant and was in the service sector.

H. Conclusions

In this section of the study, we have shown that a shift to NASA expenditures from other Federal government spending will stimulate the economy without raising prices. In particular, we found the following effects of a shift of $1 billion in 1971 dollars.

1) A higher level of NASA expenditures would not have an inflationary impact on the U. S. economy during 1975 and would probably reduce the inflation pressures in the economy.

2) A shift of $1.0 billion in 1971 dollars, or $1.4 billion in 1975 estimated prices, from other Federal non-defense expenditures to NASA expenditures will reduce the inflationary pressures in several key basic materials industries.

3) A shift to increase NASA expenditures will increase employment by 25,000 in the missile and ordnance and aircraft industries. While it will reduce employment in six other industries, the net increase in the manufacturing sector will be 20,000 jobs.

4) Output will be stimulated in twenty-one industries. The principal industries which will be affected currently have considerable excess capacity and are producing at levels well below their peak years and in most cases below the average of the past five years.

5) A shift toward higher NASA spending within the framework of a constant level of total Federal expenditures creates jobs without raising the rate of inflation, and hence is more stabilizing in a recovery period than general government spending.

3. THE LONG-RUN ECONOMIC IMPACT OF ALTERNATIVE LEVELS OF NASA R & D SPENDING

A. Introduction

While the set of short-run simulations were instructive, they were severely limited in scope. There is little question that it is important to determine whether increases in NASA spending would or would not contribute to inflation in the short run, since we are warned almost daily of the inflationary impact of increased government spending even when the unemployment rate exceeds 9%. Yet most observers would agree that if R & D spending does have a beneficial effect on the economy, it occurs primarily through an increase in the rate of technological progress, both in the originating industry and through spillover effects. These changes clearly do not work their way through the economic system during the year in which the R & D spending is originated, and in general have little effect for at least two years. Thus if we are going to explore the effects of R & D spending on the economy, we need to move to a long-run simulation scenario for that reason alone.

Yet there is an even more important reason why we need to consider the long-run implications of higher R & D spending. An increase in the rate of technological progress leads to an expansion of the production possibility frontier because more output can be produced with the same amount of input. However, this increase is not automatically transferred into a rise in aggregate demand. Instead, improvements in technology lead to lower prices, which raise real disposable income. Consumers can then spend the additional disposable income on more goods and services, including but certainly not limited to new products fashioned from the new techhology. It is this boost in real income which leads to the higher level of demand, output, and employment which we find in our simulations. This process also takes time to work through the system. As a result, the major effects of increased R & D spending are not felt until several years from the date of original expenditures. When these occur, however, they are likely to be very significant.

Thus we need to consider both the demand effects of increased spending and the supply effects of a higher rate of technological growth and hence a larger total productive capacity. Since R & D spending increases the rate of technological progress, it permits a greater rate of capacity expansion and also lowers the rate of inflation, hence increasing the real purchasing power of consumers. In the absence of technological progress, wage rate increases could not be offset by productivity gains, and thus prices would increase by the same proportion. This actually reduces real disposable income, since consumers are faced with a progressive tax schedule which is denominated in current prices. Higher prices also result in inadequate accumulation of capital consumption reserves, since these reserves are based on historical rather than replacement costs. Thus significant long-range benefits accrue to all sectors of society when the rate of productivity gain is increased.

In this section of the report we first describe the macroeconomic approach to measuring the rate of technological progress, hereafter referred to as γ. We then relate γ to a number of factors which represent the determinants of increases in productivity, including R & D spending. We next use the regression coefficient for NASA R & D spending in this equation to determine the historical rate of return with respect to supply effects which has been realized. Finally, we simulate the effects of increased (or decreased) NASA R & D spending on the U. S. economy over a ten-year period.

B. The Macroeconomic Approach to Estimating the Rate of Technological Progress

The macroeconomic approach to estimating γ has often been criticized. In a well-written and frequently-referenced article, M. I. Nadiri (51) states the case thus:

> Aggregation is a serious problem affecting the magnitude, the stability, and the dynamic changes of total factor productivity ... that the use of the aggregate production function gives reasonably good estimates of factor productivity is due mainly to the narrow range of movement of aggregate data, rather than the solid foundation of the function. In fact, the aggregate production function does not have a conceptual reality of its own; it emerges as a consequence of the growth processes at various microeconomic levels and is not a causal determinant of the growth path of an economy.

What say we to these charges?

The problem of aggregation in economics is a thorny one about which relatively little is known even today. Yet this has not hampered the development of theoretical and empirical research in other areas of economics. It has often been shown that one cannot logically proceed from an individual Engel curve to an aggregate consumption function, but this has not stopped the flow of work in this area. The concept of aggregate and industry investment functions is almost meaningless in this day and age of the multi-product, multi-division, and multi-national firms, yet no attempt has been made in the literature to trace empirical shifts in the investment pattern of a given firm among various products, industries or even countries as expected rates of profit change. The aggregate wage rate function, usually referred to as a Phillips curve, is governed primarily by inter-industry shifts; Lipsey (35) tried to develop this concept at an early stage but it has received virtually no support in the past fifteen years. Yet the aggregate consumption, investment and wage rate functions have become established as the cornerstones of macroeconomic analysis. One wonders why the admitted difficulties of the aggregation problem are focused almost exclusively on the production function.

We can shed some light on this question by examining in skeleton form the historical development of work on the aggregate production function and growth in factor productivity; the literature is reviewed in greater detail in Appendix A. Paul Douglas (20), in his pioneering work, argued strongly for the existence of an aggregate production function of the form

$$X = AL^{\alpha}K^{1-\alpha} \quad (3.1a)$$

where α = the elasticity of labor with respect to output.
X, L, and K stand for output, labor input and capital input respectively. This is universally known as the Cobb-Douglas production function.

Douglas defended his position on the grounds that the relative shares of labor and capital have remained constant over long periods of time. He also estimated functions of the form

$$X = AL^{\alpha}K^{\beta} \quad (3.1b)$$

and found that $\alpha+\beta$ was not significantly different from unity. The use of an exponential trend, written as

$$X = AL^{\alpha}K^{\beta}e^{\gamma t} \quad (3.1c)$$

was popularized by Solow in 1957 (61), who also reported that $\alpha+\beta$ was close to but slightly less than unity.

Two main flaws were perceived in this approach. First, the size of the residual γ appeared to be much too large to be ascribed strictly to random or exogenous events. Furthermore, it contained significant long-run fluctuations. The first major work to point this out was that of Abromowitz and Fabricant (1, 25); the bulk of the more recent work has been done by Denison (14, 15) and Kendrick (32). Thus research in the past twenty years has centered on alternative forms of the aggregate production function.

The large residual element measured by γ suggested a number of problems with the simple aggregate production function. One problem is clearly the possibility of omitted variables, such as those influencing the quality of labor or capital inputs. Another problem arises from the heterogeneity associated with the inclusion of vastly different industries in an aggregate function and the nature of the inputs themselves. A third problem is that the resources devoted to technological change may well be endogenously determined, or at least should be separately identified and not simply lumped into the residual category. Fourth, the Cobb-Douglas function essentially incorporates a static approach, whereas improvements in technology filter through the economy only after many years. Fifth, changes in relative factor prices may result in changes in factor demand and hence different growth rates in technology. This list could be extended almost indefinitely, but these areas represent the major criticisms of the Cobb-Douglas approach.

We deal with the last point first, since it has generated the most voluminous outpouring of discussion. The Cobb-Douglas function assumes that the elasticity of substitution between factors, usually denoted by σ, is unity. This follows directly from the assumption that α and β are equal to factor shares under the assumptions of perfect competition and cost minimization. However, a more general class of production functions for which the elasticity of substitution can take any (constant) value was developed by Arrow, Chenery, Minhas and Solow (4) in 1961. Such a function, known universally as a CES function, is derived from the equation

$$(3.2) \quad \log\left(\frac{X}{L}\right) = \alpha + \sigma \log\left(\frac{w}{p}\right)$$

where w is the wage rate and p the price of output.

If we impose the constraints of pure competition and cost minimization, this function can be transformed to

$$(3.3) \quad X = \gamma \left[\delta K^{-\rho} + (1-\delta)L^{-\rho}\right]^{-\mu/\rho}$$

elasticity of substitution $\sigma = \frac{1}{1+\rho}$ clearly tends to unity as $\rho \to 0$.

It would not be useful in this report to discuss the hundreds of esti- [illegible] ich have been calculated; some of these are cited in Appendix [illegible] er, we can summarize these findings by saying that in the vast majority of cases, the estimated values for σ are less than unity, suggesting that the Cobb-Douglas function is invalid. Yet the estimates of σ have turned out to be extremely sensitive to the method of estimation and specification. Furthermore, we cannot ignore the fact that factor shares have remained relatively constant over long periods of time.

One of the major problems in estimating production functions, whether Cobb-Douglas, CES or any other variety, is the assumption that firms are satisfying their cost-minimization criteria at all times. As a practical matter, firms almost never manage to accomplish this because they are unable to predict ahead with perfect certainty. Thus they continually find themselves in disequilibrium situations which result in underutilization of one or more factor resources. As a practical matter, firms would not adjust the number of employees for every change in output even if these were known in advance because of the substantial costs of hiring and firing. Thus when we use actual data, as opposed to only those points along the production function, it is small wonder that we obtain estimates of $\sigma < 1$. In fact, if we were to shorten the unit time period used in estimation from annual to quarterly or monthly, we would find the values of σ decreasing to zero.

The range of problems which we have just been discussing bears a striking resemblance to early work done in the area of the consumption function, where it has long been determined that (a) the cross-section estimates of the marginal propensity to consume (mpc) are smaller than the time-series estimates, and (b) the mpc decreases as the time period is shortened. Both these problems were solved by the introduction of the concept of the permanent income hypothesis, which in its empirical formulation results in a distributed lag for the income term. While some questions have been raised about the strong version of this hypothesis, namely that the long-run mpc = apc, almost no one questions the dynamic nature of the consumption function itself.

Yet virtually no attempts have been made to introduce dynamic structure into the production function. The only attempts have been by Murray Brown (9), who has used a distributed lag on factor prices. Such an equation is usually known as a variable elasticity of substitution (VES) function; many other versions of VES functions have also been formulated. However, this idea has not been adequately explored on an empirical basis. Thus even though the CES function admits the possibility of different values of σ, it has never been transformed into a dynamic equation. The emphasis has instead been spent on varying σ with respect to factor intensities but not with respect to time.

The other problem with the CES function is the question whether the firm is actually on its cost-minimization function. In this case, one way to handle the problem is to deal with full-employment equivalents of outputs and inputs. This is by no means a trivial task, as witness the large variation in series of full-capacity output which are available. However, well-defined criteria can be used to construct these series. This is the methodological approach which is used in this study.

If we estimate an aggregate production function under either of these approaches -- distributed lags or use of full-capacity data -- we indeed find that the elasticity of substitution does return to unity in equilibrium conditions. Thus the Cobb-Douglas function does represent a useful empirical approximation to an aggregate production function under these criteria. This suggests that most of the mountains of work on the CES function has been a red herring. For all of the other complaints levelled at the Cobb-Douglas function are equally applicable to the oversimplified two-factor static CES function as well.

These other complaints cannot be dismissed simply by including distributed lags or moving to full-capacity measures, however, and deserve our further attention. Thus we first turn to the methodology used to construct full-capacity estimates of γ, and then return to the question of other variables which could be included as determinants of γ.

C. Estimating a Time Series for γ

It is thus our contention, based on the foregoing discussion, that a Cobb-Douglas function with constant returns to scale accurately represents the relationship between labor, capital and output providing that full-capacity measures of inputs and output are substituted for actual values. Thus

(3.4) $X_c = AL_c^{\alpha}K^{1-\alpha}e^{\gamma t}$ and hence

(3.5) $\log X_c = \log A + \alpha \log L_c + (1-\alpha) \log K + \gamma t$

In these equations K refers to actual capital in place and hence is the same whether we consider actual or full capacity output. Since we will be referring to full-capacity measures throughout this section, we drop the subscript c. Differentiating (3.5) with respect to time, we then have

(3.6) $\frac{\Delta X}{X} = \alpha \frac{\Delta L}{L} + (1-\alpha) \frac{\Delta K}{K} + \gamma.$

Our task now is to find adequate measures of X, L, and K. We can easily estimate α from factor share data, and find it to be 2/3, as has been reported elsewhere.

We turn first to the estimates of L and K, which are reasonably straightforward. We have:

$$(3.7) \qquad L = \frac{E}{\left(1 - \frac{UN}{100} - \frac{UN_H}{100}\right)} * h_{max}$$

E = total employment including self-employed and agricultural workers

h_{max} = index of maximum hours of work per week

UN = rate of unemployment, %

UN_H = rate of hidden unemployment, %

$$(3.8) \qquad UN_H = \sum_{i=1}^{4} \left\{ \left[\left[\alpha+\beta t\right]_i - \left(\frac{LF}{POP}\right)_i \right] * \left(\frac{LF_i}{LF}\right) \right\} * 100\%$$

where

$\alpha+\beta t$ is a trend line through peak points of labor force participation rates by each age-sex classification. As t increases the value of the expression, $\alpha+\beta t$ also increases indicating that labor force participation rates increase over time.

LF_i = labor force by age-sex classification

POP_i = population by age-sex classification

$i = 1, \ldots, 4$; groups are
- males aged 16-24
- females aged 16-24
- females aged 25-54
- total aged over 55

We assume no secondary workers in males aged 25-54.

The weakest link in this definition is the use of the measured unemployment rate. For a number of reasons, a given level of unemployment now implies a tighter labor market than was formerly the case. The principal reasons are as follows: *

1) The definition of unemployment in general excludes the self-employed. Thus as this group declines in relative importance, a constant unemployment rate implies a declining rate for wage and salary workers.

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* This section follows Denison (16) pp. 95-96.

This can be seen by a simple example. Assume there are 100 workers in the labor force each year. In year 1, 80 are classified as employees and 20 are classified as self-employed; 10 employees are out of work. Thus the stated rate of unemployment is 10%, but the rate for wage and salary workers is $\frac{10}{80}$ or 12.5%. In year 2, the composition of the labor force shifts so that 90 are now classified as employees and 10 as self-employed; 10 employees are still out of work. The stated rate of unemployment remains at 10%, but the rate for wage and salary workers declines to $\frac{10}{90}$ or 11.1%.

2) Secondary workers in the labor force usually have lower marginal productivity. Thus as the percentage of these workers in the labor force increases, a constant unemployment rate indicates a declining labor reserve measured in terms of effective labor input. It is this effect which we try to measure through the use of the hidden unemployment term, which has declined secularly over the past twenty years.

3) Secondary workers are in general not close substitutes for primary workers. Hence changes in unemployment in secondary worker categories will have very little effect on the supply of labor. This term is also reflected to a certain extent in the hidden unemployment term.

4) Unemployment compensation insurance and welfare benefits have reduced the mobility of unemployed labor resources.

All of these factors tend to work in the same direction, which is that the reported unemployment rates have recently been overstated and hence our estimate of L increases too rapidly. Inasmuch as the secular trend is significant, this method ascribes too much contribution of the growth in output to L and too little to γ. In other words, the series which we produce for γ could actually understate the true residual growth in the absence of offsetting factors. However, this is probably offset by our method of measuring K, as we see next.

The calculation of K is simply given by

$$(3.9) \quad K = \sum_{i=0}^{N_1} \lambda_1^{\,i} (I_{pe})_{-i} + \sum_{i=0}^{N_2} \lambda_2^{\,i} (I_{ps})_{-i} + \sum_{i=0}^{N_3} \lambda_3^{\,i} (I_h)_{-i} + \sum_{i=0}^{N_4} \lambda_4^{\,i} (I_{gs})_{-i}$$

where

I_{pe} = purchases of producers durable equipment

I_{ps} = purchases of nonresidential structures, private sector

I_h = purchases of residential structures, private sector

I_{gs} = purchases of nonresidential structures, public sector

The λ_j are determined so that each $\lambda^N = 0.05$, representing the approximate scrappage value in each case. We choose $N_1 = 15$, $N_2 = 20$, $N_3 = 30$ and $N_4 = 20$ years.

The principal comment to be made about this formulation is that we use the economic equivalent of the capital stock rather than the physical equivalent. This is known as embodied technical change. The physical value of any particular capital good after one year is almost identical to its value when it was new, since physical depreciation or breakdown after one year is most unlikely. However, economic obsolescence may be considerable in a year when new capital goods become available which can produce the same output with less labor input. Thus inasmuch as we use the geometric lag formulation, we may be understating the effectiveness of the capital stock and hence overestimating γ. On balance the biases to γ caused by our methods of measuring L and K are likely to balance out.

We now turn to the question of estimating full-capacity output. The main problem in this task, it turns out, is removing the cyclical fluctuations in the output series. Methods which start with actual output and then try to "blow up" the series to full-capacity levels in general give unacceptable results. This is particularly true if the unemployment rate is used for the blow-up series. As we mentioned above, any method which relies on using the unemployment rate as a measure of the gap between actual and maximum output gives poor results, since it fails to take into account hidden unemployment, shifts in the age-sex composition of the labor force, or the declining share of the self-employed. Series which use capacity utilization were similarly found to be unsuitable. Here the major problem is that capacity utilization is generally available only for the manufacturing sector, which is only about 1/3 of the total economy. Thus when actual output is divided by capacity utilization the resulting series has cyclical bulges in recession years. An example of this is given in Table 3.1, where it can be seen that the potential GNP series calculated by the CEA unemployment method has very large increases either in recession years or the years following--witness 6.7%, 6.3%, 5.6% and 6.4% for 1954, 1958, 1961 and 1971 respectively. Thus we have little trouble discarding this approach.

A much more sophisticated approach has been used by Denison (16). We do not discuss Denison's method in detail; the interested reader is referred to the cited reference, pp. 86-91 and Appendix Q. However, we mention briefly that Denison does define potential national income as

> ... the value that national income would have taken if (1) unemployment had been at 4 percent; (2) the intensity of utilization of employed resources had been that which on the average would be associated with a 4 percent unemployment rate; and (3) other conditions had been those which actually prevailed in that year.

Clearly (2) is the key adjustment which must be made, and Denison performs a large number of data manipulations to handle this problem.

Table 3.1

Measures of Potential GNP

		CEA Trend			CEA Unemployment			Denison		
	Actual GNP	Gap	Potential	% Change	Gap	Potential	% Change	Gap	Potential	% Change
1954	407.0	-17.0	424.0	3.5	-20.2	427.2	6.7	-17.5	424.5	2.8
1955	438.0	- 0.8	438.8	3.5	- 5.5	443.5	3.8	0.6	437.4	3.0
1956	446.1	- 8.1	454.5	3.5	- 1.9	448.0	1.0	- 4.0	450.1	2.9
1957	452.5	-17.5	470.0	3.5	- 3.9	456.4	1.9	-10.9	463.4	3.0
1958	447.3	-39.1	486.4	3.5	-40.1	487.4	6.8	-30.8	478.1	3.2
1959	475.9	-27.6	503.5	3.5	-22.4	498.3	2.2	-13.3	489.2	2.3
1960	487.7	-33.4	521.1	3.5	-23.9	511.6	2.7	-20.2	507.9	3.2
1961	497.2	-42.1	539.3	3.5	-42.8	540.0	5.6	-27.3	524.5	3.3
1962	529.8	-28.4	558.2	3.5	-26.1	555.9	2.9	-12.4	542.2	3.4
1963	551.0	-27.6	578.6	3.6	-29.4	580.4	4.4	-12.1	563.1	3.9
1964	581.1	-19.2	600.3	3.7	-21.9	603.0	3.9	1.2	579.9	3.0
1965	617.8	- 5.0	622.8	3.8	-10.3	628.1	4.2	12.0	605.8	4.5
1966	658.1	11.0	647.1	3.9	4.4	653.7	4.1	19.1	639.0	5.5
1967	675.2	2.2	673.0	4.0	3.2	672.0	2.8	6.0	669.2	4.7
1968	706.6	6.7	699.9	4.0	9.5	697.1	3.7	4.9	701.7	4.9
1969	725.6	- 2.2	727.8	4.0	11.4	714.2	2.5	- 8.2	733.8	4.6
1970	722.5	-34.5	757.0	4.0	-21.7	744.2	4.2	-27.4	749.9	2.2
1971	746.3	-41.0	787.3	4.0	-45.9	792.2	6.4	-32.1	778.4	3.8
1972	792.5	-26.3	818.8	4.0	-42.8	835.3	5.4	-23.3	815.8	4.8
1973	839.2	-12.3	851.5	4.0	-27.7	866.9	3.8	-16.7	852.5	4.5
1974	821.2	-64.4	885.6	4.0	-44.3	865.5	-0.2	-66.3	887.5	4.1

All GNP figures are given in billions of 1958 dollars.
% change refers to the change in potential GNP for each category.