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ENVIRONMENTAL AND HEALTH/SAFETY REGULATIONS, PRODUCTIVITY GROWTH, AND ECONOMIC PERFORMANCE: AN ASSESSMENT

PREPARED AT THE REQUEST OF

HON. HOWARD W. CANNON, *Chairman*

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

UNITED STATES SENATE

and

HON. LLOYD BENTSEN, *Chairman*

JOINT ECONOMIC COMMITTEE

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LETTER OF TRANSMITTAL

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
July 1, 1980.

To Members of Congress:

Transmitted herewith is a study entitled "Environmental and Health/Safety Regulations, Productivity Growth, and Economic Performance: An Assessment," by Gregory Christainsen, Frank Gollop, and Robert Haveman of the University of Wisconsin. The study was prepared for the Office of Technology Assessment as part of a broader assessment of the impact of regulation on industrial innovation. The assessment was requested by the Committee on Commerce, Science, and Transportation in connection with its examination of U.S. industrial technology, productivity, and competitive position in international trade. Because this study deals with the relationship between Government regulations and economic growth, matters which the Joint Economic Committee has studied very carefully, we are cooperating in making it available to Congress and the public.

The study attempts to assess the importance of regulation, relative to other factors, in the Nation's serious productivity slowdown in the past decade. It defines a framework of economic analysis in which previous studies and future research can be evaluated. It examines a few of the policy options that Congress might consider in dealing with these issues.

In our view, this study represents an advance in analyzing critical issues of Government regulation and economic policy. For that reason, we commend it to your attention.

The views expressed by the authors do not necessarily represent those of the Committee on Commerce, Science, and Transportation, the Joint Economic Committee, or their individual members. The report has not been reviewed or approved by the Technology Assessment Board.

Sincerely,

HOWARD W. CANNON,
Chairman, Committee on Commerce, Science, and Transportation.

LLOYD BENTSEN,
Chairman, Joint Economic Committee.

CONTENTS

ENVIRONMENTAL AND HEALTH/SAFETY REGULATIONS, PRODUCTIVITY GROWTH, AND ECONOMIC PERFORMANCE: AN ASSESSMENT*

By Gregory Christainsen, Frank Gollop, and Robert Haveman

EXECUTIVE SUMMARY

INTRODUCTION

By almost any indicator, the macroeconomic performance of the U.S. economy during the past decade has been poor. The growth rate of output, the rate of inflation, the unemployment rate, the rate of capital formation, and the rate of productivity growth have all been disappointing.

This poor performance has occurred at a time when Government has intervened more extensively in the economy than at any other time in U.S. history. The extent of the recent increases in the number of regulations and their complexity is suggested by the evergrowing size of the Federal Register. Regulatory agencies have been required to publish their regulations in the Register since 1937. From a size of 3,450 pages in that year, it increased to 35,591 pages in 1973, to 60,221 pages in 1975, and to 77,498 pages in 1979. The Register was 21,198 pages during the first quarter of 1980.

Environmental regulations and regulations in the area of employee safety and health have been among the most prominent and most publicized of the standards promulgated during the 1970's. In many cases these regulations have imposed large costs on business enterprises. This has raised the question of a possible link between these regulations and the poor macroeconomic performance which has been observed.

It is this question which is the focus of this study. Have environmental and health/safety regulations played a significant part in the economic downturn of the 1970's?

The rate of productivity growth is the key indicator of economic performance which is analyzed. As opposed to indicators such as the growth rate of output, the rate of unemployment, and the rate of capital formation, the productivity indicator summarizes in a single measure changes in both outputs and inputs; defined most simply, productivity is output per unit of input. As such it provides a convenient measure of the efficiency with which an economy is operating.

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*The authors are, respectively, Assistant Professor of Economics, Colby College; Professor of Economics, Boston College; and Professor of Economics, University of Wisconsin-Madison. All were at the University of Wisconsin-Madison when this study was prepared.
Helpful comments by Edward Denison, Dale Jorgenson, Richard Nelson, Roger Noll, and John Young are gratefully acknowledged. John Young nurtured the study with care throughout its several stages.

APPROACH

In section II, the course of changes in productivity and macroeconomic performance during recent U.S. economic history is described. Section III presents a theoretical framework for assessing the role of environmental and health/safety regulations on output and productivity growth. Section IV presents a catalog of those factors most widely suggested as contributing to the slowdown in productivity growth, and employs the theoretical framework of section III in organizing these determinants.

In section V, the primary channels by which environmental and health/safety regulations can affect productivity and economic performance are identified. The effort here is to trace the impact of regulation in a more real-world context than is provided in the theoretical model. Then, in section VI, three case studies are presented to illustrate how regulations create incentives, costs, constraints, or resource diversion which inhibit economic performance.

In section VII, several research studies which have addressed the role of environmental and health/safety regulations on recent economic performance are reviewed and critiqued. The impact of these regulations on productivity growth is emphasized, but their impact on employment and capital formation is also examined. In section VIII, an overall appraisal of the determinants of the slowdown in productivity growth—and the role played by environmental and health/safety regulations—is made.

Finally, in section IX, the study's principal conclusions are presented. It is emphasized that a full appraisal of regulation must recognize unmeasured economic benefits not reflected in most analyses. In addition, the potential for public policy measures in reversing the slowdown in productivity growth is discussed. Two policy proposals are analyzed in detail—the "regulatory budget" and the Auerbach-Jorgenson proposal to stimulate capital formation.

FINDINGS

The facts of macroeconomic performance

All of the major macroeconomic variables have fared more poorly in the 1970's than in the 1960's. The upward trend in productivity suffered severe breaks in 1967, 1973 and perhaps, 1978. By any measure, the rate of productivity growth in recent years has been less than half the rate which prevailed in the 20 years following World War II. Analysis of the productivity performance of individual sectors indicates that three industries—mining, utilities, and construction—account for about one-half of the slowdown in measured productivity growth.

The theory of productivity growth in a regulatory environment

The ability of a firm to improve its level of productivity centers on three key factors—the introduction of technological improvements, the exploitation of economies of scale (defined to include increases in the productivity of inputs), and the intensity with which its actions are regulated by outside authorities. These factors have both direct and indirect impacts on productivity. These phenomena are themselves affected by phenomena occurring outside the firm which it must take as given.

Thus, regulatory intensity may directly impinge on productivity growth or it can do so indirectly by, for example, affecting the productivities of inputs which in turn affect the existence of scale economies which in turn influence productivity change. In addition to the channels identified in the model by which regulatory intensity can affect productivity, there are other, nonmodel channels. For example, regulations can lead to some absolute constraints on the use of certain inputs, forcing a reallocation of resources away from its optimum. Or regulations can induce a slowdown in the introduction of new facilities or the retirement of old facilities, again affecting productivity. Finally, it should be noted that regulatory intensity may bear differentially across sectors, altering the composition of outputs and thereby affecting aggregate economic performance.

Hypotheses on the causes of the slowdown in productivity growth

A reasonable case can be made for at least 25 factors having played a nontrivial role in the productivity deceleration. The slowdown in capital formation and changes in labor force composition are factors which are mentioned most frequently, but environmental and health/safety regulations have also received a great deal of attention.

The channels of regulatory impact

Environmental and health/safety regulations may impact on economic performance in a variety of ways. Mandatory installations of equipment divert capital and labor from the production of conventional outputs to activities which have benefits which are difficult to assess. Regulations have tended to be engineering rather than performance standards, hence, inducing a level of capital investment and capital intensity in excess of that required to efficiently achieve regulatory goals. Regulations tend to be more strictly enforced in the case of new firms and industries—which employ more recent advances in technology—than in the case of a more established enterprises. Finally, regulations have imposed a large legal and administrative burden.

Case studies

In all of three cases studied, regulations are seen to have had significant effects on economic performance. In the first case study, public regulations have hindered the adoption of urban waste-energy conversion systems. The second case study documents some of the adverse effects of the Davis-Bacon Act. The third study indicates that environmental regulations have had a major impact on productivity growth in the U.S. copper industry.

Evidence of the effect of environmental regulations on overall productivity growth

The studies examined indicate that environmental regulations may have reduced the annual rate of productivity growth by as much as a quarter of a percentage point during the mid-1970's. But this must be considered an upper-bound estimate in light of biases associated with the studies in question. In the presence of imperfect data, these studies have made strong—somewhat biasing assumptions—or they have omitted consideration of certain factors which may also account for part of the productivity slowdown. Macroeconometric simulations indicate a smaller impact—an annual reduction of only about 0.1 percentage points in the productivity growth rate.

The effect of environmental regulations on capital investment

Most of the studies of the determinants of capital investment have relegated a minor role to environmental regulations. Two studies for the Congressional Joint Economic Committee point to imbalances and inefficiencies caused by persistent inflation and recession as being the major factors. A leading student of capital formation, Dale Jorgenson of Harvard, emphasizes the importance of strong private sector investment for productivity growth and believes energy prices increases and tax policy to have been the primary reasons for its poor performance in recent years. A few recent studies suggest a stronger role for environmental regulations. Their results are highly tentative and limited in scope. Extrapolating their findings to the economy as a whole is of questionable validity.

The effect of environmental regulations on employment

The employment effects of environmental regulations have been estimated by a variety of methods, the macroeconometric method and microsimulation-general equilibrium method being the most sound. Studies based on these methods indicate that the overall employment impact of environmental policies, though perhaps negative, is not very severe. The impact is likely to be positive in periods when there is substantial investment in pollution abatement equipment. Whether positive or negative, the empirical work to date indicates that the effect on the Nation's unemployment rate is probably less than one-quarter of a percentage point during the 1970's.

The macroeconomic effects of health/safety regulations

There have been very few studies of the global impact of health/safety regulations. The most prominent work has been done by Denison, who estimates these regulations to have caused an annual reduction of 0.05 percentage points in the productivity growth rate from 1967–75. About three-fifths of this reduction is attributable to regulations in mining, a notable statistic in light of the small proportion of the Nation's output produced in this industry. But strong assumptions made by Denison cause his estimates to be somewhat biased in an upward direction. Thus, the effect of health/safety regulations on overall productivity appears to be slight. The impact on total output, employment, and capital formation also appears to be modest. These regulations may have caused the price level to increase somewhat, but any increase in the rate of inflation caused by these regulations is likely to have been temporary.

Allocating the slowdown in productivity among its determinants

There have been two types of studies undertaken to allocate productivity growth among its determinants—"accounting studies" (for example, Denison, Kendrick) and multiple regression studies (for example, Siegel). While both types may yield rough estimates, both have shortcomings.

In the studies which identify cyclical and weather effects, these determinants generally play a significant role. The same is true of sectoral shifts of economic activity and the combination of changes in hours worked or labor force composition. Each of these determinants is estimated to account for from 0 to 0.6 percentage points (on an annual basis) of an aggregate reduction of from 0.2 to 1.1 percentage points (depending on the statistical productivity series used or the time periods studied). The range of estimated percentage points effects due to changes in the capital stock is also large, from 0 to 0.6 percentage points. The same is true of energy prices. For environmental and other regulations, the percentage point effects range from 0.1 to 0.4. A matrix summarizing the conclusions of all of these allocation studies is presented.

Environmental and health/safety regulations and the slowdown in productivity growth: A bottom line

There is no real consensus on the relative magnitudes of the factors responsible for the slowdown in productivity growth. The slowdown in capital investment, the changing demographic composition of the labor force, the changing composition of output, and business cycle factors seem to be most prominent. The impact of changes in relative energy prices remains highly controversial. It seems clear that environmental and health/safety regulations bear some responsibility for poor productivity performance, but little evidence exists to suggest that as much as 15 percent of the slowdown can be attributed to them. A reasonable estimate would attribute from 8 to 12 percent of the slowdown to environmental regulations. This is not to say that all public regulations taken together (including those regarding, for example, new product introduction, transportation, plant location) have not had a major impact. In any case, difficult-to-measure economic benefits and various social welfare questions must be considered before a full evaluation of regulations can be made.

Regulation and the potential for public policy to improve economic performance

Many of the factors which have played an important role in the poor economic performance of the 1970's are outside of the control of conventional government policies. Changes in the composition of the labor force and world oil prices are examples. There are, however, a limited set of factors which appear both to have played some role in recent economic performance and over which government can exercise effective control. Included here are regulations in the areas of health, safety, and the environment and policies to influence the rate of capital formation. The latter might be considered to be independent of the former, or, in some cases, as an offset to the former.

Many policy options have been discussed in recent years. Among those prominent at the present time are the "regulatory budget" and the Auerbach-Jorgenson capital recovery plan. The former would place a limit—a budget— on the total economic costs which regulatory agencies could impose on the economy through their actions. The latter attempts to protect depreciation allowances against erosion by inflation. Both policy options show promise, but questions of implementation and administration prevent them from receiving an unqualified endorsement. However, some form of experimentation or policy action along the lines suggested by these proposals does seem justified in the hope of improving productivity and aggregate economic performance in the 1980's.

I. INTRODUCTION

Since 1965, measured productivity in the United States has had a disappointing and largely unexplained performance. Over the entire period, the rate of productivity change has been lower than in preceding periods. Moreover, the upward trend in labor productivity has been broken (at least) twice during this period. The decreases recorded during these periods were major and largely account for the poor overall performance of this variable—and economic conditions generally—over the period.

This paper deals with the faltering patterns of macroeconomic activity in the 1970's, as these patterns are reflected in the slowdown in productivity growth. The rate of change of productivity is selected as the focus of the analysis—the key indicator of economic performance which we will analyze. Among the range of indicators of economic performance, it is the only one which summarizes in a single measure changes in both output and inputs. This characteristic of productivity measures applies in varying degrees to the variety of such indicators which have been put forth—labor productivity indexes (output/labor input), two-factor productivity indexes (output/labor and capital inputs), and total factor productivity indexes (output/all inputs) such as those we will emphasize in this paper. As a result, the several characteristics of aggregate economic performance—the rate of growth of output (GNP), changes in labor force participation and employment, changes in capital investment, and changes in individual and aggregate price levels—will be dealt with through the more comprehensive productivity growth indicator.

In appraising the performance of this indicator, we will concentrate on the level (or, as we will call it, the intensity) of regulations in the environmental and health and safety areas. Clearly, numerous factors other than regulatory intensity also affect the level of productivity growth in the economy. These factors will be considered only to the extent that they assist in appraising the contribution of environmental and health/safety regulations. And while we will deal with both measured productivity change (as reflected in the standard productivity indexes) and change in full factor productivity, we would note that the direction of the effect of regulatory intensity will tend to be the same irrespective of the productivity concept used.

In section II, we will describe the course of changes in productivity and macroeconomic performance over the 1965–78 period. Three time series indices of productivity will be discussed, and a description of discrepancies among them will be presented. Section III will present a theoretical framework for assessing the role of the environmental and health and safety regulations on output and productivity growth. This framework uses growth in output as its dependent variable, and demonstrates how a variety of attributes of the production process interact to determine this growth rate. These factors include input changes, economies of scale, technological change, and regulation. Section IV will present a catalog of those factors most widely suggested as contributing to the slowdown in productivity growth, and will employ the theoretical framework of section III in organizing these determinants. Changes in any of these determinants could alter measured productivity change and economic performance, and account for their poor post-1965 behavior.

In section V, the primary channels by which pollution abatement and health and safety regulations can affect economic and productivity performance are identified. The effort here is to trace the impact of regulation in a more real-world context than is provided in the theoretical model. Then in section VI, three case studies which illustrate the actual operation of regulatory processes will be presented. These case studies are diverse in their characteristics, but each is designed to clearly identify how regulations by the public sector create incentives, costs, constraints, or resource diversion which inhibit economic performance and productivity growth. In these case studies, the impacts of environmental regulations, energy regulations, utility pricing regulations, transportation regulations, and labor market regulations are all identified and described, as they pertain to economic performance in three sectors of the economy.

In section VII, we review and critique several research studies which have addressed the role of environmental and health and safety regulations on recent economic performance and productivity change. These studies have focused on the effect of environmental regulations on productivity change, the level of capital investment (and, in turn, the effect of capital on productivity growth), and the level of aggregate employment in the U.S. economy. All of these lines of inquiry will be assessed. These studies differ markedly in their data and methods, and hence in their findings. We will seek to understand these differences and to explain them.

In section VIII, we turn our attention to an overall appraisal of the likely role of environmental and health and safety regulations in explaining the lagging economic performance and productivity growth in the seventies. Our appraisal will be based on the studies discussed in section VII, and will implicitly reflect our judgment of the biases and reliability of these various studies. In this discussion, we will introduce a number of other considerations relevant to forming an overall judgment on the role of environmental policy on measured economic performance. In particular, the role of rapidly rising energy prices and inflation itself will be addressed.

Then, in section IX, we will summarize our analysis and emphasize that a full appraisal of environmental and health and safety regulations must recognize unmeasured economic benefits not reflected in our analysis. Also, the potential role for policy measures in reversing the slowdown in productivity growth are appraised, and two of the major policy proposals for reducing or offsetting the adverse impacts on environmental and health and safety regulations on macroeconomic performance will be discussed. These include the regulatory budget and the first-year capital recovery system designed to increase the rate of capital formation.

II. THE FACTS OF POST-1965 MACROECONOMIC PERFORMANCE

In recent years the performance of the U.S. economy in terms of its key macroeconomic indicators has been extremely disappointing. Statistics on the growth rate of output, inflation, unemployment, capital formation, and productivity growth have all combined to paint a gloomy picture.

During the decade of the sixties there was no year in which real gross national product declined, with the average annual growth rate being 4.14 percent (Economic Report of the President, 1980). In the seventies, however, real gross national product showed a decline in 3 years—1970, 1974, and 1975. From 1970 to 1979, the average annual rate of real GNP growth was only 2.91 percent.

In contrast to the widely held view that high rates of output growth are positively related to high rates of inflation, the sixties were also a period of smaller price increases. As measured by the GNP implicit price deflator, the average annual rate of inflation was 2.53 percent from 1960 to 1969. From 1970 to 1979, on the other hand, inflation averaged 6.68 percent.

Less surprisingly, the growth in output during the sixties was also accompanied by lower rates of unemployment. From 1960 to 1969, the Nation's unemployment rate averaged 4.78 percent. The corresponding figure for 1970 to 1979 was 6.19 percent. On the other hand, growth in employment in the seventies occurred at a very high rate, as large numbers of youths and women entered the labor market and obtained jobs.

A declining rate of capital formation has been another source of concern. Real gross private domestic investment advanced at an annual rate of 4.79 percent during the sixties, but increased at a rate of only 2.49 percent during the seventies.

Statistics can, of course, be misleading, and some observers question the relevance of the variables just mentioned as indicators of an economy's performance. Apart from the rate of inflation, all of these variables refer to output or inputs, but not both at the same time. The efficiency with which an economy performs, however, is reflected in its output per unit of input—both output and inputs must be considered.

Measures of the rate of growth of productivity—output per unit of input—thus merit emphasis in assessing an economy's macroeconomic performance. To be sure, this variable has weaknesses as well. In a period when employment is increasing rapidly,[1] for example, an economy may indeed be performing rather well, but diminishing returns to labor inputs may cause measures of productivity to support an overly skeptical point of view. As a simple indicator of an economy's

[1] Employment grew at an average annual rate of 1.84 percent from 1960 to 1969, but by 2.26 percent from 1970 to 1979.

health, however, productivity does offer advantages, and is thus the macroeconomic variable stressed in this study.

In concept, a nation's productivity can be defined simply as its aggregate final output per unit of input. However, because of difficulties in aggregating the diverse outputs and inputs of a modern economy, the measurement of productivity performance is not a straightforward matter. The most common procedure has been to measure productivity by obtaining an estimate of final aggregate private sector output divided by the number of person-hours of labor input used in producing this output. This concept could be called a single-factor productivity measure, and because it does not reflect in its denominator the full set of inputs, it has clear weaknesses. Recently, however, economists have attempted to compile series for private sector output per total factor input, nonresidential business income per person employed, and several related measures. These are designed to avoid some of the weaknesses of the standard labor productivity measure.

By any of the above measures, productivity growth in the United States has undergone a sharp decline since the mid-1960's. From 1947 to 1966, output per person-hour in the private sector grew at an average annual rate of 3.44 percent.[2] During this period there were cyclical deviations from the trend rate of growth, but otherwise the series is a relatively smooth one. Then, beginning in 1966 or 1967, there appears to have been a break in the time trend. From 1966 to 1973, private sector output per person-hour grew at an average annual rate of 2.15 percent, a decline of almost 1.3 percentage points from the earlier period. In 1973, a further break seems to have occurred, and from 1973 to 1978 an annual rate of only 1.15 percent was registered—only one-third of the recorded rate for the immediate postwar period and a further decline of a full percentage point from the years of 1966–73. Estimates for 1979 suggest a very weak performance, one well below the rate of the 1973–78 period. An estimate from the Council of Economic Advisors puts the 1979 rate at −0.9 percent.[3]

If one confines attention to the private sector's nonfarm component, a similar story emerges. Output per person-hour in this subsector grew at an average annual rate of 2.83 percent from 1947 to 1966, averaging about 2.8 percent between the peak years of 1948 and 1955 and about 2.7 percent between the peak years of 1955 and 1965. From 1966 to 1973, the figure fell to 1.87 percent, and the years from 1973 to 1978 saw a further decline to 1.02 percent. Again, the average for recent years is well under one-half of the corresponding figure for the immediate postwar period. Since 1977 was not a peak year, one must be careful in interpreting the figures, but, again, the average for recent years is less than half of the corresponding figure for the immediate postwar period. As the economy approached peak levels of resource utilization in 1978, the results were truly startling. Nonfarm outut per person-hour grew only 0.5 percent for the year, one of the lowest expansion year figures on record. And during 1979, the nonfarm component fell by 1.2 percent.

The use of nonresidential business income per person employed as a measure of productivity performance implies an even more dramatic decline. This measure, which ignores changes in hours worked by the labor force, showed an average annual growth rate of 2.9 percent for

[2] Taken from Mark (1978), p. 486.
[3] "Economic Report of the President" (1980).

1947–66. For 1966–73, it averaged 1.3 percent, and for 1973–78, it actually declined by an average of 0.1 percent per year.[4]

Although single-factor productivity measures (for example, output per person-hour) have serious weaknesses, the picture of productivity change which they yield is not greatly different from that of more complete measures. While total factor productivity in the domestic business economy grew at an average annual rate of 2.9 percent for the 1948–66 period, it grew only at a 1.4 percent rate for the 1966–76 period—once again, the average for recent years is less than one-half that for the immediate postwar period. The deceleration in "labor productivity" growth was somewhat greater due to the deceleration in the growth of capital per unit of labor which occurred after 1966. These postwar patterns in productivity growth are summarized in table 1.

TABLE 1.—POST-WAR ANNUAL PRODUCTIVITY GROWTH RATES IN THE UNITED STATES, VARIOUS MEASURES OF PRODUCTIVITY

[In percent]

	Output per person-hour		Nonresidential business income per person employed	Total factor productivity in domestic private business
	Private sector	Nonfarm private sector		
1947–66	3.44	2.83	2.9	[1] 2.9
1966–73	2.15	1.87	1.3	[2] 1.4
1973–78	1.15	1.02	–.1	NA
1979	–.9	–1.2	NA	NA

[1] For years 1948–66.
[2] For years 1966–76.
Source: Figures for output per person-hour, private sector and output per person-hour, nonfarm private sector were taken from Mark (1978), p. 486. Figures for nonresidential business income per person employed were taken from Denison (1979c), p. 21. Figures for total factor productivity in domestic private business were taken from Kendrick (1978), p. 511.

For the past three decades taken as a whole then, labor productivity in the private business sector has grown at an average annual rate of about 2.8 percent. However, if the trend of the first two decades had continued, the index of labor productivity in 1980 would be about 15 percent higher than the level actually attained.

Significantly, there appears to have been less deceleration in productivity gowth in the economy's manufacturing sector than in other sectors. In 1978 productivity growth was 2.4 percent, which is close to the 1948–69 trend rate of 2.6 percent. For 1978, nonfarm, nonmanufacturing productivity actually fell 0.3 percent so that the index of manufacturing productivity had risen over 12 percent more than the total nonfarm index since the base year of 1967. In the nonmanufacturing sector, the most dramatic slowdown in the productivity growth has occurred in mining, construction, and utilities. Declines in these industries account for more than half the productivity deceleration in the private nonfarm sector during the past decade. These patterns are summarized in figure 1, which shows the pattern of productivity growth in the private nonfarm economy and some of its component sectors.

Comparing productivity trends in the United States with those in other countries is difficult because of differences in the nature and quantities of statistics among the countries. There is a consensus among the numerous studies undertaken, however, that the average

[4] Taken from Denison (1979c).

annual growth rate in labor productivity has been lower in the United States during the postwar period than in most other industrialized countries. And according to the Bureau of Labor Statistics study of manufacturing productivity for 1970–74, the performance of the United States was exceeded by all of the 11 other non-Communist countries studied and also by 1971–75 estimates for the Soviet Union.[5] Output per person-hour is still higher in the United States than in any of these other countries, but the gap has been closing.

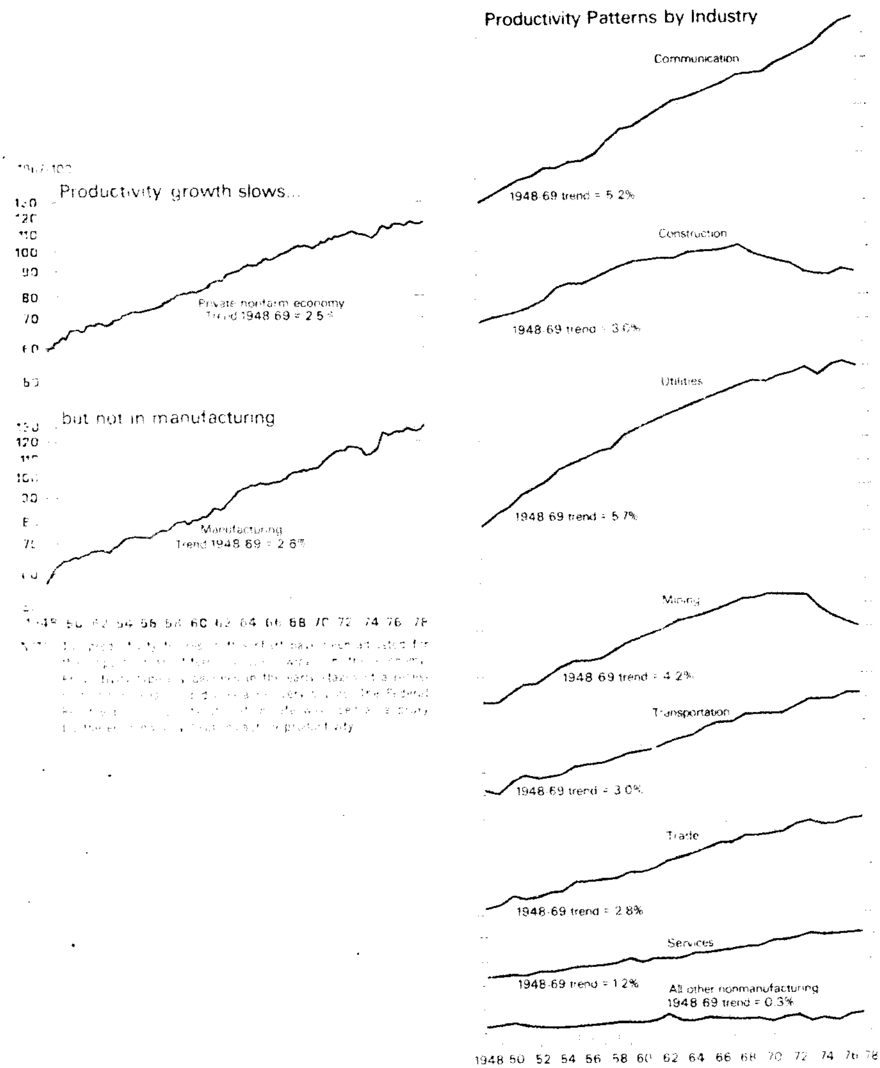

FIGURE 1.—Productivity Indices, by Sector, 1948–78

Source: "Morgan Guarantee Survey," November 1978, p. 8.

[5] See Fabricant (1978), p. 511.

III. A THEORETICAL FRAMEWORK FOR EXAMINING THE DETERMINANTS OF PRODUCTIVITY GROWTH

Productivity change in an economy is an aggregate measure of the success of individual firms and industries in transforming inputs into outputs. Many phenomena contribute to or detract from this success. They range from subtle changes in worker motivation to the propensity to innovate in both process and product improvements to sudden exogenous shocks to the production process (for example, radical energy price increases) to an alteration in the output mix from outputs which are measured in conventional national accounts (for example, autos) to those which are not (for example, worker satisfaction or environmental quality) to the nature and intensity of regulatory policy.

Not only are these determinants numerous, but they interact in a complex and dynamic way. Without some effort to structure the primary determinants in a systematic framework, little progress in disentangling the determinants of productivity change can be expected. In particular, little success in understanding the role of environmental and health and safety regulations in the productivity growth process can be expected without such an analytic framework.

In Appendix A, we present an economic model of productivity growth that formally characterizes the potential productivity effects of regulatory policy. By means of this model, a number of distinct direct and indirect productivity effects of regulation can be represented explicitly. Regulatory policy is certainly an independent source of productivity growth and therefore can make a direct contribution to a firm's productivity performance. Quite independently, important indirect effects can also result. Changes in regulatory intensity can affect the contributions of the other unique sources of productivity growth. An important motivation for our model is the need to formally identify and distinguish these direct and indirect effects.[6]

A secondary objective is to identify the technical restrictions consistent with alternative models of regulatory effect. Perhaps changes in regulatory policy affect the existence of economies of mass production but not the rate of technical change. If so, regulations may be a source of the productivity slowdown but not of the alleged decline in the rate of technical change. Each hypothesis implies a unique set of technical restrictions.

Examining the structure of models consistent with these and other regulatory hypotheses focuses attention on the various independent and often mutually exclusive mechanisms by which regulation can affect productivity. As such, the general model presented serves as the conceptual framework for our study. We attempt to discuss the central

[6] As will be noted below, regulatory policy may have impacts on economic and productivity growth, conventionally measured, which are not accounted for in this model. These will be described as extra-model impacts.

issues addressed in this study in terms of the economic concepts introduced in our model.

The structure of our model is specified by the microeconomic theory of production. A firm's output is assumed to be a function of the inputs it employs, regulatory intensity, and time. We assume that input markets are competitive but we require neither competitive output markets nor "constant returns to scale" (output always responding in proportion to a given change in all input levels).

The rates of change in output with respect to the various arguments in the production function have particular economic interpretations. The rate of change of output with respect to time indicates the firm's rate of growth. The percentage change in output with respect to a given percentage change in a particular input—constraining the levels of other inputs, regulatory intensity, and time to be constant—is that input's output elasticity. The sum of the firm's output elasticities equals the degree to which scale economies exist—the exponential factor by which output can be expected to increase given a proportional change in all input levels. The percentage change in output with respect to a given change in regulatory intensity—constraining the levels of all inputs and time to be constant—is defined as the rate of regulatory effect. Finally, the percentage change in output with respect to a given period of time—constraining the levels of all inputs and regulatory intensity to be constant—is defined as the rate of technical change.[7]

The rate of productivity growth is then seen to reflect the contributions of three factors: Scale economies, regulation, and technical change. Regardless of the reasons for changes in a firm's rate of productivity growth, these changes will be reflected in the contributions of one or more of the above factors.

Figure 2 presents a simple scheme which is based on the formal model developed in the appendix. While an incomplete representation of that model, it does capture some of its essentials. All of the source components of productivity growth—scale economies, regulatory intensity, and technical change—are themselves affected by other, prior phenomena which are not identified in the figure. For example, technical change occurs over time as knowledge from research and development activities becomes embodied in the production process of an enterprise. As this knowledge is incorporated, technical change occurs and more output is achieved with a constant level of inputs, and with no additional contribution from economies of scale and regulatory activity. In a more elaborate diagram, then, this knowledge from research and development would have a separate box with an arrow from it to technical change.

The importance of this schema, however, is that it not only identifies the three primary sources of productivity growth, but it also shows that regulatory intensity has an indirect effect on productivity growth through affecting the levels of the other two determinants—technical change and economies of scale. These indirect effects are independent

[7] As so defined, technical changes captures any phenomena associated with time which leads to an increase in output with no change in inputs or regulatory intensity. Thus, a costless innovation that reduced the waste associated with producing lumber from trees would be reflected in the measure of technical change over time. Viewed in this way, technical change is a residual variable in explaining economic and productivity growth.

of regulation's direct effect. The total effect of regulatory intensity is the sum of its direct effect and its indirect effects.

Examples of these indirect effects may make interpretation of the framework more straightforward. Consider first the effect of regulatory intensity on technical change. One hypothesis might be that environmental regulations require the diversion of the skills of engineering and technical personnel in the enterprise toward pollution control and away from activities designed to improve the production process in line with evolving research findings and knowledge regarding existing or available technology, personnel policies, or the organization of the workplace. Such diversion would retard technical change over time and consequently would lead to a decrease in the firm's technology relative to the knowledge frontier.

Similarly, consider the indirect effect of regulatory intensity on economies of scale. Occupational health and safety regulations, for example, often affect the organization of the workplace and the design of the production process. Such reorganizations or redesigns may well alter the extent to which increases in inputs—land, labor, capital, energy, et cetera—lead to expansions in output. At the same time, other occupational health and safety regulations might affect the inherent productivity of a particular input. Such a regulation might, for example, require the addition of a safety device or a noise abatement device to a machine, which device lowers the activity rate of the machine from n revolutions per minute to $n-x$ revolutions. The regulatory activity, then, decreases the inherent productivity of the machine (and, implicitly, of the worker who operates the machine). In both instances, the OSHA regulations may alter the slope of the firm's longrun average cost curve which reflects the firm's average cost of producing only its conventional outputs.

The direct effect of regulatory intensity on productivity is perhaps the easiest to visualize. If environmental regulations require the use of labor and capital in order to, say, abate residual emissions to environmental media, the inputs to the firm would now be able to produce a lower level of conventional output. The regulations, thereby, directly reduce firm productivity.

As these examples suggest, regulatory intensity affects enterprise productivity through rather distinct processes or mechanisms, some of them direct and some indirect. In analyzing the role of regulatory policy in explaining the recent decreases in productivity growth and lagging economic performance, it will prove helpful to keep these distinct channels of impact in mind.

However, like any economic model, this framework is not a comprehensive one. It does not exhaust the possible channels by which regulatory policy can affect economic growth Here we will describe some of the more prominent of these "extra-model" channels of impact.

The first extra-model channel concerns the potential impact of regulations in constraining the level of use of any of the inputs to the production process. Although such a constraint would lead the firm to input choices which are nonoptimal, the regulatory effect would be different than that described in the model as altering the marginal product of the impact. As we shall see in a later case study, current environmental regulations are believed to so limit capital investment in the copper industry. Moreover, environmental regulations are often asserted to impede the process of gaining approval for new plantsites, hence causing delays in capital investment or plant openings. This effect, if it exists, would also constrain the flow of inputs into an enterprise. It is not explicitly captured in the model.

A second extra-model effect should also be mentioned. Regulatory intensity may decrease productivity change through one of the direct or indirect channels indicated in the model. Because of this decrease, the relative prices of the affected commodities may increase. These higher prices will become costs of other producers, in turn resulting in higher prices for their commodities. These higher prices will retard the growth of demand in these impacted sectors. To the extent that there are potential economies of scale in these activities attainable only through the growth of demand, these will be foregone because of regulatory intensity. This effect is a general equilibrium effect which would affect aggregate productivity change in the economy. However, because the model concerns the determinants of productivity change in a single firm, it will not be captured in the model

A third extra-model channel should be considered as well. The production function framework underlying the model pertains to a single production activity. Aggregate performance of the economy, however, is an aggregate of the performance of numerous individual activities. Regulatory intensity may bear differentially across sectors, altering the composition of outputs and affecting aggregate economic performance. This compositional effect will not be captured in the model. In considering the full effect of environmental and health and safety regulations on economic performance. these more subtle dynamic and compositional extra-model effects must not be overlooked.

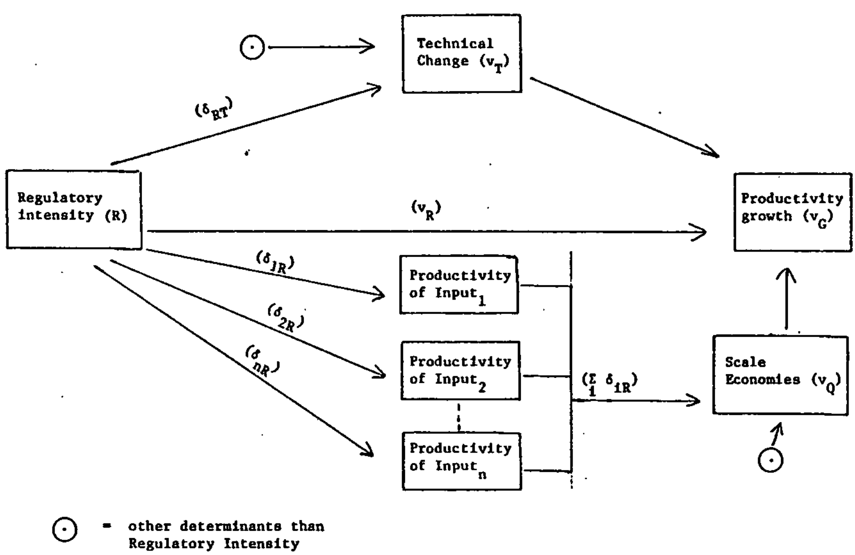

Figure 2

IV. HYPOTHESES ON THE CAUSES OF THE POST-1965 SLOWDOWN IN PRODUCTIVITY GROWTH

The model of productivity growth in the appendix is "firm specific." By specifying the nature of a firm production function, the primary unique determinants of productivity growth are isolated, including what we have called "regulatory intensity " To move from this model to a model of productivity growth for the economy as a whole, one must aggregate these "firm specific" functions. For the entire economy, then, changes in the composition of the firms over which the aggregation occurs—in addition to the primary determinants—will also affect productivity growth. Moreover, our firm specific model recognizes that each of the primary determinants is itself a function of prior variables. For example, technical change over time is likely to be determined by the growth of knowledge generally, and in turn the growth of knowledge is likely to be a function of aggregate R. & D. spending. Thus, in understanding aggregate productivity growth, the role of the primary determinants of firm productivity growth and the forces which affect them must be considered, as well as changes in the composition of firms in the economy.

A further complication also arises. The implicit notion of full factor productivity growth which is embodied in our theoretical model does not conform to the conventional measures of productivity growth. The conventional index is either a single factor index—the ratio of the aggregate time series for total output in the economy and the time series for total person-hours of input—or one which has only labor and capital inputs in the denominator. As a result, changes in some of the primary determinants of productivity growth which we have identified will not affect the conventional measures of productivity change in the same way and to the same extent. Because of the inadequacy of these measures, full factor productivity—as we have defined it—might well be increasing while some conventional measure of productivity change is decreasing. Having said this, however, it should be noted that the direct effect of regulatory intensity on productivity growth is likely to have the same sign, irrespective of the productivity measure.

In section II, we identified the changes in productivity growth which have occurred since 1965, as captured in the conventional indexes. Because part of our task is to understand why these measured indexes have performed so inadequately in recent years, we will mention a few of the most widely hypothesized causes of the post-1965 slowdown in this section. In doing so, however, we will employ the categories isolated in the theoretical model—regulatory intensity, technical change, change in individual factor productivity (which manifests itself in reduced scale economies), and change in output composition.

At the outset, however, it must be recalled that the quantitative magnitude of the decline in productivity growth varies somewhat with the empirical measure which is used. The use of nonresidential business income per person employed, for example, ignores changes in hours worked. In fact, however, part-time employment has grown in recent years, especially with the rapid growth of women and teenagers in the labor force. There have also been minor reductions in the average hours of full-time wage and salary workers. Largely for this reason, then, productivity growth for 1973–78 was actually negative by this measure (see table 1).

The difference in the magnitude of the slowdown in productivity growth implied by the use of total private sector output person-hour as opposed to private nonfarm output per person-hour is accounted for by the marked shift of labor from the farm to the nonfarm sector which has occurred over much of the last three decades. Because the level of labor productivity in the farming sector had been much lower than that for nonfarm labor, this shift has contributed to the rise in overall labor productivity which has taken place. However, most of this shift in the labor force occurred before 1966. Since 1967, very little additional movement has taken place. Moreover, levels of labor productivity in the farm and nonfarm sectors are now much closer than they have been in the past. For this reason alone, then, one of the major sources of productivity growth—as measured by total private sector output per person—in the two decades after the war was no longer available in the third decade. And, as a consequence, few gains in total private sector labor productivity have resulted from this source in recent years.

As previously mentioned, the decline in the growth of labor productivity has exceeded that of measures which consider total factor input because of recent declines in the growth rate of the aggregate capital-labor ratio.

TECHNICAL CHANGE

The contribution of technical change to productivity growth occurs over time as technical and organizational knowledge becomes incorporated into the production process of individual firms. It is, of course, difficult to measure how much more we "know" now compared with 1967 or 1973, or how much of what we "know" has been incorporated into the production process now, as opposed to 1967 or 1973. However, a prominent hypothesis is that a slowdown in technical change has accounted for a major portion of the slowdown in measured productivity growth.

There is some modest support for this hypothesis in the data on research and development (R. & D.) outlays in the United States. Undoubtedly, a major contributing factor to past advances in knowledge has been substantial and growing R. & D. outlays. In recent years, the pace of such spending has not been as rapid as in the past.

As a percentage of gross national product, R. & D. spending reached a peak in the mid-1960's during the high-water years of the NASA space effort. At that time R. & D. accounted for roughly 3 percent of GNP. Since 1966, however, R. & D. has undergone a slow decline until it now accounts for only about 2 percent of the Nation's spending.

R. & D. spending by the private sector has grown steadily with GNP, but Government-financed efforts have not.

While a plausible source of the slowdown in growth, this factor has not been assigned much weight by most observers. For example, (Denison, 1979b) notes that advances in knowledge only increase measured productivity growth if they result in innovations which reduce the unit costs of products already in existence (process innovations). To the extent that they lead to the introduction of new final products (product innovation), measured productivity growth is not affected. Much federally financed R. & D. involves advances in knowledge of the latter type. Since the proportion of private R. & D. has not fallen, Denison concludes that "there is no assurance that R. & D. spending contributed anything to the decline in productivity growth."

CHANGES IN ECONOMIES OF SCALE

A second potential cause of the slowdown in productivity growth concerns a reduction in available economies of scale waiting to be exploited by U.S. firms. Like the technical change category, this is a difficult source to document. Again, however, some circumstantial evidence does provide support for this hypothesis.

There are several considerations which have led many to conclude that economies of scale are an important factor. First, there are some industries in which there are potential economices of scale, but these economies may occur only at output levels which exceed those currently demanded by consumers. During a slowdown in general economic growth, then, it may not be possible to exploit these economies.

Another possibility is that because the U.S. economy has "matured," the number of industries to which the above discussion applies has dwindled. Demand may be sufficient to achieve the economies which are available, but there just aren't many more to be had.

Changes in the level of scale economies may also become important in a period when there are significant changes in input prices. In the electric power industry, for example, there is evidence that higher fuel prices have increased electricity rates constraining the demand for electricity and have caused utilities to choose input combinations exhibiting lower scale economies (Gollop and Roberts, 1979).

Moreover, as noted in the theoretical discussion in section III, changes in individual factor productivities—whether induced by regulatory intensity or by other factors—appear as a change in economies of scale. Numerous hypotheses have been put forward concerning the role of the decline in individual factor productivity in explaining the slowdown in aggregate productivity growth—for example, the decline of the work ethic, the lapse of "Yankee ingenuity," and the changing composition of the labor force. Again many of these hypotheses are difficult to verify, although in some cases empirical evidence does give some clues.

Consider, for example, the changing composition of the labor force. During the post-1966 period there have been sharp increases in the labor force and in labor force participation rates, and the age-sex composition of these increases has been heavily weighted toward women and teenagers. In 1964, prime-age males (those 25–54) composed 46 percent of the labor force. For 1978, the figure was 36 percent. In part this has been due to the fact that persons born during the "baby boom" reached working age and entered the labor force. It also reflects the recent explosion in labor force participation by women.

Because they lack experience and have average education levels below the prime age working groups, new entrants into the labor force are typically less productive than their more experienced counterparts. This is most apparent in the case of teenagers. In the case of women, barriers have existed into the more productive lines of work, irrespective of age, and women have also had relatively fewer opportunities for training.

In the future, the composition of net increments to the labor force is expected to have a positive effect on productivity. Because of a large drop in the birth rate in the 1960's, relatively fewer youths will reach working age in the 1980's. It has been estimated that the population aged 16 to 24 will decline by a full 6 million people. At the same time, the number of persons 25–54—the years of peak productivity—will be increasing substantially. In addition, women are expected to gain increasing access to training and more productive lines of work.

A second potential source of change in factor productivities relates to the effect on individual factor productivities due to an unexpected exogenous change in the relative price of a single factor, which change induces short-run factor substitution resulting in a shift of the firm from its long-run, least cost expansion path. The energy price change in 1973 and subsequent years is of this exogenous unexpected sort. While for many years, U.S. citizens enjoyed the availability of cheap sources of energy (largely because of public policy measures), 1973 brought an abrupt end to this situation. The quadrupling of the world price of crude oil by the OPEC cartel undoubtedly had a severe effect on the production processes of the economies of the world's industrialized nations. While changes in relative prices may occur daily without tremendous strain to whole econnomies, the magnitude of the energy price change, combined with the complementary nature of energy and capital, was a serious blow. The sharp hike in energy prices increased the obsolescence rate of a good deal of capital already invested. Plant and equipment intended to be used over a period of years suddenly became less productive to employ. Moreover, there were adjustment costs as businesses had to employ resources, first, to learn how to operate in the new energy environment, and second, to actually make the necessary adjustments in the structure of production.

A third potential source of the productivity slowdown that can be categorized under the topic of a change in factor productivities is the measured change in the capital-labor ratio. A common hypothesis is that artificial contraints—for example, taxes, reduced savings due to income transfer programs—have reduced capital investment, causing a short-run shift in production processes away from least cost optima. This shift is not unlike that related to the energy increase, resulting in a reduction in factor productivities.

An economy's rate of capital investment (which is reflected in the capital-labor ratio) is of substantial importance for achieving increases in productivity, regardless of the measure used. It is largely through new plant and equipment that more advanced technologies are introduced into the production process. Moreover, in the absence of increases in capital inputs, producers will experience diminishing marginal returns to each additional unit of labor employed. One of the most striking features of those countries which have achieved high levels of productivity has been the accompanying increases that have occurred in these countries' capital-labor ratios.

At the same time that the labor force in the United States has experienced an increase in its growth rate, the country's capital stock has grown at a somewhat reduced rate. From 1947 to 1973, the capital stock grew at an average annual rate of 4 percent. Since 1973, however, this average has been only 2.5 percent. Net of depreciation, capital per employed person rose at an average annual rate of about 2 percent from 1948 to 1969, but fell to about 1.2 percent thereafter.

Returns to capital (profits, net interest, rental income, and depreciation) have represented about one-third of private sector income throughout most of the postwar period. According to growth theory, a 1-percent decline in the capital stock will then produce a one-third percent decline in the economy's overall growth rate. A 1.5-percent annual decline in capital stock would thus have produced a 0.5-percent annual decline in the Nation's overall growth rate.

The reduction in factor productivities, then, is a potential source of the decline in productivity growth. In turn, this decline in factor productivities could well be related to the changing composition of the labor force, the unanticipated increase in energy prices, and the constraints on capital investment.

REGULATORY INTENSITY—THE EFFECT OF ENVIRONMENTAL AND HEALTH/SAFETY REGULATIONS

Over the past few years, government regulations have required that an increasing proportion of the labor and capital employed by business be devoted to the protection of employee health and safety and to pollution abatement. While such regulations may involve substantial benefits, their contribution to measured output—the marketed goods and services produced—is minimal. Capital spending as a percentage of gross national product, which has fallen to 9.5 percent from a peak of 11 percent in the mid-1960's, drops to 8.7 percent if one considers the investments mandated by these regulations to be nonproductive, in the sense of producing measurable output.

Since 1967 there have been numerous regulations issued governing worker health and safety. The Occupational Safety and Health Act (OSHA) was perhaps the most noteworthy piece of legislation in this regard. Also to be considered are safety regulations with respect to motor vehicles and legislation to protect employee health and safety in coal, metal, and nonmetal mining. The increase in health and safety regulations in the mining industry has been particularly striking.

As for pollution control measures, there were certainly undertaken prior to the mid-1960's (the Water Pollution Control Act of 1948, the Air Pollution Control Act of 1955, and the Clean Air Act of 1963), but early legislation did not affect business costs the way subsequent measures did. The measures undertaken in the more recent period include the Water Quality Act of 1965, the Motor Vehicle Air Pollution Control Act of 1965, the Air Quality Act of 1967, the Clean Air Amendments of 1970, and numerous other amendments to these basic air and water pollution laws. State and local governments have also passed a variety of measures and have enforced existing provisions more strictly.

If adapting to these changes in regulations has caused inputs to be employed which make little contribution to measured output, then measured productivity has suffered on this account. Of course, if these changes have produced benefits which are not captured by conventional measures, then "true" output has actually been somewhat higher than the official statistics indicate.

This resource diverting impact of regulations constitutes the direct impact of regulatory intensity defined in the theoretical section. In addition, it must be recognized that regulations can effect productivity growth indirectly through its effects on technical change and factor productivities—and through them economies of scale—as noted in section III.

THE COMPOSITION OF OUTPUT

The primary sources of productivity growth noted above are those identified in the firm-based model described in section III. As has been indicated, however, aggregate productivity growth reflects the aggregation of firm production functions. Hence the composition of the national output is also a relevant variable. And, a good deal of speculation has surrounded output composition as a potential source of the slowdown in productivity growth.

One obvious speculation regarding the slowdown in productivity growth in the nonfarm private business sector concerns the increasing share of output accounted for by services as opposed to manufactured goods. The relative share of manufacturing in total employment has been declining steadily now for two decades. And in the most recent period from 1972–77, output in services rose 45.8 percent (in terms of 1972 dollars) while manufacturing output rose only 39.9 percent. GNP rose 41.29 percent. Since productivity in services has been, on average, below that in manufacturing, overall productivity may have slowed as a result of the shift to services. (This slower growth in productivity in the services sector is seen in figure 1.)

Not only has productivity in services been below that in the rest of the economy; it has fallen further and further behind the rest of the economy over time. In 1948, service productivity was 96 percent of the economywide average; by 1977 it had fallen to 61 percent of the average.

If one looks at the composition of the additional hours worked within the service sector during the 1972–77 period, 43 percent of the increase occurred in health services. This had led writers such as Thurow (Thurow, 1979) to emphasize the importance of the unit cost of health care (which, of course, has been increasing rapidly) in explaining the decline in productivity growth.

In this discussion, then, we have noted many of the prominent hypotheses concerning the slowdown in productivity growth, and have related them to the theoretical framework of section III. In the next section, the factor of primary interest—regulatory intensity—will be looked at in more detail. In particular, we will attempt to describe some of the practical, real world channels by which regulatory intensity can—directly and indirectly—affect productivity growth.

V. ENVIRONMENTAL, HEALTH, AND SAFETY REGULATIONS AND PRODUCTIVITY GROWTH: THE CHANNELS OF IMPACT

In the previous section, the catalog of the most widely discussed determinants of productivity change was presented. One of the items in that catalog is environmental, health, and safety regulations imposed on enterprises. In this section, this determinant is discussed in more detail. In particular, the channels by which such regulations might effect either the output numerator or the input denominator of productivity indexes are discussed. To keep this discussion simple, we will speak of only pollution control regulations, although analogous channels of impact exist for each of the other forms of regulation as well.

The hypothesis that environmental regulations induce reductions in productivity growth is based on several conjectures. Each conjecture relates to some aspect of policy-induced business behavior which could lead to an increase in inputs with no corresponding increase in output or, conversely, a decrease in output with no corresponding change in labor input. The following represent the major types of behavioral responses by business firms in response to environmental regulations which could lead to reduced productivity growth. In our description of them, we have tried to be as realistic as possible, yet maintain consistency with the theoretical framework of section III (and Appendix A).

1. Pollution control regulations require residual reducing investments. which investments compete with normal investments in production plant and equipment, crowding out the latter to some unknown extent. Hence, labor has less capital with which to work than it would otherwise have, and as a result its output may be reduced. In this way, regulations would be input biasing.

2. Pollution control regulations tend to be engineering standards rather than performance standards, hence, inducing a level of capital investment and capital intensity which is in excess of that required to achieve the residuals reduction desired. This excess capital intensity may also crowd out normal investments in plant and equipment.

3. In both water and air pollution regulations, new sources of pollution are subjected to much more stringent standards than existing sources.[8] This uneven treatment tends to induce business to retain existing—and lower productivity—plants and equipment in use longer than otherwise, and to delay the introduction of new capital with more advanced technology.

[8] In the water pollution area in the United States, the "best available technology" (BAT) and "best practical technology" (BPT) standards were delayed or not enforced for existing plants. New plants, however, have had to meet "best available demonstrated control technology standards." In the air pollution area in the United States, existing sources deal in an ad hoc fashion with State enforcement and implementation agencies, while new sources are mandated to install the best available technology.

4. Pollution control equipment, once installed, requires manpower for its operation and maintenance. This manpower adds to labor input with no addition to salable output.

5. To avoid dislocations in the form of plant closings and manpower layoffs, environmental regulations have been enforced more stringently in the case of fast growing than of slow growing industries, hence, inhibiting an important source of productivity increase.[9]

6. Related to 5, utilities have both high productivity growth records and are relatively immune from layoffs and closing. Environmental regulations imposed on this sector, therefore, tend to be more stringent, hence, inhibiting output growth in a sector which has historically experienced a high rate of productivity increase.[10]

7. Efforts to avoid any deterioration of pristine areas—the "prevention of significant deterioration" (PSD) provision—has eliminated desirable new plant locations for growing industries, entailing retarded plant construction or choice of less productive locations.

8. The conformance to environmental regulations, including the securing of information regarding them, the obtaining of information regarding options to meet them, and the legal and administrative activities undertaken to avoid, delay, or change them requires labor services which yield no salable output.

9. Closely associated with environmental regulations are land use controls. These controls have both made some prime candidates for plant location inaccessible to cost of site choice decisions. In particular, as has been emphasized by Quarles (1978), meeting this requirement has delayed the rate of plant expansion and modernization, and has stretched out the construction period. These effects translate directly into productivity reductions and, because of their effect on capital investment, also indirectly impede the rate of productivity growth.

In principle, each of these channels of potential impact are empirically testable. In practice, however, data does not exist to quantify any one of them with reliability. However, this is not to say that efforts have not been made to attribute to environmental regulations some amount of the post-1965 reduction in productivity growth rate.

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[9] This assertion has been made in Crandall (1979a) and Crandall (1979b). Crandall documents that those industries bear'ng the bulk of required pollution control expenditures in the 1973–76 period have had higher growth rates than all industries combined in the United States. This is particularly true of the chemical and electric utility industries.

[10] Nearly 30 percent of total nonfarm private business expenditures for pollution control has been in the electric utility industry during the 1973–76 period in the United States. See Crandall (1979a), p. 7.

VI. ECONOMIC GROWTH, PRODUCTIVITY CHANGE, AND PUBLIC REGULATIONS: THREE CASE STUDIES

PUBLIC REGULATIONS AND URBAN WASTE-ENERGY CONVERSION SYSTEMS— A CASE STUDY[11]

Dependence on foreign oil is an important drag on economic growth in the United States and lies at the heart of the U.S. balance of payments problem. At the present time, about 45 percent of the Nation's oil and 5 percent of the Nation's gas are imported. Because of this dependence, U.S. energy prices have risen in line with OPEC's escalations, and legislated efforts to control the allocation and use of oil, to promote its conservation, and to stimulate exploration have been implemented. And while a good deal of discussion on petroleum substitutes and new energy sources has occurred, few new sources have emerged as financially viable. A reasonable hypothesis is that the body of public regulations—by distorting prices and incentives—has retarded the development and introduction of alternative energy sources. In this section, the case of a new set of technologies for transforming municipal waste to energy will be explored, and the role of public regulations in inhibiting this development will be appraised.

At the present time, about 150 million tons of municipal solid waste (MSW) are generated each year. This is expected to increase to 225 million tons by 1990. The vast bulk of this waste is collected and disposed of by municipal governments by means of incineration, land fill, or ocean dumping. The cost to society for this collection and disposal is $30 per ton—a total bill of $4 billion per year. In constant dollars, this total cost is expected to rise to $10 billion per year by 1985.

Much of this solid waste is combustible—about 75 percent—and each ton could provide the equivalent energy of 65 gallons of fuel oil or 9,000 feet of natural gas. Moreover, it is low in sulphur content and can be fired in available steam boilers. A number of waste-to-energy conversion processes are now commercially available, and several more are in some stage of development or testing. The primary of these new technological possibilities are:

1. Incineration with heat recovery;
2. Refuse derived fuel (RDF), to be used in conventional boilers;
3. Pyrolysis (thermal decomposition to produce oil or gas);
4. Bioconversion (biological decomposition to produce energy); and
5. Hydrogenation (high pressure conversion to produce oil).

[11] Much of the background information for this case is from U.S. Comptroller General (1979a).

Although these processes are available and widely used in Europe, only about 1 percent of U.S. solid waste is converted into energy at the present time.

Given the availability of such technologies, why have they not been adopted in the United States? Does the widespread use of this technology in Europe reflect uneconomic decisions on their part, or are there special conditions in the United States which deter this innovation here? Do public regulations form some of these special conditions?

The introduction of this new technology in the United States requires that it be commercially viable—that a private enterprise be able to make a profit on its introduction or that a municipality be able to reduce its solid waste disposal costs because of its introduction. The determination of this commercial viability or cost effectiveness depends on the benefits and costs of its introduction and these benefits and costs in turn depend on observed prices or other institutional arrangements.

The typical procedure required for introducing a waste-to-energy project involves a contract between a municipal government and an energy producing and marketing enterprise. Assuming the enterprise would finance and construct the processing technology, the municipality must be guaranteed by the contract a waste disposal alternative which reduces its costs of waste disposal, and the enterprise must be able to bear the costs of the facility (including obtaining the waste) and market the energy produced in such a way as to yield a net profit.

Assume that adoption of a waste-to-energy process is efficient in that the social benefits exceed the social costs of its introduction—it passes a national efficiency test. Apparently, however, such technologies do not pass the commercial tests of either private enterprises or municipalities or both. Otherwise, innovations of this technology would be far more prevalent than they, in fact, are.

Upon inspection, it appears that several institutional considerations, several of them public regulatory actions, impede the introduction of this technology. These include:

1. State utility rate regulation practices

Current practices by State regulatory commissions allow utilities to pass on any increases in the cost of conventional fuels—oil and coal—in the form of higher rates. At the present time, several regulatory commissions have not allowed utilities to include MSW energy investment costs in the rate base. Because utilities are the primary customers for the MSW fuel produced, this is a serious regulatory impediment.

2. Federal Government energy regulations

For decades now, a central objective of Federal policy has been to keep the domestic price of petroleum products below the real costs of producing them or buying them on the world market. Proposals for the "deregulation" of the price of crude oil involve allowing the price to move up toward its market clearing (or world price) level. Maintenance of an artificially low domestic price of crude oil restricts the ability of substitute fuels—such as MSW derived fuels—to compete with conventional fuels. In effect, current Federal energy policy subsidizes the petroleum option, thus retarding the introduction of alternative potentially lower real cost energy sources.

3. Federal and State land use and environmental regulations

As explained above, a primary mode of solid waste disposal at the present time is landfill. During the course of municipal landfill operations, serious environmental costs are imposed on neighboring sites, which costs may continue after landfill activity. Land prices do not reflect these disamenities, and environmental regulations do not require municipalities to bear these costs. As a result, use of landfill relative to MSW energy conversion appears attractive. Were environmental and land use regulations structured to require municipalities to bear the full cost of landfill disposal, alternative energy conversion processes would appear more attractive than they do.

4. Federal transportation rate regulations

At present, Interstate Commerce Commission transporation rate determinations award lower per ton freight rates to raw materials shipments than to those of recovered or recycled materials. Apparently, cost differentials do not support these rate differentials. Such regulations also arbitrarily discriminate against MSW energy conversion, and retard the introduction of this technology.

These regulations, then, all work in the direction of retarding the introduction of this new resource recovery technology. Additional institutional constraints involving tax policies biased toward the extraction of virgin raw material relative to recovered or recycled materials, legal prohibitions on long-term municipal contracts with commercial enterprises, and organizational difficulties encountered by individual local jurisdictions attempting to pursue regionally coordinated resource recovery activities reinforce these regulatory impediments. While it is not known with certainty that available MSW energy conversion technologies are cost-effective from a national efficiency point of view, there is evidence that they may well be. If their introduction would serve efficiency, cost reduction, and economic growth goals, it is clear that current regulations—both State and Federal—would retard, at best, or eliminate, at worst, the ultimate adoption of this energy-saving technology. These same regulations will reduce research and development expenditures on these technologies by decreasing the potential return to such activities.

THE DAVIS-BACON ACT AND MACROECONOMIC PERFORMANCE—A CASE STUDY [12]

Although generally not perceived as such, the Davis-Bacon Act is essentially a piece of regulatory legislation. In this brief discussion, the basic provisions of the act will be described, as well as the practices and procedures to which they have given rise. Then, the likely impact of these practices and procedures on economic growth, efficiency, and productivity will be described, as well as the processes by which these results occur.

The Davis-Bacon Act, passed in 1931, requires the Secretary of Labor to stipulate the minimum wages which can be paid to various categories of laborers and mechanics employed on construction or repair contracts (in excess of $2,000), either fully or partially financed

[12] Several reports contributed background information for this case, especially, U.S. Comptroller General (1979b).

by the U.S. Government. These stipulated wages are to be those paid for similar work on similar projects in the area. The original purpose of the act was to discourage nonlocal contractors from winning Government contracts by hiring low-paid labor from outside the project area. In 1977, the act covered about 600,000 contracts and 22 percent of the Nation's 3.8 million construction workers.

Under the act, the responsibility for setting these wages falls on the Secretary of Labor. He, in turn, has delegated it to the Wage and Hour Division of the Employment Standards Administration of the Department of Labor (DOL). This division issues two types of wage standards—a project standard (which pertains to a particular project) and an area standard (which applies to all projects within a defined region).

Before suggesting some of the likely macroeconomic impacts of the act, it is necessary to identify how the wage determinations are made by the DOL. As indicated above, the original purpose of the act was to keep contractors from eroding wage levels in relatively high wage areas by using labor from relatively low wage areas. As the act has been administered, local wages often have not been chosen by the DOL; rather the agency has looked to union-negotiated, collectively bargained wage rates, many times in proximity to the locality but often quite distant from the site. In other cases, DOL has apparently set wages which are below the prevailing rates which the law stipulates. Judgment, rather than surveys, have served as the bases for these determinations. In short, actual wage determinations by DOL show a wide variance around actual prevailing rates.

Because of both the regulations implied by the law and the way the law is administered, several deleterious impacts on the performance of the economy can be identified:

1. The effect of higher-than-prevailing wage determinations

When DOL wage determinations are above prevailing wage levels, it is because of union-dominated wage rates in other localities. As a result: (a) Local contractors are discouraged from bidding in fear of the necessity of having to adjust upward the wages paid in the same locality for similar work (this discouragement implies decreased competition); (b) outside contractors, which are usually unionized, win the contracts, hence extending union practices and wage structures to other localities; (c) the contract prices were higher—and hence more inflationary—than they would have been if union wages had been paid;[13] (d) these higher than prevailing wages reduce the probability that otherwise unemployed workers in the relevant communities would be brought into employment by the new construction; and (e) in much the same way, the market demand for low skilled, disadvantaged workers would be shifted toward more highly paid, highly skilled workers.

2. The elimination of wage competition through wage regulation

Within the constraints of the national minimum wage law, the wage and job competition in the labor market serves an important function. It constrains monopoly power and restrictive practices engaged in by

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[13] The GAO (*op. cit.*) indicated that in these cases, the costs of Government construction contracts were 3–4 percent higher than they would otherwise have been.

some unions; it gives incentive for laborers to move when employment demands are low in their communities, and incentive for businesses to expand or to locate in these same communities. The responses to these incentives are an integral part of a mobile, productive, and competitive society. The administration of the Davis-Bacon Act, by regulating wage levels in nonunion communities to bring them into conformance with those in union-dominated communities, erodes these characteristics of a productive and competitive economy.

3. The reporting characteristics associated with Davis-Bacon are costly and burdensome

Associated with the Davis-Bacon Act is the Copeland Anti-Kickback Act, which require major contractor wage posting, detailed recordkeeping, detailed weekly wage reporting and weekly compliance affirmation, subcontractor monitoring, and data storage and retrieval activities. The GAO has estimated that these private sector contractor costs totaled nearly $190 million in 1977, which when added to DOL and other Federal agency administrative costs, totaled over $200 million. These costs reflect a diversion of real resources from businesses (especially) and result in no increase in measured output. Their presence indicates a direct reduction in measured productivity.

While these regulations, then, take quite a different form from those involved discussed in the MSW-to-energy case, their net result is quite the same—reduced measured productivity, increased prices, reduced demand for unemployed workers, and the diversion of investment activities from their lowest cost, most efficient location, size, and composition.

FEDERAL AIR AND WATER POLLUTION CONTROL REGULATIONS AND THE ECONOMIC PERFORMANCE OF THE U.S. COPPER INDUSTRY—A CASE STUDY [14]

In the first case study, we focused on a particular set of technologies—those for transforming municipal solid waste into energy—and inquired regarding the impact of public regulations in general on the probability of the introduction of that technology, and, if introduced, the effect of regulations on the timing of the introduction. The second case study took a specific set of regulations—those mandated by the Davis-Bacon Act and requiring public setting of wage levels for particular types of workers—and inquired regarding the impact of these provisions on several aspects of economic performance—unemployment, inflation, competition, and factor mobility. In this final case study, our focus will be on a particular set of regulations—Federal air and water pollution control regulations—and their impact on the economic performance of a particular industry—the copper industry. We shall first briefly describe the regulations and then after discussing the nature and structure of the copper industry, indicate how these regulations have affected economic performance in this sector.

Since 1970, both Federal air and water pollution regulations have sought to reduce emissions of pollutants into the environment by means of regulations mandating the installation of particular tech-

[14] Much of the background information for this case is taken from R. Hartman, K. Bozdogan, and R. Nadkami (1979).

nologies by offending industries. For example, the 1972 Water Pollution Act Amendments required offending point sources to install "best practical (control) technology" (BPT) by 1977 and "best available (control) technology" (BAT) by 1983. The Clean Air Act Amendments of 1970 required attainment of national ambient air quality standards by means of (1) the designation of technology-based regulations for new plants, (2) the maintenance of high air quality in presently "clean" areas, and (3) the improvement over time of air quality in currently "dirty" areas. Note that in both the air and water pollution control cases, the imposition of technology-based standards is central to the regulatory strategy.

The U.S. copper industry consists of four principal production processes—mining, milling, smelting, and refining. The first three of these stages are heavily impacted by Federal air and water pollution control regulations, the first two by the water regulations and the smelting process by the air regulations. In this case study, we will concentrate on the air quality regulations and their effect on the smelting stage in the copper industry production process. This stage has been a target of emissions regulations because of its substantial discharge of sulfur dioxide into the atmosphere.

Consider first, the primary characteristics of the air quality regulations, as they pertain to the smelting of copper:

1. The national air quality standards must be met by permanent technologies, and not by intermittent controls such as the dispersal of emissions through tall smokestacks or the reduction of output under stagnant or other poor meteorological conditions. There permanent installations culminate in what is known as the "ultimate emissions limit" which must be met by 1988.
2. All new smelting capacity must contain the best available emissions control technology. "New" is interpreted to mean reconstructed or modified capacity as well.
3. Proposed smelting capacity additions or expansions in "clean" areas must meet particularly strenuous technological requirements.
4. In "dirty" areas, modifications to smelting capacity must result in reduced total emissions throughout the installation of processing equipment capable of the "lowest achievable emissions rate" (often known as LAER).

These regulatory characteristics become transformed into detailed requirements which result in significant reductions of SO_2 emissions of the smelting process of the copper industry. The following gives some notion of the degree of emissions reductions which are achieved by the regulations: [15]

1. The permanent emissions control equipment which is required to meet the 1988 "ultimate emissions limit" will result in at least 90 percent of the sulfur entering a smelter to be "captured."
2. The "reasonably" available control technologies required currently for most existing smelting facilities required the capture of from 50 to 70 percent of the sulfur entering a smelter.

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[15] Since 1977, some variance from these strict controls has been permitted by means of an order permitting existing smelting plants not able to meet (either economically or technically) the ultimate emissions control requirement to temporarily operate with intermittent controls or production cutbacks during adverse meteorological conditions.

3. For any new, reconstructed, or modified smelter, a control technology must be installed which requires 99.6 percent of SO_2 in the gas stream to be recovered. For existing "nonreverberatory" smelters—the most modern of the existing facilities—this implies the capture of over 90 percent of the sulfur entering the facility.

As a result of these specific requirements, the copper industry has been required to both refrain from several activities and to incur substantial investment and operation and maintenance costs in order to meet the regulations.

As examples of constrained activities, consider the following. The current regulations do not permit small expansions to capacity in an existing facility, a traditional means of meeting anticipated intermediate-term demand expansions. While new capacity may be constructed which meets best available control technology (BAT) standards, leadtime requirements keep such capacity additions from being brought "onstream" until 1985. For existing plants which have secured a temporary variance from EPA, an additional uncertainty arises—after the 5-year term of the variance has expired, the agency might well order a total plant shut down. Because of these constrained activities, then, growth of smelting capacity will be severely constrained until at least 1985, and some existing plant shutdowns might well occur.

The major additional investment and operation and maintenance expenditures stem from the need to transform existing reverberatory capacity to nonreverberatory technology capacity by 1988 in order to avoid shutting down. A recent study indicates that if the existing regulations are strictly enforced, total capital investment of from \$1.7 to \$1.9 billion (in 1974 dollars) will be required from 1974 to 1987, in addition to about \$1 billion (in 1974 dollars) of additional operation, maintenance, and control costs—a total of nearly \$3 billion (in 1974 dollars).

Employing a dynamic econometric model of the U.S. copper industry, the economic impacts of these capacity constraints and investment, operating, maintenance, and control cost impacts were evaluated over the 1974–87 period. First, a baseline scenario implying modest environmental regulations was defined and the paths of total output, prices, net imports, consumption, and capacity were estimated. Then, two alternative scenarios were identified, both implying stiff enforcement but with one permitting a more relaxed EPA stance regarding the issuance of variances than the other. In both of the enforcement strategies, the effects of the regulations on the performance of the industry was substantial. By 1987, prices would be 29 to 39 percent higher than in the baseline case, domestic production would be reduced from 25 to 33 percent, net imports would increase from 13 to 21 percent, employment would be reduced from 25 to 33 percent, smelter capacity would fail to grow at all (though capacity utilization rates would increase markedly), and scrap copper prices would increase from 27 to 34 percent above the baseline.

While these impacts are enormous, implying major price and import increases and output, consumption, and employment decreases, it is more the process by which environmental regulations are likely to impact economic performance than the magnitude of the impacts which is of the primary interest. To be sure, the $3 billion of additional 1974–87 cost—about $230 million per year—is not trivial. However, the major impact of the environmental controls stems from the curtailment of capacity expansion which is involved. It is this restriction which drives up the rate of capacity utilization and with it average and marginal costs. Moreover, by delaying or reducing capacity increments, the technological advances embodied in new capital are delayed or forgone and domestic markets are lost to foreign suppliers. And, it should be noted that in the same way that capacity expansion in the mining, milling, and refining stages of the copper industry are linked to capacity levels in copper smelting, so too is the output and capacity of both suppliers and customers of the copper industry linked to the output and employment levels of this industry. It is this process by which environmental regulations affect capacity and the introduction of new technology in the private sector that this case study illustrates.

VII. ASSESSING THE IMPACT OF ENVIRONMENTAL AND HEALTH/SAFETY REGULATIONS ON MACROECONOMIC PERFORMANCE

THE EFFECT OF ENVIRONMENTAL REGULATIONS ON PRODUCTIVITY CHANGE

Environmental regulations and reductions in productivity growth are both phenomena of the 1970's in the United States. Are they independent phenomena, or has the imposition of regulations caused—or at least contributed to—the slowdown in productivity growth? Numerous studies have directly or indirectly attempted to answer this question, and many more assertions have been made on both sides of the issue. In this section, the primary research studies which have attempted to answer this question will be described, compared, and critiqued.

Without question, the most influential study of the effect of environmental regulations on productivity is that by Edward Denison, reported in the January 1978 Survey of Current Business.[16] This study is part of a larger project which also seeks to estimate the effects of health and safety regulations and rising crime.

In this study, productivity is measured in terms of output (defined as final product in the national income and product accounts) per unit of factor input. Denison confines his analysis to the nonresidential business sector because it is in this sector that environmental regulation is concentrated. Output in this sector is valued at factor cost (including profits) instead of market prices so as to exclude the effects of indirect business taxes. Factor input refers to a combined measure of labor, capital, and land. These three factors of production, and the various types of each factor, are combined by using their earnings as weights. The set of inputs used is not exhaustive. Energy and materials inputs, for example, are not explicitly analyzed. Nonetheless, the aggregate measure of total factor input used by Denison is derived from the national product accounts and, thus, reflects their usage. Denison then estimates the incremental costs of production made necessary by environmental regulations. These costs as a percentage of total factor cost are used as an estimate of the percentage reduction in output per unit of input attributable to regulation. This procedure, in effect, assumes that the factor inputs required for environmental control are diverted directly from producting marketed output, resulting in an equivalent decrease in the numerator of the productivity index.

To estimate the incremental costs of production made necessary by environmental regulations, Denison considers environmental expenditures made by business but not by consumers or government since the latter do count as part of measured output. Capital goods purchased

[16] Denison (1978).

by business for pollution abatement also count as part of measured output, but measured output is reduced by an amount equal to the value of the services this capital would have provided if used to produce final products instead of improved environmental quality. The value of these alternative services (which can be thought of as an opportunity cost) is measured by the sum of depreciation on pollution abatement capital and an imputed net return on his capital which is calculated as the product of the net stock of pollution abatement capital and the ratio of earnings of the capital stock net of depreciation which is observed for capital generally.

Incremental costs attributable to environmental regulations are computed as the difference between the total costs of pollution abatement and a baseline cost level which is defined as either (1) the cost that would have been incurred in the absence of an increase in the stringency of environmental requirements since 1967, or (2) the cost that would have been incurred if the 1967 level of abatement costs had continued unchanged after allowance for economic growth and price level changes.

These environmental policy induced incremental costs are computed for the current costs and depreciation costs for motor vehicle emission abatement, other air and water pollution abatement, solid waste disposal, and for payments to use public sewer systems.[17] Against these incremental opportunity cost estimates are set the value of materials reclaimed as a result of increased environmental expenditures.

Denison then uses this net incremental cost estimate to construct an index of the effect of post-1967 environmental regulations on productivity growth. The index shows that these regulations began to have a significant negative impact on growth by 1970 and that by the mid-1970's this impact was increasing. The impact increased from an average annual effect of .05 percentage point from 1967–69, to 0.1 percentage point from 1969-73, to about 0.22 percentage point from 1973-75. Recently, Denison (1979a) has estimated the average annual effect on productivity growth for 1975–78 to have been only 0.08 percentage point—simply because the percentage of labor and capital devoted to pollution abatement was not rising as fast.

Apart from any biases associated with the excluded factors (see footnote 17), there remain questions regarding the implicit assumptions embodied in the estimates. Two should be explicitly noted. First, Denison implicitly assumes that, for a given level of inputs, marketed output is crowded out by pollution-control-mandated investments on a dollar-for-dollar basis. The decrease in final output which he attributes to pollution control regulations is based upon the output which would have been produced if all mandated pollution abatement expenses had been, instead, expenditures on regular capital or labor and land devoted to producting marketed output. If in fact, because of factor subsitution, pollution control expenditures did not divert equivalent expenditures on standard factor inputs, output would not

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[17] Denison excludes four types of possible incremental costs because of data limitations or because their inclusion might be conceptually questionable: Those involving land and inventories; those for noise, radiation, and pesticide pollution abatement; those for agriculture, real estate operators, and independent professional practitioners; and those involving R. & D. expenditures. Data for the first and third type are not available. The second category of costs are not made by business according to BEA accounts. As for R. & D. expenditures, they are not counted as part of measured output.

fall to the extent estimated by Denison. Denison's estimate is, in fact, an upper bound estimate of the direct (as opposed to the indirect) impact of environmental regulations.

Second, Denison assumes no diminishing marginal rates of return to additional expenditures on standard capital, labor, and land inputs. This is done by attaching average rates of return estimates to the incremental standard inputs which would have been employed had not environmental regulations diverted them. If, as seems likely, these additional inputs would have confronted diminishing marginal rates of return, their implicit contribution to output would have been less than Denison's estimates. Again, an upper bound estimate on the (direct) impact of environmental regulations is struck by Denison.

In a recent provocative article, Robert Crandall attempted a number of statistical approaches to quantify the impact on measured labor productivity of environmental regulations.[18] In a first analysis, Crandall compared the productivity growth performance of the primary "pollution-control impacted industries"[19] in the 1958–70 (or 1973) period—before policy-induced pollution control expenditures really took their bite—with their performance in the post-1970 (1973) period. For the pre-1973, post-1973 comparison, for example, he found that prior to 1973, the impacted industries experienced productivity growth of about 5 percent per year, while manufacturing as a whole had a productivity growth rate of about 3 percent per year. After 1973, however, the situation reversed itself. While the productivity growth rate in the total manufacturing sector fell to an annual rate of 1.4 percent from 1973–76, the productivity growth rate in the impacted sectors fell to less than 1 percent.[20] This simple comparison, of course, says nothing about the other forces affecting these impacted industries which could also have contributed to a reduction of productivity. Changes in energy prices, investment levels, labor force composition, and intraindustry output composition come immediately to mind. It is not unreasonable to believe that pollution-control impacted industries are also energy-price-impacted, cyclical-output-impacted, et cetera, industries as well.

Crandall's second analysis was somewhat more rigorous than this simple comparison. In it, Crandall employs a cross section regression model (using as observations 36 industries for which adequate pollution control expenditure and productivity data are available) to explain the variance in productivity growth rates during the 1973–76 period. The dependent variable is the deviation of an industry's index of productivity from forecasted 1976 productivity based on the historical growth rate of productivity from 1958 to 1973. The explanatory variables are: (1) the ratio of an industry's actual 1976 output to its forecasted 1976 output based on the 1960–73 annual growth rate of output (designed to capture the effect of cyclical swings in output) and (2) pollution-control operating costs as a percent of value added. From the estimated coefficients, he concludes that (1) a 50-percent in-

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[18] Crandall (1979a).

[19] These impacted industries are paper, chemicals, petroleum refining, steel, copper, cement, grain milling, and aluminum in the manufacturing sector, and electric and gas utilities in the nonmanufacturing sector.

[20] For this period the impacted *manufacturing* industries displayed a negative rate of productivity change.

crease in pollution control costs in the 36 industries from their 1976 level would reduce productivity growth by 1.2 percentage points (or about one-third of average annual productivity growth) and (2) if the results are extrapolated to all manufacturing, the reduction in productivity by 1976 attributable to the bulk of pre-1976 pollution control expenditures would be 1.5 percent.[21]

In his final analysis, Crandall fit time series regressions to the 10 impacted industries—plus electric utilities and all manufacturing—over the 1954–76 period. The dependent variable was labor productivity and the dependent variables were (1) two alternative measures of the business cycle and (2) a time trend. By examining the residuals of the regression for each industry for the post-1970 period or (subperiods), Crandall sought to determine if a productivity growth shortfall during this period existed which was not accounted for by the independent variables. He concluded that pollution-control impacted manufacturing industries had larger negative residuals—indicating the productivity growth in the post-1970 period is less than the variables in the model would predict—in the post-1970 period than manufacturing as a whole, but that the difference was not substantial. Electric utilities had a substantial negative residual in all post-1970 subperiods. The relatively small size of the negative residuals for the pollution-control impacted manufacturing industries suggests that cyclical output changes in the post-1970 period accounts for much of the productivity shortfall. The effect of pollution control regulations estimated in this analysis is substantially smaller than that estimated by Denison for 1973–75.

While Crandall's analysis is consistent with other studies suggesting a nontrivial role for environmental regulations in explaining the recent productivity slowdown, his analyses are in no way definitive, as he clearly recognizes. The magnitude of the pollution-control burden does appear to explain some of the shortfall in productivity performance in his cross section analysis with the coefficient on the pollution control expenditure variable being significant at the 0.01 level of a one-tail test. His extrapolated estimate of a 1.5-percent reduction in productivity growth due to environmental controls—which is the cumulative effect of (at least) 3 years—is higher than the impact suggested by Denison, who estimates that output per unit of input was only 1 percent lower in 1976 than it would have been in the absence of environmental regulation. But this cross section analysis controls only roughly for but one additional potential determinant of productivity declines during the 1973–76 period—cyclical swings in output. Hence, the effects of the host of other potential determinants of productivity change—the pattern of R. & D. spending, changes in energy prices, changes in labor force composition—are either reflected in the constant term of the regression or, if positively correlated with environmental control expenditures, partly picked up in that variable.

[21] In an updated version of this cross section analysis, Crandall presents estimates which imply a substantially reduced impact of pollution abatement expenditures (Crandall, 1979b). In the more recent version, energy use and capital-labor ratio change explanatory variables are added to the cyclical and pollution control variables. For some of the equations, the pollution control variable has the right sign, for others, it does not. In no case is the variable statistically significant. When the regression is specified in first-difference form, the pollution control variable has a significant effect. Crandall notes the difficulty of reaching "definitive conclusions" from his analysis.

If the latter is the case,[22] the productivity reducing effect of pollution-control expenditures, as measured in the regression equation, is overstated to some unknown degree.

Crandall's industry-specific time series analysis is subject to much the same omitted variable problem, as again only cyclical output swings—plus a time trend—are entered into the equation. The entire residual productivity shortfall is then attributed to pollution control regulations, even though a host of other potential determinants could just as well have contributed to it. Interestingly, this residual—to be attributed to all remaining determinants of productivity change—is very small, with cyclical output changes accounting for the lion's share of the productivity decrease.

Crandall's estimates, then, are rough and would appear to attribute more of the productivity decrease to mandated environmental regulations than is warranted. If an implicit adjustment is made to his conclusions to account for the potential omitted variable problem,[23] the effect of environmental regulations on productivity, while present, would appear to be rather small—substantially smaller than those suggested by Denison for 1973–75.

At a minimum, then, the Crandall analysis emphasizes the need for a more completely specified model which accounts for other significant changes in the determinants of productivity and interactions among them before any reliable estimate can be made of the net effect of environmental regulations on productivity.

An alternative disaggregative approach to measuring the impact of environmental regulations on productivity change has been undertaken by R. J. Kopp and V. K. Smith.[24] The Kopp-Smith analysis is designed to correct a potential bias in conventional measure of appraising the effects of regulations on productivity changes. Using a micromodel of firm behavior based on a cost-minimizing objective, they demonstrate that appraisal of the effects of regulation must take into account all of the possible factor substitutions and production process adjustments available in meeting the regulations. Most of the conventional "growth accounting" appraisals assume that environmental regulations simply add a cost to existing total cost, neglecting these possible substitutions. As a result, these conventional appraisals may be biased.

To determine if actual production activities alter input usage other than those used in the conventional appraisals—that is, labor, capital, and land in the case of Denison, or labor only in the case of appraisals based on single-factor productivity measures—Kopp and Smith make use of detailed process analysis models of three types of steelmaking plants—basic oxygen, open hearth, and electric arc. They first impose a common set of regulations on the three plant types and then, through

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[22] Casual observation suggests that the pollution-control impacted industries are also those likely to be heavily impacted by the post-OPEC rise in energy prices. Consider, for example, aluminum, electric utilities, chemicals, and petroleum refining. Crandall's updated analysis confirms this (Crandall, 1979b). The simple correlation between pollution control/value added variables is 0.63.

[23] It should be noted, however, that potentially important productivity-related variables—e.g., energy prices, environmental expenditures, reduction in capital investment—could be correlated with cyclical output changes and, hence, be measured in the coefficient on the latter variable in Crandall's time series analysis. This could account for the small remaining residual.

[24] Kopp and Smith (1979).

the process analysis models, observe the adjustment patterns. Using a translog cost function—similar in structure to the production function employed in the theoretical model in appendix A—to summarize the responses of the plants, and then a regression model applied to these results, they estimate the extent to which the regulations affect the input usage—and, hence, productivities—of a wide range of inputs in addition to just labor or labor and capital. In all, nine inputs were included in the model.

Their results indicate that inputs other than labor and capital are affected by the regulations, and that these effects vary widely among the different technologies. Moreover, to the extent that these impacts on inputs other than labor and capital (that is, materials) require the use of higher quality, more scarce, or more expensive inputs (that is, low sulfur rather than standard coal), the conventional appraisals of the impact on productivity of environmental regulations will understate the true effect. Kopp-Smith provide no evidence as to whether such input changes are induced, or if use of inputs of "lower" real quality would be induced by environmental regulations—in which case the conventional estimates of the productivity impact of environmental regulations would overstate the true effect.

While the potential effect of pollution control regulations on productivity growth can be illuminated by disaggregated industry-specific analyses such as those undertaken by Crandall and Kopp-Smith, a more aggregative approach to understanding this relationship is also viable. The most recent of these analyses relied upon the detailed macroeconometric model constructed by Data Resources Inc. (DRI).[25] The pollution control expenditures analyzed were those for the 1978–86 period, and were defined to be those expenditures undertaken in response to policy measures. Capital investment, annualized capital and operation, maintenance, and repair costs by industry plus State and local government and induced mobile source costs were the data which motivated the operation of the model.[26]

The analyses compared the base trend of the economy without the pollution control expenditures with the size and structure of the economy with these induced expenditures. The model provides a full, dynamic simulation of the economy with and without these incremental expenditures.

The macroeconomic results of the simulation indicate that environmental policy measures induce somewhat higher prices (averaging .3 percentage points per year) throughout the 1970–86 period. These measures also include a mild increase in real GNP until 1982, with only a slight decrease resulting thereafter. Employment increases significantly throughout the entire period.

This increased employment effect combined with the effect on output (GNP) implies a reduction in labor productivity. This conclusion results in part from the induced pollution control investment "crowding out" alternative capital investments in plant and equipment. In

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[25] See Data Resources Incorporated (1979).

[26] The incremental pollution investment for both air and water pollution control was $2.5 billion [in constant 1977 dollars] in 1970, rising to a peak of $8.4 billion in 1984. Over the 8-year historical period (1970–77), outlays averaging $3.3 billion of total capital investment were required to comply with the standards. For 1978 to 1986, CEQ estimates show incremental expenditure requirements which average 4.1 percent of the total.

describing the results of the simulation analysis on labor productivity, the study stated:

The increased factor demands associated with the operating and maintenance of pollution abatement equipment resulted in a drop in labor productivity. Any given firm would now require additional employees to produce the same level of output. Further, the capital stock, which helps make the workers produce more, had been diluted with a portion which made no contribution to production. *The DRI model solution results indicate that productivity was 0.5 percent lower by 1978 and 1.4 percent lower in 1986, given the pollution requirements. Over the entire period, productivity growth averaged 0.1 percentage point a year less.* The reduction in productivity growth produces higher unit labor costs (the cost of labor associated with the production of a given unit of output). Initially these produce reduced profit margins, eroding corporate profits, but over time they get passed on in the form of higher prices.[27]

TABLE 2.—*The effect of policy induced pollution control expenditures on the Labor Productivity Index, 1970–86*

Year:	*Percentage points*	Year:	*Percentage points*
1970	+0.2	1979	−.4
1971	+.3	1980	−.3
1972	+.3	1981	−.6
1973	+.1	1982	−.8
1974	−.1	1983	−1.0
1975	−.1	1984	−1.1
1976	−.1	1985	−1.3
1977	−.3	1986	−1.4
1978	−.5		

Source: Supplemental data submitted to the Environmental Protection Agency by Data Resources Inc.

Table 2 shows the effect of pollution control policies on the annual labor productivity index over the 1970–86 period, as estimated by the model analysis. By the end of the 17-year period, the index of labor productivity was estimated to be 1.4 percent lower with than without the policy. By the end of the 1970–80 decade, the productivity index with the controls was estimated to be only .3 percentage points below that without the controls. Without the policy in place, labor productivity was estimated to grow 42 percent over the entire 1970–86 period; with the policy, the growth of labor productivity was estimated to be 39.9 percent. Note that the index of productivity used in this analysis is a single factor index, and deviates substantially from the full factor productivity measure defined in appendix A.

REGULATIONS, ENERGY PRICES, CAPITAL INVESTMENT, AND THE SLOWDOWN IN PRODUCTIVITY GROWTH

Regulations, energy price increases, capital investment, and productivity growth are interdependent phenomena. Of their interrelationships, the dependence of economic growth and productivity growth on capital investment is the most widely recognized and accepted. In turn, capital investment depends on a number of factors—profit and sales expectations, the cost of borrowing, the price of capital relative to labor, the relative price of energy, and the role of Government regulations and other policies. Hence, nonregulatory factors could account for a slowdown in the rate of investment, which in turn

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[27] See Data Resources Inc. (1979).

could cause a reduction in the rate of productivity change. On the other hand, any slowdown in capital formation could be caused by governmental regulations. In this case, a slowdown in productivity growth would appropriately be attributed to these regulations, operating indirectly through their effect on capital investment.

In this section, we will deal with three linkages. First, the relationship between capital investment and productivity growth will be explored. The literature on the role of investment in economic and productivity growth is voluminous—we can only briefly summarize it here. Then the determinants of capital investment will be discussed. The literature on this topic is also very large. Finally, we will focus on the causes of the slowdown in investment during the last decade, in particular the rapid increase in energy prices and the increasing impact of environmental and health/safety regulations.

The 1970's was not a good decade for capital investment. Especially during the middle of the decade—1974–76—the rate of capital investment fell to low levels. When its pattern is combined with the rapid growth in labor, the rate of growth of the capital-labor ratio, describing the input structure of the economy's production process, fell substantially. From 1956–66, the capital stock grew at an average rate of 3.7 percent per year. In the following decade—from 1966–75—this growth fell to 3.4 percent per year. Especially slow growth was recorded in 1973–75. Conversely, the growth rate of hours worked was 1 percent per year from 1955–66, but rose to 1.8 percent per year in the years from 1966–75. The net effect on the capital-labor ratio is shown in table 3. There the much lower pattern of growth in the 1970's relative to the 1960's is clearly seen. Note especially the post-1973 period.

TABLE 3.—*Annual percentage changes in the capital-labor ratio in the United States, 1960–77*

Year:	*Capital-labor ratio*	Year:	*Capital-labor ratio*
1960	2.4	1969	2.3
1961	2.1	1970	1.3
1962	3.0	1971	1.5
1963	2.3	1972	1.9
1964	2.8	1973	2.4
1965	3.4	1974	1.2
1966	3.4	1975	−.2
1967	2.1	1976	.2
1968	2.6	1977	1.1

Source: McCarthy (1978).

The first question to be addressed is: What is the role of capital in the process of economic growth, and to what extent is the recent slowdown in the growth of the capital-labor ratio related to the concomitant slowdown in productivity growth? The contribution of three studies to this debate will be mentioned.

In a recent paper, Fraumeni and Jorgenson (1979) investigate the sectoral sources of U.S. economic growth during the postwar period. Their estimates are based on a unique data base which includes output, labor, capital, intermediate input, and technical change information on 46 industries. Employing a translog production function of the form described in the appendix, Fraumeni and Jorgenson fit value-added functions for each of the sectors. They then aggregate these sectoral functions, using appropriate weights, to yield an aggregate value-added function. In this function, aggregate value-added is a translog function of capital and labor inputs and time. After making standard equilibrium assumptions, aggregate output in the economy can be interpreted as a translog function of capital and labor inputs and technical change.

From this formulation, the authors analyze the patterns of growth of labor, capital, and the level of technology and growth in the level of output. They find the contribution of capital growth to the growth in value added and output to be even and steady over time, relative to the uneven contributions of labor input and technical change. The negative rates of growth of technical change in the 3 years—1973, 1974, and 1975—were unprecedented in the postwar period. On the basis of their estimates, they conclude that: "the contribution of capital input is the most important source of growth in output, the rate of technical change is the next most important source, and the contribution of labor input is the least important." From this, they describe the 1973–76 experience as being triggered by the sharp reversal in the growth of technical change which led to the subsequent collapse of capital input, which collapse sustained the slowdown. The role of capital investment is thus assigned an important role in the growth—and by implication—productivity process.

The role of lower rates of capital formation in the 1970's in explaining the slowdown in productivity growth was addressed directly in a recent paper by Peter K. Clark (1978). In his study, Clark first develops a time series of productivity growth for the private nonfarm business sector which has to some extent been purged of cyclical effects. Then, he purges that series of effects of changes in the age-sex composition of the labor force. For four relevant periods, this resulting labor productivity series shows the following pattern:

Labor productivity growth adjusted for cyclical and labor force composition factors

Years:	
1948–55	2.71
1955–65	2.94
1965–73	2.34
1973–77	1.24

These figures suggest little productivity growth slowdown unrelated to cyclical and labor force changes until 1973.

Then, working with this adjusted productivity growth series, Clark attempts to account for the role of capital in explaining productivity growth. He does this by fitting a Cobb-Douglas type production function in which the adjusted labor productivity series is regressed on a cyclically adjusted measure of the capital-labor ratio. This regression attributes a substantial proportion of the change in labor productivity to changes in the capital-labor ratio, implying that technical progress is embodied in new capital goods. The coefficients which he obtains on the capital-labor ratio—0.4–0.7—are substantially higher than the share in private output accruing to the capital stock of about 0.2. Using his estimates, he calculates the contribution of the capital-labor ratio to productivity growth, and arrives at the following figures:

	Rate of adjusted productivity growth	Contribution of—	
		Capital-labor ratio	Other factors
1948–55	2.71	1.15	1.56
1955–65	2.94	1.29	1.65
1965–73	2.34	.62	1.72
1973–76	1.24	.25	.94

Note: The numbers in the 1st column are taken from the previous table.

From these results, Clark concludes that a major portion—and perhaps nearly all—of the productivity slowdown from 1965 to 1973—adjusted for cyclical and labor-force composition factors—can be attributed to the slow growth in the capital-labor ratio. However, only about 35 percent of the very slow growth in adjusted labor productivity in the 1973–76 period can be attributed to the very slow growth in the capital stock in this period.

While the Clark study attributes an important role to capital formation in explaining the productivity growth slowdown, it is not without challenge. In a comment on the paper, Norsworthy challenges a number of Clark's procedures, including his adjustment of the productivity series for cyclical effects, his data for the labor force composition adjustment, and his use of capacity utilization in developing an adjusted capital-labor ratio series. Norsworthy reports that his own work on the contribution of the capital-labor ratio to the productivity slowdown does not show a strong effect for the capital-labor ratio—at least for the years 1965–73—suggesting that Clark's results are an artifact stemming from the cyclical adjustments of labor inputs and labor productivity which he employs. In a more recent article (Norsworthy, Harper, and Kunze, 1979), however, Norsworthy finds capital investment to have been the dominant factor in the productivity slowdown from 1973 to 1978.

Finally, a recent study by McCarthy (McCarthy, 1978) seeks to allocate the slowdown in productivity growth among its determinants, concentrating on the role of the capital-labor ratio, and, to a lesser extent, energy prices. He finds that changes in the capital-labor ratio have contributed about 0.8 percentage points to productivity growth in the pre-1970 period, but that this contribution has dropped to about 0.6 in the 1970–73 period, and to about 0.2 in the 1973–77 period. He speculates that the energy price increase may account for the major portion of the large unexplained residual in the post-1973 period.

Although the role of environmental and health/safety regulations are not explicitly addressed in these studies, the decrease of both technical change and the capital-labor ratio in the recent period is suggestive—especially in light of the Denison calculation discussed earlier.

The contribution of environmental regulations to the slowdown in the growth of the capital-labor ratio is the second relevant issue. If one accepts the invitation to relate the decline in capital investment relative to labor to the bite of environmental regulations, it is not a large step to attributing the retardation of capital investment to these policy actions. On the other hand, numerous other phenomena were at work during this period—including the dramatic rise in energy prices and price controls. There is nothing in the evidence provided by Fraumeni-Jorgenson, Clark, or McCarthy which would establish environmental regulations as the primary culprit explaining the poor technical change and capital-labor performance of this period.

A direct effort to estimate the effect of environmental regulations on productivity operating through their effect on capital investment is presented in a Ph. D. thesis by Leahey (1978) and a research paper based on that thesis. Noting that the five industries incurring the largest impact of environmental regulation as measured by required expenditures—copper, oil refining, iron and steel, chemicals and paper—are also capital intensive industries. Leahey focuses on the impact of pollution control on the economic performance of these sectors. These five industries account for almost three-fourths of total pollution control investment in the United States.

In Leahey's framework, environmental regulations imply cost increases, price increases, and as a result a reduction in quantity demanded of the output of sectors which are heavily impacted. In his framework, two questions are relevant: How much will total investment be affected by the regulations? How much investment will be diverted from capacity expansion to pollution abatement?

First, Leahey demonstrates that the rate of expansion of capacity in these industries in the 1971–81 period relative to the 1961–71 period was substantially lower than for all manufacturing industries. Leahey first calculated the real user cost of capital in these industries with and without the capital expenditures mandated by the regulations. Then, he estimated the change in investment in each of these industries from the investment equations in the Wharton annual model, using capital user cost values with and without environmental regulations. These equations model investment as a function of the lagged capital stock, distributed lags of output, and distributed lags of the real user cost of capital. The cumulative decrease in gross investment in these industries from a 1-year environmental control induced increase in user cost of capital ranges from 5 percent (chemicals) to 17 percent (iron and steel). These values imply a nontrivial slowdown in capacity expansion and economic growth in the economy.

Leahey then takes one of these industries—paper—and analyzes the effect of regulations using an econometric model of the industry. From 1975 to 1986, he estimates that environmental regulations will reduce the rate of output growth by .7 percentage point per year (from 5.5 percent to 4.8 percent), increase the rate of price increase by 1.5 percentage points per year (from 4.9 percent to 6.4 percent), and reduce the growth rate of capacity expansion by .8 percentage point (from 4.5 percent to 3.7 percent). He concludes that if effects of this magnitude occur in the other four industries as well, aggregate output growth would be reduced by from .5 to 1 percent per year and wholesale prices will be increased by about 1 percent per year.

These results, operating primarily through the displacement of capital investment, are substantial. In many ways, they parallel those of the copper industry presented in the earlier case study. For several reasons, however, Leahey's estimates would appear to be biased upward. First, he is working with the industry for which the estimated increase in the user cost of capital is the greatest among the five industries. The investment results for this industry are then extrapolated to the other five industries, and then to the economy as a whole. The potential for exaggeration is clear. Second, no account is taken of the likely shift in demands from heavily impacted sectors with rising relative prices to sectors which are less pollution intensive. Third, while his methodology is not clearly presented in the study, it appears that no account was taken of the induced increase in investment required for pollution control equipment and the investment, capacity, and output implications of the manufacturing sector producing this equipment. Fourth, again while the model is incompletely described, it appears that the potential for substituting labor and other inputs for capital as the user cost of capital increases is not well accounted for. This, too, would tend to exaggerate the adverse investment effects of the regulatory policy. And, finally, Leahey is measuring the cumulative decrease in investment (from the summed distributed lag coefficients) due to a 1-year increase in capital cost. The implied annual changes in investment over the period are, as a result, not well defined.

While these results are suggestive of a potent negative impact of environmental regulations on capital investment, they are in no way definitive. Many of the shortcomings in the Leahey analysis—neglect of demand shifts and input substitutions, neglect of the investment stimulated in the pollution control industry—also pervade the other estimates (for example, those for the copper industry). Moreover, the only macroeconomic analysis which accounts for both investment displacement and the additional investment generated (the DRI model analysis), implies a much smaller negative impact on investment of environmental controls. In sum, we judge that such partial equilibrium analyses are presenting upper bound estimates of the impact, with the truth lying closer to the DRI macroeconometric analysis reported earlier. As will be recalled, the estimates yielded by this model suggest that the impact of environmental policy on real GNP and employment, though perhaps negative, is quite small. Over the time frame studied, real GNP and employment would continue to grow, albeit at a somewhat reduced rate. Thus, the models suggest that although pollution-abatement investments might ultimately reduce real GNP and employment by a small amount, they are not sufficient to seriously inhibit economic growth over the long haul.

This conclusion is supported by two recent studies on the availability of private-investment capital (Bosworth 1976; Eisner 1976) commissioned by the Joint Economic Committee of Congress. Both concluded that the slow rate of capital formation in recent years is the result of imbalances and inefficiencies caused by persistent inflation and recession. Rather than readjusting environmental targets to more realistic levels because of capital shortage, the studies indicated that fiscal policy should aim for consistent, noninflationary expansion of demand to stabilize the setting within which investment decisions must be made.

This conclusion—and the small amount of research on the environmental regulations-capital investment relationship—is not conclusive, however. Environmental and health/safety regulations could deter and defer capital investment in subtle and difficult to measure ways. Malkiel (1979) attributes the slowdown in investment to an uncertain climate and sees the nature of governmental regulations as contributing to this climate of uncertainty. Similarly, Quarles emphasizes the difficulties in securing approval for new plantsites from land use and environmental agencies. If these difficulties result in delays or "stretch outs" in capital investments in plants, the effect will be a retardation in the rate of capital investment and the extended use of older, outmoded capital facilities. While these potential impacts are real and not able to be dismissed, they are very difficult to verify. There is no statistical evidence on their magnitude, and any effort to attribute some quantitative significance to them would be sheer speculation.

If, then, the negative effect of environmental regulations on aggregate capital investment is not dominant, and if Clark's conclusion that some unexplained factor—or set of factors—in addition to cyclical effects, labor force composition changes, and a slowdown in the growth of the capital-labor ratio must account for the post-1973 slowdown in productivity growth, the potential role of the post-1973 exogenous energy price increases must be explicitly considered. Unfortunately the research undertaken on this potential determinant of the productivity slowdown is not extensive. And, what research exists is highly controversial.

The most prominent of these energy price-capital investment-productivity studies is that by Hudson and Jorgenson (1978) which attempts to sort out the determinants of the poor macroeconomic performance during the recent period. Using a dynamic general equilibrium model of the U.S. economy, energy prices were found to bear the brunt of the responsibility for the Nation's poor economic performance during the 1972–76 period. Increases in energy prices were found to have lowered real GNP by 3.2 percent over the period, and energy consumption by 8.8 percent. The level of the capital stock was $103 billion (measured in 1972 dollars) lower than it would have been if the relative price of energy had remained constant over the 1972–76 period. This can be compared with 1976 gross investment of $165 billion (in terms of 1972 dollars).

Despite the reduction in GNP growth attributed to energy prices, they were estimated to have caused only a 0.6 percent decline in employment during the period, the equivalent of about 500,000 jobs. But this modest employment impact, combined with the large negative effect on GNP, implies that energy prices were responsible for a huge drop in labor productivity during the period. In fact, 1976 labor productivity was estimated to be 2.57 percent lower than it would have been had the relative price of energy not changed from its 1972 level.

This is a spectacular result, and it differs markedly from Denison's estimate that energy prices have been responsible for only a 0.1–0.2 percentage point annual decline in measured productivity growth. The Hudson-Jorgenson result has the intuitive appeal of explaining a major portion of the slowdown in measured productivity growth, with the timing of the rise in energy prices coinciding with the unexplained post-1973 slowdown in productivity growth noted in the Clark study. Despite the attention given to the energy problem, however, the value of energy used in the nonresidential business sector of the economy is still only about 4 percent of total factor input in the U.S. economy. Thus, the spectacular magnitude of the Hudson-Jorgenson result is somewhat difficult to believe.

Much depends on assumptions made concerning the elasticities of substitution among the various factors of production. In the Hudson-Jorgenson model, capital and energy are viewed as being highly complementary. That is, the magnitude of the energy impact is largely a consequence of the reduction in capital usage which the rise in energy prices induced. At the same time, the elasticity of substitution between labor and the energy-capital input package is viewed as being rather high. Thus, a rise in energy prices causes labor to be substituted for energy and capital. In fact, the impact of energy prices on employment is negative only because of the large, negative price effect on output—hence, the dramatic effect on labor productivity.

Even if the elasticities of substitution used were somewhat different, however, the Hudson-Jorgenson results indicate that energy prices have probably played a major role in the post-1973 slowdown in measured productivity growth. The paper thus fills a large part of the gap left by the Jorgenson-Fraumeni paper. Capital inputs have been seen as perhaps the most important source of economic growth, but a question remained as to whether environmental and health/safety regulations had been a decisive factor in the decline in the rate of capital formation. The Hudson-Jorgenson paper suggests that the rise in energy prices has been more important than regulation. Indeed, regulation is not even mentioned in the Hudson-Jorgenson paper.

This same powerful effect of post-1973 energy prices is also reported in a study by Rasche and Tatom (1977). They concluded that the increase in the price of energy resulted in a permanent reduction in potential output of from 4 to 5 percent. This sizable impact results from a rather high estimate of the elasticity of demand for energy—namely, about unity—and a rather high weight given to energy input in the production process. More modest values—and, some would say, more reasonable—would yield a smaller estimate of the output and productivity effect.

While these models attribute an important—though controversial—impact of the post-1973 energy price increase on productivity growth, there are some potential productivity effects of the energy price change which are not captured by the models. Consider the following:

- The costs from substituting among fuel sources—for example, from fuel oil to coal—due to changing relative fuel prices is not captured in the estimates. The large drop in productivity in the utility industry gives some indirect evidence that these costs may be substantial.
- The rapid increase in energy costs is likely to have increased the obsolescence—or the de facto retirement—of existing capital, in addition to reducing the expected return on investment. This increase in obsolescence would result in a reduction in the observed average rate of return on capital, for which there is some evidence. Moreover, the energy price increase could well have made obsolete new technologies which were energy intensive prior to their introduction. The evidence regarding increasing obsolescence might

exist in the observed decline in the share of nonwage payments in GNP over the cycle.[28]

- The energy price increase has generated new uncertainties which are reflected in lower investment propensities. This uncertainty factor undoubtedly interacts with the lower expected return on new and developing technologies based on lower expected energy prices.

The conclusion of this evidence can be summarized as follows: Capital investment is a major source of economic growth and productivity improvement. Moreover, the slowdown in investment and the capital-labor ratio in the 1970's appears to account for a nontrivial share of the post-1973 productivity growth, though this conclusion is controversial. The role of environmental and health-safety regulations in accounting for the reduced growth in the capital-labor ratio in the 1970's does not appear to be large. A substantially more important determinant of the reduction in the growth of the capital-labor ratio is the post-1973 increase in energy prices. Some (controversial) studies indicate this effect.[29] In addition, reasonable speculations regarding the role of energy prices not captured in the studies suggest that the energy price increase may explain a nontrivial share of the otherwise unexplained slowdown in productivity growth.

THE EFFECT OF ENVIRONMENTAL REGULATIONS ON EMPLOYMENT

There are several channels through which environmental and employment issues interact. Perhaps the most important concerns the impact of regulations imposed on potential polluters to reduce total emissions. For many firms, complying with these regulations causes increases in production costs and, ultimately, prices. As noted in the theoretical framework presented in section III, production costs may increase either as a result of the direct impact or regulation or its indirect impact on technical change or input productivities and through them scale economies. If price increases in turn lead to reductions in consumer demand for specific commodities, the demand for inputs, especially labor and raw materials, that are essential to the production of these commodities will also decline. A potential effect of environmental regulations, then, is that the demand for labor may decline. Moreover, a reduction in the output of firms meeting regulatory requirements may lead to indirect effects on other inputs and related products, and hence to a reduced demand for labor involved in their production.

Because some industries inherently generate more pollution than others and have different costs for reducing pollution, environmental regulations will have potentially different effects in the various economic sectors. As a result, the composition of employment could be

[28] McCarthy states the following with respect to this obsolescence case: "It might be argued that capacity destruction was a consequence of the very large changes in relative-energy prices in 1974 which rendered some plant and equipment obsolete. . . . If some of the capital stock was actually scrapped we should expect to find large writeoffs in the form of capital consumption allowances. The capital consumption allowances in book value terms, however, have shown little more than the normal steady trend. A more plausible argument might be that, because of the large increases in energy costs, the (marginal) productivity of all capital (new and old) fell, but not to a level justifying large-scale scrapping."

[29] Based on an examination of the movements of the relative prices of energy, capital, and labor, Norsworthy, Harper, and Kunze (1979) also suggest this result in their paper.

changed. The possible effect of these regulations on the overall level of employment is less certain, however, because it depends on a complex network of changes in relative wages and prices that can result as the effects of these regulations are felt throughout the economy.

A second channel linking environmental policy and employment issues concerns mandated public and private expenditures for the construction and installation of pollution control equipment. In this regard, it seems clear that public policy also influences the composition of employment. That is, the restrictions which our theoretical model identify as being necessary to preclude input bias stemming from environmental and health-safety regulations are not likely to be satisfied. Depending on the means used to finance increased public or private spending and the specific uses to which such funds are put, overall employment may be increased. The compositional effects result as labor is drawn into the production of pollution control equipment and related goods and services. Workers are drawn either from the pool of unemployed or from other activities. The overall impact on employment levels, however, involves the same fundamental macroeconomic questions that face other public expenditure programs: To what extent do public expenditures increase the aggregate demand for real output? To what extent do any increases in aggregate demand increase employment in the short run or over the long haul? Although these questions remain controversial among economists, it is clear that changes in aggregate demand and its composition caused by environmental policy are another channel through which employment can be affected, for better or worse.

A third channel through which environmental and employment issues interact reflects the often expressed view that economic growth is incompatible with a healthy environment. This argument holds not only that such growth is accompanied inevitably by pollution, but that continued growth is apt to lead to rapid depletion of natural resources. Proponents of this view recommend a policy of reduced growth, so that natural resources can be conserved and the environment protected. Employment issues enter the debate with the claim that the policies of the "slow-growth" school induce cutbacks in employment. Though it is true that cyclical slowdowns in the rate of growth of gross national product (GNP) are generally accompanied by employment reductions and unemployment increases, permanently lower growth rates need not inevitably result in higher rates of unemployment. Much would seem to depend on the specific policies employed for reducing GNP growth—some of which might even be specific environmental policies. As the model presented in appendix A makes clear, it is at least possible for regulation to avoid biasing input choices.

The effect of employment conditions on environmental policy itself indicates a fourth channel of interaction. For many years, little attention has been paid to the effect of economic variables on policy decisions. Now, however, it is widely recognized that not only can policymakers intervene to influence economic variables, but economic conditions and political pressures can influence the way in which microeconomic public policy decisions are made and enforced. This interdependence has been documented for several Federal regulatory agencies, and attention is now being focused on the formation and enforcement of environmental policy. Specifically, the claim has been made that the environmental regulations tend to be enforced less vigorously when employment conditions are unfavorable, but quite strictly when unemployment is of less concern.

A topic that deserves special consideration in connection with employment and environmental issues is the energy problem. There is little question that the dramatic rise in oil prices during the 1970's was the cause of severe unemployment in industrialized nations, just as natural gas shortages in the United States caused substantial layoffs during the winters of 1976–77 and 1977–78. Escalating petroleum prices and the potential for future shortages will place increased importance on alternative energy sources, such as nuclear power and coal, both of which entail environmental problems, in a direct clash with employment goals.

The workplace itself is a final arena in which employment and environmental issues interact. In the post-World War II period, there has been concern that conditions in the workplace may cause injury to workers in a variety of ways. This has led labor unions, government, and business to try to establish safeguards. With respect to safety, it is often obvious that a particular production process is potentially dangerous. However, it may be many years before some processes—for example, one involving inhalation of certain gases—can be determined to be hazardous. In any case, attempts to articulate safety and health regulations must confront the fact that such regulations are apt to increase production costs and eventually affect the level and composition of employment.

Since occupational health and safety regulations have cost, productivity, and investment implications similar to those of environmental regulations, the general observations made here also relate to occupational health and safety.

The discussion that follows focuses on the first two channels of interaction: (1) the direct employment implications of antipollution regulations, and (2) the macroeconomic impact of public and private expenditures for pollution control equipment.

Estimating the employment effects of environmental policies: "Bottom-up" approaches

There are two basic techniques that have been used to measure the consequences of environmental policies on employment. One can be called a "bottom-up" approach, since it initially attempts to measure the impact of a specific policy change on individual households and businesses, and then to trace in a very detailed way the changes in demand, output, and prices that this change induces. The numerous individual responses are added to calculate the aggregate impact of the policy. The second technique, discussed later, is a "top-down" approach. The bottom-up approach is often referred to as a microsimulation technique; in recent years, it has been widely used by researchers to evaluate policy measures in a number of areas, especially in the tax and income-transfer areas. The basic methodology was described by Bergmann (1974) and Guthrie et al. (1972).

The first step is to identify a population of individual firms or households that will be affected by the policy in question. Each unit in this population is differentiated according to a number of individual characteristics, such as income level, family size and composition, age, sex, and educational and racial characteristics. Similarly, firms might be classified by sector, size, and age of equipment. Then, the impact of a specific policy on each household or firm is estimated. The magnitude and nature of the impact will, of course, depend on both the nature of the policy and the characteristics of each firm or household. The next step is to evaluate how specific environmental policies will affect decisions that the household or firm reaches. That is, the behavior of the various agents must be incorporated in a model which builds on a theoretical framework such as that described earlier in this report. Will any additional consumption or investment be undertaken? Will the demand for or supply of labor change? If so, by how much?

Once these questions have been answered satisfactorily, the final step is to determine whether these "induced" decisions will affect other households or firms, inducing still more responses. In turn, supply and demand in various markets will be affected, and hence prices and wage rates. When all these effects have been worked out, according to the rules of the economic model, the ramifications of the policy can be evaluated and described by classes of units, as for example, income groups for households, industries for firms, and regions for both firms and households.

Clearly, the larger the number of variables, the more complex the modeling task. Grouping by class makes the effort more manageable, but some detail is lost in the process. In such cases, the effect of environmental policy on a group of firms is estimated, and the induced effect on unit production costs, prices, and input demand for the group is simulated. These changes are passed on through the economy, thereby altering relevant economic variables—prices, costs, sales, and incomes—concerning other groups. Ultimately, such changes will result in an altered mix of goods and services produced in the economy, different relative prices, and new input allocations, as each of the affected markets reaches a new equilibrium.

Perhaps the most comprehensive microsimulation model for evaluating the economic impact of environmental policy was developed by Hollenbeck (1976) and Hollenbeck (1979), who applied his model to the stationary-source regulations of the amendments to the Clean Air Act of 1970.[30] Hollenbeck used estimates of the actual air-pollution-abatement expenditures made in 1973, and the investment required to achieve and maintain compliance over the 1971–79 period.

Hollenbeck merged a microsimulation model of household decisions with a 17-sector, input-output model of industry behavior. Four occupations and five income classes are distinguished in the study. The structure of the combined model incorporates several fundamental economic relationships that are necessary for estimating the full economic effects of the policy. These relationships include, among others: (1) the effect of pollution control investment induced by policy on the final demand for goods in each sector of the economy; (2) the effect of the policy on the price level of the goods produced by polluting industries; (3) the effect of relative price changes on the composition of

[30] The stationary-source regulations of the amendments to the Clean Air Act of 1970 sets uniform performance standards for all new sources of air pollution other than vehicles, including powerplants, municipal incinerators, oil refineries, and other fixed-point sources.

consumer demand; (4) the effect of price changes on wage rates and, in turn, the effect of changes in wage rates on the quantity of labor supplied; (5) the effect of changes in the demand for goods on the outputs of industries which directly supply these goods, and on industries which are second, third, and later round suppliers of the directly affected industries; (6) the effect of industrial output changes on the demand for labor, employment, the wage rate, earnings, and household incomes; and (7) the effect of household income changes on the level and composition of household consumption. When the economy receives the direct impacts of the policy, responses occur which reflect these relationships and the economy adjusts until a new equilibrium is achieved.

The net result of this simulation was an estimate that employment declined 0.21 percent as a result of the amendments to the Clean Air Act of 1970, with employment prospects for low-skilled workers most seriously affected. In the aggregate, he estimated there could be an annual reduction of nearly 160,000 jobs because of the imposition of stationary-source regulations.

Microsimulation techniques make it possible to analyze in detail the economic effects of various policies by identifying such effects by category of household and firm. However, these techniques are not without limitations. One major disadvantage is that they give no indication of the timing of the impact. In a sense, the microsimulation approach represents an opportunity to compare a snapshot of the structure of the economy, as affected by environmental policy. Another problem is that the elaborate detail that characterizes these models sometimes impedes their reliability and reduces confidence in the estimates they yield, placing the value of the ultimate results in doubt.

Estimating the employment effects of environmental policies: "Top-down" approaches

The second type of approach to assessing the effect of environmental policies on employment is a top-down approach. The strategy here is first to specify a system of aggregate relationships in the economy, then to identify how a given policy change will affect one or more of the key aggregate economic variables in the system—for example, the demand for investment goods—and, finally, to predict the performance of the economy in both the presence and the absence of the policy change in question. Only after measuring the impact of the policy on the variables in the aggregate is an effort made to estimate the probable effects on individual sectors of the economy.

This approach has been conducted with a class of models referred to as macroeconometric models, generally those that are also used in preparing forecasts of the level of overall economic activity. The use of these models in estimating the impact of environmental policy addresses more successfully the problems of timing and reliability of aggregate estimates that are characteristic of the bottom-up approach. Their use, however, is at the cost of detail concerning the effects on individual sectors of the economy.

Most of the successful macroeconometric models are based on some variant of standard Keynesian economic theory. Accordingly, a number of aggregate variables are estimated, including GNP and total employment. In addition, these variables are decomposed into subcategories. In the case of GNP, for example, such subcategories would include consumption, investment, imports, exports, and Government spending. Consumption and investment spending, in turn, are related to variables, such as income, interest rates, and the stock of inventories. Within most of these models, the interrelationships between industries are described by an input-output matrix, and the amount of employment is jointly determined by the labor demands of producing sectors and the labor supply of various types of workers. Typically, a financial sector is included in the model, as well as a system of equations (sometimes called mark-up relations) designed to reflect the impact on prices of changes in production costs and the utilization of industrial capacity.

To evaluate the economic effects of environmental policy using a macroeconometric framework, one must first decide how a given policy will alter one or more of the exogenous factors of the model so as to set it in motion. Second, the internal structure of the model must be altered if the structure of the policy is such as to change some fundamental relationship that is part of the model.

In the analyses discussed in this study, the primary outside factors presumed to be altered by environmental policy include the level of investment (representing the purchase of pollution-abatement equipment by business firms) and the level of Government spending for pollution abatement. The level of these expenditures in various years was first estimated. These estimates were then entered into the model as a description of changes in investment spending induced by environmental policy. The analyses discussed also assumed that the environmental policy altered some of the basic relationships that are a part of the model. For example, new pollution-control investment was presumed to be nonproductive. As a result, the value of industrial assets (against which returns are measured) increased, with no concomitant increase in total productive capacity. Hence, the rate of return was reduced. Moreover, it was assumed that required maintenance of the equipment would add to the production costs of the affected industries and to the prices charged for their output. Both of these adjustments to the model were difficult to specify accurately in advance; as a result, a good deal of judgment and ad hoc estimation was involved.

The first comprehensive evaluations of the macroeconomic implications of environmental regulations were conducted by Chase Econometric Associates (1975), with support from the Environmental Protection Agency. Subsequently, the Chase analysis has been replicated several times, and has been included in the annual report of the Council on Environmental Quality (CEQ).

The Chase model forecasts that, until 1981, environmental measures served to reduce the unemployment rate from the levels that would exist in the absence of environmental policies. Beyond 1981, the model predicted small increases in the unemployment rate because of environmental legislation. By 1983, Chase predicted that the unemployment rate would be about 4 percent higher than would otherwise be the case. Thus, if the rate without the policy were 6 percent, with the policy it would be about 6.25 percent. Analyzing the data, the employment-generating effects outweigh those that tend to reduce employment during periods when investments to protect the environment are large. However, effects taper off and finally reverse as investment demands are offset by the loss in productivity and slowdown in the rate of growth of real GNP, caused in part by higher prices.

The predicted impact of environmental legislation on specific sectors of the economy is also quite interesting. Environmental measures appear to have their greatest adverse effect on housing starts and financial markets. The negative impact on housing starts is easily understood, since approximately 40 cents of each dollar spent on pollution-control operations is derived from reductions in other private investment. In residential construction, credit availability, increases in construction costs, and a tightening of the labor market all serve to constrain housing starts.

As previously mentioned, Data Resources (1979) has recently employed incremental abatement cost estimates (provided by CEQ) to evaluate the macroeconomic impacts of U.S. pollution-control legislation for 1970–86. The DRI model is optimistic with respect to the employment effects of pollution-control legislation. Employment opportunities show an increase throughout the 1970–86 period. As one might expect, the pollution-control sector accounts for most of the gains in employment. Jobs are created in manufacturing and installing pollution-control equipment and operating and maintaining this extra capital investment. From 1982 to 1986—even when real GNP falls below DRI's estimate of what otherwise would have occurred—the unemployment rate is consistently about 0.2 percentage points below what it would otherwise have been. This is explained by the finding that the incremental abatement costs have a negative effect on the productivity of employed labor. Because of this, more workers are required to produce any given level of GNP, and, as a result, GNP can fall, employment rise, and unemployment fall all at the same time.

Studies of the impact on employment in other countries

The Chase and DRI analyses can be compared with two other macroeconometric studies—one for the Netherlands (Netherlands Central Planning Bureau 1975) and the other for Japan (Shishido and Oshizaka 1977). Both of these studies estimate impacts on aggregate variables similar to those in the Chase and DRI studies. However, the nature of the environmental policies that are evaluated differs from those of the United States because of the rather different policy mixes in the Netherlands and Japan.

Consider first the Dutch analysis. This study is a regular part of the econometric modeling program at Holland's Central Planning Bureau. The policies evaluated in the study are: (1) Construction and operation of waste-treatment plants; (2) end-of-pipe controls on industrial waste discharges; (3) the adaptation of automobiles for pollution-abatement purposes; (4) the desulfurization of gas and fuel oil; and (5) the removal of nonchemical wastes.

The estimated investment and annual costs necessitated by these policies were used as inputs in the Dutch model in much the same way as in the Chase analysis. The policy alternatives were differentiated according to the time period over which the expenditures were implemented. Both 7- and 12-year variants were considered. The directions of the impacts on aggregate variables were similar in both variants. As one might expect, the magnitude of the impacts for most variables is greater when the policy is assumed to be implemented during a shorter period. The results are similar in direction to those of the Chase and Hollenbeck studies with employment declining by 1.3 percent after 7 years.

The impacts on specific sectors of the economy differ in the Dutch study and in the U.S. studies; this is to be expected, given the rather different kinds of policies that are evaluated. The increases of employment in building construction predicted in the Dutch study would seem to contradict directly the implications of the Chase analysis (where substantial private investment is foregone because of the diversion of investment capital into pollution-abatement equipment). In the Chase model, one expects and finds a decline of employment in the construction industry.

The Dutch and U.S. studies also show contradictory effects for the agriculture and service sector, where the Chase results forecast employment increases rather than decreases. The Dutch and U.S. results may be explained by differences in the policies, the composition of the sectors, or the structure of the economies themselves. They highlight a basic point, however; namely, that our understanding of the sectoral impacts of environmental policy is quite limited.

This uncertainty becomes even more troublesome when the Japanese results are considered. Like the Chase, DRI, and the Netherlands studies, the Japanese results are also derived from simulations with a macroeconometric model. The Japanese model, however, contains substantially more sectoral detail than the other two. Three direct impacts of environmental policy are accounted for in the Japanese analysis: (1) The expansionary effects of the required antipollution investment; (2) the contractionary effects of the cost and price increases necessitated by pollution control investments; (3) the structural changes in sectoral demand and output. These effects are assumed to be stimulated by government regulations designed to reduce air and water emissions to target levels in the period from 1972 to 1977.

This study estimated the required annual private investment to achieve both the air and water targets by using technical coefficients describing the "required investment per unit of pollution abatement" for 60 sectors. The cost and price effects were also estimated in great detail. The model predicted that employment would rise during the first years of policy implementation, but would fall subsequently, with the net effect being a slight increase in employment.

The effects of substituting certain forms of environmental spending for other forms of spending

There have been a number of other studies of the employment effects of environmental programs. A study by Hannon and Bezdek (1973) develops a methodology that gained acceptance as the basis for later research. The authors analyzed the following question:

> What would be the effect on the net demand for labor in various occupations if the water resources investment budget in the U.S. Federal Government were reduced by X billions of dollars while spending on a range of alternative Federal programs was increased by a comparable amount?

Using the composition of final demands by the industrial sectors plus direct labor requirements per unit of investment in water resource projects and per unit of investment in waste treatment plant construction, they calculated gross output requirements for each sector resulting from alternative final demand assumptions. Labor demands implied by the gross output requirements were estimated by sector using industry-specific labor-output ratios. Labor demands were further disaggregated by occupation.

The Hannon-Bezdek analysis showed that a $1.13 billion expenditure for improvement of water quality would generate nearly 96,000 jobs. A shift in spending from water resource investments to waste treatment plant construction would create nearly 23,000 work-years. In effect, the waste treatment plant alternative was 30 percent more labor intensive than water resource investments, taking into account direct and on-site labor requirements and indirect effects stemming from the structure of interindustry requirements.

In addition, the analysis yielded estimates of the net jobs created or eliminated in 185 detailed occupations, due to the transfer of funds: In moving funds from water resource to waste treatment plant construction, the occupational categories of clerical workers and office workers were the largest net gainers (3,200 and 1,800 jobs, respectively) and mine operators and laborers and sales workers were the largest net losers (−600 and −430 jobs, respectively).

Although this analysis does take into account the direct and indirect impacts stemming from interindustry relationships, and though it yields estimates of labor demands on detailed occupational categories, it has a number of weaknesses.

First, the study is limited only to the waste treatment plant construction component of the total Federal water pollution control program; no other environmental programs are included. Moreover, none of the manpower requirements for operating and maintaining waste treatment plants are included in the analysis. Third, the model includes no price, wage, or behavioral response impacts, which also give rise to changes in employment demands.

Similarly, the model accounts for no induced consumption (multiplier) or investment (accelerator) expenditures. Hence, numerous channels of indirect impact are left unexplored. Finally, the model rests on the fixed coefficient and constant cost assumptions of the input-output model, and extends these to the demand for labor by occupation. This assumption implies that increases in output in an industry require the same composition of labor inputs as does the average unit of output.

After publication of the Hannon-Bezdek study, the U.S. Bureau of Labor Statistics (BLS) in 1975 undertook a study of the entire Federal program for pollution control and abatement, employing a methodology very similar to that used by Hannon and Bezdek. While the focus of this study was on the demand for labor with technical and scientific training, employment requirements generated by Federal pollution-control expenditures over the full range of occupations were included. As with Hannon-Bezdek, these requirements ranged from employment construction sites (if construction was involved) and jobs created by industries supplying the necessary equipment, to jobs generated in industries that, because of interdependencies in the economy, were suppliers of the industries on which the primary demands were made.

In a few important respects, the BLS study represents an improvement on the Hannon-Bezdek research. First, in contrast to Hannon-Bezdek, the authors of the BLS study appear to have been extremely careful in distinguishing the category of work-years from that of "jobs" (which includes part- and full-time employment). Second, the BLS study includes employment in Federal and other agencies administering environmental programs, a source of labor demand that appears not to have been recognized in Hannon-Bezdek. Third, the BLS seems to have made substantial efforts to obtain accurate estimates of both the direct labor demands and the industrial composition of the product generated by the expenditure. This involved detailed data collection from the Federal agencies involved, State and local governments, and the enterprises to which contracts were awarded.

The BLS estimates also differed from those of Hannon-Bezdek. Whereas the latter estimated that about 84,000 jobs would be generated per $1 billion expended on waste-treatment-plant construction, the BLS estimated that only about 54,000 work-years would be generated. Part of this discrepancy could be accounted for by the differential treatment of work-years versus positions (or jobs) in the two studies. Because Hannon and Bezdek did not analyze the occupational breakdown of labor demand created by waste-treatment-construction expenditures, a direct comparison of the sectoral impact projections generated by the two studies is not possible. For example, considering Federal pollution-control expenditures other than waste-treatment-plant construction (largely research and program administration), the BLS estimated that about 78,000 jobs would be generated per $1 billion of Federal expenditures. The report estimated that for the entire pollution-control program, 67,000 jobs would be generated per $1 billion of expenditure.

Studies of sectoral impacts

The impact of environmental policies on specific sectors of the economy has also received attention. Among the significant studies were those involving the pollution-abatement equipment industry, the construction industry, the public sector, plant closing, and the capital goods sector.

In 1972, the Environmental Protection Agency (EPA) released a contracted study of the pollution-abatement equipment industry prepared by Arthur D. Little, Inc. (Arthur D. Little, Inc., 1972). That organization evaluated the implications of existing Federal air- and water-pollution-control regulations for the abatement-equipment industry.

The researchers made alternative assumptions about the rate of industry compliance with Federal standards over the 1972–80 period and translated these estimates into projections of pollution-abatement equipment purchases for each year. The impact on labor demand generated by these purchases was estimated by applying average-sales-per-employee ratios to the projected incremental sales estimates. These ratios were based on information obtained from a small sample of equipment manufacturers and ranged from 25,000 to 35,000 workers per $1 billion of sales.

For example, had there been no Federal policy in effect, the study estimated that employment in the pollution-abatement industry would have been 21,000 in 1972, 24,000 in 1975, and 31,000 in 1976. Assuming a reasonable enforcement schedule of existing policy, the study projected that employment in the industry would have been 35,000, 49,000 and 75,000, respectively, for the same years. The study concluded that the 1972 Federal legislation, if enforced, would lead to an additional 25,000 jobs in 1975 and 43,000 jobs in 1980 in the pollution-abatement industry alone.

Concurrent with the Arthur D. Little study, the EPA released the results of a study of the effects of Federal environmental legislation on the construction industry (Stephen Sobotka Co. and McKee-Berger-Mansuets, Inc., 1972). This study reflected the fact that one of the most basic goals of the legislation was to stimulate construction of waste water and other effluent treatment facilities.

The method of analysis in this study was similar to that of the A. D. Little study; only the labor demands required for the new construction stimulated by the legislation were estimated. Using constant construction sales to labor ratios, which ranged from 25,000 to 35,000 workers per $1 billion of forecast industry sales, it was estimated that 35,000 additional jobs would be created in the industry in 1976.

In April 1976, the U.S. Census Bureau released its survey study of 1972–74 employment in the public sector, including Federal, State, and local governments, resulting from environmental-quality control programs. The programs included in the survey accounted for approximately $7 billion of public spending: $4.6 billion in water quality, $2 billion in solid waste management, and $300 million in air-quality control. These programs employed 226,000 full-time equivalent workers: 94,000 in water-quality control programs, 124,000 in solid-waste programs, and 8,000 in air-quality control. Fewer than 7,000 workers were employed by the Federal Government, while 11,000 were employed by State governments, and 208,000 by units of local government. The concentration of employment at the local level is accounted for by the inclusion of sewage and trash collection and street cleaning services in the definition of environmental-quality control programs.

Because of possible negative effects of regulations on employment, the EPA initiated an "economic dislocation early warning system" that reported the number and size of plants closed because of the imposition of environmental standards, and the associated loss of jobs. Evidence from these reports suggests that the number of plants closing and jobs lost was minimal from a national perspective. A 1977 report (U.S. Environmental Protection Agency, 1977) by the system suggested that from January 1971 through December 1976, 98 plants were closed because of the imposition of environmental standards, causing a loss of 19,580 jobs, more than one-fourth of which were concentrated in the Midwest.

Conclusion

In estimating the effects on employment of environmental policies, the overriding importance of methodology cannot be overemphasized. By and large, the studies cited have considered only the direct impact of the policies in question. A more complete analysis, however, must also consider the indirect effects of these policies, with the realization that these may at least partially offset the direct effects.

Thus, there is a need for studies based on a general equilibrium (Hollenbeck) as well as on a macroeconometric (Chase, DRI) model, though each has its limitations. Based on these studies, a reasonable statement of the relationship between employment and environmental policy would appear to be: The overall employment impact of environmental policies, though perhaps negative, is not very severe. The impact is likely to be positive in periods when there is substantial investment in pollution-abatement equipment. Whether positive or negative, the empirical work to date indicates that the absolute value of the effect on the Nation's unemployment rate is probably less than one-quarter of a percentage point.

That policies may have significant effects on specific sectors is unchallenged. The pollution-abatement equipment and related industries are undoubtedly benefited by strong environmental measures. On the other hand, certain marginal plants concentrated in the Midwest may have had to close because of such measures.

THE EFFECT OF OSHA AND OTHER REGULATIONS ON PRODUCTIVITY AND MACROECONOMIC PERFORMANCE

There have been only a few studies of the macroeconomic effects of safety and health regulations. The majority of these consist of "inflationary impact statements" which were commissioned by the Occupational Safety and Health Administration (OSHA) in order to assess the effects of various standards to be imposed on industry. In this section we will examine "statements" pertaining to OSHA standards for noise levels, coke oven emissions, inorganic arsenic, and benzene. An independent study of the impact of OSHA's standards for asbestos is also critiqued. Finally, we examine the portion of Denison's article in the Survey of Current Business (1978) which estimated the productivity effects of OSHA, safety and health regulations in mining (an industry not covered by OSHA), and safety requirements for motor vehicles.

In 1976, the consulting firm of Bolt Beranek & Newman (BBN) completed a study of the impact of proposed noise regulation (Bolt Beranek & Newman, 1976). Existing regulations had restricted worker exposure—on a time-weighted basis—to noise levels not to exceed 90 decibels (dBA). The proposed regulation maintains the 90 dBA standard and adds provisions for audiometric testing and noise monitoring in cases where workers are exposed—again, on a time-weighted basis—to noise levels greater than 85 dBA. When noise levels are at 85 dBA, workers standing a yard apart can converse without shouting. The difference between 85 and 90 dBA may seem slight, but an 85 dBA noise has only half the energy and sounds only three-quarters as loud as 90 dBA noise.

The authors first estimated the incremental costs of complying with the proposed standard and possible future regulations. The effects of these additional capital and operating costs on the national economy were then simulated under four possible regulation scenarios using a macroeconometric model.

Information for the incremental cost estimates was obtained from industry testimony given at hearings held by the U.S. Department of Labor, from visits to plants in representative industries, and from "the knowledge and experience of senior BBN staff members gained from a variety of industrial noise control projects performed during the past 26 years * * *." Sixty-eight plants were visited to aid in the attempt to estimate worker exposure to various noise levels and the costs of noise control. The total number of production workers in the plants sampled amounted to approximately one-half percent of all the production workers in the 19 major industrial classifications considered.

Noise monitoring was estimated to cost an additional $12 per worker annually for 13 million production workers (about $155 million) because of the proposed standards. Audiometric testing was estimated to impose incremental costs of approximately $20 per worker annually for 4.3 million production workers exposed to noise levels in excess of 85 dBA ($84 million). Thus, the proposed regulation was estimated to carry an annual cost of $241 million.

Given a 90 dBA noise level attainment, full compliance with an 85 dBA standard was estimated to entail additional investments amounting to $8 billion over a 5-year compliance period. The total capital expenditures required over 5 years to quiet workplaces to this level would then be $18.5 billion. Annual maintenance costs were estimated to be 5 percent of these capital expenditures. At the existing rate of capital investment on safety and health related items—just over $3 billion a year—the capital costs required over a 5-year compliance period would be roughly equal to all other safety and health related capital expenditures. If 10- and 15-year compliance periods were in effect, however, the incremental capital costs required would be reduced by 18 and 25 percent respectively, assuming a 3-percent-per-year rate of cost reduction due to technological improvements.

If full compliance with an 85 dBA were required, the noise standards would surely be the most significant of all those promulgated by OSHA in terms of compliance costs for the whole of industry. As of late 1979, OSHA had still not decided whether or not to even impose the proposed standard requiring just audiometric testing and noise monitoring in workplaces where 85 dBA are common.

The scenarios simulated with a macroeconomic model were as follows:

1. Firms are required to conduct audiometric tests of workers exposed to noise levels greater than 85 dBA and to monitor noise levels in production workplaces. No programs to reduce workplace noise levels are required. (This is the standard proposed by OSHA.)
2. Firms are required to quiet workplace environments to 85 dBA within 5 years, to conduct audiometric tests until compliance is achieved, and to monitor noise levels every year.
3. Same as 2, but with a 10-year compliance period.
4. Same as 2, but with a 15-year compliance period.

As is done in macroeconometric analyses of environmental regulations, the simulations performed compared the base trend of the economy without the expenditures induced by regulation with the size and structure of the economy with these induced expenditures. The induced expenditures are presumed to be unproductive in the sense of conventional national income and product accounts—that is, no additional final measured output is yielded by the expenditure.

All the scenarios were estimated to have unfavorable effects on the Nation's major macroeconomic variables. Real gross national product was estimated to decline in all cases, the largest decline occurring under the first scenario. Under this scenario, industries incur the costs of testing and monitoring but do not experience any productivity increases associated with the replacement of noisy equipment with quieter, more productive equipment embodying more recent technology.

The major reason for the decline in real GNP, however, was the impact on employment rather than on productivity. The pattern of the effect of noise control on employment closely paralleled the pattern for real GNP, with the largest employment decline—and the largest increase in unemployment—occurring under the first scenario. The smallest impacts on employment and unemployment occurred under scenario 2.

As one might expect, the shorter the compliance period, the greater the inflationary impact. Thus, the second scenario had inflationary consequences which were statistically significant. A 15-year compliance period (scenario 4), on the other hand, had a relatively unimportant impact. The first scenario had the smallest inflationary impact of all since no noise control equipment is installed, and consequently no maintenance, interest, and depreciation expenses are incurred by firms to be passed along to consumers. It should be emphasized that any increase in the rate of inflation would not be permanent, but would apply only to the period of adjustment. It represents a once for all cost increase. It should also be noted that the macroeconomic estimates reported by the study were only of a qualitative nature. The quantitative magnitude of the estimates were not provided.

A study of the impact of standards for coke oven emissions (D. B. Associates, 1976) is more explicit in this regard, but the estimates performed must be viewed with considerable skepticism.

Though public awareness of coke as a product is nearly nonexistent, it has a significant place in the Nation's economy. Coke is the solid residue which remains after bituminous coals are baked at high temperature in the absence of air until most of the volatile matter has been driven off. The partially graphitized and cellular form of the carbon allows it to burn rapidly in the lower regions of a blast furnace, thereby creating a high temperature for melting iron and slag. At the time the study was undertaken, coke production by and for steel companies amounted to more than $5.6 billion a year.

Unfortunately, the escape of volatile matter during the coking process has been associated with high rates of cancer among coke oven workers. OSHA has responded with emissions standards. These standards require firms to establish "regulated areas" within their plants. Access to these areas is restricted to authorized persons. The level of coke oven emissions to which employees are exposed must be monitored. In some cases respirators must be used. Finally, work practices must be modified and/or engineering controls employed to reduce emissions levels.

The impact study subsequently commissioned by OSHA estimated that employment would increase by 10 million man-hours annually as a result of the emissions standards. This represents about 5,000 jobs. Compliance was found to require a number of different forms of labor, including inspectors, maintenance workers, and installors of equipment. The increase in manpower was to be accompanied by an estimated 18-percent decline in labor productivity in the coke industry. The inflationary impact was estimated to be slight—adding only 0.01 to 0.07 percentage points to the Consumer Price Index. Within the steel industry, the annual impact on prices was estimated to be from 1 to 2 percent depending on the assumptions one makes about how prices are set within the industry.

Most of the above estimates are the product of a faulty methodology, however. The employment estimate was based on calculations of the gross addition of manpower required to meet the emissions standards. No displacement effects were allowed for. Although investments for meeting the standards could "crowd-out" ordinary investments to some extent, this result was not accounted for. Moreover, cost and price increases resulting from the standards could result in a lower quantity of final output—and hence, labor—being demanded, and this effect, too, was neglected. In any event, the authors of the study went on to estimate the effect on labor productivity assuming their employment effect was correct and assuming (measured) output would be constant. Industry spokesmen, however, have indicated that the (measured) output of coke producers would decline by about 12 percent because of the increased time needed for coking. Hence, neglect of the reduced output induced by the anticipated price increase would lead to an understatement of the expected productivity decrease.

The inflation estimate was obtained by taking the increased costs required for compliance and passing them through an input-output table for the U.S. economy. A Laspeyres price index was then constructed for the table's final demand sectors. Regardless of the methodology employed, the inflationary impact would apparently be slight, but the input-output technique assumes perfectly inelastic product demands. Possibilities for substitution at each stage of production means that the impact on the prices of final goods and services is probably even less than the estimates performed by the authors. This adjustment would offset, to some extent, the understatement of the decreased productivity effect mentioned above.

A reasonable assessment of the macroeconomic impact of the standards for coke oven emissions then, would be that they would not have a substantial macroeconomic impact. Even if the authors' employment estimates did not represent an overstatement, the employment increase would be insignificant relative to the level of employment in the Nation as a whole. Likewise, the effects on total output and overall labor productivity are probably slight, as are the effects on the rate of inflation. This is not to deny that there could be important price, output, and productivity effects within specific industries such as iron and steel.

Inorganic arsenic is another occupational health hazard faced by many workers. A number of epidemiological studies have provided evidence that the extent of this hazard ranges from dermatitis to acute or chronic poisoning and carcinogenic effects. This hazard is common among producers of arsenical herbicides, pesticides, and desiccants and defoliants.

Arthur Young and Co. (1976) assessed the economic impact of OSHA standards designed to mitigate health risks to workers. As was probably the case for coke oven emissions, standards for inorganic arsenic are inconsequential from a macroeconomic perspective. The authors estimated that the product accounts for only 0.00032 percent of GNP, so again, the various sectoral impacts are what merit attention. The employment impact was estimated by constructing a simple supply-demand microsimulation model for industries closely related to inorganic arsenic. The increased costs of production resulting from OSHA standards were then passed through the model, and the effects on employment were compared with the baseline forecast of a Data Resources-like macroeconometric model. It was estimated that between 2,900 and 3,7000 jobs were at stake. About 1,600 of the jobs were in the arsenical wood preservative industry, representing 29 percent of that industry's employment.

The impact of OSHA regulations with respect to benzene and asbestos likewise appears to be confined to industry effects. The former commodity, used as a basic feedstock for aromatic chemicals, was estimated (Arthur D. Little, 1977) on the basis of a simple, competitive partial equilibrium model to experience a long-run price increase of 1 percent because of standards deemed necessary to reduce a number of possible toxic effects. Labor demand was estimated to increase by 69,700 man-hours in order to comply with these standards, implying a reduction in labor productivity—holding output constant—of 0.6 to 1.4 percent among benzene producers.

As for asbestos, the compliance costs necessary to reduce the risks of bronchogenic cancer and mesothelioma have been estimated to increase the prices of asbestos products (used for fireproofing and insulating) by 3.7 percent—again, on the basis of a simple, partial equilibrium model (Settle, 1974). A simple model of demand and the assumption of a fixed-coefficient production function were then used to estimate output and employment effects from this price increase. Output and employment were estimated to decline by about 2.9 percent, with 2,660 workers experiencing spells of unemployment averaging 10 weeks in duration. Note that labor productivity (output ÷ employment) was constant by assumption!

This discussion, then, summarizes the studies which have attempted to estimate the effects on OSHA regulations on output, jobs, prices, and productivity. Unfortunately, all of them are studies of specific regulations—to our knowledge no study seeking to evaluate the aggregate impact of OSHA regulations on macroeconomic variables has been undertaken. And any effort to extrapolate from the few studies which are available to the entire program would be highly misleading.

A rather different approach to this aggregate impact has been taken by Denison through his growth accounting framework. Denison's work on the effect of health and safety regulations on measured productivity is, as with his study of environmental regulations, confined to the nonresidential business sector with output valued at total factor cost so as to exclude the effects of indirect business taxes. Again, total factor input refers to land, labor, and capital combined by using their respective earnings as weights. The estimated increase in production costs due to health and safety regulations taken as a percentage of total factor cost provides a measure of percentage reduction in productivity for which they are responsible. The increase in costs due to regulation is calculated for safety requirements for motor vehicles, safety and health regulations in the mining industry, and standards set by OSHA.

To estimate the impact of regulations for motor vehicles, only safety features added to vehicles sold to business are considered. Those purchased by consumers are reflected in conventional measures of total output. Denison also confines his computations to capital costs, because current costs might be either favorably or unfavorably influenced by safety requirements. Improved bumpers, for example, may reduce the costs of damages sustained in collisions, but their increased weight may reduce gas mileage. In the absence of information, favorable and unfavorable effects are assumed to be offsetting.

Using Bureau of Labor Statistics data which enumerate the retail value of various changes in automobile design, Denison estimates that by 1975, 8.9 percent of the price of a new car represented incremental safety equipment. He assumes that trucks bought by business with a gross weight of 10,000 pounds or less carried the same incremental cost. For heavier trucks, Denison strikes a compromise between the estimates of two Government agencies for the impact of required improvements to air brake systems. This is assumed to be the only significant regulation of heavy trucks. Two-thirds of the trucks purchased by business were assumed to be in compliance with the standards in 1975, at an incremental cost of $1,000 per truck. Summing the effects on trucks and autos, it is estimated that safety requirements created a drag on measured output per unit of input of 0.09 percent by 1975, the rather modest impact having increased steadily since the baseline year of 1967.

A much more significant impact seems to have occurred in the case of safety and health regulations for the mining industry. Oil and gas extraction have not been noticeably affected, but coal, metal, and nonmetallic mining have been the subject of close Federal scrutiny independently of OSHA. The Federal Metal and Nonmetallic Mine Safety Act of 1966 and the Federal Coal Mine Health and Safety Act of 1969 were both major pieces of legislation.

Limiting dust levels has been perhaps the primary—and most costly—objective of this legislation. Thirty-six percent of all coal miners exposed to existing levels of dust for 35 years or more had contracted black lung disease. Other regulations included the mandated use of spark-free equipment, the sealing of abandoned areas where gases might accumulate, and lighting standards for work areas.

Productivity in all three sectors of the mining industry affected by the legislation has declined after rising sharply for several years. The question at hand, of course, is the extent to which regulation is responsible for the decline. Lacking adequate information to pursue the methodology followed elsewhere in his study, Denison assumes—on the basis of the testsimony of industry and union leaders—that all of the productivity slowdown in mining is due to the legislated safety and health standards. Other factors such as the influx of inexperienced workers, wildcat strikes, increased absenteeism, and—for 1974 and 1975—recessionary influences are ignored.

Denison furthermore assumes that the percentage reduction in measured productivity due to mining regulations equals the percentage increase in employment which he estimates it necessitated. Ex-

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trapolating past trends in output per worker in mining (other than oil and gas) and comparing them to output per worker since the legislation, Denison estimates the amount by which the actual number employed exceeds the number that would have been required to produce current output had past trends continued. This amount as a percentage of total employment in the nonresidential business sector is used as the estimate of the percentage reduction in measured productivity growth due to safety and health regulation, the justification being that labor is a large percentage of total factor cost. This assumes that the ratio of depreciation and the net opportunity cost of invested capital to labor cost in mining was not affected by regulation. In fact, however, the increase in the labor-output ratio could reflect the substitution of labor for other inputs. Increased levels of safety might lower the risk premiums which have to be included in the wages paid to workers in order to attract them into mining. Substitution of labor for other inputs would thereby be encouraged. If this is the case, labor productivity would indeed show slower growth, but output per total factor input might not be affected significantly.

In any event, safety regulations in the mining industry are estimated to have increased nonresidential business employment by 0.24 percent between 1968 and 1975. Again, the impact is estimated to have increased steadily since 1968. Given the rather strong assumptions made, however, 0.24 percent must be considered an upper-bound estimate of the impact on the level of measured productivity, the overstatement being stronger in the case of metal and nonmetal mining than in coal.

Finally, Denison assesses the impact on industries other than mining—those covered by OSHA. Again, the incremental costs can be divided into capital costs and current account expenditures. The impact on capital costs is estimated by comparing trends in existence before OSHA went into effect with current outlays, as reported in surveys undertaken by the McGraw-Hill Publications Co. Information on current-account expenditures for safety and health items is not available so it is assumed they bear the same relation to capital costs as do those for air- and water-pollution abatement. The impact of regulation once again appears to rise steadily over time, but all of OSHA's standards combined are estimated to have caused only a 0.09 percent decrease in the level of measured productivity between 1970 and 1975. It should be noted, however, that some safety standards for trucks and certain OSHA health standards had scarcely begun to have an effect during this period.

In total, then, these estimates account for 5 to 10 percent of the slowdown in productivity growth during these years. Combining all the safety and health regulations examined, then, the total impact on measured output per unit of input is estimated to have been minus 0.42 percentage points from 1968 to 1975, mining regulation accounting for about three-fifths of the decline.

Two assumptions made by Denison which were noted in discussing the impact of environment regulation should again be mentioned. First, it is assumed that, for a given level of inputs, regulation-induced expenditures have a dollar-for-dollar crowding out effect on marketed output. In addition, factors of production are assumed to experience no diminishing marginal rates of return. As noted earlier, both of these assumptions create an upward bias in Denison's estimates—at least for the direct (as opposed to indirect) impact of regulation.

The macroeconomic effects of major Federal safety and health regulations, then, have not been great. A 0.42 percent decline in output per unit of input from 1968 to 1975 represents a decline in the productivity growth rate of only 0.05 percent per year. And we have indicated that this is an upper-bound estimate. The overall impact on total output, employment, and capital formation is modest. And, as emphasized above, any increase in the price level due to safety and health regulations is not a permanent increase in the inflation rate. Particular industries, of course, may be impacted more or less heavily. The impact of mining regulation, for example, is small from a national perspective when one considers that mining is such a small part of the Nation's economy.

As for OSHA, it must be emphasized that its regulations consist primarily of a codification of prevailing standards in the field of safety, and that safety has been promoted by business for many years both on its own volition and under the prodding of State agencies and workers compensation insurers. Note that to the extent that safety measures result in fewer accidents, workers compensation premia—which are costs to the firm—will fall. To the extent that average outlays for health and safety have increased they can even promote productivity by decreasing time lost due to illness or accident, as well as by raising vitality and reducing debilitating health conditions. Despite much publicity, then, OSHA's macroeconomic effects are slight and pertain if at all to standards issued in the area of health.

VIII. ALLOCATING THE SLOWDOWN IN PRODUCTIVITY GROWTH AMONG ITS DETERMINANTS

Section IV of this study presented a number of hypotheses regarding the slowdown in productivity growth in the 1970's. All of the determinants mentioned there have some credibility, and each could account for some portion of the slowdown. Moreover, these factors interact with each other in unknown and complex ways. A number of analysts have attempted to allocate the observed change in productivity growth among these potential contributing factors. In these analyses, environmental controls are not the focus of the analysis; they are but one factor among many.

There are two basic techniques employed in these allocation studies. One approach is that employed by Denison in his important work on accounting for the sources of economic growth.[31] In it, separate estimates of the role of various determinants are made, often on the basis of rough, ad hoc analyses along with a good dose of judgment. Then the remaining, unaccounted-for residual is assigned to a broad, catchall category. The second approach is a good bit more systematic. In it, the time series of productivity are observed and breaks in the series are identified using statistical analysis. Then, using a time series regression framework, the determinants of the breaks are statistically estimated and the contribution of each is measured.

Because the studies allocating productivity change among its determinants are numerous, only two will be described here. The first, an allocation study by Denison, characterizes the first approach. The second, by Siegel, is representative of the more statistical approach.

In his allocation study, Denison considers productivity in terms of nonresidential business income per person employed—a single factor productivity index—and estimates the contribution, of various determinants to its growth during the 1948–49, 1969–73, and 1973–76 periods.[32] The central problem, of course, is to account for the slowdown in productivity growth during the latter two periods relative to the first period. Estimates for 1948–69 are taken from the author's "Accounting for United States Economic Growth, 1929–1969" with minor changes resulting from the measurement of output in 1972 prices instead of 1958 prices and from revisions in the data. The estimates for 1969–73 and 1973–76 are preliminary ones which the author has undertaken as part of an effort to update his earlier work.

Denison begins by adjusting his productivity data for what he terms "irregular factors"—weather, work stoppages, and cyclical factors. These factors are estimated to have had a trivial effect on productivity growth during 1948–69 and 1973–76, but they account for about half of the 1 percentage point difference in the growth rates for 1948–69 and 1969–73.

[31] Denison (1974).
[32] See Denison (1979b) or (1979c).

Changes in labor force characteristics are the first major set of factors to be considered. Given the author's productivity measure—which ignores changes in the hours worked by the labor force—hours worked is one obvious factor to consider in explaining the recent deceleration in productivity growth. This is found to have had a negative impact during all three of the periods under study, and this impact appears to have increased over time. The same can be said for changes in the labor force's age-sex composition. By way of contrast, education has had a consistent positive impact, and its effects also appear to have increased over time. Presumably, the health of the labor force has improved over time, but this factor is not considered by Denison, as it is by others.

The amount of capital and land with which the labor force works is the next major category Denison examines. This, in comparison to other studies, is not estimated to have undergone much of a decline in its contribution to productivity growth. The reallocation of labor out of agriculture and out of self-employment appears to have had a more significant effect. This reallocation appears to have made no contribution to productivity growth during 1973–76, whereas it made a 0.4 percentage-point-per-year contribution during 1948–69.

Changes in environmental and other regulations are also estimated to have played a significant role. While these regulations—or the absence thereof—are estimated to have had no impact on 1948–69 growth, by 1973–76 they are estimated to have caused an annual reduction of 0.4 percentage points.

Economies of scale arising from expanded markets are estimated to have made a smaller contribution in recent years than they did in the past. What is truly striking is that Denison is left with a huge residual factor which he labels "advances in knowledge and not elsewhere classified." This residual factor accounts for over half of total 1948–69 productivity growth. For 1969–73, the figure of 1.6 percent per year equals the measured rate of productivity growth for that period. And for 1973–76, the residual factor suddenly drops to −0.7 percent per year which is greater in absolute value than the −0.5 percent per year rate of productivity growth which occurred during these years.

Denison argues plausibly that, although advances in knowledge may have contributed less to recent growth, his study leaves unanswered the question as to why his final category shows such a sudden decline during the most recent period. He considers several alternative explanations. He dismisses some of them—for example, "people don't want to work any more"—on the grounds that they were also operative during high-productivity periods or have only operated gradually in comparison to the sharp downturn in productivity growth. Inflation is admitted to be a possible explanation, but Denison says he simply does not know how much of a factor it has been.

The sudden increase in energy prices is estimated to have only contributed 0.1–0.2 percentage points annually to the decline. But Denison's discussion may be criticized in that it does not consider the long-run (dynamic) effects of the energy problem. These involve plant adaptation costs required by the need for fuel substitution and the increased obsolescence of some plants and equipment attributable to energy price induced factor substitutions. Denison's estimate also ignores the enormous diversions of labor and capital to the redesign of products and the retooling for production of them when energy prices induce a switch in the pattern of consumer demand for example, from large to small, fuel-efficient cars).

Also troublesome are difficulties in capturing changes in technological advance. To some extent, technological change is embodied in physical capital, and its rate of change depends in part on the rate of change in the stock of physical capital. By the same token, Denison's estimate of the contribution of physical capital may be entangled with the contributions of technology and other factors which lower the real price of capital goods. In any case, inclusion of a variable to capture changes in R. & D. spending might have been appropriate. In theory, at least, the model presented in section III and appendix A captures the contributions of all inputs and separates them from the effects of technical change.

Clearly, Denison's study attributes a negative and increasing impact—at least through 1975—on productivity change to environmental and other regulations.

In any case, these regulations still appear to account for a relatively small portion of the measured productivity slowdown—about 0.1 percentage points annually from 1965 to 1973, 0.22 percentage points from 1973 to 1975, and only 0.08 percentage points from 1975–78. This decrease in impact for the most recent period is noteworthy.

In an important and recent article, Robin Siegel has attempted to statistically identify breaks in the trend of productivity growth and to account for the slowdown in trend.[33] Utilizing Chow tests to verify statistically significant breaks in the series, the author found such interruptions in both 1967 and 1973. In her statistical analysis, change in the demographic composition of the labor force was a consistent contributor to the productivity slowdown. From 1973 on, however, changes in relative energy prices were the single most important negative factor. Pollution abatement expenditures were a significant negative factor in the post-1967 slowdown, and continued to contribute to the productivity slowdown until 1975. After 1975, these expenditures declined as a percentage of the gross national product.

Output per man-hour in the private nonfarm sector—again a restrictive single factor productivity index—served as the dependent variable for Siegel's regressions. Regressing this on a time trend variable and the inverse of the GNP gap, in order to control for cyclical factors) produced a good fit for quarterly data covering much of the post-war period. But F-statistics on Chow tests were consistently high, with severe breaks in the productivity trend indicated for 1967 and 1973.

The goal of the analysis was thus to identify variables which could be added to the equation to produce a consistent time trend. The change in the composition of output away from manufactured goods and toward services was one obvious factor to be considered, but it was found that productivity in manufacturing had itself experienced a break in trend.

In any case, the share of manufacturing in total output was added as a variable. Also added were the percentage of prime age males in

[33] Siegel (1979).

the labor force, relative energy prices, pollution abatement expenditures as a percentage of GNP, the capital-labor ratio, and other variables. The capital-labor ratio was found to have had a significant, positive effect on productivity growth until 1973, but the ratio declined thereafter and made no contribution to post-1973 productivity change.

It is noteworthy that the addition of these variables still could not prevent F-statistics on Chow tests from being significant at the 5 percent level for the 1967 and 1973 break points, but Siegel points out that they are barely significant. Previously, they were highly significant even at the 1 percent level.

Thus, Siegel's analysis does account for a large portion of the productivity slowdown—with energy prices being assigned a much more significant role than in other analyses—but the sharpness of the decline and the breaks in trend remain unexplained. Siegel suggests looking at the age of the capital stock, additional Government regulations such as those in the health and safety area, and changes in attitudes toward work. In addition to these variables, one should also employ variables to control for education and training expenditures, expenditures on research and development, and changes in scale economies. These variables have typically been included in other analyses. Of course, data for these variables may be difficult to obtain on a quarterly basis, but their inclusion is likely to alter the results. It would also be of interest to estimate the impact of the new jobs tax credit, which went into effect at the end of 1975, and which encouraged the hiring of low-skilled workers.

Table 3 summarizes the results of all of the allocation studies we have been able to identify. Each of these studies seeks to account for the difference in productivity growth from a pre-1970's period to a 1970's period. The varying periods of comparison and the varying definitions of productivity account for differences in the percentage points of the decrease in productivity growth which are being allocated (see the bottom row). Across all of the studies, 25 separate determinants of productivity growth are identified, of which pollution abatement regulations are one (No. 17).

Among the studies identified, the decreases in productivity growth which are to be allocated range from 1.0 to 3.1 percent. If the Denison (2) estimate is eliminated because the comparison it makes does not include the productivity experience beyond 1973, the range becomes 1.2 to 3.1 percent. Moreover, the Denison (1) productivity change estimate does not include in it the change in hours worked overtime. If this adjustment is made, the 3.1 percentage point change is reduced to 2.8 percent, and the range is further narrowed 1.2 to 2.8 percent.

In the studies which identified cyclical and weather effects, these determinants generally played a modest role. The largest role was assigned by Kendrick, who estimated that cyclical changes accounted for 40 percent of change he was analyzing—0.6 out of 1.5 percent. A somewhat more significant role was assigned to changes in the sectoral composition of output or the age-sex composition of the labor force. These factors have been allocated from 11 to 40 percent of the change, with the bulk of the estimates in the 20–30 percent range. The range of estimated effects due to changes in the capital stock is large. One of the analysts (Kendrick) assigns it a zero role, three assign it a 10–15 percent role, and 2 of the analysts (Siegel and Evans) attribute about one-third of the total decline to the decrease in the capital stock. Most of the allocators did not explicitly consider the role of energy prices, wrapping it into their residual category. However, those studies that did consider it, allocated it a substantial role—up to one-third of the total decrease. For environmental and other regulations, the percentage point changes range from 0.4 percent (Denison) to 0.1–0.2 percent. In no case are pollution abatement regulations assigned more than 15–20 percent of the responsibility for the decrease in productivity growth. The typical estimate of the role of environmental regulations is in the range of 5–15 percent.[34]

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[34] This estimate is based on an equal allocation of impact when pollution abatement is aggregated with other categories.

TABLE 4.—CHANGE IN THE EFFECT OF VARIOUS FACTORS ON PRODUCTIVITY GROWTH: CONTRIBUTION IN PERCENTAGE POINTS OF VARIOUS FACTORS TO THE GROWTH RATE OF PRODUCTIVITY IN RECENT YEARS MINUS THE CONTRIBUTION IN PAST YEARS

[Numbers in parentheses indicate the percentage of the change in productivity growth explained by the factor in question]

Factor/Author	Denison (1)[1]	Denison (2)[2]	Kendrick[3]	Seigel[4]	Kutscher, Mark[5] and Norsworthy	Mark[6]	Evans[7]	Clark[8]	Norsworthy, Harper[9] and Kunze[10]
1. Labor market tightness				0.2(11.1)					
2. Cyclical effects 3. Weather, work stoppages	0.2(6.5)	−0.4(−40.0)	−0.6(−40.0)	−0.4(−22.2)				−0.2(−10.5)	
4. Shifts from manufacturing to services			−0.1(−6.7)	0(0)	0 to −0.1 (0 to −8.3).	0.1 to −0.1 (6.7 to −6.7).			
5. Shift from farm to nonfarm 6. Shift out of self-employment	−0.4(−12.9)	−0.3(−30.0)	−0.1(−6.7)		−0.3(−25.0)	−0.3(−20.0)			−0.2(−9.5).
7. Changes in hours worked	−0.3(−9.7)	−0.1(−10.0)							
8. Labor force composition	−0.1(−3.2)	−0.3(−30.0)	−0.3(−20.0)	0.2(11.1)	−0.2 to −0.3 (−16.6 to −25.0).	−0.2 to −0.3 (−13.3 to −20.0).	−0.5(−33.3)	0.1(5.3)	0(0).
9. Education	0.4(12.9)	0.2(20.0)	0.2(13.3)						
10. Health and vitality			0(0)						
11. Nonresidential structures and equipment 12. Inventories	−0.1(−3.2) −0.1(−3.2)	−0.1(−10.0) 0(0)		−0.6(−33.3)	0 to −0.1 (0 to −8.3).	−0.2 [8](12.8)	−0.5(−33.3)	−0.3 to −1.2 (−15.8 to −63.2).	−0.7(−33.3).
13. Other capital									
14. Economies of scale	−0.2(−6.5)	0(0)	−0.2(−13.3)						
15. Land	0(0)	−0.1(−10.0)	−0.1(−6.7)						
16. Energy prices				−0.7(−38.9)			−0.3(−20.0)		
17. Pollution abatement 18. Other regulation	−0.4(−12.9)	−0.2(−20.0)		0(0)	−0.1 to −0.2 (−8.3 to −16.6)				−0.1(−4.8).
19. Government services			−0.1(−6.7)						
20. Taxes				0(0)					
21. Expectations				−0.4(22.2)					
22. Formal advances in knowledge 23. Informal advances in knowledge	−2.1(−67.7)	0.2(20.0)	−0.15 (−10.0) 0(0)				−0.2(−13.3)		−0.2(−9.5).
24. Diffusion of knowledge 25. Residual factors			−0.15 (−10.0) 0.1(6.7)		[11]−0.2 to −0.6 (−16.6 to −50.0)	[11]−0.6 to −0.9 (−40.0 to −60.0)		−0.6 to −1.6 (−31.6 to −84.2)	−1.1(−52.4).
Total change explained	−3.1	[12]−1.0	−1.5	[12]−1.8	−1.2	−1.5	−1.5	[12]−1.9	−2.1.

Sources: Denison (1979b), Kendrick (1978), Siegel (1979), Kutscher, Mark, and Norsworthy (1977), Mark (1978), Evans (1978), Clark (1978), and Norsworthy, Harper, and Kunze (1979).

[1] Compares nonresidential business income per employed person in 1973–76 versus 1948–69.

[2] Compares nonresidential business income per employed person in 1969–73 versus 1948–69.

[3] Compares private sector output per total factor input in 1976–76 versus 1948–66.

[4] Compares private nonfarm output per person-hour in 1973–78 versus 1955–65.

[5] Compares private output per person-hour in 1966–77 versus 1947–66.

[6] Compares private output per person-hour in 1966–77 versus 1947–66.

[7] Compares private nonfarm output per person-hour in 1968–77 versus 1947–68.

[8] Compares 1973–77 versus 1966–73 and is emphasized as a tentative estimate.

[9] Compares private nonfarm output per person-hour in 1973: II–1976: IV versus 1955: IV–1965: II.

[10] Compares private output per person-hour in 1973–78 versus 1948–65.

[11] The portion of the decline in productivity growth not accounted for by the authors was assigned to the "residuals factors" category.

[12] The sum of the component parts does not equal the total because of rounding errors.

IX. PRODUCTIVITY GROWTH, ENVIRONMENTAL AND HEALTH/SAFETY REGULATIONS, AND SOME POLICY OPTIONS

In this study, we have reviewed the anatomy of the productivity slowdown in the 1970's and have discussed numerous hypotheses concerning the causes of this slowdown. We were guided in our analysis by a formal model which linked productivity growth in a firm to its primary unique determinants, one of which we labelled "regulatory intensity." Our review focussed on regulations in the environment, health, and safety areas, and we tried to pry out of the numerous studies which have been done on the determinants of macroeconomic performance and productivity growth some assessment of the role of environmental and health/safety regulations.

ENVIRONMENTAL AND HEALTH/SAFETY REGULATIONS AND THE SLOWDOWN IN PRODUCTIVITY GROWTH: A BOTTOM LINE

Our survey and review of investigations of the post-1965 slowdown in productivity growth has produced no real consensus on the relative magnitudes of the contribution of the numerous factors studied. The changing demographic composition of the labor force and hours worked, together with sectoral shifts in the composition of output, seems to receive substantial weight in most estimates, accounting for between 20 to 30 percent of the observed slowdown. The slowdown in the rate of capital investment, resulting in a declining capital-labor ratio and a capital stock which embodies a technology which increasingly deviates from what is possible is also assigned a major role. Considering both the microeconomic and the "growth accounting" studies, it seems reasonable to attribute from 25 to 35 or 40 percent of the slowdown to this factor. In thinking of this determinant, however, it should be recognized that many analysts included the potential effect of the post-1973 energy price increase in the capital variable. This procedure presumes that the main effects of the energy price increase were to reduce both investment and the return (productivity) of existing capital, and hence to reduce the capital-labor ratio. Perhaps one-third to one-half of the 25–40 percent role assigned to the capital factor is attributable to the energy price increase. The third important factor appears to be cyclical—for much of the late 1960's and the 1970's the economy has shown many characteristics of a quasi-permanent recession. High unemployment and low utilization of the capital stock has persisted. These factors together with weather and work stoppages would appear to account for another 10–20 percent of the productivity slowdown.

If this characterization is correct, between 10 and 40 to 45 percent of the slowdown is to be allocated to the large number of other determinants, of which environmental and health/safety regulations are one. It seems clear that these regulations cannot escape some of the blame. However, little evidence exists to suggest that as much as 15 percent of the contribution to the overall slowdown can be attributed to them. This is based in part on the results of the macroeconomic model estimates which emphasize that until now environmental regulations have had both productivity increasing and productivity reducing effects which largely offset each other. A reasonable estimate, then, would attribute, say, 8 to 12 percent of the slowdown in productivity growth to environmental regulations.

This conclusion implies that we attach less weight to the results of some of the studies than to others. Those studies which yield large estimates of the productivity impact of environmental regulations include Denison's and some of the findings of Crandall. We have indicated in the text why we find these to be upper-bound estimates—at least for the direct impact of regulatory policies.

Our bottom-line estimate, we would note, accounts for both the direct and the indirect effects of environmental and health safety regulations. As a result, whatever effects environmental and health/safety regulations have on capital investment and the capital-labor ratio are included in the estimate assigned to the regulations. In this vein, it will be recalled that the evidence on the adverse impact of environmental and health/safety regulations on the capital stock and its productivity is very weak. We discuss why Leahey's estimates of this impact are excessive. Health and safety regulations—for example, those affecting the mining industry and those designed to reduce the noise level in plants—can have major adverse output and productivity impacts in certain sectors or industries. These impacts tend to be localized, however, and because of the small size of these sectors relative to the national economy, they appear to have a rather trivial impact on macroeconomic performance. These localized impacts are not unique to health and safety regulations, however. The study by Leahey and the case study on the copper industry illustrate the rather major adverse effects which air and water pollution control policies can have on particular industries.

In arriving at our "bottom-line" estimate, several points should be made. First, a wide range of uncertainty pervades our bottom line estimates. We have relied on the existing research which has been done on this topic. This research is varied in methodology, data, and the time periods analyzed. Our estimate is an amalgam which tries to sort through these differences, and to filter out the total effect of environmental and health/safety regulations. It is an estimate which compares the pattern of productivity growth in the post-1970 period to that which preceded it. Hence, it suppresses some important differences in the determinants of productivity growth within the post-1970 period. For example, the impact of the energy price increase would be reflected in post-1974 productivity growth patterns, and not those of the earlier post-1970 period.

Second, our estimate is of the effect of only environmental and health/safety regulations, and not public regulations in total. In addition to rules for residual emissions and occupational health and safety, Government has imposed mandates in a large number of other areas during the last decade—energy usage, new product introduction, plant location, transportation, and forest management are all examples. Clearly, the total impact of these measures is in excess of that for environmental and health/safety regulations themselves.

Third, as we have seen, the studies which have attributed substantial productivity effects to environmental and health/safety regulations have done so in a framework which omits the potential effects of numerous other factors.

In our review, we were struck by the rather easy dismissal of the economic dislocations caused by the rapid, post-1973 increase in energy prices, and their effect on productivity growth and macroeconomic performance in general. While a few studies suggest a nontrivial role for this exogenous price shock—for example, Hudson-Jorgenson and Gollop-Roberts—we judge that this effect has not been adequately accounted for in the studies which have attempted to allocate output or productivity growth among its determinants. As a result, some of the slowdown in productivity growth that we (and others) have attributed to lagging investment and the decrease in the capital-labor ratio is probably due to the rapid increase in energy prices and the required adjustment to this increase. The category of the exogenous price increase should probably be included as a separate factor, and not wrapped into the category of the capital stock or its productivity. In addition, the uncertainties introduced and operating adjustments required by periods of double-digit inflation should be independent factors in any full appraisal of the causes of the productivity slowdown. Similarly, the last decade has also seen an unprecedented rise in total employment and labor force participation, even though the unemployment rate has not fallen substantially. Increments to employment of this magnitude are bound to encounter diminishing marginal productivities, which diminutions will be reflected in measured aggregate labor productivity. Indeed, the same periods in which productivity growth has decreased have seen policies subsidizing incremental private sector employment. Because such policies induce the hiring of workers whose productivity is below market wage rates, the fall in measured productivity may actually signal the success of these programs.[35] All of these factors have been given too little weight.

Fourth, it is quite possible that some portion of the observed decline in labor productivity growth reflects a measurement problem. In a period of rapid product price increase, aggregate time series statistics on changes in labor inputs may be more reliable than those for changes in real output. Estimates of the latter variable over time must be based on deflations using composite price indices which may contain substantial distortions in a period with rapid relative price shifts.

Finally, although we have attempted to accurately account for both the direct and indirect effects of environmental and health/safety regulations in the impact attributed to them, some potential indirect effects which these regulations might have on other variables considered independent may have been underestimated. For example, to what extent is the reduction in the rate of investment due to an increase in uncertainties caused by environmental regulations? To what extent

[35] See Bishop and Haveman (1979).

have R. & D. activities been shifted by environmental and health/safety regulations toward seeking ways of reducing residual emissions or improving the environment of the workplace as opposed to improving the efficiency of production processes or the introduction of new products? Environmental and health/safety regulations may have larger indirect impacts than we have attributed to them. If so their total effect on productivity growth will be greater than we have attributed to them.

One basic and overriding point should be made with respect to environmental and health/safety regulations. The contributions to economic welfare which they are intended to make are, by and large, not reflected in marketed or measured output. These effects include improved health (implying less demand for medical care services), longer lives, expanded outdoor recreation opportunities, greater enjoyment of existing recreation opportunities, and reduced demands for cleaning and other "defensive" activities. Were the standard productivity measures effective indicators of economic welfare, these outputs would be included in the numerator of the measure. Although they are difficult to quantify, let alone value, numerous studies have indicated that marked increases in these outputs have resulted from environmental policy. In some cases, benefit-cost analyses which have been made of them suggest benefit-cost ratios in excess of one.[36] If this is in fact the case, the effect of these regulations on "true" productivity would be less negative or even positive and the inclusion of the outputs of these regulations in the numerator of standard productivity measures could tend to offset the negative effects of other factors on productivity growth and change the sign of the effect attributed to environmental regulations. Given that it is a reliable measure of "true" productivity which is desired, it is essential that additional benefit-cost analyses of environmental and other regulations be undertaken.

THE AVAILABLE POLICY OPTIONS AND THEIR POTENTIALS

In the studies we have examined, numerous potential determinants of the slowdown in productivity growth have been examined. These studies have differed with regard to the relative importance assigned to the various factors. Of the several factors which appear to have played some nontrivial role, some appear amenable to change by policy action, others do not. Given the desire to improve productivity growth, what are the policy options which appear viable and what is their potential?

For many of the factors we have discussed, Government policies would appear to have little if any control. Change in the composition of demand is one example. A high proportion of the growth in income which accompanies economic development tends to be allocated toward the service sector and away from outputs produced by the agricultural and manufacturing sectors. Unfortunately, relatively low levels of productivity and rates of productivity growth seem to be an inherent feature of service industries. It is not clear what policy measures could alter the slowly shifting pattern of demand or improve productivity performance in the service sector. Of the two possibilities, however,

[36] See, for example, Lave and Seskin (1977), Chapter 10, and Freeman (1979).

efforts to control inefficiency and waste in some service sectors—for example, the health care system—would appears to hold the more promise.

The existence of economies of scale is another factor over which Government has little control. To the extent that other factors (for example, specific forms of R. & D.) affect productivity growth through economies of scale, Government may possess some viable policy instruments. If, for example, policy measures can increase the relative growth of industries experiencing economies of scale, aggregate productivity growth could be improved. Or, if policy can affect the relative prices of inputs, the relationship of average costs to output could be so altered as to encourage scale economies. Such alterations, however, would likely be mere window dressing. Unless policy-induced changes in input prices offset existing distortions, such changes are likely to further retard productivity growth by inducing resource misallocation.

The demographic composition of the labor force is another factor over which Government has little control. It too is a factor which many investigators agree has been a major source of the productivity slowdown. There is every indication, however, that the future change in the demographic composition of the labor force will have favorable consequences for aggregate productivity. The age composition is shifting to more experienced (productive) workers, and the women now entering the labor force have better opportunities for obtaining training and experience than was formerly the case. With no future policy actions, then, this factor should positively influence productivity change.

There are other factors over which the Government can or has exercised but limited control. The prospect for productivity growth of likely changes in many of these determinants is not favorable, unless policy measures for influencing them are either found or improved. Factors in this category include business cycle effects, inflation, energy prices, and innovation.

These factors are, of course, often interrelated and their interdependence may help to explain the tenuousness of the control that governmental policies have over them. For example, in the short run, efforts to reduce the rate of inflation may reduce output and productivity growth and increase the rate of unemployment. In this case, efforts to mitigate one potential adverse impact on productivity growth are likely to exacerbate another. While steady longrun monetary and fiscal policy could have beneficial effects on all three fronts—inflation, unemployment, and productivity—Government has had substantial difficulty formulating such a longrun policy.

Some observers contend that the situation with respect to inflation and unemployment represents a dilemma only if the policy problem is viewed as one of managing aggregate demand. If, as they suggest, the real problem is with constraints and impediments on the supply side—minimum wage laws, high marginal tax rates, unemployment benefits, labor union practices, energy supply constraints, et cetera—effective policy measures could have beneficial effects on all three fronts, even in the short run.

However, even if supply side constraints are the real problem, the policy options are not striking. Consider, for example, efforts to increase energy supplies to combat upward price pressures and bottlenecks. Some measures to improve the domestic supply of energy are being implemented and many others are being debated. But the OPEC cartel appears to be a long-term feature of the world economy. Policy options with respect to it are limited.

Innovation is a related factor in that macroeconomic conditions affect the rate at which new products or processes are introduced into the economy. Changing rates of inflation, uncertain demand for goods and services, and sporadic energy supplies combine to create an environment in which those who are risk-averse will hesitate to make investments even if the expected rate of return is relatively high (Malkiel, 1979). And, we have suggested, Government has only tenuous control over these factors which may have an indirect impact on innovation. While some have argued that Government could have a beneficial influence on innovation and productivity growth by increasing R. & D. support, the ultimate potential of this factor is in dispute.

Finally, there is that limited set of factors which appear both to have played some role in the slowdown in measured productivity growth and over which Government can exercise effective control. Included here are regulations in the areas of health, safety, and the environment and policies to influence the rate of capital formation.

In the previous section we have stressed the fact that regulations in the areas of health, safety, and the environment may have benefits which are not captured in conventional productivity indices. If, after a careful consideration of the benefits and costs, it appears that some regulations have imposed net social costs, however, regulatory reform may be in order.

One of the causes of the productivity slowdown is a deceleration in the rate of capital formation. Undoubtedly due to a large number of causes, the ratio of investment to gross national product is now lower in the United States than nearly all other industrialized countries. An immediate response is to suggest that capital investment would increase if regulations were relaxed. We have concluded, however, that environmental and health/safety regulations have not contributed strongly to the declining capital-labor ratio. Others have suggested that productivity growth would best be served by reducing the taxation of capital gains or profits by the Federal Government, or by providing direct incentives for private capital investment. A third group argues that neither regulation nor tax disincentives are at the heart of the issue, but that large Government deficits have diverted potential investment funds from the private to the public sector.

Many proposals have thus been put forth with respect to both the issues of regulation and capital formation. In the section which follows we will review their potentials for improving both productivity growth and macroeconomic performance in general.

TWO POLICY PROPOSALS: AN EVALUATION

The evidence cited in this paper has led to the conclusion that environmental and health/safety regulations are responsible, either directly or indirectly, for some nontrivial portion of the slowdown in productivity growth. Not only have these regulations caused some diversion of capital investment in plant and equipment into pollution control and health/safety expenditures, but they have also created uncertainties about future costs which may have, to some limited extent, restricted capital investment. These regulatory-induced reductions in capital investment have supplemented similar, though in all likelihood larger, impacts caused by the rapid increases in energy prices. This interaction of regulations, capital investment, productivity growth, and macroeconomic performance has generated two major types of policy recommendation. The first concerns what is known as the regulatory budget; the second involves a wide range of proposals designed to increase capital investment directly, so as to offset whatever forces have led to the recession in the growth of the capital-labor ratio.

The regulatory budget

This proposal involves the establishment of a quasi-accounting framework, in which Government regulatory programs would be assigned a "budget allocation" which could not be exceeded over some specified period of time. The "budget" to be allocated would not consist of Federal moneys to be spent, which is the standard budget concept. Rather, the budget in this case would be a total economic cost figure. The regulator could issue regulations which impose an economic cost, but the total economic costs so generated could not exceed the budget so allocated.

The basic notion here is that any regulator desiring to maximize, say, the improvement in water quality attainable by the regulations to be issued would evaluate each potential regulation to determine the improvement obtained per dollar of economic cost (or "budget" cost). A rational choice would involve those regulations which simultaneously exhausted the budget and secured the maximum improvement in water quality. The implicit benefit and cost calculations required here are directly analogous to those required to rationally allocate a fixed investment budget among the available projects so as to secure the maximum net benefits attainable from the budget.

The appeal implicit in such a budget is substantial. There are, however, substantial problems in implementing such an arrangement. Here we will first list some of these problems and then present an overall appraisal of the merits of proceeding to the design and imposition of such a framework. The form of the proposal on which we will focus is that described by Miki and Humphrey (1978). It involves, as a first step, the development of a "Special Analysis" in the U.S. Government Budget. In this analysis, regulations would be grouped by category (for example, health, safety, environment, et cetera) and by agency (for example, Department of Commerce, Environmental Protection Agency, et cetera). Associated with each category would be an estimate of (1) the direct Federal outlays required to implement and enforce the regulations; (2) the indirect public sector costs of imposing the regulations (for example municipality costs incurred to, say, meet clean drinking water standards); and (3) the private sector costs required to meet the regulations. While this special study would set forth a management framework for increased attention by regulators to impacts and costs, it would not serve as a budget control instrument. This

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control function would come, as a second step, with the imposition of absolute budget constraints on agencies involved with regulation setting and enforcement. We will focus on this ultimate use of the regulatory budget concept; in this way the problems of implementation mentioned will include those relevant for the first step of implementation (the special analysis) as well.

The main impediments to the use of a regulatory budget for control purposes are as follows:

While the direct public sector costs of particular regulations may be determined with some accuracy, the same cannot be said of the indirect public sector costs and, especially, the costs imposed on private consumers and producers. Because these latter costs are likely to substantially exceed the direct regulatory costs for many regulations, the benefits to be obtained by such a framework could well be quite limited.

The time period over which the cost impacts of regulations must be estimated is not clear. Because a sizable portion of these costs (especially the private sector component) are capital costs, this issue is an important one. If an annual budget concept is adopted, the present value of all induced costs should be calculated, requiring discounting. Such an annual budget concept, however, should be used to estimate the costs in year *x* of introducing a regulation in that year.[37]

An inherent problem in developing reliable cost estimates is what could be called a "joint cost" problem. A substantial volume of, say, pollution control investments are a part of ongoing plant construction or equipment modernization. There is no sound means of segregating that portion of the expenditure which is due to the regulation from the total expenditure. Moreover, in the process of investment in plant or equipment, modifications or additions designed to meet several regulations simultaneously are likely to be included.

In any given year, the number of new regulations promulgated is very large. In a recent year, over 7,000 were issued. The costs required to estimate both the direct and indirect effects of this number of regulations is likely to be very large.

Implementation of a full-blown regulatory budget for control purposes would require Congress and the executive to set dollar limits on the full economic costs which a particular agency or regulation area cannot exceed. However, there exists no procedure for the public sector to determine an allocation which is efficient, or even to frame a reasoned judgment on the optimal level of total regulatory costs.

The implementation of a full-scale regulatory budget for control purposes implies a significant change in the economic planning and regulatory role of the Government. The implications of the expansion of economic planning functions of the Federal Government needs to be carefully considered.

Finally, the implementation of a regulatory budget puts the focus of policy attention on the cost side of the account. The benefits of regulatory measures could tend to be lost in the shuffle. The potential impact of this emphasis in biasing the direction and level of policymaking in the environmental and health/safety areas could be serious.

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[37] An alternate view would involve an estimate of the costs in year *x* of all extant regulations, irrespective of the date of their imposition.

While these problems of implementation and concerns about larger issues of governmental planning are real and important ones, the potential gains from a regulatory budget should not be neglected. Some gains in addition to the focus on the cost effectiveness of the regulations chosen include the following:

It would encourage the accountability of regulators, where little now exists.

It would encourage the integration of regulatory measures, hence eliminating duplication and contradictory policies.

It would encourage consideration of a wider range of policy measures than the issuance of regulations; for example, property rights auctions, effluent charges, et cetera.

The creation of a budget including a ceiling on the costs to be imposed would create strong pressure for the development of reliable estimates of the economic benefits of regulations. Only with such benefits in hand, can efficient policy choices be made.

It would tend to force modification of existing regulatory legislation so as to reduce the stipulation of absolute standards. The costs of achieving some absolute level of control (in terms of the foregoing of the "budget" available to achieve other regulatory objectives) would have to be considered by legislators in a way in which they are not now considered.

Given the difficulties of implementing a regulatory budget and the obvious benefits from having such a budget in place, where should one come out in terms of a concrete policy recommendation? In our view, the most responsible position was that stated by James Miller (1979) in his congressional testimony on this matter. He stated:

> Now, if a regulatory budget is such a good idea, should not Congress move forward with it expeditiously? Frankly, I recommend caution. The reason is that with any program of such magnitude, unanticipated problems, as well as unanticipated opportunities, are bound to arise. Thus, it would seem advisable to initiate the program slowly and deliberately in order to learn from experience.
>
> What I would suggest * * * is an "experiment" under which a single agency, or perhaps a few agencies, would be given regulatory budgets for all or even part of their programs. Prime candidates would be agencies that have a reasonably good track record in producing good analyses of the costs of regulatory initiatives. One possibility is the Environmental Protection Agency. If a smaller agency were to be chosen, consideration should be given to the Consumer Product Safety Commission. In any event, such an "experiment" would generate a great deal of information that would be useful in structuring a regulatory budget program applied on a broader scale.

Capital investment stimulation—The first-year capital recovery system

Given the significant role of the slowdown in the growth of the capital-labor ratio in explaining the reduction in productivity growth—and the potential indirect adverse effect of regulations on capital investment—it is not surprising that a substantial number of proposals designed to stimulate capital investment have been forthcoming. These proposals range from the relaxation of the taxation of capital gains to accelerated depreciation provisions to investment tax credits to a reduction in the corporate income tax. All of these proposals are designed to increase the present value of the net revenue stream of productive investments, as this stream is perceived by potential investors.

Rather than evaluate the full range of these proposals, we have chosen a single proposal—the first-year capital recovery system proposed by Alan Auerbach and Dale Jorgenson in recent congressional testimony. Most of the comments offered on it will be applicable in some degree to the other proposals as well. This proposal was chosen because of both its direct impact in increasing the perceived return to productive investment and its accounting simplicity.

In light of the belief—supported by both theoretical and empirical research—that capital formation plays an important role among the determinants of productivity growth, Auerbach and Jorgenson have recently put forth a proposal (1979) to stimulate capital investment. For those who judge that environmental and health/safety regulations have had detrimental effects on capital formation, support for such a proposal could be viewed as an offset to effect of these regulations. However, as we have seen, Jorgenson's own research (with Hudson) and work by Bosworth and Eisner suggest that energy, tax, and cyclical factors, and not environmental or health/safety regulations, have been largely responsible for the investment slowdown. Nevertheless, whatever the reason for lagging capital formation, the Auerbach-Jorgenson proposal merits serious consideration for its potential role in increasing economic growth and reversing the productivity slowdown.

The proposal is a deceivingly simple one. Instead of taking arbitrary depreciation allowances as expenses in the calculation of taxes throughout the life of an asset, as is now done, the present value of the depreciation would be expensed in the same year as the investment is put in place.

The proposal's appeal lies in its protection of depreciation allowances against erosion by inflation. Ideally, a tax system should enable taxpayers to recover economic depreciation—the decline in the value of an asset with age—on each asset they hold. Under existing tax law, depreciation is measured by looking at the historical prices of assets of different ages. But in the presence of inflation, the prices of newly produced assets have been rising rapidly. As a consequence, even capital consumption allowances that accurately reflect the profile of asset prices when an asset is originally acquired tend to fall short of the true resource costs of depreciation. In essence, the capitalized sum of correctly determined depreciation expenses would be insufficient to replace an asset with an identical model when it wears out. Because of this shortfall, the level of formation is likely to have been slowed. Moreover, the composition of capital investments may also have been adversely affected. Lengths of capital lives differ among assets, and rates of price increase affect them differentially as well. In either case, the effect is to retard productivity growth.

The tax system has attempted to compensate for the effects of inflation by reducing the asset lifetimes used in calculating depreciation expense allowances. This has been done through accelerated deprecation formulas, and through the use of investment tax credits. But such changes have generally lagged behind increasing rates of inflation. With inflation sometimes topping double-digit levels in the 1970's, these changes have proved inadequate. Moreover, because of their arbitrary nature, they create unknown biases into the compositional incentives for investment. Some types of capital may be arbitrarily favored relative to others, with efficiency conquences.

Under the Auerbach-Jorgenson plan, capital consumption allowances would be described by a schedule of present values of economic depreciation for $1 worth of investment in various classes of assets. In the Auerbach and Jorgenson plan, capital consumption allowances would be described by a schedule of present values of economic depreciation for $1 worth of investment in various classes of assets. Auerbach and Jorgenson propose using about 30 classes of assets—perhaps 10 classes for structures and 20 for equipment. The plan thus differs from the widely discussed Conable-Jones bill under which structures could be written off for tax purposes in 10 years, long-lived equipment could be written off in 5 years, and short-lived equipment could be written off in 3 years. The "3–5–10" proposal would retain the present investment tax credit for equipment and would simultaneously simplify and liberalize the capital recovery provisions of the present tax system. In fact, under a moderate rate of inflation, say 6 percent, the accelerated depreciation formulas and investment tax credit provisions of the 3–5–10 plan would result in effective tax rates for certain types of equipment which were negative; the Government would in effect be paying taxpayers to hold these assets rather than taxing income which these assets produce. Under the Auerbach-Jorgenson proposal, the effective tax rate would be equal to the statutory rate on corporate income for all assets.

The Conable-Jones proposal would also have the effect of widening the differentials in effective tax rates among classes of assets which exist under the present tax system. The result would be an increased misallocation of the capital stock and retardation of its contribution to productivity growth.

While neither outright subsidization of certain assets nor gross misallocations of capital resources would be a consequence of the Auerbach-Jorgenson plan, the calculation of the present value of economic depreciation under their proposal could be highly controversial. Citing a Treasury study by Charles Hulten and Frank Wykoff, the authors claim the measurement of economic depreciation from data on asset prices is quite feasible. Apart from any problems in performing these estimates, however, there are questions as to the discount rate(s) to be used in calculating present values. The history of benefit-cost analyses performed by and for Government demonstrates that the implementation of an idea (discounting) which is rather simple in concept is often fraught with difficulties. What is the appropriate interest rate? Should it not vary across classes of assets? Can calculations be safeguarded against the influence of those holding assets who are well aware of the large difference in present values resulting from alternative interest rates? And what of questions concerning the plan's impact on the distribution of income—including possible windfall gains or losses during the period of transition to the new system?

Almost any tax proposal will, of course, face questions of a similar sort. A fair assessment of the Auerbach-Jorgenson plan must compare it, not with an unattainable ideal, but with the realistic alternatives. The plan does offer protection for capital consumption allowances against inflation without causing large misallocations of the capital stock. And this is a major benefit if one's interest is the stimulation of capital investment. Moreover, even contemplating the potential difficulties in implementing the plan, it would be likely to generate less serious investment misallocation than the 3–5–10 plan. The latter, and other schemes which include investment tax credits, are largely "ad hoc" responses to the distortions caused by the present tax system. Not surprisingly, these schemes introduce distortions of their own. The Auerbach-Jorgenson plan, on the other hand, is a direct attack on the existing divergence of capital consumption allowances from economic depreciation.

Simulations conducted by the authors using the Data Resources Inc. macroeconometric model indicate that real investment in durable equipment would increase by about 9 percent as a result of their plan, assuming a real discount rate of 4 percent for calculating the present value of economic depreciation. Real investment in nonresidential structures would increase by over 20 percent. Real gross national product would increase by roughly 2 percent, and with a somewhat smaller increase in employment, labor productivity would also increase.

On the negative side, the simulations indicate that the plan would result in a substantial revenue loss to the Treasury. Despite the increase in real gross national product, the Federal deficit would grow, resulting in increases in the rate of inflation approaching 1 percent—unless alternative revenue raising measures are enacted, of course.

The levels of inflation which already exist have had a serious impact on capital formation under current provisions of the tax system. Low levels of saving, increased uncertainty, and perhaps public regulations have also been factors in the investment slowdown. If the importance of capital formation for productivity be granted, strong measures to improve the investment climate in the U.S. economy are needed. The Auerbach-Jorgenson plan would not provide a remedy to all the factors contributing to the capital formation slowdown, but by insuring that capital consumption allowances would more accurately reflect economic depreciation, it would provide an important first step. In the short-run, at least, it would appear to have more promise for improving macroeconomic performance than would enactment of some form of regulatory budget.

APPENDIX A

In this appendix, we make a formal presentation of the theoretical framework sketched in section III. We begin from a microeconomic model of a representative firm's technology. We impose no restrictions on the technology's returns to scale, the marginal rates of substitution among the variables in the production function, the form of technical change, or the manner in which regulatory policy affects productivity growth. In this unrestricted setting, the unique sources of productivity growth can be identified. While the primary sources of productivity growth identified in this model are themselves functions of prior variables, the sources are emphasized because of their central role in the production process and their relationship to regulatory policy.

Productivity Growth. Consider a twice differentiable production function F

$$Q=F(X_1, X_2, \ldots, X_n, R, T), \tag{1}$$

where Q is output, the X_i are inputs, R is a measure of regulatory intensity, and T is time. We assume all factor markets are competitive, but we do not require competitive output markets.

The regulatory intensity variable R is of primary interest. In our model, R is an index number bounded from below by zero. The variable would take a zero value only in the unlikely instance that absolutely no regulations applied to the firm. Otherwise, R has some positive value whose magnitude is determined by the scope and severity of the regulations imposed on the firm. The measure R takes successively higher positive values as the number of regulations increases, the standards of existing regulations become more strict, and/or the compliance requirements (e.g., reporting) become more complex.

Logarithmically differentiating (1) with respect to time decomposes the rate of growth in output (economic growth) into its source components

$$\frac{d\ln Q}{dT}=\sum_i \frac{\partial \ln Q}{\partial \ln X_i}\cdot\frac{d\ln X_i}{dT}+\frac{\partial \ln Q}{\partial R}\cdot\frac{dR}{dT}+\frac{\partial \ln Q}{\partial T}. \tag{2}$$

In equation (2), the rate of growth in firm output equals the output elasticity weighted sum of rates of growth of inputs, plus the elasticity weighted rate of change in regulatory intensity, plus the rate of technical change.

The logarithmic partial derivatives appearing in (2) have particular economic interpretations. Given competitive factor markets and optimizing behavior by the firm, each logarithmic marginal product equals the product of the corresponding input's cost share and the degree of scale economies

(3)

$$\frac{\partial \ln Q}{\partial \ln X_i}=\frac{\partial Q}{\partial X_i}\cdot\frac{X_i}{Q}=\frac{P_iX_i}{P_QQ\left(1-\frac{1}{\epsilon}\right)}=\frac{P_iX_i}{\left(\frac{\partial C}{\partial Q}\right)Q}=\frac{P_iX_i}{C}\left(\frac{\partial \ln C}{\partial \ln Q}\right)^{-1}=\frac{P_iX_i}{C}\left(\sum_i \frac{\partial \ln Q}{\partial \ln X_i}\right),$$

where P_Q is the product's market price, ϵ is the absolute value of the price elasticity of demand, C is total production cost, and

$$P_i=P_Q\left(1-\frac{1}{\epsilon}\right)\frac{\partial Q}{\partial X_i} \qquad (i=1, 2, \ldots, n)$$

$$P_Q\left(1-\frac{1}{\epsilon}\right)=\frac{\partial C}{\partial Q} \tag{4}$$

$$\sum_i \frac{\partial \ln Q}{\partial \ln X_i}=\left(\frac{\partial \ln C}{\partial \ln Q}\right)^{-1}.$$

The sum of these output elasticities equals the conventional measure of returns to scale

$$(5) \qquad v_Q \equiv \sum_i \frac{\partial \ln Q}{\partial \ln X_i} (X_1, X_2, \ldots, X_n, R, T).$$

If v_Q equals unity, output proportionally responds to changes in all inputs. This condition characterizes constant returns to scale. If v_Q is greater (less) than unity, output responds more (less) than proportionally with increases in all inputs, thus implying the existence of increasing (decreasing) returns to scale. Regardless of its value, v_Q isolates that change in output which is related to changes in all inputs. It is independent of technical change and changes in regulatory policy.

The partial derivatives of output with respect to regulatory intensity v_R and time v_T define the rates of regulatory effect and technical change, respectively

$$(6) \qquad v_R \equiv \frac{\partial \ln Q}{\partial R} (X_1, X_2, \ldots, X_n, R, T)$$

$$(7) \qquad v_T \equiv \frac{\partial \ln Q}{\partial T} (X_1, X_2, \ldots, X_n, R, T).$$

Holding all inputs and time constant, v_R measures the effect of changes in regulatory intensity on the level of output. A positive (negative) value indicates that increased regulations induce higher (lower) production. Similarly, if v_T is greater (less) than zero, then, holding all inputs and regulations constant, technical change leads to increased (decreased) rates of production.

Given this characterization of economic growth, the sources of productivity growth can be identified. Formally defined, the rate of productivity growth v_G equals the rate of growth in output less the constant returns to scale weighted average of rates of growth in inputs

$$(8) \qquad v_G \equiv \frac{d \ln Q}{dT} - \sum_i \frac{P_i X_i}{C} \cdot \frac{d \ln X_i}{dT}$$

since, given constant returns to scale in (3),

$$\frac{\partial \ln Q}{\partial \ln X_i} = \frac{P_i X_i}{C} \qquad (i=1, 2, \ldots, n).$$

Consequently, any nonproportional change in output that cannot be explained by a proportional change in all inputs is modeled as the firm's productivity growth.

Subtracting the cost share weighted average of input growth rates from both sides of (2) permits us to express the rate of productivity growth as the sum of its three source components

$$(9) \qquad v_G \equiv \frac{d \ln Q}{dT} - \sum_i \frac{P_i X_i}{C} \cdot \frac{d \ln X_i}{dT} = \sum_i \frac{P_i X_i}{C} [v_Q - 1] \frac{d \ln X_i}{dT} + v_R \cdot \frac{dR}{dT} + v_T.$$

Equation (9) states that the rate of productivity growth equals the sum contribution of scale economies, regulatory intensity, and technical change.

If the technology exhibits constant returns, v_Q equals unity and (9) reduces to

$$(10) \qquad v_G = v_R \frac{dR}{dT} + v_T;$$

that is, productivity growth is affected only by changes in regulatory policy and technical change. If, however, v_Q is greater (less) than unity, there are increasing (decreasing) returns and scale economies (diseconomies) are a positive (negative) source of productivity growth; that is, given $d \ln X_i / dT > 0$ for all i

$$\sum_i \frac{P_i X_i}{C} [v_Q - 1] \frac{d \ln X_i}{dT} > 0 \text{ for } v_Q > 1$$

and

$$\sum_i \frac{P_i X_i}{C} [v_Q - 1] \frac{d \ln X_i}{dT} < 0 \text{ for } v_Q < 1.$$

Similar interpretations apply to regulatory effect and technical change. if v_R equals zero, changes in regulatory intensity have no *direct* impact on productivity growth. If v_R is greater (less) than zero, increased regulation generates a positive (negative) contribution to productivity growth v_G. Analogously, if v_T is zero, there is no technical change. Technical change exists (makes a positive or negative contribution) only if v_T is greater or less than zero.

Direct and Indirect Regulatory Effects. The rate of productivity growth v_G defined in (9) is expressed as the sum of three source components

$$v_G(\cdot)=\sum_i \frac{P_iX_i}{C}[v_Q(\cdot)-1]\frac{d\ln X_i}{dT}+v_R(\cdot)\frac{dR}{dT}+v_T(\cdot), \tag{11}$$

where v_Q, v_R, and v_T defined in (5), (6), and (7), respectively are each functions of all input levels (X_i), the degree of regulatory intensity (R), and time (T). Consequently, changes in the intensity of regulation can affect a firm's productivity growth in direct and indirect ways.

Regulation's direct or first-order effect is modeled by the partial derivative v_R. Holding the firm's inputs and level of technology constant, changes in regulation can impact productivity growth directly. Increased regulations, for example, may shift managerial attention from the production of the firm's "conventional" output to the filing of detailed government reports. The expected *direct* effect in this case is negative.

Important indirect effects also can result since regulation can influence the contribution of *each* source of productivity growth. These indirect or second-order effects are captured by the partial derivatives of scale economies and the rates of regulatory effect and technical change with respect to regulatory intensity. The important inference of equation (5), for example, is that changes in regulatory policy affect scale economies by affecting the marginal productivities of individual inputs. Requiring workers to wear cumbersome protective clothing or requiring firms to employ laborers whose only responsibility is to perform safety inspections affect labor's average and marginal ability to produce the firm's conventional, saleable output. The marginal products of all other inputs, whether substitutes or complements, are affected as well. The result is an indirect effect of regulation on the firm's productivity growth, a second-order effect transmitted through a change in scale economies.

Identifying explicit hypotheses corresponding to these direct and indirect effects requires that we impose some second-order functional form on the general production function described in (1). We choose the translog form. It is a second-order form and meets the unrestrictive criteria discussed in the introduction to this section. The translog approximation to F in (1) is

$$\begin{aligned} \ln Q &= \ln F(X_1, X_2, \ldots, X_n, R, T) \\ &= \alpha_0+\sum_i \beta_i \ln X_i+\beta_R R+\beta_T T \\ &\quad +\frac{1}{2}\sum_i\sum_j \delta_{ij}\ln X_i \ln X_j+\frac{1}{2}\delta_{RR}R^2+\frac{1}{2}\delta_{TT}T^2 \\ &\quad +\sum_i \delta_{iR}\ln X_i\cdot R+\sum_i \delta_{iT}\ln X_i\cdot T+\delta_{RT}R\cdot T. \end{aligned} \tag{12}$$

The expressions for v_Q, v_R, and v_T follow directly from (5), (6), (7), and (12)

$$\begin{aligned} v_Q &\equiv \sum_i \frac{\partial \ln Q}{\partial \ln X_i}(X_1, X_2, \ldots, X_n, R, T) \\ &= \sum_i\Big(\beta_i+\sum_j \delta_{ij}\ln X_j+\delta_{iR}R+\delta_{iT}T\Big) \end{aligned} \tag{13}$$

$$\begin{aligned} v_R &\equiv \frac{\partial \ln Q}{\partial R}(X_1, X_2, \ldots, X_n, R, T) \\ &= \beta_R+\delta_{RR}R+\sum_i \delta_{iR}\ln X_i+\delta_{RT}T \end{aligned} \tag{14}$$

$$(15) \qquad v_T \equiv \frac{\partial \ln Q}{\partial T}(X_1, X_2, \ldots, X_n, R, T)$$

$$= \beta_T + \delta_{TT} T + \sum_i \delta_{iT} \ln X_i + \delta_{RT} R.$$

The direct productivity effect of regulation is modeled by the parametric expression defined in (14). A positive (negative) value for the complete expression implies that increased regulation has a positive (negative) effect on the firm's productivity growth.

The indirect effects are modeled by the second-order partial derivatives

$$(16) \qquad \frac{\partial v_Q}{\partial R} = \sum_i \delta_{iR}$$

$$(17) \qquad \frac{\partial v_R}{\partial R} = \delta_{RR}$$

$$(18) \qquad \frac{\partial v_T}{\partial R} = \delta_{RT}.$$

If the expression $\sum_i \delta_{iR}$ equals zero, regulation does not affect the firm's scale economies. If it is greater (less) than zero, it increases (decreases) the scale economies available to the firm. If δ_{RR} equals zero, changes in regulatory intensity may affect the rate of productivity growth (i.e., $v_R \neq 0$) but at a constant rate. If δ_{RR} is greater (less) than zero, regulation affects productivity growth at an increasing (decreasing) rate. Similarly, if δ_{RT} equals zero, regulation does not affect the rate of technical change. However, if δ_{RT} is greater (less) than zero, regulation leads to higher (lower) rates of technical change.

While these second-order effects may be small in relation to the first-order effect, their importance cannot be ignored. This is especially true for δ_{RT}—the effect of regulation on the rate of technical change. If, as alleged, regulations increase the expected cost of actually adopting any innovation (perhaps because of increased reporting and testing expenses or because of required pollution control or safety attachments), then added regulations reduce the firm's expected discounted net benefits from investing in research and development. If this hypothesis is true and assuming that there is some positive relation between R & D expenditures and technical innovation, δ_{RT} would have a negative value. Regulation would have a negative indirect effect on productivity growth transmitted through a reduced level of R & D expenditures and, hence, a reduced rate of technical change.

Input Bias.[38] In addition to its direct and indirect productivity effects, changes in regulatory policy may also lead to input biases and therefore to changes in the distribution of income among factors. Stated more formally, the marginal rates of substitution among inputs may be functions of regulatory intensity.

If changes in regulatory policy do not bias input choice, an unambiguous set of technical restrictions can be imposed on the firm's production function. Necessary and sufficient conditions require that each input's marginal product not be a function of regulatory intensity

$$(19) \qquad \frac{\partial^2 F}{\partial X_i \partial R} = 0 \qquad (i = 1, 2, \ldots, n)$$

Parametric restrictions corresponding to this hypothesis can be derived from the translog production function defined in (12). Since the unrestricted translog is a second-order function, each factor's marginal product is a function of all input levels, regulatory intensity, and time

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[38] "Input bias" is defined as a pattern of input combinations which differs from that which would exist in the balance of regulations. For example, regulations might increase or decrease the labor intensity of the production process. Input bias will occur if regulation differently affects the "efficiency content" of the inputs.

$$(20)\qquad \frac{\partial Q}{\partial X_i}=\frac{Q}{X_i}\left(\beta_i+\sum_j \delta_{ij}\ \ln X_j+\delta_{iR}R+\delta_{iT}T\right) \qquad (i=1, 2, \ldots, n).$$

The n restrictions corresponding to (19) are

$$(21)\qquad \frac{\partial^2 Q}{\partial X_i \partial R}=\delta_{iR}=0 \qquad (i=1, 2, \ldots, n).$$

If all δ_{iR} equal zero, regulation does not distort input choice. If any one δ_{iR} does not equal zero, regulation induces input bias. Positive values imply increased marginal products; negative values indicate reduced marginal productivities.

It is important to note that a non-zero value for δ_{iR} does not necessarily imply that regulation has directly affected the efficiency content of the ith input. (That issue will be addressed in the following subsection.) What a non-zero δ_{iR} suggests is that regulation has affected the efficiency content of either the ith input *or* any of its substitutes or complements. An input's marginal product, recall, is a function of *all* input levels, regulation, and time. If regulation augments the jth input and the ith and jth inputs are substitutes, then the ith input's marginal product is a negative function of regulation ($\delta_{iR}<0$), even though regulation has had no direct effect on its marginal productivity. Conversely, if the ith and jth inputs are complements and regulation increases the efficiency content of the *j*th input, then the marginal product of the ith input is a positive function of regulation ($\delta_{iR}>0$). The precise direction and magnitude of the input bias therefore depend not only on regulation but also on the technology's substitution possibilties.

Should the restrictions in (21) not hold, the resulting input bias also affects the distribution of income. The distributional implications of regulation can be identified by substituting (3) and (5) into (20)

$$(22)\qquad \frac{P_iX_i}{C}=(v_Q)^{-1}\left(\beta_i+\sum_j \delta_{ij}\ \ln X_j+\delta_{iR}R+\delta_{iT}T\right) \quad (i=1, 2, \ldots, n)$$

so that

$$(23)\qquad \frac{\partial\left(\frac{P_iX_i}{C}\right)}{\partial R}=(v_Q)^{-1}\delta_{iR}-\frac{\left(\beta_i+\sum_j \delta_{ij}\ \ln X_j+\delta_{iR}R+\delta_{iT}T\right)\left(\sum_j \delta_{jR}\right)}{(v_Q)^2} \qquad (i=1, 2, \ldots, n).$$

Note that the distributional impact of regulation on the income share of the ith input is a function of the effect of regulation on all inputs; i.e., the δ_{jR} for all j appear on the right-hand side of (23). If and only if the restrictions defined in (21) hold for all inputs will regulation not affect the functional distribution of income. If one or more δ_{iR} are non-zero, the expression in (23) must be evaluated. Positive values of equations (23) indicate that increased regulation and the technology's substitution possibilities have combined to increase the income shares of the corresponding inputs. Negative values identify those inputs whose income shares are declining functions of regulation.

Factor Augmentation. If the "no bias" hypothesis (21) is rejected, it becomes important to evaluate the direction and magnitude of regulatory bias. In particular, how does regulation affect the "efficiency content" of *each* input? Stated alternatively, which inputs are the mediums of regulatory bias? To address these questions, we consider a model of production maintaining factor augmenting regulation. This model is a restricted form of the general model of production introduced above. Inputs are now defined in terms of efficiency units. Stated more precisely, the number of efficiency units E_i of each input is measured as the product of the input level and its corresponding augmentation coefficient

$$(24)\qquad E_i(R)=X_iA_i(R) \qquad (i=1, \ldots, n)$$

where A^i represents a factor specific augmentation function of a single argument R.

Given factor augmentation, the production function F in (1) is respecified as a function E of efficiency units and time

(25) $$Q=E[A_1(R)\cdot X_1,\ A_2(R)\cdot X_2,\ \ldots,\ A_n(R)\cdot X_n,\ T].$$

We assume that each augmentation function A_i is a first-order function of regulatory intensity

(26) $$A_i(R)=\exp\ (\eta_i R) \qquad (i=1,\ 2,\ \ldots,\ n)$$

Given (26), the translog approximation to the factor augmented function E becomes:

(27) $$\begin{aligned} 1nQ=&\alpha_0+\sum_i\beta_i 1nX_i+\sum_i\beta_i\eta_i R+\beta_T T\\ &=\frac{1}{2}\sum_i\sum_j\delta_{ij}1nX_i 1nX_j+\frac{1}{2}\sum_i\sum_j\delta_{ij}\eta_i R 1nX_j\\ &+\frac{1}{2}\delta_{TT}T^2+\sum_i\delta_{iT}1nX_i\cdot T+\sum_i\delta_{iT}\eta_i RT\\ &+\frac{1}{2}\sum_i\sum_j\delta_{ij}\eta_i\eta_j R^2. \end{aligned}$$

From the unrestricted model of production F, we previously derived expressions for each input's marginal product, scale economies, and the rates of regulatory effect and technical change. The factor augmentation model (27) has a parallel though restricted structure. The corresponding expressions are:

(28) $$\frac{\partial Q}{\partial X_i}=\frac{Q}{X_i}\left[\beta_i+\sum_j\delta_{ij}1nX_j+\delta_{iT}T+\sum_j\delta_{ij}\eta_j R\right] \quad (i=1,\ 2,\ \ldots\ n)$$

(29) $$v_Q=\sum_i\left[\beta_i+\sum_j\delta_{ij}1nX_j+\delta_{iT}T+\sum_j\delta_{ij}\eta_j R\right]$$

(30) $$v_R=\sum_i\left[\eta_i\left(\beta_i+\sum_j\delta_{ij}1nX_j+\delta_{iT}T+\sum_j\delta_{ij}\eta_j R\right)\right]$$

(31) $$v_T=\beta_T+\sum_i\delta_{iT}1nX_i+\delta_{TT}T+\sum_i\delta_{iT}\eta_i R.$$

Since the model of factor augmentation (25) is a restricted form of the more general model (1), one would expect that there is some identifiable set of restrictions distinguishing the two translog models (12) and (27). Comparing the fixed parameters in the two models reveals that the first and second-order regulation parameters in the general model (12) (i.e., β_R, δ_{RR}, δ_{RT}, and δ_{iR} for all i) are replaced by the parameters η_i in the augmentation model (27). The substitutions are of the form:

$$\begin{aligned} \beta_R&=\sum_i\beta_i\eta_i\\ \delta_{RR}&=\sum_i\sum_j\delta_{ij}\eta_i\eta_j\\ \delta_{RT}&=\sum_i\delta_{iT}\eta_i\\ \delta_{iR}&=\sum_j\delta_{ij}\eta_j \qquad (i=1,\ 2,\ \ldots,\ n) \end{aligned}$$

Consequently, $n+3$ parameters in the general model of production are respecified in terms of already included second-order parameters and n new parameters. There are thus three augmentation restrictions. If these three restrictions are appropriate, then changes in regulatory policy influence productivity growth wholly by affecting the marginal products of the firm's inputs.

The critical parameters in the model, of course, are the η_i. If any η_i equals zero, the corresponding augmentation coefficient defined in (26) equals unity. It necessarily follows that regulation does not augment the *i*th input. If, however, η_i is greater (less) than zero, $A_i(R)$ is greater (less) than unity and increases in regulatory intensity augment (retard) the efficiency content of the *i*th input. The η_i therefore identify the mediums of regulatory impact.

Moreover, restrictions on these augmentation coefficients identify alternative structures of regulatory impact

(33) Production neutrality: $\eta_1=\eta_2=\ldots=\eta_n$

(34) Input neutrality: $\eta_i\neq 0,\ \eta_j=0 V_j (j\neq i)$ $(i=1, 2, \ldots, n)$.

The former is the regulatory analogue of Hicks-neutral technical change. All inputs are augmented equally. The latter is the regulatory counterpart of Harrod-neutrality or Solow-neutrality. Regulation augments or retards only a single input. Identifying these augmentation coefficients and examining the structure of regulatory effect is the key to understanding how changes in regulatory policy differentially affect the efficiency content of individual inputs.

These same parameters also permit us to decompose the regulation induced change in each input's marginal product among its sources. As demonstrated in (32), the measured change in any input's marginal product is a weighted sum of the augmentation parameters

$$\delta_{iR}=\sum_j \delta_{ij}\eta_j \qquad (i=1, 2, \ldots, n), \tag{35}$$

where the second-order parameters δ_{ij} model the substitution possibilities inherent in the technology.

The important implication of (35) is that regulation may augment or retard the efficiency content of a single input (only one $\eta_j\neq 0$) and yet affect the marginal products of inputs (all $\delta_{iR}\neq 0$). For example, regulation may not affect the efficiency content of labor or energy inputs and yet may have significant implications for both employment and energy use. In short, regulation need not change the efficiency content of more than a single input in order to bias input choice and the distribution of income.

Concluding Remarks. Most observers believe that regulation has had some impact on economic performance, particularly productivity growth. Some economists (e.g., Denison and Kendrick) have begun to generate informal estimates of regulation's "retarding" effect. However, none of the procedures on which these estimates are based has characterized the technical mechanisms by which productivity growth is affected by changing regulatory policy. The primary purpose of the above technical description is to offer those concerned with the productivity slowdown a formal structure within which to categorize and consider the impacts of regulatory policy.

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