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Environmental Regulations and Productivity Growth

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ENVIRONMENTAL REGULATIONS AND PRODUCTIVITY GROWTH

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One of the primary mysteries of economic performance in the 1970s has been the slowdown in the rate of productivity growth—and an even more serious absolute reduction in productivity in the later years of the decade. As Barry Bosworth points out in this volume, this decline in productivity reflects a fundamental problem in macroeconomic performance, and underlies other symptoms of economic malfunction. For example, accelerating inflation rates may well generate inefficiencies in the economy which contribute to a decline in productivity growth. Conversely, to the extent that deficiencies in the aggregate supply of output relative to aggregate demand create inflationary pressures, low rates of productivity growth may contribute to these pressures. Stagflation and declining rates of productivity growth are part of the same phenomenon.

Many causes have been suggested for stagflation and declining productivity growth, including increased energy prices, a slowdown in capital investment, changing composition of outputs (from high to low productivity growth industries), changing composition of the labor force (from prime-age males toward youths and females, both with relatively short histories of labor market activity), a decline in the nation's work ethic, and regulatory activities—in particular environmental regulations.

The first section of this paper discusses the concept and measurement of productivity growth and its performance over the past several years. In the second section, the main hypotheses concerning the recent slowdown in this indicator of economic performance are identified. The third section examines one of these hypotheses: that governmental regulations are responsible for slowing down productivity growth. In particular, it identifies the channels by which regulations,

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especially environmental regulations, could affect productivity growth. The fourth section estimates the impact of these policies on the manufacturing sector.

Numerous other efforts to identify how environmental regulations contribute to the slowdown in productivity growth are discussed in the fifth section. Finally, an estimate or "guestimate" is made of the role environmental regulations play in this slowdown in productivity growth.

INDEXES OF PRODUCTIVITY AND THEIR RECENT PERFORMANCE

Economic performance is gauged by statistical indicators that reflect changes in both output (e.g., changes in gross national product) and inputs (e.g., unemployment rates, labor force growth rates, and rates of capacity utilization). However, only one indicator–productivity–simultaneously captures both aspects of economic performance.

Theoretically, a nation's productivity can be defined simply as its aggregate final output per unit of input. However, because of the diversity in both outputs and inputs, this measurement is not a straightforward matter. The most common procedure is to measure productivity by obtaining an estimate of final aggregate private sector output divided by the number of worker-hours of labor input used to produce this output. This results in a single-factor productivity measure; it does not reflect in its denominator the full set of inputs. Because of this weakness, efforts have been made to construct more comprehensive productivity indicators–for example, private sector output per total factor input.[1]

Irrespective of the indicator employed, productivity performance in the 1970s has been far weaker than in the 1960s. For example, between 1965 and 1975, labor productivity grew at a rate of 2.2 percent per year, compared with a 3.4 percent annual rate of growth over the two preceding decades. Beginning in 1973, a further falloff occurred, and between 1973 and 1978 the annual growth rate of productivity barely exceeded 1 percent. In both 1979 and 1980, productivity not only failed to grow, but actually declined. A similar picture emerges if productivity indicators other than labor productivity are observed. Indeed, using any of the indicators, if the productivity

1. *See, e.g.*, J. KENDRICK, POST-WAR PRODUCTIVITY TRENDS IN THE UNITED STATES: 1948–1969 (1973); E. DENISON, ACCOUNTING FOR SLOWER ECONOMIC GROWTH (1979); and F. Gollop & D. Jorgenson, *United States Factor Productivity by Industry, 1947–1973*, in NEW DEVELOPMENTS IN PRODUCTIVITY MEASUREMENT AND ANALYSIS (J. Kendrick & B. Vaccara eds. 1980).

growth trend of the 1950s and 1960s had continued through the 1970s, the average productivity of the economy at the end of the decade would have been at least 15 percent above the level actually attained.

If one delves below the aggregate indexes of productivity growth, substantial disparity among sectors can be seen. For example, in the manufacturing sector, the slowdown was marked but relatively mild. In 1979, when overall productivity fell, manufacturing productivity grew by 1.8 percent. In the nonmanufacturing sectors, growth slowed most noticeably in the mining, construction, and electric utility industries. In fact, a major share of the overall productivity slowdown is attributable to the poor performance of these industries.[2]

POSSIBLE CAUSES OF REDUCED PRODUCTIVITY GROWTH

Numerous reasons have been put forward to explain the deceleration in productivity growth. A few of these factors are briefly discussed.

Composition of Output

There have been two major sectoral shifts in the composition of output in recent decades. The first shift is from the farm to the nonfarm sector. Second, within the nonfarm sector, output has shifted away from manufactured goods toward services.

Because the level of labor productivity in the farm sector has on average been much lower than that for nonfarm labor, the shift of output from farm to nonfarm sectors has contributed to the overall rise in labor productivity since World War II. However, most of this shift 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 were two decades ago. Therefore, one of the major sources of productivity growth in the two decades after the war no longer existed in the 1970s.

The second shift–from production of manufactured goods to services–has contributed to the slowdown in the nonfarm private business sector. The relative share of manufacturing in total employment has been decining steadily for two decades. Because the opportunity for introducing mass production techniques or achieving economies of scale are relatively limited in the service sector, productivity is below that in manufacturing and has tended to grow more slowly as

2. The preceding statistical information is derived from E. DENISON, *supra* note 1.

well. As a result, the shift away from manufacturing and toward services has tended to reduce overall productivity growth.

Advances in Knowledge and Research and Development (R&D)

Advances in knowledge can enhance productivity in either of two ways. They can directly enhance the quality of inputs (e.g., better educated workers), or they may enable producers to combine inputs of existing quality in a more efficient manner. As a percentage of gross national product, R&D spending reached a peak in the mid-1960s during the high-water years of the nation's space effort. At that time R&D accounted for roughly 3 percent of the gross national product. Since 1966, however, R&D has undergone a slow decline until it now accounts for only about 2 percent of the gross national product.[3]

Composition of the Labor Force

The changing demographic nature of the nation's work force has been postulated as a cause of the decline in productivity growth. Since 1966 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. Because these groups have modest amounts of work experience and job training, they are typically less productive than their more experienced counterparts. This is most apparent in the case of teenagers. In the case of women, there have been barriers to the more productive lines of work, irrespective of age, and women have also had relatively fewer opportunities for training. This expansion in the less skilled portion of the labor force may be reducing the average growth rate of labor productivity. Of course, as these workers develop skills, they will contribute to productivity growth.

Capital-Labor Ratio

The level of investment in the economy and, in turn, the capital-labor ratio are important in achieving increases in productivity. 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 for each additional unit of labor employed.

At the same time that the labor force in the United States has increased its growth rate, the country's capital stock has grown at a

3. NATIONAL SCIENCE FOUNDATION, SCIENCE INDICATORS (1979).

somewhat reduced rate. Net of depreciation, capital per employed person rose at an average annual rate of about 2.0 percent from 1948 to 1969, but between 1969 and the present, the annual rate of growth fell to about 1.2 percent.[4]

Energy Prices

For many years, the United States enjoyed the availability of cheap energy. The increases in the world price of crude oil by the OPEC cartel that began in 1973 have undoubtedly seriously affected productivity and economic performance in a number of industrialized Western nations.

While changes in relative prices occur daily without tremendous strain to the economic system, 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 of much of the capital already invested. Plant and equipment intended to be used for years suddenly became less profitable to employ. Moreover, businesses faced adjustment costs in learning how to operate in the new energy price environment, and in making necessary changes in the structure of production.

Other Factors

Several other factors have been cited as possible causes of the slowdown in productivity growth: disincentive effects of income taxes, disruption of expectations brought about by rapidly changing rates of inflation, and negative attitudes toward work are some examples. In general, however, investigations to date have relegated these factors to a minor role. The factors we have discussed here, plus government regulations, are thought to have been among the more decisive ones.

GOVERNMENT REGULATIONS AS A SOURCE OF THE PRODUCTIVITY SLOWDOWN

By definition, government regulations are interventions into market processes. They alter the utility and profit-maximixing decisions of individual decision makers. In a smoothly functioning market economy (without externalities such as pollution), such interventions will cause the private sector production levels to deviate from those which could have been attained without intervention. Holding output composition constant, this deviation means that additional inputs are

4. *See* E. DENISON, *supra* note 1, at 52.

required to reach any given level of output. Under these conditions, *increases* in government regulation will be associated with *larger deviations* from the potential level of private output, and equivalently, reduced rates of growth of output per unit of input–in other words, decreases in productivity.

The channels by which government regulations are likely to affect either the output (numerator) or input (denominator) of productivity indexes are complex. A discussion of environmental regulations illustrates these channels.

Over the past several years, government regulations have required that increasing amounts of labor and capital be devoted to pollution abatement. While such mandated investments may generate substantial benefits, their contribution to the output of marketed goods and services produced is minimal. In the mid-1970s, capital spending stood at about 9.5 percent of gross national product. This figure drops to 8.7 percent if one considers the investments mandated by these regulations to be nonproductive. If adapting to these regulations causes inputs to be employed which make little contribution to *measured* output, then *measured* productivity suffers on this account.[5]

The hypothesis that environmental regulations cause reductions in productivity growth is based on several conjectures. If environmental regulations cause businesses to increase labor input with no corresponding increase in output, or conversely, decrease output with no corresponding change in labor input, their effect will be to decrease productivity growth. The following is a summary of business responses to environmental regulations which could lead to reduced productivity growth.

1. Pollution control regulations require investments in control equipment which compete with normal investments in productive plant and equipment, crowding out the latter to some unknown extent. Hence, labor has less capital than it would otherwise have, and as a result its output may be reduced.
2. Pollution control regulations tend to be engineering standards rather than performance standards and thus induce an inefficiently high level of capital investment and intensity.
3. In both water and air regulations, new sources of pollution are subjected to much more stringent standards than existing sources. This uneven treatment may cause businesses to retain existing–and lower productivity–plants and equipment in use longer than otherwise, and to delay the introduction of new capital and more advanced technology.

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5. For a discussion of measured and unmeasured outputs in the national income accounts, *see* H. Peskin's paper in this volume.

4. Pollution control equipment, once installed, requires labor for its operation and maintenance. This labor input makes no contribution to salable output. The same is true for manpower required to comply with the paperwork and legal burdens of regulation.
5. To avoid plant closings and layoffs, environmental regulations are written and enforced more stringently for fast-growing than for slow-growing industries, and thus inhibit an important source of productivity increase. This may have been true for the electric utility industry, which had an excellent record of productivity growth until the early 1970s.
6. Efforts to avoid any deterioration of pristine areas—the "prevention of significant deterioration" (PSD) provision—has retarded plant construction or resulted in the choice of less productive locations for new plants.

In principle, the dislocations occurring through each of these channels could be measured. In practice, however, data do not exist to reliably quantify any one of them. However, this is not to say that no efforts have been made to blame environmental regulations for some of the post-1970 reduction in productivity growth.

Analogous channels exist for the possible effect of environmental regulations on prices. As we have emphasized, the relationship between outputs and inputs—productivity—has implications for the relationship between output and costs. As a result, factors that affect productivity are apt to affect prices as well.

The precise magnitude of the increases in production costs caused by environmental control efforts is open to debate, but is generally agreed to run in the tens of billions of dollars. The Council on Environmental Quality estimated that the annual private costs of water and stationary air quality control will be $31.5 billion by 1988 (in 1979 dollars).[6]

In considering any of the alleged effects of environmental regulation on prices, two important distinctions must be kept in mind. First, one must distinguish changes in *relative* prices from changes in the *general* level of prices. Environmental regulation may cause the price of a commodity heavily affected to increase relative to other prices, but without the spiralling effect Barry Bosworth describes in his paper, it does not necessarily follow that there will be a general rise in prices throughout the economy. Second, one-time increases in prices must be distinguished from *continuing* increases. The fact that the rate of inflation was higher during the 1970s than in the 1960s

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6. *See* COUNCIL ON ENVT'L QUALITY, ELEVENTH ANNUAL REPORT (1980).

means not only that the price level became higher during the 1970s but that the *rate of increase* of the price level rose as well. While it is clear that environmental regulation could cause the relative prices of particular goods and services to increase on a one-time basis, it is not necessarily responsible for an increase in the general level of prices, let alone *a growth in the rate of increase* of this level.

ESTIMATES OF THE SLOWDOWN IN MANUFACTURING PRODUCTIVITY GROWTH

Given these conjectures, it would seem important to measure, where possible, the relationship between government regulatory activities and productivity growth in industries that have been heavily affected by them. However, because of the difficulty of obtaining data and serious deficiencies in those that can be obtained, it is not easy to make such estimates.

On a more aggregate level, it is possible to obtain a "first-cut" estimate of the contribution of federal regulations to the productivity slowdown in the manufacturing sector by using a straightforward time series regression model.[7] First, it is assumed that a definable set of production relationships underlies economic activity in this sector. These relationships relate the flow of output (*Q*) to the flow of total factor input (*TFI*). The function shifts over time in response to changes in relative factor prices, business cycle shocks, and to what could be called "regulatory intensity."

These production relationships can be estimated for the U.S. manufacturing sector from 1958 to 1977 using the quantities and proportions of total cost accounted for by labor, capital, energy, and materials, and price and quantity data pertaining to output. These inputs can be combined into a measure of TFI by using their respective shares in total cost as weights. Because of this comprehensive set of inputs, the effect of some factors often assigned responsibility for the productivity slowdown (e.g., energy prices) is accounted for in the TFI measure.

It is difficult to define the concept of "regulatory intensity," let alone quantify it. Here, the definition is based on the view that regulatory agencies distort private sector decisions which would, in general, maximize the rate of productivity growth. Three alternative measures of regulatory intensity were constructed and used for the analysis. The first is based on an estimate of the cumulative number

7. A complete description of this analysis is found in G. Christainsen & R. Haveman, *Public Regulations and the Slowdown in Productivity Growth*, 71 AM. ECON. REV. 320 (May 1981).

of "major" pieces of regulatory legislation in effect during any of the years in question.[8] The second and third indexes are based on the volume of real federal expenditures on regulatory activities for the years in question[9] and the number of full-time federal personnel engaged in regulatory activities. Though they are crude proxies for regulatory intensity, these indexes do provide a reasonable characterization of postwar trends in the regulation of the manufacturing sector. Table 1 shows the results of time series regression estimates of the contribution of public regulations to the slowdown in productivity growth.[10]

TABLE 1

CONTRIBUTIONS TO THE RATE OF GROWTH OF LABOR PRODUCTIVITY IN U.S. MANUFACTURING, 1958-77

Source	Contribution during: 1958-65	1965-73	1973-77
Regulatory intensity (R)	0 to −0.1	−0.1 to −0.3	−0.2 to −0.3
Time trend (T)	0.9 to 1.0	0.9 to 1.0	0.9 to 1.0
Cyclical adjustment (Q/Q*)	0 to 0.1	0	0 to −0.1
Unexplained	0.4 to 0.5	−0.1 to −0.2	−0.3 to −0.4
Growth in total factor productivity	1.4	0.6	0.3
Capital/labor ratio (K/L)	1.6	1.9	1.4
Average growth rate of *labor* productivity	3.0	2.5	1.7

8. Basic data on the number of major prices of regulatory legislation, both in the traditional areas and the newer environmental and social areas, are found in CENTER FOR THE STUDY OF AMERICAN BUSINESS, DIRECTORY OF FEDERAL AGENCIES (Formal Publication No. 31:1980). Our series is calculated from those data.

9. Ideally, one would wish to have a consistent time series of the net changes in average and marginal firm costs attributable to regulations, or even a time series of the incremental expenditures required of firms. See the paper by Paul Portney in this volume.

10. The equation estimated is as follows:

$$\ln(TFP) = \ln A + \alpha R + \beta T + \gamma \ln\left(\frac{Q}{Q^*}\right) + \delta \ln\left(\frac{Q}{Q^*}\right)_{-1} + U$$

where α, β, γ, and δ are parameters, *TFP* is total factor productivity [a measure that differs from labor productivity by a factor reflecting the ratio of nonlabor to labor inputs (K/L)], R is the regulatory intensity variable, T is an annual time variable, Q is actual manufacturing output, Q^* is a measure of the level of output which would have been produced in the absence of cyclical influences, U is a random error term, and A is a constant. This equation was estimated for the U.S. manufacturing sector from 1958 to 1977 using unpublished annual data (obtained from the U.S. Bureau of Labor Statistics) on the quantities and proportions of total cost accounted for by labor, capital, energy, and materials and price and quantity data pertaining to output. These measures were combined into a measure of total factor input using their shares in total costs as weights. This input measure was then used to calculate total factor productivity.

These results suggest that federal regulations are responsible for from 12 to 25 percent of the slowdown in the growth of labor productivity in U.S. manufacturing for 1973–77 compared with 1958–65.[11] Reductions in the ratio of nonlabor to labor inputs (K/L) are responsible for about 15 percent of the slowdown. The contribution of the average cyclical impact could fall anywhere in the 0–15 percent range. The portion of the slowdown in the rate of labor productivity growth attributed to a change in labor force composition, R&D expenditures, or sectoral output shifts is captured in the row labeled "unexplained." These are the factors not measured explicitly in the regression model. Their impact remains substantial.

CONTRIBUTION OF ENVIRONMENTAL REGULATIONS TO THE DECLINE IN PRODUCTIVITY GROWTH

On the basis of the results reported for the manufacturing sector, it is reasonable to suggest that between, say, 12 and 25 percent of the slowdown in productivity growth in the private sector of the economy between the early 1960s to the mid-1970s can be attributed to the entire bundle of federal regulations. The contribution of only those regulatory activities designed to secure an improved environment must, as a result, be assigned a smaller role. How much smaller, however, is an open question.

During the past decade, several researchers have attempted to sort out the contribution of environmental regulation among the numerous other causes of the productivity slowdown. Some of these studies have adopted a comprehensive accounting framework, requiring that the sum of the contributions of all factors explaining productivity growth not exceed 100 percent. Others have been more specific, emphasizing only environmental regulations or the performance of industries particularly affected by them. In this section, some of the more prominent studies dealing explicitly with the role of environmental regulations will be discussed and critiqued.

Perhaps the most comprehensive approach seeks to allocate the total decrease in productivity growth among a host of its determinants within a "growth accounting" framework. In this approach, typified by the work of Edward Denison,[12] separate estimates of the

11. As the table indicates, the growth rate of labor productivity in the 1958–65 period was 3 percent. By 1973–77, it had fallen to 1.7 percent, a decrease of 1.3 percentage points. Between the same two periods, the negative contribution of regulations (R) increased from 0 to −0.1 to −0.2 to −0.3. If one takes the estimate for the early period to be essentially zero, the range of the R contribution to the 1.3 percentage points is from 0.15 (0.2/1.3) to 0.23 (0.3/1.3). Hence, our 12–25 percent estimate.

12. E. DENISON, ACCOUNTING FOR UNITED STATES ECONOMIC GROWTH 1929–1969 (1974) and E. Denison, *Explanations of Declining Productivity Growth*, 59 SURVEY OF CURRENT BUS. 1 (Aug. 1979).

role played by 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, catch-all category. Denison measures productivity in terms of output (defined as final product in the national income and product accounts) per unit of factor input, and confines his analysis to the nonresidential business sector, where environmental regulation is concentrated. Output is valued at factor cost (including profits), and factor input is a combined measure of labor, capital, and land. Energy and materials inputs, not being primary input factors like labor and capital, are not explicitly and separately analyzed by Denison. Nonetheless, the aggregate measure of factor input which he uses is derived from the national income accounts. As a result, his overall estimates reflect these inputs as well as the primary factors which he analyzes.

Denison estimates the contribution of various determinants to productivity growth during the 1969–76 period relative to 1948–69. After adjusting his productivity data for what he terms "irregular factors"—weather, work stoppages, and cyclical factors—he considers changes in labor force characteristics, such as hours worked and age-sex composition. These factors had a negative impact on productivity growth during both pre- and post-1969 periods. By contrast, education had a positive impact in both periods.

The amount of capital and land with which the labor force works is the next major category Denison examines. The contribution of this factor to productivity growth over the years has declined only slightly. The movement of labor out of both agriculture and self-employment appears to have had a more significant effect, making a 0.4-percentage-point-per-year contribution to productivity during 1948–69, and none in 1973–76.

Denison then turns to the role of environmental regulations and measures the incremental costs in production resulting from these regulations. These costs are used to indicate the reduction in output attributable to regulation. This procedure, in effect, assumes that the factor inputs required for environmental control are diverted directly from marketed output, resulting in an equivalent decrease in the output numerator of the productivity index.

Although capital goods purchased by business for pollution abatement count as part of measured output, Denison reduces measured output by an amount equal to the value of the services this capital would have provided if it were used to produce final products instead of improved environmental quality. The value of these alternative outputs is treated in his analysis as an opportunity cost.

This net incremental cost estimate is then used to construct an index of the effect of post-1967 environmental regulations on productivity growth which shows that these regulations had no effect from 1948 to 1967, an average annual effect of 0.05 percentage point from 1967 to 1969, a 0.1 percentage point effect from 1969 to 1973, and a 0.22 percentage point effect from 1973 to 1975. In an update to his earlier study, Denison estimated the average annual reduction in productivity growth due to environmental regulation for 1975–78 to have fallen to 0.08 percentage point. Relative real expenditures on labor and capital mandated by the regulations had slowed down by this period.[13]

One of the striking aspects of the Denison study is the huge residual factor (which he labels "advances in knowledge and not elsewhere classified") with which he is left. This factor accounts for *over half* of the total 1948–69 productivity growth. For 1969–73, the residual figure of 1.6 percentage points per year equals the measured rate of productivity growth for that period. And for 1973–76, the residual factor suddenly drops to 0.7 percentage point per year, which is *greater* in absolute value than the −0.5 percentage point rate at which productivity fell during these years. Although Denison argues plausibly that advances in knowledge may have contributed less to recent growth, his study leaves unanswered the reasons for such a sudden decline in his residual category during the most recent period.

With respect to this mysterious change in the residual component, Denison's evaluation of the role of the post-1973 increase in energy prices takes on significance. In Denison's analysis, this factor is estimated to have contributed only 0.1–0.2 percentage point annually to the productivity decline. This approach, however, does not consider the long-run (dynamic) effects of the energy problem, which involve the costs of adapting plants to use substitute fuels and the increased obsolescence of some plant and equipment because of other factor substitutions. Denison's estimate also ignores the diversion of labor and capital to the redesign of products and retooling for production when energy prices induce a switch in the pattern of consumer demand (e.g., from large to small, fuel-efficient cars).[14]

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

13. E. Denison, *Pollution Abatement Programs: Estimates of Their Effect upon Output per Unit of Input, 1975–78,* 59 SURVEY OF CURRENT BUS. 58 (Aug. 1979).

14. These effects have been emphasized in E. Hudson & D. Jorgenson, *Energy Prices and the U.S. Economy, 1972–1976,* 18 NAT. RES. J. 877 (1978).

with the contributions of technology and other factors which lower the real price of capital goods.

Denison's study, then, concludes that environmental regulations affect productivity negatively and have had an increasing effect, at least through 1974. But these regulations still appear to account for a relatively small portion of the measured productivity slowdown. The decrease in impact for the most recent period is noteworthy.

A second empirical approach to explaining the slowdown in productivity growth employs a time series macroeconomic methodology. While the growth accounting approach is rather ad hoc, this second approach relies on statistical estimates of the effect of various factors. The productivity time series is observed and breaks in the series are identified by statistical analysis. Then, using a regression framework, the determinants of the breaks are statistically estimated and the contribution of each is measured.

An important and recent example of this approach is contained in a study by Robin Siegel.[15] In this research, Siegel identified breaks in the series in both 1967 and 1973. In statistically explaining these breaks, change in the demographic composition of the labor force was found to be consistently important, while (from 1973 on) changes in relative energy prices were the single most important factor. Pollution abatement expenditures were a significant negative factor in the post-1967 slowdown, and continued to contribute to the productivity slowdown until 1975.

Output per worker hour in the private nonfarm sector served as the dependent variable for Siegel's regressions. In addition to those mentioned above, variables to control for cyclical factors, the share of manufacturing in total output, and the capital/output ratio were included in the regression. Even with the addition of these variables, there were statistically significant break points in 1967 and 1973.

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 Denison's analysis, 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 to control for expenditures in education and training, research and development, along with changes in economies of scale should be employed. They have been significant in other studies and their omission in Siegel's

15. R. Siegel, *Why Has Productivity Slowed Down?*, DATA RES. U.S. REV. 1.59 (March 1979).

work may result in biased estimates of the effects of the included variables.

In the time series macroeconometric approach, the pattern of changes in aggregate productivity over time is studied in conjunction with the time pattern of other aggregate variables which might be expected to relate to, or explain, it. In this way, an association between productivity change and its determinants—say, regulatory intensity or cyclical change—can be established. An alternative approach is to study patterns of productivity change in individual industries. This can be done either over time within an industry or across industries at a point in time. Again, the effort is to see if high and low levels of change are associated with variations in the intensity of environmental regulations and other relevant independent variables.

Such microeconometric estimates have been made by Robert Crandall.[16] His first analysis involved a comparison over time of productivity growth in selected industries. He compared the primary "pollution-control impacted industries" in the 1958–73 period (before policy-induced pollution control expenditures really took their bite) with their performance in the post-1973 period. He found that the affected industries experienced productivity growth of about 5 percent per year prior to 1973, 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 rate of productivity growth in the total manufacturing sector fell to 1.4 percent, the rate in the sectors heavily affected by regulations fell to less than 1 percent. This simple comparison, of course, says nothing about the other forces affecting these industries which could also have contributed to a reduction in productivity. Changes in energy prices, investment levels, labor force composition, and the composition of intraindustry output come immediately to mind. It is not unreasonable to believe that industries affected by pollution control are also affected significantly by energy prices, cyclical changes, and other factors.

Crandall's second analysis employs a cross-section regression model (using 36 industries for which pollution control expenditures and productivity data are available) to explain the variance in productivity growth rates during the 1973–76 period. The dependent variable in Crandall's analysis is the deviation of an industry's productivity index from the forecast 1976 productivity, which was based on the histor-

16. R. Crandall, Is Environmental Policy Responsible for Declining Productivity Growth? (Dec. 28, 1979) (paper prepared for Annual Meeting of Society of Government Economists) and R. Crandall, *Pollution Controls and Productivity Growth in Basic Industries*, in PRODUCTIVITY MEASUREMENTS IN REGULATED INDUSTRIES (T. Cowing & R. Stevenson eds. 1980).

ical growth rate from 1958 to 1973. Of the numerous factors which could explain changes in productivity growth rates, only two variables are used: one to account for the effect of cyclical swings in output and the other to reflect pollution control costs. Crandall concludes that a 50 percent increase in pollution control costs over 1976 levels for the 36 industries would reduce productivity growth by 1.2 percentage points (or about one-third the average annual productivity growth). Also, if the results are extrapolated to all manufacturing, the 1976 reduction in productivity attributable to the bulk of pre-1976 pollution control expenditures would be 1.5 percentage points.

In his final analysis, Crandall estimated time series regressions for 10 heavily affected industries (plus electric utilities and all manufacturing) over 1954–76. The dependent variable was labor productivity and the independent variables were measures of the business cycle and a time trend. By examining the measured errors of the regression for each industry for the post-1970 period (or subperiods), Crandall sought to determine if there was a shortfall in productivity growth that was not accounted for by the independent variables. He concluded that in the industries affected by pollution control, productivity growth in the post-1970 period is less than in manufacturing as a whole, but that the difference was not substantial. Electric utilities had a substantial negative error in all post-1970 subperiods. The relatively small size of the negative impact of the highly regulated industries suggests that cyclical changes in output in the post-1970 period account for much of the productivity shortfall.

While Crandall's analysis is consistent with other studies suggesting a nontrivial role for environmental regulations in 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, and his extrapolated estimate of a 1.5 percentage point reduction in productivity growth as a result of environmental controls over a three-year period is higher than the impact suggested by Denison. Crandall's 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 a host of other potential determinants of productivity change—the pattern of R&D spending, changes in energy prices, changes in labor force composition—are not accounted for and may seriously bias the results. Crandall's industry-specific time series analysis has much the same problem of omitted variables, as again only cyclical output swings (plus a time trend) are entered into the equation. The entire unexplained productivity shortfall is then attributed to pollution control regulations, even though a number of other potential determinants could just as well have contributed to it.

Crandall's microeconomic estimates, then, are rough and 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 variables, the effect of environmental regulations on productivity, while present, would appear to be rather small–substantially smaller than those suggested by Denison.

A final approach to estimating the effect of environmental regulations on productivity is through adoption of standard, intermediate-term, econometric models. With these models, the impact of aggregate expenditure or cost changes induced by environmental policy can be traced through the economy over time.[17]

The Data Resources macroeconomic study discussed by Portney indicates that environmental policy measures reduce productivity as the induced pollution control investment "crowds out" alternative capital investments in plant and equipment. In describing the results of their simulation analysis of labor productivity, DRI stated:

> The increased factor demands associated with the operating and maintenance and 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% lower by 1978 and 1.4% 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.[18]

Table 2 shows the effect of pollution control policies on the annual labor productivity index over the 1970–86 period, as estimated by DRI. By the end of the seventeen-year period, the index of labor productivity was estimated to be 1.4 percentage points lower with than without the policy. However, by the end of the 1970–80 period, the productivity index with the controls was estimated to be only 0.3

17. This approach is discussed in detail in the paper by Portney in this volume.

18. Data Resources Inc., The Macroeconomic Impact of Federal Pollution Control Programs: 1978 Assessment (Jan. 29, 1979) (report submitted to the Environmental Protection Agency and the Council on Environmental Quality, Washington, D.C.).

TABLE 2

THE EFFECT OF POLICY-INDUCED POLLUTION CONTROL EXPENDITURES ON THE LABOR PRODUCTIVITY INDEX, 1970-86, IN PERCENTAGE POINTS

1970	+0.2	1979	−0.4
1971	+0.3	1980	−0.3
1972	+0.3	1981	−0.6
1973	+0.1	1982	−0.8
1974	−0.1	1983	−1.0
1975	−0.1	1984	−1.1
1976	−0.1	1985	−1.3
1977	−0.3	1986	−1.4
1978	−0.5		

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

percentage point 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.

The studies we have identified and described represent a wide variety of analytical approaches to discerning the effect of environmental regulations on productivity. While each approach contributes to a fuller understanding of the processes by which government regulations affect economic performance, each has its own special limitations and weaknesses.

Consider, first, the growth accounting analyses, as represented by Denison. First, Denison implicitly assumes that, given the level of total factor input, 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 producing marketed output. Because of underemployed resources or factor substitution, however, output might not fall to the extent estimated by Denison. In this respect, then, his estimate is likely to be higher than the actual effect.

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 if they had not been diverted by environmental regulations. 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 upward-biased impact of environmental regulations is struck. On the other hand, Denison's estimates take no account of other, more subtle effects of regulation on productivity.

A clear strength of the growth accounting approach, however, is the comprehensiveness of its framework. The analyst is required to give recognition to the full set of factors which may be important in determining productivity growth—a requirement which a number of the more ad hoc or partial analyses do not fulfill. Having said this, however, it should be noted that Denison has been criticized for downplaying the effect of the post-1973 energy price increase on productivity growth.

The failure to consider relevant variables in the analysis is nowhere more clear than in the time series and microeconometric studies. All of these results remain open to question so long as potentially important variables, such as the age of the capital stock, expenditures on education, training, research and development, and changes in economies of scale are left out of the analysis. When the impacts of these variables are omitted, the estimated effects of the included variables are likely to be biased.

In defense of those who have attempted these time series and microeconometric studies, however, the serious data problems confronted should be emphasized. Some relevant aggregate time series data simply do not exist, and, at the industry level, important data (e.g., energy prices and usage and environmental or health/safety expenditures) are either unavailable or unreliable. Given these constraints, criticism of efforts which seek to do what one can with what is available should not be pushed too far.

The main strength of the macroeconomic models is their ability to capture a rather full set of behavioral relationships in a single framework. Moreover, only through these models can the problems of timing of impact be addressed. These strengths are offset by some notorious weaknesses. First, the underlying structure of the prominent models have been designed to yield short- and intermediate-term forecasts of the economy under various aggregate monetary and fiscal measures. When expenditures in a specific area (e.g., pollution control) are to be analyzed, the model is forced to treat them as generalized investment spending, with little recognition of their particular characteristics or impacts. Second, when adjustments have been made in the models in order to accommodate environmental policy measures, the adjustments have been crude and ad hoc. For this reason as well, the reliability of the estimates yielded by those models is open to question.

Two final points must be made with respect to all of the studies which have been undertaken to date. First, nearly all of them have taken, as the direct economic impact of regulations, estimates of the expenditures which these regulations have required. However, these data have serious weaknesses.[19] It is, for example, difficult to claim that these estimates across industries are likely to give a correct ordering of impact among them, let alone provide reasonable point estimates of resource requirements.

Finally, none of these studies has done justice to the role of regulations in creating an uncertain environment for business activity. Malkiel, for example, has emphasized the debilitating effect on investment and location decisions of regulations whose application and enforcement is problematic and unknown to the regulatee.[20] Similarly, Quarles has emphasized that clean air legislation, in particular, has led to serious delays and "stretch-outs" in investment plans, delays which have the inevitable effect of extending the use of outmoded facilities and retarding technical change and economic growth.[21] While these effects are difficult to model and estimate, their potential impact is nonetheless real.[22]

ENVIRONMENTAL REGULATIONS AND PRODUCTIVITY GROWTH— AN ASSESSMENT

This review of investigations of the causes of the post-1965 decline in productivity growth produces no clear-cut answers. It does, however, provide the basis for judging the contribution of environmental regulations to the decline. This assessment must, of course, consider

19. See Portney's discussion of these issues.

20. B. Malkiel, *Productivity–the Problem Behind the Headlines*, 57 HARV. BUS. REV. 81 (May-June 1979).

21. J. Quarles, *Federal Regulation of New Industrial Plants*, 10 ENVT'L RPTR. (BNA) (Monograph No. 28: May 4, 1979).

22. In addition to the few studies discussed here, a number of other studies have also attempted to assess the role of regulations and other factors in accounting for the slowdown in productivity growth. *See, e.g.*, Special Study on Economic Change (Part 2): Hearings Before the Joint Congressional Economic Committee, 95th Cong., 2d Sess. 476-87 (1978) (statement of Jerome A. Mark); *id.* at 596-616 (statement of Michael K. Evans); *id.* at 616-36 (statement of John W. Kendrick). *See also* J. Norsworthy, M. Harper, & K. Kunze, *The Slowdown in Productivity Growth: Analysis of Some Contributing Factors*, in 2 BROOKINGS PAPER ON ECONOMIC ACTIVITY 387 (Brookings Inst. ed. 1979) and L. Thurow, *The Productivity Problem*, 83 TECH. REV. 40 (Nov./Dec. 1980). These studies are reviewed and critiqued in G. Christainsen, F. Gollop, & R. Haveman, Environmental and Health-Safety Regulations, Productivity Growth, and Economic Performance: An Assessment (1980) (report prepared for the Office of Technology Assessment of the Joint Economic Committee of the United States Congress).

the role of environmental regulations in the context of a large number of other contributing factors and is admittedly tentative.

The changing demographic composition of the labor force and hours worked, together with sectoral shifts in the composition of output, appear to account for 20-30 percent of the slowdown in productivity. The slowdown in the rate of capital investment–resulting in a declining capital-labor ratio and a capital stock that embodies a technology which increasingly deviates from what is possible–should be credited with 25-30 percent of the slowdown.[23] A third important factor involves cyclical changes. The high unemployment and low utilization of the capital stock of the late 1960s and the 1970s, together with weather and work stoppages, appear to account for another 10-20 percent of the productivity slowdown. Finally between 10 and 40 percent of the slowdown is caused by a large number of other determinants, of which environmental regulations are but one. Little evidence exists to suggest that as much as 15 percent of the overall slowdown can be attributed to these regulations. A reasonable estimate–but one resting on a good deal of judgment–is that 8 to 12 percent of the slowdown in productivity is attributable to environmental regulations.

This estimate, it should be emphasized, accounts for both the *direct* and the *indirect* effects of environmental regulations. As a result, it includes whatever effects environmental regulations have on capital investment and the capital-labor ratio.[24]

Clearly, there is a wide range of uncertainty in this estimate. The research from which it is drawn varies 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 regulations. In this vein, it should be noted that the evidence for an adverse impact of environmental regulations on the capital stock and its productivity is very weak. While the requirements of environmental policy could have major adverse effects on output

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23. It should be noted that many analysts have included the potential effect of the post-1973 energy price increase in this capital determinant. This procedure presumes that the energy price increase reduced both investment and the return (productivity) to existing capital, and hence reduces 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.

24. *See* B. Fraumeni and D. Jorgenson, The Sectoral Sources of Aggregate U.S. Economic Growth 1948-1976 (1979) (unpublished report); B. Bosworth, *The Issue of Capital Shortages,* in CONG. JOINT ECON. COMM., 94TH CONG., 2D SESS., U.S. ECONOMIC GROWTH FROM 1976 TO 1986: PROSPECTS, PROBLEMS, AND PATTERNS (VOL. 3: CAPITAL) 1 (Comm. Print 1976); R. Eisner, *The Corporate Role in Financing Future Investment Needs, id.* at 16; and G. Christainsen, F. Gollop & R. Haveman, Environmental and Health-Safety Regulations, Productivity Growth, and Economic Performance: An Assessment (1980) (report prepared for the Office of Technology Assessment, U.S. Congress).

and productivity in certain sectors or industries, these effects tend to be localized. The sectors affected are small relative to the national economy, and reduced capital investment in them has a small effect on aggregate investment. Although both the direct and indirect effects of environmental regulation have been considered, some potential indirect effects may have been underestimated. For example, the rate of investment may have been depressed because of *uncertainties* caused by environmental regulations. This channel of impact was not explicitly considered.

One basic and overriding point should be made with respect to environmental regulations. The contributions to economic welfare which they are intended to make are, by and large, not reflected in 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. If the standard productivity measures were effective indicators of economic welfare, these outputs would be included in the numerator of the measure.[25] Although they are difficult to quantify, let alone to value, numerous studies have indicated that marked increases in these social benefits have resulted from environmental policy. If this is in fact the case, the effect of these regulations on "true" productivity would be less negative than that estimated here—or even positive.

25. On this point, see H. Peskin's paper.