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THE IMPACT OF OSHA AND EPA REGULATION ON PRODUCTIVITY

Wayne B. Gray

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1050 Massachusetts Avenue
Cambridge, MA 02138
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ABSTRACT

This paper presents estimates of the impact of OSHA and EPA regulation on productivity. Production information for 450 manufacturing industries from 1958 to 1980 is merged with measures of regulation, including both information on compliance expenditures by industry and enforcement efforts by OSHA and EPA.

Industries that faced higher regulation during the 1970s had significantly lower productivity growth, and a greater productivity slowdown, than industries that faced lower regulation. Under certain assumptions, the regulation is estimated to have reduced average industry productivity growth by .57 percent per year, 39 percent of the average productivity slowdown. These results are robust to variations in the model and the inclusion of other productivity determinants, including poor output growth and dependence on energy. The results also suggest a one-time cost of adjustment to regulation, so the long-run impact may be less than that estimated here.

Both OSHA and EPA are found to target their enforcement effort towards those industries that are doing poorly in meeting the goals of the regulation. However, in the only area where benefits from regulation can be examined, worker injury rates and OSHA safety inspections, no significant benefits are found.

Wayne B. Gray
National Bureau of Economic Research
1050 Massachusetts Avenue
Cambridge, MA 02138
(617) 868-3900

1. INTRODUCTION

The slowdown in productivity growth in the U.S. economy during the 1970s has been a matter of great concern to policymakers, associated as it is with inflation, unemployment, and declining real wage growth. Many possible explanations for the slowdown have been proposed, and much research has been done to determine the contribution of these factors to the slowdown. The research presented here examines the impact on productivity growth of government regulation, specifically environmental and worker health and safety regulation by the Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA). Looking at data for 450 manufacturing industries between 1958 and 1980, the study finds a large, negative relationship between this regulation and productivity growth. Under certain assumptions, a large part of the decline in productivity growth during the 1970s may be attributed to such regulation. However, the study also finds some evidence that this decline could be a temporary one, representing a one-time cost of adjusting to the regulation rather than a recurring cost to society.

The major innovation of the study lies in the creation of a data set that has information on output and inputs for many industries, allowing the calculation of their productivity growth rates, along with data concerning the extent of regulation of each industry. The regulatory data are taken from surveys of the cost of compliance with regulation and from regulatory agency records of the enforcement efforts directed toward different industries. The basic result is that high levels of regulation are associated with low and falling rates of productivity growth. This result is not fundamentally changed when measures of other factors that have been suggested as causes of the productivity slowdown are added to the model.

An attempt is made to measure the benefits from regulation, with very limited success due to problems with the available data. It is clearly shown that the regulatory agencies focus their efforts upon industries which are performing poorly in the areas of concern: worker safety and health, and environmental pollution. However, other results suggest that in the one area where there is a useable measure of benefits, worker safety, it is difficult to attribute significant benefits to regulation.

2. PRODUCTIVITY MEASUREMENT AND REGULATION

2.1. Definition and Measurement

Productivity is the ratio of output produced to inputs used. Because output and inputs are measured in different units, it is the growth of productivity over time, rather than its level, that is of greatest concern. The simplest measure of productivity is the single-factor measure, where only one input is measured. In this case, productivity growth is given by the difference between the growth rates of output and that input. The most commonly used productivity statistics, measuring labor productivity, are of this form. These statistics are easy to calculate, but ignore changes in other factors of production, such as capital or materials, which could affect output growth.

Other productivity statistics, called total factor productivity (TFP) measures consider the contribution of all factors to output growth.

Consider a production function for a firm,

$$Y = TF(X_1,\dots,X_n) ,$$

where output, Y, is a function of the productivity level, T, and n inputs X_i. For a competitive, profit-maximizing firm, an index of total input growth can be calculated as

$$\sum_i \alpha_i dx_i ,$$

where α_i is the cost share, and dx_i the growth rate, of input i. Then productivity growth $\tau = d \log T$ is given by

$$(1) \qquad \tau = dy - \sum_i \alpha_i dx_i .$$

This calculation of the growth rate of productivity using the cost shares of inputs and output and input growth rates is called growth accounting.

2.2. Effect of Regulation

A simple model of the impact of regulation on productivity would assert that the production function remains unchanged, but the firm is required to use some additional inputs, R_i, to comply with the regulation. If productivity growth is calculated for the firm without knowing how much of each input was used to produce output and how much to produce compliance, inputs and productivity would be measured as

$$X_i' = X_i + R_i \qquad \text{and} \qquad \tau' = dy - \sum_i \alpha_i' dx_i' .$$

Suppose that the fraction of each input used in compliance is given by

$$\delta_i = R_i/X_i' ,$$

where δ_i is near zero. True productivity growth τ is then approximately

$$(2) \qquad \tau = \tau' + \sum_i \alpha_i'\delta_i \quad .$$

Therefore, one would expect an ordinary productivity growth measure, which ignores the existence of compliance inputs, to understate true productivity growth by an amount equal to the sum of the cost share of each input times the fraction of that input used for compliance.

Regulation may affect the firm's production beyond simply requiring the use of some inputs for compliance activities. Regulation commonly imposes constraints on the firm's choice of production processes. These constraints could force firms to change existing procedures, reducing productivity during the period of adjustment. Additionally, the presence of regulation and the possibility of future changes in regulation, increases the uncertainty faced by firms, which could reduce investment in new methods of production and inhibit productivity growth.

A simple test for the presence of an impact of regulation on productivity beyond the measurement impact is available. Suppose that productivity growth before regulation is imposed is τ_0. Also suppose that the fraction of each input used for compliance with regulation is δ_i. If actual productivity growth remains unchanged, equation 2 gives the change in measured productivity after regulation as

$$(3) \qquad d\tau = \tau_1 - \tau_0 = -\sum_i \alpha_i\delta_i \quad .$$

Now consider taking observations on compliance costs and productivity growth for many different industries, indexed by j. Restating Equation 3:

$$(4) \qquad d\tau_j = \alpha_0 + \sum_i \gamma_i(\alpha_{ij}\delta_{ij}) + \varepsilon_j \; .$$

Here we recognize that actual productivity growth is likely to change over time for various reasons, and use α_0, the average productivity change for all industries, and ε_j, an industry-specific component, to account for this change.

If we believe that there is no relationship between regulation, as measured by compliance costs, and changes in actual productivity growth, we would expect the regression indicated in Equation 4 to yield $\gamma_i = -1$. If there is some impact of regulation on actual productivity, we would expect $\gamma_i \neq -1$ and probably $\gamma_i < -1$, since most of the impacts of regulation would be expected to reduce actual productivity.

When measures of compliance costs are not available, but other measures (say M_{ij}) of different levels of regulation applied to different industries are available, such as enforcement effort, we can rewrite Equation 4 as

$$(5) \qquad d\tau_j = \alpha_0 + \sum_i \gamma_i M_{ij} + \varepsilon_j \; .$$

There is no longer a way to separate the impact of regulation into measurement and actual effects, but it is possible to examine the magnitude of the impact of regulation on changes in measured productivity growth.

We could attempt to model directly the impact of regulation on the demands for and marginal products of different inputs, using a more detailed model of the production process, with impacts on productivity being derived as a result. As the model becomes more involved, it becomes more sensitive to possible misspecification or errors in the variables. Since compliance costs tend to be poorly measured, and are often not measured at all, this can cause problems for the more complex models. This study tends to avoid the more complicated analysis in order to get some basic results from simpler techniques.

2.3 Growth of Regulation

There was a substantial increase in government regulation of business during the early 1970s. Both the Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA) were created in 1970. The pattern followed by both agencies is similar: before the early 1970s, the primary responsibility for regulation lay with the states. The states varied enormously both in regulatory standards set and in the enforcement effort they used to ensure compliance. Public dissatisfaction with the poor performance of the state-level regulation led to pressure for federal action, and federal agencies were empowered to tighten the standards and especially to increase the enforcement effort. In the case of OSHA, this meant setting standards on a national level, and using a large force of federal compliance officers to enforce compliance.1

For EPA, the states still bore the responsibility for developing and administering State Implementation Plans (SIPs) to achieve reductions in pollution, but the law set strict timetables for the SIP development and gave EPA the power to force the states to prepare a plan. There were some national inspectors, to help check on the effectiveness of the states' effort, but not as many as at OSHA. On the water pollution side, the EPA was required to establish a permit system for all effluent discharges, designed to met certain water quality standards. Compliance with both types of regulation was to be enforced through the courts.

Both EPA and OSHA are required by law not to consider compliance costs when deciding what standards to propose. The standards proposed often specify the control techniques to be used, and tend to require capital-intensive compliance methods. The standards have also changed over time, in response to new information on health risks, political pressures from various groups, and court decisions.

There is some doubt about the power of the agencies to enforce compliance with the standards, because rare inspections are combined with low fines for violations to yield very low expected penalties for non-compliance. Table 2.1 presents data on the manufacturing inspections carried out by OSHA and EPA during the time period of the study. Because OSHA concentrates on manufacturing to a great extent, the inspection rates are not completely negligible, with about 10 percent of all manufacturing workplaces inspected each year. Also, the inspections are not randomly allocated, so some establishments can have quite a high probability of being inspected in a given year.

Table 2.1 also provides some information on penalties assessed and an estimate of expenditures on compliance by the firms. The penalties are quite low relative to the compliance expenditures, suggesting that most compliance expenditures are motivated by other reasons. The historical measure of pollution abatement capital, also presented in Table 2.1, showed that pollution abatement capital has grown much more rapidly than other capital, especially from the late 1960s through the middle 1970s. We do not have such time series data for worker health and safety investment. It seems likely that such investment has increased since OSHA's inception, but was probably not zero before.

Table 2.1

Regulation of Manufacturing Sector

OSHA

	Inspections		Penalties($M)	Worker Health and Safety Capital Expenditures	
	Number	Percent of Establishments		Amount ($M)	Percent of Investment
1973	30112	9.41	2.87	868.1	3.22
1974	37828	11.55	3.23	1264.9	3.56
1975	40397	12.06	4.93	1203.4	3.22
1976	34945	10.20	6.60	1010.5	2.49
1977	32925	9.41	9.16	1407.1	2.95
1978	29428	8.24	13.87	1692.6	3.06
1979	28600	7.84	14.36	1621.0	2.63
1980	26962	7.24	12.80	2081.3	2.95

EPA

	Inspections		Pollution Abatement Capital Expenditures		Pollution Abatement Operating Costs	
	Number	Percent of Establishments	Amount($M)	Percent of Investment	Amount($M)	Percent of Total Cost
1973	73	0.02	2351.8	8.71	2442.4	0.28
1974	484	0.15	3098.5	8.72	3101.0	0.30
1975	2516	0.75	3634.7	9.73	3662.2	0.35
1976	4887	1.43	3529.1	8.70	4538.6	0.38
1977	7288	2.08	3480.3	7.29	5424.5	0.40
1978	9012	2.52	3262.5	5.91	6260.5	0.41
1979	10389	2.85	3558.9	5.78	7399.8	0.43
1980	11478	3.08	3502.8	4.97	8142.2	0.44

Pollution Abatement Capital Stock (Real)

	Level($B)		Growth Rate	Other Capital Stock Growth Rate
1960	3.36			
1967	5.39	1960-1967	9.9	2.9
1970	11.46	1967-1970	16.3	4.8
1975	24.25	1970-1975	16.1	3.3
1981	36.14	1975-1981	8.3	3.4

Pollution abatement capital stock data from Kappler and Rutledge (1982). Sources of other data listed in Section 4.

3. PRODUCTIVITY SLOWDOWN - EVIDENCE AND EXPLANATIONS

3.1. Evidence for Slowdown

The most widely observed measure of productivity is the labor productivity index produced by the Bureau of Labor Statistics. This measures productivity as the real output produced per worker-hour of all workers. It is calculated for several sectors of the economy, including the private business, nonfarm business, and manufacturing sectors. Average growth rates for these sectors during several periods are given in Table 3.1.

During the early postwar period, all three sectors showed impressive growth rates: between 1950 and 1969 output per worker hour rose about 2.5 percent per year. The most rapid growth came during the long expansion of the 1960s. Some slowdown in the non-manufacturing sector is seen by the period between 1969 and 1973, and manufacturing follows suit in the 1973-1980 period. During the 1970s all three sectors showed very low rates of labor productivity growth by postwar standards, dropping to less than half their 1950-1969 levels.

Table 3.1

Labor Productivity Growth Rates
(output per worker-hour)

Sector / Period:	1950-69	1958-69	1969-73	1973-80
Private Business	2.84	2.93	2.61	0.61
Nonfarm Business	2.32	2.57	2.45	0.48
Manufacturing	2.49	3.02	3.98	1.28

Source: U.S. Bureau of Labor Statistics (1983).

As mentioned in Section 2, this study concentrates on measures of total factor productivity rather than labor productivity. Because the input index is more complicated for total factor productivity measures, a wide variety of total factor productivity measures exists, each using different procedures to calculate total factor input. This leads to a much greater dispersion in estimates of productivity growth, with no single, generally accepted measure. The results from several such studies are presented in Table 3.2.

These studies indicate that total factor productivity growth fell substantially during the 1970s, relative to the rest of the postwar period. The studies cited here suggest that the decline in productivity growth began in the early 1970s (around 1973), although others have found the decline beginning in the late 1960s. There seems little doubt from these data that there was a slowdown in productivity growth, however measured, during the 1970s (although Darby (1982) argues that the slowdown is an illusion, caused by the imposition and later lifting of price controls in the early 1970s).

3.2. Possible Explanations for the Slowdown

What factor or factors could have caused such a decline in productivity? As indicated earlier, this paper focuses primarily on the impact of increasing government regulation on productivity, looking at OSHA and EPA regulation. However, almost every change in the economy that coincided with this decline in productivity has been proposed as an explanatory factor.2 Factors suggested frequently include a rise in energy prices, a long and severe recession, a

Table 3.2

Multifactor Productivity Growth Rates

(annual percentage growth rates)

Author	Time Period	Total Factor Productivity	Labor Productivity
	Before Slowdown		
Griliches and Jorgenson[1]	1950-62	1.03	3.20
Kendrick[2]	1950-62	2.1	-
	1948-69	2.3	-
	1948-66	2.5	3.4
Denison[3]	1950-62	1.38	-
	1948-69	1.76	2.69
	1964-69		
	After Slowdown		
Denison[4]	1969-73	1.13	2.28
	1973-76	-0.65	0.50
Fraumeni and Jorgenson[5]	1948-76	1.14	2.22
	1969-73	0.95	2.08
	1973-76	-0.70	0.31
Kendrick and Grossman[6]	1948-80	1.43	1.73
	1969-73	1.89	2.51
	1973-80	0.15	0.62
U.S. BLS[7]	1948-80	1.51	2.43
	1969-73	1.64	2.61
	1973-80	0.01	0.61

1. Source: Griliches and Jorgenson (1972)
2. Source: Kendrick (1973).
3. Source: Denison (1972 and 1974).
4. Source: Denison (1979).
5. Source: Fraumeni and Jorgenson (1981).
6. Source: American Productivity Center (1981).
7. Source: U.S. Bureau of Labor Statistics (1983).

decline in capital investment by business, a fall in research and development activities, and a decline in the quality of inputs (especially labor).

Denison (1979) uses economy-wide data and calculations based on the growth accounting framework to measure the contribution of different factors to the slowdown. His is the most complete attempt to measure the contributions of various factors. He discusses all of them, provides estimates for some (including government regulation) and concludes that many were involved in the slowdown. He ascribes some of the slowdown in total factor productivity growth of 2.17 percent to resource allocation (.30), the legal and human environment (.30), economies of scale (.13) and other minor factors. However, he is left with an unexplained fall in residual productivity growth of 1.68 percent after accounting for those factors he could measure.

Studies which calculate the contribution of regulation to the slowdown based on compliance cost estimates tend to produce small estimates. Denison (1979) estimates that such regulation contributed .35 percent to the productivity slowdown in the 1972-1975 period, and in a later study (1983) concludes that the contribution fell to .15 percent in the 1973-1981 period. Portney (1981) notes that little of GNP is spent on pollution control (under 2 percent).

Estimates using cross-industry or time-series data have generally given slightly larger, but similar results. Norsworthy, Harper and Kunze (1979) find that pollution abatement capital had a limited effect on labor productivity. Scherer (1982) finds that pollution and health and safety investment reduced productivity growth by .19 to .27 percent, but this effect is not significant.

Using time series data and measures of total federal regulation, Christainsen and Haveman (1981) find regulation responsible for about 20 percent of the slowdown. Crandall (1981) finds a strong relationship between pollution abatement capital and productivity, but this relationship disappears when a measure of energy intensity is included. Using time-series data, Siegel (1979) observes a significant contribution (.5 percent) from pollution control expenditures to the productivity slowdown for 1965-1973, but not for later years. Finally, Gollop and Roberts (1983) examine data for a set of electric utilities and find that regulation of emissions had a large impact on total factor productivity, lowering it for regulated firms by .59 percent. The conclusion of these studies (except perhaps for Gollop and Roberts) is that pollution abatement costs in particular, and regulation in general, explain about 10 percent of the productivity slowdown.

We can reach four general conclusions from previous work. First, there was a productivity slowdown during the 1970s, at least in measured productivity. Second, many different factors seem to have contributed to it, to different degrees. Third, government regulation contributed a small but significant amount to the slowdown. Fourth, a sizeable fraction of the slowdown remains unexplained by the estimated contributions of all the factors considered. We now proceed to the empirical analysis in Section 5, after discussing the data sources used.

4. DATA DESCRIPTION

4.1. Introduction

The data set used in this analysis consists of data for 450 manufacturing industries at the 4-digit level, based on the 1972 Standard Industrial Classification (SIC). Annual data from 1958 to 1980 on real and nominal output and inputs are used in the calculation of industry productivity growth. Data are also available on the extent of government regulation of these industries for the more recent years of the period (as we saw in Section 2, there was relatively little regulation before the early 1970s). Additional data include measures of industry performance on pollution abatement and protection of worker safety and health. The major data sources are listed in Table 4.1. We now turn to a brief description of each type of data and the way in which they are combined. A more extensive description of the data is provided in Gray (1984).

4.2. Productivity Data

The principal source of the data needed to calculate productivity growth was a joint project by the University of Pennsylvania, the Bureau of the Census, and SRI, Inc. This project assembled basic input and output data from 1958 to 1976 on all 450 industries. It is referred to here as the PCS data set.3 Much of this data, including inputs, outputs, and factor shares, was taken from the Annual Surveys of Manufactures and Censuses of Manufactures. The major contribution of the project was the development of measures of the real capital stock of each industry, using data on the composition of investment goods

Table 4.1

Major Data Sources

Source	Period	Data
Productivity Sources		
U Penn - Census - SRI	1958-1976	Output, inputs, prices
Census of Manufactures	1977	Output, inputs
Annual Survey of Manufactures	1978-1980	Output, inputs
Census Bureau - BLS	1958-1980	Price Deflators
Regulation Sources		
McGraw-Hill Safety Investment Survey	1973-1980	Investment in worker health and safety
Census - Pollution Abatement Costs Survey	1973-1980	Pollution control capital and operating costs
OSHA Management Information System	1972-1980	OSHA inspections, citations
EPA Compliance Data System	1970-1980	EPA enforcement actions
Other Data Sources		
NIOSH Injury Survey	1958-1970	Injury rates
BLS Occupational Injuries and Illness Survey	1972-1979	Injury rates
OSHA Industry Priority Report	1981	Health hazard rankings
EPA National Emissions Data System	1970-1980	Emission levels, control equipment efficiencies

purchased by each industry. The PCS data was then updated through 1980, using data from the 1977 Census of Manufactures and the 1978 through 1980 Annual Surveys of Manufactures. Price deflators for output (value of shipments), material inputs, and energy usage were obtained using data from the Bureau of Labor Statistics and the Census Bureau.

4.3. Regulation Measures - Compliance Costs

There is very limited data on costs to firms of complying with OSHA regulation. The data we consider here are taken from an annual McGraw-Hill survey on capital spending for the 1973 to 1980 period. Each year McGraw-Hill collects information from a few hundred large firms on current-year capital expenditures and projected expenditures for the next year, and for two years later. One question asks what fraction of total capital spending is allocated to worker safety and health. Problems with this data include the non-representative nature of the firms sampled, the low response rate (especially on the safety and health question), and the small size of the total sample. These data are examined briefly in Section 5, but they prove unsatisfactory.

The data for EPA-related compliance costs were also taken from a survey, but this survey was far superior to that used for OSHA-related costs. These data are from the Pollution Abatement Costs and Expenditures Survey, taken annually by the Bureau of the Census since 1973. The survey is sent to about 20,000 establishments, a subsample of those in the Annual Survey of Manufactures excluding establishments in major group 23.[4] The survey asks respondents to report capital expenditures and operating costs for pollution abatement, disaggregated by type of pollutant abated and type of cost.

One problem for both the EPA and the OSHA compliance cost measures is that they don't measure the incremental cost of complying with the new regulations. If firms, for some reason, had been spending money to clean up pollution before EPA existed, this survey of total pollution abatement costs will overstate the additional burden imposed by EPA. A more general problem with both surveys is that it is very difficult to measure compliance costs, especially when considering costs of new production processes or equipment that is both cleaner, safer, and more productive.

Following the model of Section 2, the inputs used for compliance are expressed as a fraction of the total use of that input. Capital expenditures for compliance are deflated by the new investment price deflator and then divided by real capital stock to express them as a share of real capital input. Operating costs are more difficult to allocate to a particular input, but most of the operating costs would count as materials cost, so operating costs for compliance are expressed as a fraction of total materials cost.

4.4. Regulation Measures - Enforcement

To measure OSHA enforcement efforts we have a copy of OSHA's Management Information System (MIS) database, which contains a record of all (538,796) OSHA inspections carried out from late 1972 to 1980. The data on each inspection is very detailed, in keeping with the use of the MIS for enforcement purposes. Each establishment is identified by name and industry. We have a number of possible measures for the amount of enforcement effort applied by OSHA, including citations issued and duration of inspection.

The enforcement data available for EPA from the Compliance Data System (CDS) is not as comprehensive as the OSHA MIS data. The major problem is that the CDS contains only air pollution enforcement data. The CDS data contains records for 49,087 establishments. Each establishment is identified by name and industry. Its current compliance status with respect to major pollutants is indicated. All enforcement actions directed at that establishment (including inspections, both state and federal) are found on the record, with information on the type of action and the effective date.

For both the OSHA and the EPA data, an annual inspection rate is calculated for each industry, taking the number of inspections and dividing that by the number of establishments. Because the size of plant inspected (number of employees) is also available on the OSHA data, an alternative measure is constructed, weighting each inspection by the number of employees in the establishment and divides the total by the number of employees in the industry. An inspection of a larger plant generally takes more inspector time, has more citations, and affects a larger fraction of total industry output than an inspection of a smaller plant. Any tendency to inspect larger plants in one industry than another would be captured by this employee inspection rate but not by the establishment inspection rate, although in practise the two measures are closely correlated.

Why use enforcement measures? Without any enforcement of regulation, it is not generally in the interest of firms to comply with the regulation. Neither

EPA nor OSHA regulation has been uniformly obeyed by firms. Some of this may be due to firms misunderstanding the rules, but there are many cases where firms deliberately violate the rules, either because that is cheaper than complying with the rules or to convince the regulatory agency to change the rules.

We expect the enforcement effort from each agency for an industry to be positively correlated with the compliance cost imposed by the regulation on that industry. Each agency engages in some targetting of inspections and other compliance activities towards those industries which are performing poorly, with high accident rates or pollution emissions. These industries are those which face the highest compliance costs. There may be some tendency for the agencies to avoid enforcement in high compliance cost industries because those industries are more likely to resist the regulations. However, the data show a tendency for high enforcement industries to have high compliance costs and to perform poorly on measures of compliance with regulation.

If we had exact and complete measures of compliance costs imposed by regulation, enforcement measures might not be necessary to measure the impact of regulation on productivity. However, perfect measures of compliance costs are difficult or impossible to obtain, due to problems with separating the use of inputs in production from compliance usage. The measure we do have of the costs of complying with worker health and safety regulation is inadequate, and the measure of pollution abatement costs may have some problems. We have enforcement data for both OSHA and EPA regulation, and this data can be used to supplement or replace the compliance cost data.

4.5. Other Data Sets

Industry accident rate data is taken from two data sets, a NIOSH survey between 1958 and 1970 and a BLS survey between 1972 and 1979. Although both surveys are similar, the accident measures differ slightly (the BLS one only counts accidents which resulted in lost workdays). Despite comparability problems over time, this data does let us look at changes in industry accident rates over time, as well as the relative safety hazards to workers in different industries at a given time.

The OSHA Industry Priority Report ranks 309 4-digit industries, based on worker exposure to health hazards and industry employment size. The exposure measure used is based on a 1974 survey done by NIOSH, which gathered rough counts of worker exposure to different substances. The survey did not consider the intensity of the exposures, so it may not properly measure relative hazards across industries. Nonetheless, it is used by OSHA to target health inspections towards hazardous industries because better measures are not available. Its main disadvantage for our purposes is that no examination of changes in health hazards over time is possible.

The National Emissions Data System (NEDS) is used by EPA to record air pollution emission information from almost 50,000 large, stationary point sources. Establishments are identified by name and industry. The information includes data on the emissions of five basic pollutants. The emissions data may come from engineering estimates or actual measurements, and have generally been updated at some point between 1973 and 1980. Since the system contains no history of emissions, it is not possible to measure changes in emissions over time. The later analysis uses the mean annual particulate emissions for establishments with emissions data to measure relative pollution emitted by different industries. Particulates are analyzed because they are the most commonly emitted pollutant; still, only 339 industries have establishments with this emissions data present. The limited scope of the NEDS data is troublesome, but there is no alternative emissions data available on an industry basis.

5. REGULATION'S IMPACT ON PRODUCTIVITY - BASIC RESULTS

5.1. Productivity Slowdown

Before attempting to explain the slowdown in productivity growth, one should be certain that the data used here show a productivity slowdown, and that they generally agree with the aggregate productivity statistics discussed earlier. The average industry growth rates for both labor and total factor productivity growth are presented in Table 5.1 and Chart 5.1. The labor productivity growth rates are obtained for each industry by subtracting the growth rate of worker hours from the growth rate of output (real industry shipments). Total factor productivity is calculated as the growth rate of output minus the growth rates of five inputs (non-production worker hours, production worker hours, non-energy materials, energy, and real depreciated capital stock), with each input's growth rate weighted by its share in total cost.5

Table 5.1 shows that there was a slowdown in average industry productivity growth during the 1970s. The average industry growth rate of labor productivity fell from 2.9 percent per year in 1958-1969 to 0.9 percent per year in 1973-1980, similar to the drop in labor productivity growth, as measured by the BLS, from 3.0 percent to 1.3 percent across these periods. Total factor productivity growth rates also fell during this period, as they did in the studies previously cited. For closer comparison with the aggregate numbers from other sources, growth rates weighted by industry size (value of shipments for total factor productivity and worker hours for labor productivity) are also included in the table and are presented in Chart 5.1. The slowdown is similar in magnitude and timing to that described in Section 3. The highly cyclical nature of productivity fluctuations is apparent from Chart 5.1. We turn now to an examination of the determinants of this slowdown.

Table 5.1

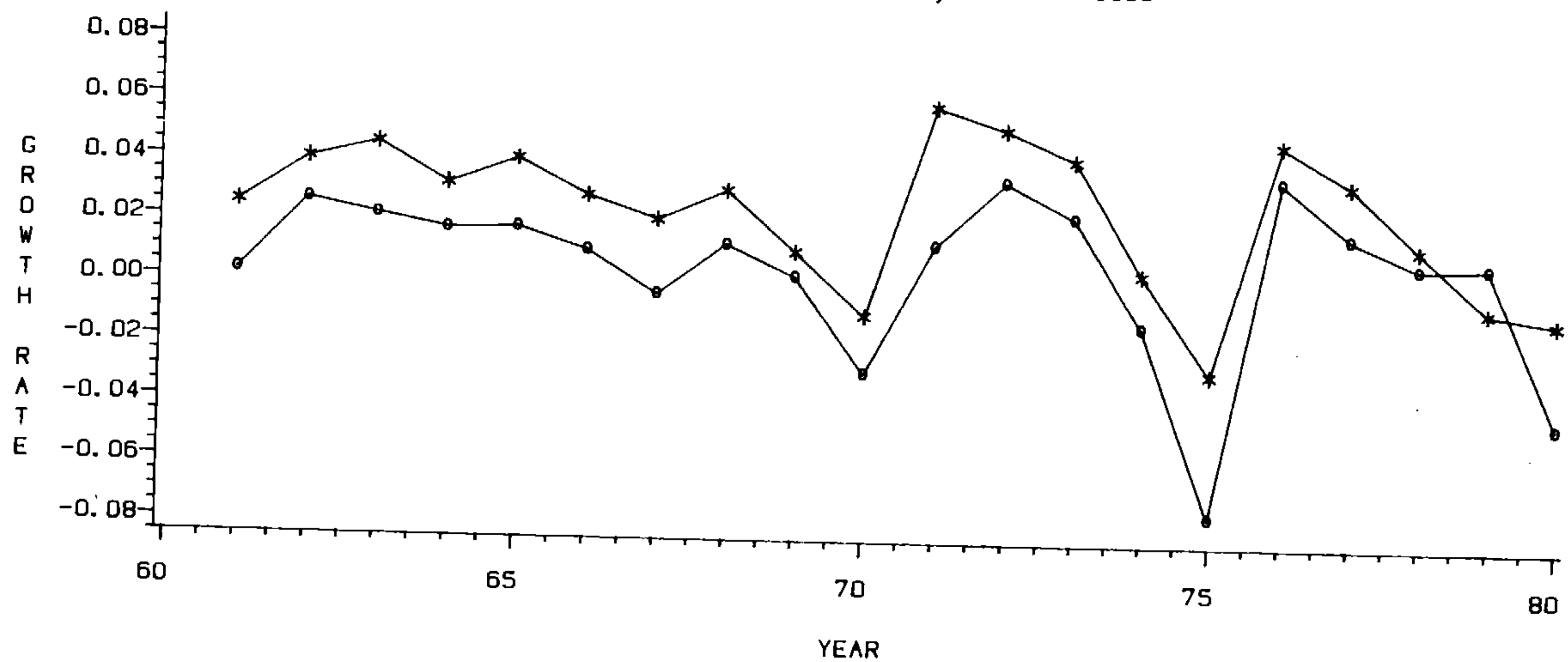
Average Industry Productivity Growth Rates

Period:	1958-80	1958-69	1969-73	1973-78	1973-80
Industry Average					
Labor Productivity	2.37	2.88	3.62	1.48	0.87
Total Factor Productivity	0.44	0.96	0.95	-0.54	-0.67
Weighted Industry Average[1]					
Labor Productivity	2.44	3.03	3.60	1.50	0.86
Total Factor Productivity	0.49	1.15	1.06	-0.52	-0.86

1. Labor productivity averages are weighted by total employee hours. Total factor productivity averages are weighted by value of shipments.

Chart 5.1

Weighted Industry Productivity, 1961 - 1980



* = Labor Productivity   o = Total Factor Productivity

5.2. Simple Regulation - Productivity Relationship

We have two measures of productivity growth: labor productivity and total factor productivity. To reduce the impact of strong cyclical fluctuations in productivity on the analysis, the average annual productivity growth rate for each industry is calculated for the periods 1959-1969 and 1973-1978. The analysis seeks to explain differences across industries in productivity growth rates in the latter period, and differences in the slowdown in productivity growth between the former and latter periods. The periods were chosen to match the cycle of productivity fluctuations from peak to peak, averaging out the impact on productivity of single years with cyclically high or low demand.[6] The earlier period was chosen to end before the regulatory agencies studied here began operating, to ensure that the measures of levels of regulation in the later period would also measure changes in regulation from the earlier period.

For measures of regulation we have the OSHA inspection rate per establishment and per employee, capital expenditures for employee safety and health as a share of the industry's capital stock, pollution abatement capital expenditures as a share of the industry's capital stock, pollution abatement operating costs as a share of the industry's materials cost, and the EPA establishment inspection rate. The analysis uses the average of each regulation measure over the 1974 to 1978 period.[7]

Table 5.2 presents means and standard deviations of these variables, as well as a correlation matrix. Several things can be learned from the correlations. First, all of the productivity measures are strongly positively correlated. Second, all of the regulation measures (except safety and health

Table 5.2

Descriptive Statistics

Index-Name	Description
1 TFPCHG	Change in annual TFP growth rate: 1959-69 to 1973-78
2 TFP7378	Annual TFP growth rate 1973-78
3 LPCHG	Change in annual LP growth rate: 1959-69 to 1973-78
4 LP7378	Annual LP growth rate 1973-78
5 OSHINS	OSHA employee inspection rate 1974-78
6 OSHEST	OSHA establishment inspection rate 1974-78
7 EPAINS	EPA establishment inspection rate 1974-78
8 PACE	Pollution abatement capital expenditures as share of real capital stock, 1974-78
9 PAOC	Pollution abatement operating costs as share of materials cost, 1974-78
10 SAFINV	Employee safety and health investment as share of real capital stock, 1974-78

Index	Name	Mean (s.d)
1	TFPCHG	-.0146(.032)
2	TFP7378	-.0054(.029)
3	LPCHG	-.0130(.037)
4	LP7378	.0148(.034)
5	OSHINS	.5404(.665)
6	OSHEST	.1908(.212)
7	EPAINS	.0441(.114)
8	PACE	.0041(.007)
9	PAOC	.0056(.009)
10	SAFINV	.0026(.001)

Number of observations 450

Correlations

	1	2	3	4	5	6	7	8	9	10
1	1.0	.86	.76	.66	-.14	-.12	-.12	-.11	-.18	.14
2	.86	1.0	.67	.76	-.16	-.16	-.17	-.15	-.21	.12
3	.76	.67	1.0	.85	-.22	-.23	-.18	-.18	-.16	.14
4	.66	.76	.85	1.0	-.20	-.20	-.11	-.13	-.10	.14
5	-.14	-.16	-.22	-.20	1.0	.71	.37	.45	.27	-.13
6	-.12	-.16	-.23	-.20	.71	1.0	.57	.65	.42	-.11
7	-.12	-.17	-.18	-.11	.37	.57	1.0	.64	.62	.03
8	-.11	-.15	-.18	-.13	.45	.65	.64	1.0	.64	.10
9	-.18	-.21	-.16	-.10	.27	.42	.62	.64	1.0	.01
10	.14	.12	.14	.14	-.13	-.11	.03	.10	.01	1.0

investment) are negatively correlated with all of the productivity measures. Finally, all of the regulation measures (again except for safety and health investment) are positively correlated with each other.

The safety and health investment variable appears to be a poor measure of compliance costs associated with OSHA regulation, not especially surprising given its limitations mentioned in Section 4. Although the variable was tested in other parts of the analysis the results are not reported, and were never significant.

The regression results found in Table 5.3 show the connection between total factor productivity growth and the measures of regulation.8 Each measure of regulation has a significant negative impact on each of the productivity measures when the regulation measures are considered independently. When the regulation measures are entered in pairs (one OSHA and one EPA) the coefficients for both measures fall. This is reasonable given the positive correlations between types of regulation noted above. The coefficients, however, generally remain significant. The results for OSHA establishment rates and pollution abatement capital expenditures are not shown here. They are similar to the results for OSHA employee inspection rates and pollution abatement operating costs, respectively.

Given this evidence for a regulation-productivity link, can we tell how important it is quantitatively? The R^2s from the regressions indicate what fraction of the variation in productivity growth across industries can be explained by the regulation measures. They tend to be small, indicating that, even using the 'best' model, only about 4-5 percent of productivity growth

Table 5.3

Initial Regression Results
(Basic Data Set, N=450)
(standard errors in parentheses)

Dep.Var.	Mean	Model	Const.	OSHINS	EPAINS	PAOC	R^2(SSE)
TFPCHG	-.0146	A1	-.0110 (.0019)	-.0068 (.002)	-	-	.020 (.445)
		A2	-.0132 (.0016)	-	-.033 (.013)	-	.014 (.447)
		A3	-.0109 (.0018)	-	-	-.659 (.17)	.032 (.440)
		A4	-.0108 (.0019)	-.0055 (.002)	-.021 (.014)	-	.025 (.442)
		A5	-.0089 (.0020)	-.0048 (.002)	-	-.556 (.18)	.041 (.435)
TFP7378	-.0054	B1	-.0015 (.0018)	-.0072 (.002)	-	-	.027 (.374)
		B2	-.0035 (.0015)	-	-.043 (.012)	-	.028 (.373)
		B3	-.0015 (.0016)	-	-	-.701 (.16)	.042 (.368)
		B4	-.0012 (.0017)	-.0052 (.002)	-.031 (.013)	-	.040 (.369)
		B5	.0007 (.0018)	-.0051 (.002)	-	-.591 (.16)	.055 (.363)

Fraction of Total Drop In Productivity Growth
Attributed to Regulatory Variables

Model	All-Reg	OSHINS	EPAINS	PAOC
A1	.25	.25	-	-
A2	.10	-	.10	-
A3	.25	-	-	.25
A4	.26	.20	.06	-
A5	.39	.18	-	.21

For each of the TFPCHG equations the constant term measures the estimated change in productivity growth if regulation had been zero. The mean of the dependent variable is the actual change in productivity growth. The difference between these two numbers is the estimated contribution of regulation to productivity growth (negative in all cases). This is expressed above as a fraction of the actual productivity decline.

variation is explained. This is due in large measure to the calculation of productivity as a residual: input growth accounts for most of the variation in output growth rates, so much of the remaining variation in output growth is due to random disturbances.9

The significant coefficients on the regulation measures in the regressions indicate that regulation is related to productivity growth. What is needed is a way to predict what productivity growth would have been in the absence of regulation. Consider again Equation 2 from Section 2: measured productivity growth is actual productivity growth minus the effect of inputs used for compliance. In the absence of regulation (when all regulatory measures would be zero) the predicted mean productivity growth rate would be the constant term from the regression. The difference between this no-regulation productivity growth and the actual productivity growth is the estimated impact of regulation on productivity growth.

Table 5.3 presents this impact as a fraction of the observed productivity decline for each of the productivity change equations. From equation A5 (the productivity equation with the best fit), we estimate that regulation was responsible for slowing annual productivity growth by 0.57 percent. This represents 39 percent of the average industry slowdown in productivity growth (1.46 percent), due in roughly equal measure to OSHA and EPA regulation.10 The next section examines some possible problems with this analysis and considers alternative explanations of the productivity slowdown.

6. POTENTIAL BIASSES AND ALTERNATIVE EXPLANATIONS

6.1. Possible Objections

Although the results of the previous section suggest that regulation has had a significant impact on productivity, we should consider some possible objections to these results. There are (at least) four major lines of attack on the results presented above. First, there could be a problem with the measurement of productivity or regulation. Second, the linear regression model might be giving excessive weight to a few outlying industries with high regulation and poor productivity performance. Third, there could be some other explanation for the slowdown, omitted here, that happens to coincide with the regulatory measures. Finally, the regulation itself might be endogenous to the model, a possibility which is not addressed here but which could provide an important topic for future research.

6.2. Measurement Problems

Concerning the measurement problem, it is often argued that productivity indexes contain substantial measurement errors, especially due to the need to deflate output and some inputs, using imperfect price indexes. Unless these measurement errors are correlated with the regulation measures, they should not affect the estimated impact of regulation. Similarly, errors in the measurement of regulation will tend to bias the estimated coefficients on regulation towards zero. Neither source of measurement error seems a likely explanation of the results.

Allocation of missing values for pollution abatement operating cost might create a measurement problem. Since these allocated values tend to be small, dropping all industries with average annual pollution abatement operating cost less than $1 million eliminates most of the industries with allocated values. When this correction is made, the basic results are not affected (see Table 6.1 below).

6.3. Outliers and Non-Linearity

Linear regression results may be greatly affected by the values for a few outlying observations when the majority of the observations lie close together. In these data, there are a few industries with very high regulation values.11 If these industries had very poor productivity performance they could by themselves produce large, negative coefficients on the regulation variables. Two procedures for dealing with this are considered: first, eliminate the outliers and repeat the regressions; second, use alternative estimation methods not so dependent on outlying values.

Table 6.1 presents results obtained when a few industries with exceptionally high regulation values are excluded from the regression. The coefficients on PAOC are almost identical to those found earlier. The coefficients on OSHINS are nearly twice as large as those found earlier. This could be due to the influence of the outlying industries, showing less additional impact from regulation at high regulation levels. This non-linearity is also tested for in Table 6.1 by including squared and interacted regulation variables in the regression on the complete data set. No significant nonlinearity is found, and the average impact of regulation on productivity is

Table 6.1

Outlier and Non-Linearity Analysis

Regressions on Subsets Excluding Outliers
(standard errors in parentheses)

Subset:	Exclude High OSHINS, PAOC1			Also Exclude Low PAOC2		
	Mean	TFPCHG	TFP7378	Mean	TFPCHG	TFP7378
OSHINS	.475 (.45)	-.0094 (.004)	-.0085 (.003)	.550 (.48)	-.0091 (.004)	-.0083 (.003)
PAOC	.0050 (.007)	-.5826 (.228)	-.6578 (.208)	.0064 (.008)	-.5345 (.234)	-.6443 (.209)
constant		-.0069 (.0023)	.0023 (.0021)		-.0076 (.0028)	.0022 (.0025)
mean dep var		-.0143 (.032)	-.0050 (.029)		-.0160 (.031)	-.0065 (.028)
R2 (SSE)		.045 (.428)	.054 (.357)		.047 (.284)	.066 (.226)
N		438	438		304	304

1. Excludes 7 industries with OSHINS > 3.0 and 5 with PAOC>.04 .
2. Excludes 134 additional industries with 1974-78 average pollution abatement operating costs < $1M .

Basic Model: Non-linearity Test
(standard errors in parentheses)

Dep Var	Constant	OSHINS	PAOC	OSH*PAOC	OSH*OSH	PAOC*PAOC	R2(SSE)
TFPCHG	-.0044	-.0150 (.005)	-.980 (.522)	.092 (.211)	.0026 (.0014)	10.03 (11.3)	.054 (.429)
TFP7378	.0032	-.0098 (.005)	-.950 (.479)	.014 (.194)	.0013 (.0013)	9.34 (10.4)	.060 (.361)

not greatly affected, but there is an indication that the marginal impact of OSHINS falls for industries with very high OSHINS values. Deleting industries with small dollar values for PAOC (which might be poorly measured) does not noticeably change the results.

In Table 6.2 we see two alternative tests of the connection between regulation and productivity. The first test separates the data set into quartiles, based on the value for each of the regulation variables. The average productivity growth rate and change in growth rates are presented for each quartile. In every case, both productivity growth rates and changes in productivity growth rates fall as regulation rises across quartiles. This confirms that the earlier results are not due solely to the presence of a few industries with high regulation and poor productivity performance.

The Spearman rank correlation measure shown in Table 6.2 provides a test for the connection between regulation and productivity that is not sensitive to outlying values. The results from this test indicate the same negative correlations between regulation and productivity that were found in Table 5.2 for Pearson correlations. All of these correlations are significant. These analyses support the conclusion that the results presented earlier, which showed a significant relation between regulation and productivity growth, are not the result of a few outliers or the limitations of the linear regression model.

6.4. Omitted Alternative Explanations

For the omission of an explanation for the slowdown to bias the estimated relationship between regulation and productivity, two things must be true. The

Table 6.2

Non-Parametric Analysis

Mean TFP by Regulation Quartiles

Name	Quartile	Mean	TFPCHG	TFP7378
OSHINS	1	.122	-.0072	.0009
	2	.256	-.0087	.0002
	3	.461	-.0204	-.0104
	4	1.325	-.0223	-.0125
EPAINS	1	.0003	-.0085	.0004
	2	.0032	-.0126	-.0016
	3	.0123	-.0150	-.0064
	4	.1613	-.0225	-.0141
PAOC	1	.0008	-.0075	-.0003
	2	.0021	-.0126	-.0021
	3	.0038	-.0180	-.0074
	4	.0158	-.0205	-.0120

Spearman Rank Correlation Coefficients
(P-values in parentheses)

	TFPCHG	TFP7378	OSHINS	EPAINS	PAOC
TFPCHG	1.0	.81(.001)	-.19(.001)	-.13(.006)	-.17(.001)
TFP7378	.81(.001)	1.0	-.19(.001)	-.18(.001)	-.18(.001)
OSHINS	-.19(.001)	-.19(.001)	1.0	.46(.001)	.36(.001)
EPAINS	-.13(.006)	-.18(.001)	.46(.001)	1.0	.61(.001)
PAOC	-.17(.001)	-.18(.001)	.36(.001)	.61(.001)	1.0

missing factor must be correlated with differences in productivity growth across industries during this period. It must also be correlated with differences in the regulatory measures across industries. Most of the potential factors would seem to fail one or the other of these tests, but a prime candidate is the increase in energy prices. Energy-intensive industries tend to have high pollution control expenditures, especially for air pollution, and the increase in energy prices may have forced the retirement of a substantial fraction of the capital stock in these industries, contributing to the productivity slowdown.

Table 6.3 tests the importance of energy usage as an alternative explanation by including energy intensity (measured by the share of energy in total cost) in regressions of productivity growth on regulation variables. Energy intensity has a significant negative effect on productivity growth rates and changes in productivity growth rates when regulation variables are not present in the model. However, when regulatory variables are added, with or without interacting regulation with energy intensity, the impact of energy intensity becomes insignificant. The estimated effect of the regulation variables on productivity growth is only slightly reduced by the presence of the energy intensity variable. This effect is concentrated on pollution regulation, as expected.

A possible decline in the productive efficiency of the measured capital stock is examined in the latter half of Table 6.3. More capital-intensive industries do have slower productivity growth, but including capital intensity in the basic regressions reduces only slightly the estimated impact of regulation on productivity. One way in which regulation might affect

Table 6.3

Energy Intensity and Capital Intensity
(Basic data set, N = 450)
(standard errors in parentheses)

Dep Var	Const.	OSHINS	PAOC	ENSH1	CAPSH2	R^2(SSE)
A1 TFPCHG	-.0112			-.212		.021
	(.0019)			(.07)		(.444)
A2 TFP7378	-.0016			-.233		.030
	(.0017)			(.06)		(.372)
B1 TFPCHG	-.0085	-.0049	-.439	-.066		.042
	(.0021)	(.0023)	(.24)	(.09)		(.435)
B2 TFP7378	.0012	-.0051	-.441	-.085		.057
	(.0019)	(.0021)	(.22)	(.09)		(.362)
C1 TFPCHG	.0011				-.060	.022
	(.0052)				(.02)	(.444)
C2 TFP7378	.0031				-.032	.007
	(.0048)				(.02)	(.381)
D1 TFPCHG	.0055	-.0057	-.452		-.055	.059
	(.0054)	(.0023)	(.18)		(.02)	(.427)
D2 TFP7378	.0074	-.0055	-.543		-.026	.059
	(.0049)	(.0021)	(.17)		(.02)	(.361)
E1 TFPCHG	.0056	-.0057	-.380	-.041	-.054	.059
	(.0054)	(.0023)	(.24)	(.09)	(.02)	(.427)
E2 TFP7378	.0075	-.0055	-.415	-.074	-.024	.061
	(.0049)	(.0021)	(.22)	(.09)	(.02)	(.361)

Fraction of TFP Drop Attributed to Regulation

Model	All-Reg	OSHINS	PAOC	Controlling For ENSH	CAPSH
B	.35	.18	.17	X	
D	.38	.21	.17		X
E	.36	.21	.15	X	X

1. Energy cost share (in total cost), 1969-73, mean= .016, s.d.= .022 .
2. Capital cost share (in total cost), 1969-73, mean= .263, s.d.= .078 .

productivity is through obsolescence of the capital stock, so part of the impact of capital intensity on productivity might be due to regulation. Other input cost shares were tested, but they had little or no impact on productivity growth rates and no impact on the estimated regulation coefficients. These results are not included in the table.

Two additional explanations are considered in Table 6.4. The first is that the poor macroeconomic performance of the 1970s contributed to slower productivity growth by depressing output growth over the entire business cycle. Measuring this on an industry level is difficult, because measures of output and input growth already enter the calculations of the dependent variables. The measure used here is the change in the growth rate of production worker hours between the 1959-1969 and the 1973-1978 periods. Its coefficient is significant, with the expected positive sign (industries not cutting back on their use of production workers do not suffer as large a productivity slowdown), but its inclusion does not affect the regulation coefficients.

The second explanation is that, for some reason, regulation is applied most heavily to mature industries, which have declining productivity growth relative to other industries. The measure used is the change in productivity growth between the 1959-1963 and the 1963-1969 periods. It is significantly positively related to productivity growth during the 1970s, indicating that industries with rising productivity growth during the 1960s also did better in the 1970s. However, the measure is not significantly related to the productivity slowdown, and does not affect the regulation coefficients substantially. Entering both explanations together also has little effect on the regulation coefficients.

Table 6.4

Cyclical and Declining Industry Controls

(Basic data set, N=450)
(standard errors in parentheses)

	Cons.	OSHINS	PAOC	GLPCHG1	TFPCHGX2	R2 (SSE)
TFPCHG	-.0068 (.0021)	-.0049 (.0023)	-.570 (.177)	.094 (.027)		.066 (.424)
TFP7378	.0018 (.0019)	-.0051 (.0021)	-.599 (.163)	.052 (.025)		.064 (.360)
TFPCHG	-.0088 (.0020)	-.0050 (.0023)	-.547 (.179)		-.024 (.028)	.043 (.435)
TFP7378	.0003 (.002)	-.0044 (.0021)	-.635 (.160)		.118 (.025)	.098 (.346)
TFPCHG	-.0067 (.0021)	-.0050 (.0023)	-.563 (.177)	.093 (.028)	-.018 (.028)	.067 (.424)
TFP7378	.0016 (.0019)	-.0044 (.0021)	-.645 (.159)	.060 (.025)	.122 (.025)	.110 (.342)

1. Change in growth rate of production workers between 1959-69 period and 1973-78 period.
2. Change in TFP growth rate between 1959-63 period and 1963-69 period.

6.5. Long-run Relationship

One final issue concerning the impact of regulation on productivity is the long run relationship between regulation and productivity growth. Many of the possible connections between regulation and productivity are temporary, lasting only until firms can adjust their use of fixed inputs. Perhaps the productivity slowdown of the 1970s represents a temporary cost of adjustment to a new business environment, so continuation of regulation at the same level will not adversely affect future productivity. Alternatively, the increased level of regulation in the 1970s may permanently reduce future productivity growth.

Because the period when regulation data are available (1973-1980) does not contain two complete business cycles, one cannot look at changes in average productivity growth across cycles as was done before. However, one can see in Table 6.5 whether those industries with high regulation values during the 1974-1978 period continue to perform poorly in the 1978-1980 period.

The levels of regulation during the 1974-78 period, which were significantly negatively correlated with productivity growth during that period, are not significantly correlated with later productivity growth rates. This suggests that the large impact of regulation on productivity estimated earlier may not be as great a concern in the long run, after the initial adjustment.

Table 6.5

Long-Run Impact of Regulation

Dep. Var.	Const.	OSHINS	PAOC	R2(SSE)
TFP7880	-.010 (.003)	-.0022 (.0037)	.294 (.283)	.003 (1.09)

Note: The productivity variable is from the 1978-1980 period, while the regulation measures are from the 1974-1978 period.

7. BENEFITS FROM REGULATION

7.1. Introduction

Sections 5 and 6 concentrated on the costs of OSHA and EPA regulation, measured in terms of foregone output. These costs are estimated to be quite large: if productivity growth in manufacturing is slowed by .5 percentage points per year between 1973 and 1978, manufacturing output in 1978 is 2.5 percent, or $13 billion, lower than it would otherwise have been. However, if one is trying to determine whether these regulations have helped or hurt society one must also consider the benefits which these regulations are supposed to provide in reducing environmental pollution and work-related injuries and illnesses. This chapter examines the available data for such benefits.

7.2. Previous Estimates

Estimates of potential benefts from OSHA and EPA regulation are quite large, similar in magnitude to the estimates of the compliance costs presented earlier. Lave and Seskin (1977) estimate that complete compliance with EPA air pollution standards could reduce total deaths and illnesses by 7 percent, with a health benefit of $16.1 billion. Waddell (1974) estimates other benefits from cleaner air at $7.5 billion. In a comprehensive review of earlier studies, Freeman (1979) estimates that regulation of stationary source air pollution yielded benefits of $20.3 billion, based on previous studies of the costs of pollution and an assumed 20 percent reduction in emissions of particulates and sulfur oxides. He also calculates benefits from water pollution control (assuming best control technology in use) of $12.3 billion. Of course, these benefits are from pollution abatement throughout the economy, not just in manufacturing. If manufacturing was responsible for one-third of stationary source air pollution and one-fifth of water pollution, the potential benefit of regulation would be $9.2 billion.12

Occupational injuries and illnesses also impose substantial costs on society. Ashford (1976) presents evidence from the National Safety Council that occupational injuries cost $10 billion in 1971. More recent estimates cited in Green and Waitzman (1979) find even greater costs of occupational injuries, $23 billion in 1978, with a possible additional $10 billion if occupational illnesses are included. If we assume that manufacturing is responsible for about one-third of these costs, potential benefits from reducing workplace hazards would be $11 billion.13 Eliminating all hazards is clearly not feasible, but in the interest of calculating potential (rather than actual) benefits, we come up with a total benefit from OSHA and EPA regulation of manufacturing totalling over $20 billion, which exceeds the cost estimate mentioned above, so there is the potential for a conclusion favorable to regulation. The question still remains, has regulation really reduced these problems, and if so, by how much?

The principal difficulty with trying to analyze the benefits of regulation is the scarcity of available data. To measure benefits, we need a measure of industry performance in a dimension addressed by regulation (such as air pollution emissions), and we need this measure for at least two dates, to see whether industry performance has improved or worsened, and by how much. Inter-industry differences in the rates of improvement (positive or negative) can then be compared with differences in the measures of regulatory intensity used earlier. If heavily regulated industries have improved their performance relative to lightly regulated ones, we might view this as evidence of benefits from regulation. The only area for which we have measures over time is worker safety, using industry injury rates, so we cannot test for benefits from worker health or pollution control regulation, although all three areas can be examined for targetting of regulation towards industries with poor performance.

7.3. Targetting

Table 7.1 presents results which strongly suggest that regulation is targetted towards industries with poor performance. OSHA safety inspection rates are significantly higher in industries with high injury rates, and health inspection rates are significantly higher in industries with high health hazard levels. Each type of OSHA inspection rate is also related to the other performance index (based on analyses not presented here), but less strongly than to its own index, suggesting that there really is targetting at work. In fact, the OSHA national office mandates such targetting by the area offices.

The EPA inspection rates are positively correlated with a particulate emissions measure. Because of possible problems with this measure (related to differences across establishments in the date when the emissions variable was last updated), the EPA analysis is also done using air pollution operating costs, on the grounds that such abatement costs are positively correlated with emissions across industries. Over half of the inter-industry differences in EPA inspection rates is explained, mostly by differences in control expenditures.[14]

Table 7.1

Targetting of Enforcement Effort

Dep Var:	Mean(s.d)	SAFETY	HEALTH	EPAINS	EPAINS[6]
Const.		-.238 (.076)	-.074 (.028)	-.010 (.012)	.081 (.017)
UNION[1]	.458(.146)	.978 (.165)	.265 (.060)	.023 (.027)	.118 (.035)
ESTSIZE[2]	.099(.163)	.526 (.142)	.400 (.065)	.123 (.024)	.043 (.028)
INJ7478[3]	.512(.274)	.280 (.087)			
HAZINDEX[4]	.607(.472)		.099 (.019)		
PAOC	.0020(.0049)			15.34 (.80)	
EMITAVG[5]	.107(.289)				.033 (.017)
Dep var mean (s.d)		.405 (.511)	.149 (.178)	.044 (.114)	.146 (.094)
R^2		.166	.282	.513	.060
SSE		97.84	7.00	2.82	2.82
N		450	309	450	339

1. UNION is the fraction of production workers unionized, 1973-75.
2. ESTSIZE is the mean number of production workers per establishment, 1974-78.
3. INJ7478 is the mean lost workday injury rate, 1974-78.
4. HAZINDEX is the OSHA health hazard index (based on 1974 survey).
5. EMITAVG is the mean annual particulate emissions for establishments with emissions data (only available for 339 industries).
6. Here EPAINS is the mean inspection rate for establishments on the Compliance Data System (i.e., inspections/CDS establishments, not inspections/total establishments).

In both cases, we find evidence that OSHA and EPA inspections are concentrated on industries with poor performance.

7.4. Benefits

If we believe that these inspections produce the benefits they are supposed to, we might conclude that the inspections are being allocated properly across industries, with more attention being paid to those industries which most need improvement. Unfortunately, Table 7.2 provides no evidence of such benefits, although the results may be due to the complicating influence of targetting on the analysis. The first regression considers the change in injury rates between the 1959-1969 and 1974-1978 periods. The significant positive relation between safety inspection rates and injury rates may well be due to the contemporaneous nature of injury and inspection rates during the 1974-1978 period, as explained earlier. Changing the end-period to the year 1979, regression 2 also finds a positive inspection-injury relationship. Looking at changes in injury rates between 1972 and 1979 yields smaller, but still significant coefficients. Finally regressions 4 and 5 attempt to purge the inspection rate of its connection with injuries by including the industry's 1976, 1977, and 1978 injury rates in the regression and then replacing the inspection rate with its predicted value from the Table 7.1 regression. There is still a significant and positive relation between inspection rates and changes in injury rates.

It seems quite difficult to use this data to demonstrate positive benefits of safety inspections on injury rates. This does not mean that such benefits are not there, although if the benefits were large one would have expected to

Table 7.2

Benefits from OSHA Safety Inspections

Dependent variable: changes in injury rates
(standard errors in parentheses)

	(1)	(2)	(3)	(4)	(5)
Time Period	59-69:73-78	59-69:79	72:79	72:79	72:79
Const.	-.036 (0.42)	.044 (.072)	.279 (.051)	.212 (.053)	.186 (.054)
PRSHIP[1]	-.001 (.083)	.130 (.077)	.047 (.075)	.026 (.073)	.033 (.075)
PRODEMP[2]	.103 (.058)	.108 (.052)	.195 (.070)	.210 (.068)	.217 (.069)
PRCAP[3]	.035 (.072)	-.029 (.064)	-.0001 (.075)	.043 (.074)	.061 (.076)
SAFETY	.236 (.037)	.267 (.039)	.113 (.027)	.091 (.027)	
SAFETYP[4]					.178 (.076)
INJRAT Controls[5]				X	X
Dep var mean (s.d)	.075 (.418)	.259 (.442)	.363 (.296)	.363 (.296)	.363 (.296)
R^2	.092	.124	.080	.152	.139
SSE	71.3	76.8	36.2	33.3	34.2

1. Percentage change in real value of shipments per production worker.
2. Percentage change in number of production workers.
3. Percentage change in real capital stock per production worker.
4. Predicted SAFETY from regression, Table 8.1.
5. Regressions include 1976, 1977, and 1978 injury rates as controls.

observe some evidence of them. Previous studies examining the relationship between OSHA inspections and injury rates have yielded mixed results.

On the positive side, Bartel and Thomas (1982) and Cooke and Gautschi (1981) both find a significant negative relationship between inspections and injury rates. Viscusi (1979) and McCaffrey (1983) find no significant relation between inspections and injury rates. Mendeloff (1979) and Smith (1979) find beneficial results estimated for some versions of their models, no benefits from other versions.

In general, the studies which use data on individual plants tend to find benefits, while studies (such as this one) which use industry data are less likely to find benefits. When benefits are found, they are usually small: Bartel and Thomas find that a 10 percent change in inspection rates reduces injury rates by only .4 percent. Mendeloff concludes that relatively few injuries are caused by violations of OSHA standards, and most of these violations would not be detectable by an inspector. Therefore, the potential influence of OSHA safety inspections is limited.

8. CONCLUSIONS AND FUTURE WORK

This study is in an important sense a preliminary study. Its primary goal was to determine whether or not a connection existed between the productivity slowdown during the 1970s and the concurrent growth in federal regulation, especially through OSHA and EPA. A secondary goal was to provide an estimate of the magnitude of the connection and contrast it with previous estimates. Both of these tasks have been accomplished.

A connection between regulation and productivity is clearly shown by the data. Industries which faced a large amount of regulation experienced a larger than average productivity slowdown. This connection is not dependent on a few outlying industries, as the sensitivity analysis makes clear. This result does not seem to be the result of an omitted variable, since the inclusion of a variety of alternative explanations for the slowdown leaves the regulation coefficients essentially unchanged. Of course, one cannot hope to control for all possible omitted variables, but as more and more variables are tested without effect, one's confidence in the basic result increases.

In the process of establishing the connection between regulation and productivity, estimates of its magnitude are generated. These estimates seem quite high: a .57 percent contribution to the productivity slowdown, compared with Denison's largest estimate of .35 percent and many smaller estimates. There are three points that should be made regarding comparisons of the results presented here with others.

First, these results refer to the manufacturing sector, while many of the other estimates were based on economy-wide measures. Since manufacturing is more highly regulated than other sectors (with the notable exceptions of electric utilities and mining), a higher estimate here is not especially surprising. Estimates of EPA's impact on utilities are even higher than these. Also, manufacturing suffered less of a productivity slowdown than other sectors, an important point when comparing percentages of the slowdown explained by regulation in different studies.

Second, the estimates presented here implicitly assume that regulation was zero during the 1960s, because they use measures of the level of regulation during the 1970s to measure the change in regulation between the 1960s and the 1970s. It is clear that regulation was much higher during the 1970s than it had been before (otherwise it wouldn't have been considered a likely candidate to explain the slowdown). It is also clear that there was some regulation earlier, before OSHA and EPA were created.

Consider how this affects the estimated impact of regulation. The calculation of a regulation variable's contribution to the slowdown is calculated by multiplying the mean of that variable (measured during the 1970s) times its regression coefficient. First, if there was some regulation earlier the variable's mean will overestimate the additional impact of the new regulation, so the contribution of regulation will be overestimated even if the coefficient is accurate. In addition, the coefficient may be affected if the distribution of the new regulation across industries was not simply a proportional increase above the old regulation. Neither of these effects is likely to be very important, as long as the new regulation is several times as strong as the old regulation.

Third, many of the previous estimates of regulation's impact on productivity are calculations based on the growth accounting model and cost of compliance data. The results obtained here seem to be about twice as large as would be obtained using growth accounting. There are reasons why one would expect regulation to have a larger impact on productivity than growth accounting would indicate. These are described in Section 2; many are related to the need for businesses to adjust their production in the face of regulatory constraints. An implication of this is that some of the impact of regulation on productivity will diminish over time as these adjustments are made. Some evidence supporting this is presented. Perhaps the long-run impact of regulation on productivity will be closer to the growth accounting estimates.

Some mention should be made of the analysis of benefits from regulation. The basic problem is the lack of available data on any level of industry detail. This is particularly true for measuring benefits from pollution abatement. There is substantial evidence that air pollution was reduced during the 1970s, almost certainly due to the existence of EPA regulation. However, this evidence is based on ambient air quality measures, with no way to link the improvement in air quality to reduced pollution from particular plants or industries.

More can be done with OSHA regulation, since injury data are observed for individual industries. That this study does not find benefits from the regulation does not preclude the existence of such benefits, and other studies have found some (small) benefits. More important to note is that worker safety is the area where one would least expect to find benefits from regulation, due to the presence of compensating differentials and the difficulties of developing useful standards. Thus, the results of this study should not be read as a call for the dismantling of these regulations, especially since a large part of the costs of regulation, in terms of lower productivity growth, may represent a one-time adjustment cost, already paid during the 1970s.

Where do we go from here? Three possible areas on the research agenda should be mentioned: collecting more data, doing microeconomic analyses, and developing and estimating a more detailed model.

The collection of more data can proceed along two dimensions. As time passes, more years of data will become available. A few more years of data would provide the two complete business cycles needed to look properly at the impact of changes in regulation over time. The other way to extend the data is through adding new variables. These could be measures of other explanations of the productivity slowdown, or they could be better measures of the benefits of regulation.

A different and more difficult process of data collection is needed to provide microeconomic data (on individual firms or establishments) which could be used to test for a connection between regulation and productivity at that level. The enforcement measures of regulation are available already on an establishment level. Compliance cost measures and productivity measures will be much more difficult to gather, although some researchers are beginning to put in the required effort. These case study analyses will be a valuable complement to the more aggregate numbers considered here.

Finally, more effort needs to be put into the underlying model connecting regulation and productivity. The results here indicate the connection, but a better understanding of how that connection operates is needed to see why higher regulation was associated with lower productivity, whether this connection is likely to continue, and what (if anything) can be done to reduce the harmful impact of regulation on productivity while maintaining or increasing the benefits that regulation was designed to provide.

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FOOTNOTES

1. However, the states were permitted to develop their own regulations and enforcement plans, which the Secretary of Labor could approve as a substitute for OSHA regulation in the state by certifying that the state plan was at least as effective as OSHA.

2. The interested reader is referred to Denison (1979) for seventeen such proposed explanations.

3. The author is grateful to Zvi Griliches and Frank Lichtenberg for making available their copy of the PCS data.

4. This sector (Apparel and Other Textile Products) has a very large number of establishments which typically have very small pollution abatement expenditures. The Census Bureau omits the sector from the sample in order to concentrate observations on the remaining sectors which provide much more information on total compliance costs.

5. The equation used to calculate productivity growth between two observations at times T and T-1 is

$$(1) \quad \tau_T = (\log Y_T - \log Y_{T-1}) - \Sigma\, 1/2(\alpha i_T + \alpha i_{T-1})(\log X i_T - \log X i_{T-1}) \quad ,$$

6. The results are not materially affected by extending the later time period to 1980 or changing the earlier period, though they are somewhat sensitive to the choice of 1973 as the starting year.

7. The regulation measures refer to a level of regulation during a year, while the productivity measures refer to productivity growth from one year to the next (measured at the end of the year). Therefore, productivity growth between 1973 and 1974 would be explained by 1974 regulation. Similarly, the five years of productivity growth from 1973 to 1978 are explained by five years of regulation data, 1974 to 1978.

8. The results obtained from an analysis of labor productivity growth are similar to those reported here for total factor productivity growth. Only total factor productivity results are reported here, because controlling for the usage of all inputs is needed to compare the productivity growth of different industries.

9. Regressions of output growth rates on inputs growth rates and regulation measures (presented in Gray (1984)) show high $R2_s$ and coefficients on the regulation measures similar to these.

10. Recall from Section 3 Denison's (1979) estimates that pollution abatement and protection of employee safety and health explained 0.35 percent per year of the productivity slowdown. He concluded that regulation explained only 15 percent of the slowdown, partly because of his lower estimate of regulation's impact, but also because the slowdown for the private business sector (2.4 percent) greatly exceeded that for manufacturing.

11. Appendix Table A-1 presents a list of the top 10 industries for each of the major regulation variables, and some measures of the distribution of each variable.

12. The fractions used here are the fractions of all compliance expenditures accounted for by manufacturing, based on data from the U.S. Council on Environmental Quality report (1980) which presents estimates of total compliance costs, and the manufacturing cost data.

13. From U.S. Bureau of Labor Statistics (1980) which indicates that manufacturing was responsible for about 44 percent of all workplace injuries and 25 percent of fatalities.

14. One could argue that these abatement expenditures are a beneficial result of the EPA inspections, not a determinant of them. However, differences in changes in these expenditures over time are negatively (not positively) related to differences in the EPA inspection rates.

APPENDIX TABLE A.1

Regulation Measures
Top 10 Industries and Distributions

OSHINS - OSHA employee inspection rate

3332	Primary lead	5.95
3621	Motors and generators	4.27
3316	Cold finishing of steel shapes	4.21
3731	Ship building and repairing	4.19
3312	Blast furnaces and steel mills	4.02
3732	Boat building and repairing	3.94
3324	Steel investment foundries	3.50
2452	Prefabricated wood buildings	2.90
3511	Turbines and turbine generator sets	2.76
3671	Electron tubes, receiving type	2.71
	First quartile .60	
	Median .33	
	Third quartile .19	

EPAINS - EPA establishment inspection rate

3334	Primary aluminum	.912
3333	Primary zinc	.872
2951	Paving mixtures and blocks	.725
2061	Raw cane sugar	.644
3332	Primary lead	.636
2895	Carbon black	.621
2911	Petroleum refining	.597
3241	Cement, hydraulic	.493
3274	Lime	.492
3331	Primary copper	.482
	First quartile .023	
	Median .006	
	Third quartile .001	

PAOC - pollution abatement operating costs / materials cost

3241	Cement, hydraulic	.0585
2892	Explosives	.0557
3333	Primary zinc	.0516
2816	Inorganic pigments	.0491
2611	Pulp mills	.0474
3339	Primary nonferrous metals, nec	.0393
3296	Mineral wool	.0375
2646	Pressed and molded paper goods	.0373
2631	Paperboard mills	.0369
3313	Electrometallurgical products	.0355
	First quartile .0054	
	Median .0027	
	Third quartile .0016	