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The Impact of Environmental and Occupational Health Regulation on Productivity Growth in U.S. Manufacturing

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This study analyzes the impact of environmental and occupational health regulation upon productivity levels and productivity growth rates in 445 U.S. manufacturing industries between 1974 and 1986. Costs imposed by regulation are much more significant in terms of diminished productivity than in terms of direct compliance expenditures. The study does not support a "technology-forcing" interpretation of EPA and OSHA regulations, which avers that regulation pushes firms to adopt more efficient products and processes. On the contrary, the data suggest that regulation diverts economic resources and managerial attention away from productivity-enhancing innovation. These productivity losses may be a one-time event, caused by the dramatic rise in public concern and subsequent regulation of the most polluting and unsafe industries during the 1970s. If regulatory initiatives are to continue and we are to sustain society's commitment to environmental quality and occupational health, creative risk management approaches are needed that promote rather than impede technological innovation and productivity growth in regulated industries.

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Introduction

The debate over the economic impact of environmental and occupational health regulation has been long, acrimonious, and inconclusive. Critics of EPA and OSHA argue that regulatory command and control diverts economic resources and managerial attention from productivity-enhancing technological innovation and impairs the nation's ability to compete in world markets. Supporters counter that well-designed regulations force the development and diffusion of cleaner, safer, and more productive technologies. The President, Congress, and the courts have joined the fray with Executive Orders, legislative initiatives, and judicial reviews demanding more information and more analysis.

The contrasting views of environmental regulation result from different interpretations of managerial incentives and of the role of market competition in stimulating economic efficiency. Critics of EPA and OSHA argue that management generally selects the best mix of capital, labor, and material inputs and combines them in the most efficient manner, given the scientific and technological knowledge available at the time. Firms that do not are eliminated by profit-seeking rivals. Market competition motivates efficiency and governmental intervention gets in the way. Critics cite the temporal coincidence of the post-1973 increase in environmental standard-setting and decrease in economic productivity growth as a consequence of regulatory enthusiasm.[1]

Supporters of EPA and OSHA regulation adopt a different interpretation of market and governmental impacts on technological innovation and diffusion. In their view, management exhibits considerable uncertainty and inertia in adopting new production methods. Governmental regulations mandating the adoption of best available pollution control technologies promote the use of more efficient methods of production. Economic impact studies often report that the expenditures incurred to comply with a particular standard fall far short of predicted levels. This is consistent with the principle that regulation motivates management to explore new and cheaper ways to promote safety and environmental quality. This "technology-forcing" interpretation argues that the long run economic impact of regulation can be positive because the productivity-enhancing impetus for technological innovation outweighs the productivity-constraining diversion of resources towards regulatory compliance.[2]

This debate turns on empirical data, and there is no shortage of numbers that purport to measure the expenditures incurred by industry in response to regulatory mandates.[3] EPA and OSHA routinely prepare or contract for estimates of compliance costs for major rules. Industry

1. Prominent papers in this tradition include Anthony J. Barabera & Virginia D. McConnell, *The Impact of Environmental Regulations on Industry Productivity*, 18 J. ENVTL. ECON. & MGMT. 50 (1990); Robert W. Crandall, *Pollution Controls and Productivity Growth in Basic Industries*, *in* PRODUCTIVITY MEASUREMENT IN REGULATED INDUSTRIES 347-68 (Thomas G. Cowing & Rodney E. Stevenson eds., 1981); Frank M. Gollop & Marc J. Roberts, *Environmental Regulations and Productivity Growth: The Case of Fossil-Fueled Electric Power Generation*, 91 J. POL. ECON. 654 (1983); Wayne B. Gray, *The Cost of Regulation: OSHA, EPA, and the Productivity Slowdown*, 77 AM. ECON. REV. 998 (1987); Michael Hazilla & Raymond J. Kopp, *Social Costs of Environmental Quality Regulations: A General Equilibrium Analysis*, 98 J. POL. ECON. 853 (1990); Dale W. Jorgenson & Peter J. Wilcoxen, *Environmental Regulation and U.S. Economic Growth*, 21 RAND J. ECON. 314 (1990).

2. Prominent papers in this tradition include Nicholas A. Ashford et al., *Using Regulation to Change the Market for Innovation*, 9 HARV. ENVTL. L. REV. 419 (1985); D. Bruce LaPierre, *Technology-Forcing and Federal Environmental Protection Statutes*, 62 IOWA L. REV. 771 (1977). *See generally* Nicholas A. Ashford & George R. Heaton, *Regulation and Technological Innovation in the Chemical Industry*, 46 L. & CONTEMP. PROBS. 109 (1983); M.E. Porter, *America's Green Strategy*, SCI. AM., Apr. 1991, at 168.

3. *See generally* A.B. Jaffe et al., ENVIRONMENTAL REGULATIONS AND THE COMPETITIVENESS OF U.S. INDUSTRY (1993); Robert W. Hahn & John A. Hird, *The Costs and Benefits of Regulation: Review and Synthesis*, 8 YALE J. ON REG. 233 (1991); Adam B. Jaffe et al., *Environmental Regulation and the Competitiveness of U.S. Manufacturing*, 33 J. ECON. LITERATURE 132 (1995); Richard B. Stewart, *Environmental Regulation and International Competitiveness*, 102 YALE L.J. 2039 (1993).

organizations often submit their own figures. University researchers and think-tanks sometimes follow up with assessments. Although illuminating in many ways, these diverse sources of information typically share one major limitation: the analyses focus on short run direct compliance expenditures on capital, labor, and materials and ignore long run impacts on productivity. We learn much about the first year cost of workplace ventilation systems and smokestack scrubbers but little about the effect regulation has on management's ability to engineer more output from any given set of inputs. Over the long term, the indirect effect that regulation has on innovation and productivity dominates direct compliance outlays.

This study analyzes the impact of environmental and occupational health regulation upon productivity levels and productivity growth rates in U.S. manufacturing for the period from 1974 to 1986. The study covers 445 manufacturing industries, with data consisting of regulatory compliance costs and multifactor input and output totals for each industry. Productivity is measured both in terms of an index of output minus weighted inputs and through an econometric production function analysis. The impacts of EPA and OSHA regulations are identified both separately and in combination. Effects are measured for the entire 1974-86 period and for individual years. These findings must be interpreted cautiously because of the limitations of the underlying data sources. However, by conducting a detailed analysis over the time frame of the most aggressive EPA and OSHA regulations, this study identifies the major productivity impacts of regulation.

I. Innovation, Productivity, and Regulation

Economic growth is caused by the accumulation of inputs and technological innovation.[4] Inputs that expand a nation's productive capacity include labor, primary and intermediate materials, and the stock of plant and equipment. Historically, capital has grown faster than labor, increasing output per person and yielding more wealth available for consumption. Innovation in technology and organization permits greater output to be achieved with any given quantity of inputs. Through innovation, the economy becomes more productive beyond corresponding increases in capital, labor, and material inputs.[5]

4. BUREAU OF LABOR STATISTICS, U.S. DEP'T OF LABOR, PRODUCTIVITY AND THE ECONOMY: A CHARTBOOK, BULLETIN 2298 (rev. 1988).

5. *See* Martin N. Baily & Alok K. Chakrabarti, INNOVATION AND THE PRODUCTIVITY CRISIS (1988).

Theoretical models attempting to predict the impact of regulation on economic efficiency and growth often reach different conclusions depending upon which source of growth the model identifies as primary. In static economic models, governmental regulation invariably reduces productivity because it constrains the choices available to management as to inputs and outputs. In this perspective, market competition drives firms to select the most efficient quantities and types of capital, labor, and material inputs and the optimal scale and mix of outputs. Environmental and occupational health regulations necessarily push management away from the most efficient choices. Regulations that require the purchase of new capital equipment, mandate particular work rules for employees, prohibit the use of particular materials, or ban or tax certain outputs alter management decisions away from those dictated by the market. Regulations effectively shrink society's stock of productive inputs by removing some inputs from management's control, thus inhibiting economic efficiency and retarding economic growth.

Models focusing on the dynamic process of innovation and productivity growth do not reach such simple conclusions about expected regulatory effects. Growth in outputs relative to inputs results from product and process innovations, which depend on scientific, institutional, market, and firm-specific developments. Governmental entities have an important role to play in furthering science and technology, although the optimal division of labor between the public and private sectors is debatable. It is difficult to study multifactor productivity growth because such study requires an understanding of the determinants of innovation over time and among different industries. Nevertheless, considerable progress has been made in recent years in understanding the roles played by scientific and engineering knowledge, market structures and institutional frameworks, and the characteristics of economic organizations in encouraging or impeding innovation. Because the efficiency impact of regulation on innovation and productivity dominates direct resource misallocation costs in the long run, policy prescriptions for social regulation must be formulated in light of this evolving interpretation of innovation and productivity.[6]

6. *See generally* Wesley M. Cohen & Richard C. Levin, *Empirical Studies of Innovation and Market Structure*, *in* 2 HANDBOOK OF INDUSTRIAL ORGANIZATION (Richard Schmalensee & Robert D. Willig eds., 1989); G. Dosi, *Sources, Procedures, and Microeconomic Effects of Innovation*, 25 J. ECON. LITERATURE 1120 (1988).

A. *The Determinants of Economic Innovation*

A key feature of technology and economic performance in the capitalist era has been the systematic application of scientific knowledge to production techniques. The scientific understanding of chemical, physical, and other properties of materials and processes functions as a pool of knowledge which can be drawn on by any firm and used to develop more efficient processes of production or new products altogether. This "common pool" interpretation of scientific knowledge underlies public subsidies for scientific research in universities, governmental entities, and other consortia. Advances in technology in particular industries and particular time periods are due partly to the general state of knowledge at that time.[7]

This view of science and technology explains only part of the changes in products and processes in modern economies. It cannot explain the wide differences among firms in similar industries in developing or adopting new products and processes. Other factors impact technological change. First, institutional and market environments have significant effects on a firm's willingness to invest in the development of new products and processes and upon its ability to capitalize on innovations and thereby increase sales, revenues, and market share. Second, statutory and regulatory provisions in patent, intellectual property, and antitrust law affect the appropriability of innovations and influence the ability of different firms to cooperate in the research, development, and diffusion of new products.[8] Third, the scale and price elasticity of consumer demand influence the rate of technological change in a given market. Investment in research and development will generally be more attractive for products with high consumer demand since the initial fixed costs can be allocated over a larger number of individual units. Similarly, research and development is more attractive with more price-elastic market demand because reductions in production costs and prices yield more than proportionate increases in sales and revenues. Fourth, the structure of product markets, in terms of how many firms account for the majority of

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7. *See generally* Edwin Mansfield, *Academic Research and Industrial Innovation*, 20 RES. POL'Y 1 (1990); Richard R. Nelson, *The Simple Economics of Basic Scientific Research*, 67 J. POL. ECON. 297 (1959).

8. Zvi Griliches, *Patent Statistics as Economic Indicators: A Survey*, 28 J. ECON. LITERATURE 1661 (1990). *See generally* Thomas M. Jorde & David J. Teece, *Antitrust Policy and Innovation: Taking Account of Performance Competition and Competitor Cooperation*, 147 J. INSTITUTIONAL & THEORETICAL ECON. 118 (1991); David J. Teece, *Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing, and Public Policy*, 15 RES. POL'Y 285 (1986).

output and revenues, appears to influence innovation differently in different sectors. In some industries, large firms and concentrated markets account for the majority of significant product and process improvements because they are able to capture the economic returns from investments in research and development. In other industries, however, small specialized firms that move more quickly from concept to market and that are attentive to user needs account for most innovation. Some industries manifest a life-cycle with alternating phases of concentrated and competitive structures depending on whether products compete primarily on performance or price.[9]

The capabilities of individual firms also determine where and when innovation occurs. In the conventional economic model of the firm, individual organizations choose among publicly available technologies based on relative prices for different kinds of capital and labor. Modern interpretations of the firm highlight the firm-specific nature of much knowledge, the costs of transmitting knowledge among firms, and the difficulties in profitably utilizing information.[10] Much of the knowledge and insight relevant to developing new products and processes is gained through experience. This knowledge is often tacit and imbedded in routines and work groups rather than explicitly codified in blueprints and manuals. Past success in one class of products and processes promotes future success in related endeavors, whereas failure to compete at one stage may preclude re-entry into the market.[11] The internal structure and product mix of individual firms also influence their ability to innovate. In order to protect the value of innovative breakthroughs, firms may need to be vertically and/or horizontally integrated to manufacture products which embody the new techniques. They face tradeoffs between investments in large scale specialized assets which reduce manufacturing costs for any one product design (static efficiency) and investments in flexible generalized assets which permit rapid adaptation to new product designs (dynamic efficiency).

The locus and nature of innovative activities vary widely among industries, but a three-part taxonomy captures many of the essential

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9. William J. Abernathy & J. Utterback, *Patterns of Industrial Innovation*, TECH. REV., June/July 1978, at 39-47. *See generally* Philip Anderson & Michael L. Tushman, *Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change*, 35 ADMIN. SCI. Q. 604 (1990).

10. *See generally* RICHARD R. NELSON & SIDNEY G. WINTER, AN EVOLUTIONARY THEORY OF ECONOMIC CHANGE (1982); OLIVER E. WILLIAMSON, THE ECONOMIC INSTITUTIONS OF CAPITALISM (1985).

11. C.K. Prahalad & Gary Hamel, *The Core Competence of the Corporation*, 68 HARV. BUS. REV. 79 (1990).

differences.[12] For some traditional manufacturing industries, such as textiles and printing, and for many non-manufacturing industries, innovations are developed primarily by supplier industries, such as equipment manufacturers and producers of intermediate materials. The textile industry, for example, relies on specialized machinery firms for new equipment and on the chemical industry for new synthetic fibers. Firms in supplier-dominated industries compete on the basis of rapid adoption of new equipment and materials and invest little directly in innovation.

A second broad class of industries is characterized by large-scale production and heavy reliance on internally-generated product and process innovations. This sector includes producers of standardized materials, such as cement and glass, and producers of high volume and complex durables, such as transport equipment and electrical machinery. While many firms in these sectors have their own research and development units, they also rely on learning-by-doing in actual manufacture. Some segments of these industries rely on small, specialized suppliers, such as advanced machinery firms, which work in close cooperation with larger producers.

The third principal class of industries consists of science-based firms and products, where there is a direct and continuous link to new developments in science. This segment, which includes parts of the chemical, biotechnology, and electronics industries, engages in performance competition on the basis of often dramatically new products. Firms invest heavily in in-house research and development and interact frequently with university researchers, governmental entities, and professional organizations.

B. *The Role of Environmental Regulation*

The net effect of social regulation on economic innovation is an empirical matter. Nevertheless, the theoretical framework and the three-sector taxonomy developed by economists provide a useful context within which to consider the likely pattern of effects.

1. *Supplier-Dominated Industries*

For supplier-dominated manufacturing sectors such as textiles and most nonmanufacturing industries, the key to both productivity growth and

12. Richard R. Nelson, *Capitalism as an Engine of Progress*, 19 RES. POL'Y 193 (1990); Keith Pavitt, *Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory*, 13 RES. POL'Y 343 (1984).

pollution prevention lies in the diffusion of new capital equipment and materials. In principle, governmental regulations that mandate the adoption of "best available control technologies" (BACT) and analogous technology-based approaches to worker exposure could accelerate the adoption of new capital and materials that are more productive, cleaner, and less toxic.[13] Some observers have claimed, for example, that OSHA's cotton dust standard induced the cotton textile industry to invest in new machinery which raised production speed and product quality in addition to reducing levels of respirable cotton dust. The textile industry exhibited strong growth in multifactor productivity during the 1970s, when many manufacturing sectors suffered a historic slowdown.

The actual impact of technology-based regulations may diverge from this productivity-enhancing ideal. Once the mandated level of control is achieved, BACT standards give no incentive to innovate, and may even give disincentives for multiplant firms to develop more efficient controls in one plant which could then be transferred to others.[14] Many statutes require stricter pollution controls on new or renovated plants, which discourages new investment and encourages the retention of antiquated capital equipment. Due to the heterogeneous and competitive nature of supplier-dominated industries, survival strategies often rely on quick responses to changes in consumer preferences and a continual search for new market niches. More vulnerable firms may be easily crushed by heavy, uniformly-applied standards. Observed gains in average industry productivity may be due to a winnowing of the less productive competitors, with consequent declines in output and employment. These considerations shed doubt on the technology-forcing interpretation of OSHA's cotton dust standard, for example. In fact, the superior productivity performance of the textile industry as compared to the rest of manufacturing predated the imposition of the cotton dust standard in 1978, and was due largely to market-driven improvements in textile machinery.[15] There was also a very serious decline in output and employment in the textile industry during the 1970s and 1980s, due in large part to competition from low cost foreign firms. The survivors presumably consisted of mills with the most productive technologies.

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13. LaPierre, *supra* note 2.

14. *See generally* Marshall J. Breger et al., *Providing Economic Incentives in Environmental Regulation*, 8 YALE J. ON REG. 463 (1991).

15. *See generally* RUTH RUTTENBERG, OFFICE OF TECHNOLOGY ASSESSMENT, COMPLIANCE WITH THE OSHA COTTON DUST RULE (1983); Baily & Chakrabarti, *supra* note 5; W. Kip Viscusi, *Cotton Dust Regulation: An OSHA Success Story?*, 4 J. POL'Y ANALYSIS & MGMT. 325 (1985).

2. *Scale-Intensive Industries*

The large-scale continuous process, transport equipment, and related industries generate improvements in process and product performance internally, with some reliance on small, specialized suppliers. Innovation in these industries is spurred by competitive market forces. Regulatory demands for lower emissions and exposures may create an analogous incentive for innovation.[16] In this interpretation, mandates for reduced emissions lead to "greener" products and processes that are profitable and environmentally benign.[17] The benefits of government mandated investments in new materials and equipment may spill over to other sectors of the economy in a manner akin to technology spillovers from governmental support for military research.

While appealing in principle, this interpretation of regulation as a spur to innovation should be reviewed critically. Regulatory mandates for innovative approaches to pollution reduction may compete for the same engineering resources that would otherwise have focused on innovative approaches to cost reduction. The total investment by firms in research and development may shrink if managerial attention is diverted away from the development of new products and processes toward regulatory compliance. In this respect, it is important to emphasize that most innovations in the core manufacturing sectors are developed by user firms themselves, with substantially lower contributions by other private firms, and only very small reliance on universities and governmental research entities.[18] The poor record of centrally planned economies to stimulate innovation of any type highlights the relative merits of decentralized, market-driven searches for new ways to make cleaner and safer products.[19]

3. *Science-Intensive Industries*

Regulatory constraints on toxic products and by-products directly stimulate shifts in the mix of outputs in the chemical industry. Firms enjoying economies of scope in the production of new and related products can benefit from new markets opened by social regulation. However,

16. Ashford et al., *supra* note 2.

17. *See* M.E. Porter, *America's Green Strategy*, SCI. AM., Apr. 1991, at 168.

18. *See* Keith Pavitt, *Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory*, 13 RES. POL'Y 343 (1984).

19. *See* Richard R. Nelson, *Capitalism as an Engine of Progress*, 19 RES. POL'Y 193 (1990).

existing investments in capital equipment, research and development, marketing, and other activities designed around one mix of products may face accelerated obsolescence. The path-dependent nature of innovation within particular firms may make fundamental changes quite difficult. Major breakthroughs in products and processes are often accompanied by a process of "creative destruction," as new firms and products displace their predecessors.[20]

In summary, no strong predictions can be made a priori concerning the likely influence of environmental and occupational health regulation on innovation and productivity growth. On the one hand, regulatory mandates for cleaner and safer products and processes may stimulate innovative responses that reduce the actual cost of compliance below what would be predicted based on engineering data derived from existing control technologies. On the other hand, regulatory demands may shift managerial and engineering resources away from the pursuit of cost-reducing innovation, thereby impairing the productivity performance of an industry. Moreover, significant adjustment effects are likely as firms scramble to shift from one trajectory of innovation and productivity to another.

II. Measurement of Multifactor Productivity

This study uses two productivity measures to evaluate regulatory impacts. The first productivity index subtracts changes in inputs from changes in outputs for each industry and year. This index is easy to interpret and facilitates direct comparisons with measures of regulatory intensity. However, it imposes a structure on the statistical relationship between inputs and outputs which may not correspond closely to the actual production relations. The second productivity measure uses an econometric production function approach to estimate the true statistical relationship between inputs and outputs. The econometric approach examines the relationship of differences across industries and years in rates of output growth to differences in rates of growth of capital, labor, and material inputs. The two approaches should produce qualitatively similar results and can provide useful checks on each other.

20. *See generally* JOSEPH A. SCHUMPETER, CAPITALISM, SOCIALISM, AND DEMOCRACY (1942).

A. *The Productivity Index*

The productivity index measures multifactor productivity growth in terms of the residual increase in output for each industry and year, over and above what would be expected given the changes in capital, labor, and material inputs.[21] For each industry, the three types of inputs are assigned weights corresponding to their marginal contribution to the production of the final output. The productivity index calculates weights for each input in terms of the share of production cost for the manufacturing sector as a whole that is devoted to purchasing that input. These manufacturing-wide weights are then assigned to each detailed manufacturing industry.

Formally, the index is based on the production relationship:

$$(1.1)\ Q_{it} = B_1L_{it} + B_2K_{it} + B_3M_{it}$$

where Q measures output in industry i for year t, L measures labor inputs, K measures capital inputs, and M measures intermediate materials. The weights B_1, B_2, and B_3 measure the marginal contribution of labor, capital, and materials to the production of salable output. Both inputs and outputs are measured in logarithmic units so as to capture the multiplicative relationships between capital, labor, and material inputs in the production process.

Productivity growth G_{it} is measured in terms of changes in equation (1.1) between year t-1 and year t:

$$(1.2)\ G_{it} = (Q_{it} - Q_{it-1}) - B_1(L_{it} - L_{it-1}) - B_2(K_{it} - K_{it-1}) - B_3(M_{it} - M_{it-1})$$

The weights B_1, B_2, and B_3 are calculated as the average between year t-1 and year t of the share of payroll, capital, and materials expenditures in the total cost of production:

$$(1.3)\ B_1 = 0.5\ ((\text{payroll}_{t-1} / \text{total costs}_{t-1}) + (\text{payroll}_t / \text{total costs}_t))$$

$$(1.4)\ B_3 = 0.5\ ((\text{materials costs}_{t-1} / \text{total costs}_{t-1}) + (\text{materials costs}_t / \text{total costs}_t))$$

21. William Gullickson & Michael J. Harper, *Multifactor Productivity in U.S. Manufacturing, 1949-83*, 110 MONTHLY LAB. REV. 18 (1987) (developing multifactor productivity index); *see also* BUREAU OF LABOR STATISTICS, U.S. DEP'T OF LABOR, BLS HANDBOOK OF METHODS, BULLETIN 2414 (1992).

$$(1.5)\ B_2 = 1 - (B_1 + B_3)$$

Annual expenditure data on labor and materials for each industry are readily available. Data are also available on the value of the total stock of capital but not on the marginal contribution of capital services in each year. A given plant or piece of equipment typically is useful for multiple years and it is impossible to ascertain what fraction of its lifetime value is used up in any one year. The marginal contribution of capital services can be calculated as a residual from the contributions of labor and materials, however, since together labor, materials, and capital account for all production costs. The value of shipments for each industry in each year is used as the denominator in calculating the cost share weights.

The productivity index for each particular industry i and year t (I_{it}) is calculated as the product of the previous year's index (I_{it-1}) times the productivity growth rate ($1 + G_{it}$), with the 1974 value set to 1.0.

$$(1.6)\quad I_{it} = 1.0 \qquad \text{for } t = 1974$$

$$I_{it} = I_{it-1}\,(1 + G_{it}) \qquad \text{for } t > 1974$$

B. *The Production Function*

The econometric approach to multifactor productivity adopts a more flexible form for the relation between inputs and outputs. The general form of the relationship posits output in industry i in year t (Q_{it}) as a function of labor inputs in that industry and year (L_{it}), capital inputs in that industry and year (K_{it}), material inputs in that industry and year (M_{it}), a year effect which captures the overall level of technological knowledge publicly available, i.e., to all industries, in year t (Y_t), and a stochastic term which captures the deviation of output in industry i and year t from what would be expected, given inputs used in that year (U_{it}).

$$(2.1)\ Q_{it} = F(L_{it}, K_{it}, M_{it}, Y_t, U_{it})$$

The functional form F() is the commonly used translog, which can be interpreted as a second order polynomial approximation to the true underlying but unknown technological relationship between inputs and outputs in manufacturing in any particular year.[22]

22. Lauritis R. Christensen et al., *Transcendental Logarithmic Production Frontiers*, 55 REV. ECON. & STAT. 28 (1973).

$$(2.2)\ Q_{it} = Y_t A_0 + B_1L_{it} + B_2K_{it} + B_3M_{it} + B_{11}(L_{it} * L_{it}) + B_{22}(K_{it} * K_{it}) + B_{33}(M_{it} * M_{it}) + B_{12}(L_{it} * K_{it}) + B_{13}(L_{it} * M_{it}) + B_{23}(K_{it} * M_{it}) + U_{it}$$

Outputs and inputs are measured in logarithmic units. If the labor, capital, and material inputs are indicated as a vector $X_{it} = [L_{it}, K_{it}, M_{it}]$, and the translog functional form is indicated as F(X), the production function can be described in more compact notation:

$$(2.3)\ Q_{it} = A_0 + \Sigma_i X_{it} B_i + \Sigma_i \Sigma_j X_{it}X_{jt} B_{ij} + U_{it}$$

$$= A_0 + F(X_{it}) + U_{it}$$

Here A_0 serves as an intercept term since the year effect Y_t is the same for every industry i and thus can be suppressed for notational convenience.

Productivity growth is measured using output growth $(Q_{it} - Q_{it-1})$ and the vector of input growth rates $(X_{it} - X_{it-1})$ in translog form:

$$(2.4)\ (Q_{it} - Q_{it-1}) = A_0 + F(X_{it} - X_{it-1}) + (U_{it} - U_{it-1})$$

where A_0 now captures the effect of the change in year effects $(Y_t - Y_{t-1})$.

C. *Data on Outputs, Inputs, and Productivity*

In order to measure productivity across the whole manufacturing sector at the most detailed level of analysis available, this study used several databases from the U.S. Department of Commerce, Office of Business Analysis (OBA), containing input and output data from 1974 to 1986 at the detailed four digit Standard Industrial Classification (SIC) level. This divides the manufacturing sector into 445 industries, which vary widely in size and over time. The statistical analyses adjust for this variance when calculating impacts for all manufacturing and for major (two digit SIC) sectors by weighting each four digit industry observation according to its value of shipments for each year.

While the four digit SIC level provides a detailed picture of the manufacturing sector, it nevertheless retains considerable heterogeneity within each industry. Each industry produces a range of outputs with a multitude of different capital, labor, and material inputs. These heterogeneous outputs and inputs need to be aggregated into one measure of output and one measure of each of the three types of inputs per industry per year.

For output, a straightforward method of aggregation is to weight each industry product by its price, which implies using the value of shipments as the measure of output. This not only permits one to aggregate products, since they are all in the same metric (U.S. dollars), but weights each output by an indicator of its quality. In general, higher priced components within an industry's output stream reflect higher input demands. It is necessary, however, to take out the effects of general price inflation over the 1974-86 period. This study used the OBA Production Data Base, which contains value of shipments data at the four digit SIC level and price deflators for each four digit industry.[23] Inflation-adjusted data are used here, with 1982 as the benchmark year.

Labor and material input data were obtained from the OBA Industry Profile Data Base, derived in turn from the Annual Survey of Manufactures and the Census of Manufactures.[24] This data base provides the number of hours worked for production workers and the number of employees for nonproduction workers (who are assumed to work a constant 2000 hours per year in this analysis), plus the value of expenditures on intermediate materials. Data are available for the same 445 four digit industries contained in the OBA Production Data Base. The production labor input measure is hours worked rather than persons employed, since hours vary strongly over the business cycle due to temporary layoffs, and thereby provides a much better measure of the actual quantity of labor inputs utilized.[25] Capital inputs were obtained from the OBA Capital Stock Data Base.[26] This data base developed detailed measures of constant (1982) dollar gross and net capital stocks from historical book values and annual information on new capital investment and capital depreciation. This study used the net capital stock to reflect the actual potential for capital services, i.e., after removing depreciated capital. It aggregates the data for plant and equipment.[27]

23. OFFICE OF BUSINESS ANALYSIS, U.S. DEP'T OF COMMERCE, PRODUCTION DATA BASE (1989).

24. *Id.*

25. Expenditures on intermediate materials are presented in non-deflated, current dollar terms in the Industry Profile Data Base. For this study, they were deflated to 1982 levels using the manufacturing sector average for the value of shipments deflators in the Production Data Base.

26. OFFICE OF BUSINESS ANALYSIS, U.S. DEP'T OF COMMERCE, CAPITAL STOCK DATA BASE (1989); *see also* JACK FAUCETT ASSOCS., CAPITAL STOCKS DATA UPDATE: FINAL REPORTS AND PROCEDURES (1990).

27. This measures the stock of capital available in each year, not the flow of capital services. It contrasts with the measures of labor and material inputs, which indicate the flow of labor and material services. An unknown percent of the total lifetime value of available plant and equipment is used up in each year. Given the impossibility of obtaining measures of capital services separate from capital stocks, this study used stocks under the assumption

The capital, labor, and material input measures all reflect the quantity of inputs available for use rather than the intensity of utilization. This is of particular importance in the analysis of productivity since the rate of utilization varies extensively over the course of the business cycle. As consumer demand rises and falls, firms must adjust the volume of production more or less proportionately, although inventories act as a buffer. This in turn implies a cyclical fluctuation in the utilization of capital, labor, and material inputs. However, in the short run, firms have much less control over their purchase of inputs than over their rate of input utilization. For example, capital stocks can be slowly changed only by altering the rate of new investment. Labor and material inputs are more variable, but even they are subject to considerable rigidities. White collar workers are typically employed on a monthly basis, regardless of production levels. Blue collar workers are often employed on an hourly basis and their rate of utilization can be adjusted to reflect variations in consumer demand through temporary layoffs and overtime. However, management can be reluctant to vary blue collar employment because of the potential to alienate the workforce and lose their best employees. Hence, employment falls more slowly than output in a business cycle downturn and rises more slowly than output in a business cycle upturn. Intermediate material inputs are most easily varied with changes in consumer demand, but long term purchasing contracts cause materials purchases to fall slowly in a business downturn and rise slowly in a business upturn.

Cyclical rigidities of capital and, to a lesser extent, labor and material inputs impart a distinct and well-known cyclical fluctuation to productivity. When consumer demand falls, firms reduce output but reduce their demand for inputs less than proportionately. Thus, the ratio of output to input, measured in terms of multifactor productivity, declines. Conversely, when consumer demand rises and firms increase output, their demand for new capital, labor, and material inputs rises at a lower rate and multifactor productivity increases. The subsequent statistical analyses examine the impact of environmental regulation in terms of the year to year changes in productivity in order to account for these cyclical fluctuations.

Figure II.1 presents in graphical form the index of multifactor productivity over the 1974-86 period based on equation (1.6). These numbers reflect the average productivity performance across 445 detailed manufacturing industries, weighted by the value of shipments in order to

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that the flow of services from a given quantity of capital stock is constant across manufacturing industries.

account for the substantial differences in scale across the individual industries. Productivity growth was poor during most of the period, declining sharply during the recessions of 1974-75 and 1980-82, but improved significantly between 1983 and 1986. By 1986 multifactor productivity for the manufacturing sector as a whole was 12.8% higher than in 1974.

Figure II.2 presents the year to year fluctuations in productivity growth based on equation (1.2). Figure II.2 highlights the pronounced cyclical nature of productivity caused by employers adjusting output rapidly while adjusting employment, investment, and material purchases slowly in response to changes in consumer demand. The annual rate of change in productivity was negative in 1974 and 1975, rose dramatically with the recovery in 1976, declined gradually through the late 1970s, plunged as the recession of the early 1980s began, and then grew at a moderately high rate between 1983 and 1986.

Considerable variation in productivity growth exists both among manufacturing industries in any one year and across years for all industries combined. Table II.1 presents the distribution of multifactor productivity across the 445 industries. The median industry did not experience any net growth in productivity during the 1970s and did not consistently outperform the 1974 level until the mid-1980s. However, some industries did quite well during this period. Industries in the top quartile experienced productivity growth of greater than 12% over the 12 year period, with the top five percent achieving a cumulative growth of over 33%. In contrast, the bottom quartile of industries experienced productivity losses exceeding five percent over the 12 year period, with the worst five percent suffering a decline of almost 20%. High-performing industries were typically of greater size than low-performing industries, as indicated by the fact that the mean industry index presented in Figure II.1 rises faster than the median industry index in Table II.1.

Considerable inter-industry variation exists in annual rates of productivity change, as evidenced in Table II.2. The median industry tracks the overall manufacturing industry experience, as Figure II.2 indicates. Productivity growth is negative in 1974-75, positive but declining for the next three years, sharply declining in 1979-80, negative for the next two years, and consistently positive thereafter. However, some industries experienced positive productivity growth each year, even when the manufacturing sector as a whole performed badly. During the 1979-80 plunge, for example, one quarter of the industries reported growth rates exceeding 1.3% and the top five percent grew in excess of 7.1%. Conversely, some industries posted dismal performance even during the best of years. One quarter of the industries experienced negative productivity growth of more than 1.4% in 1985-86 and five percent experienced productivity declines exceeding 6.7% in those years.

III. Measures of Regulation

The economic impact of environmental and occupational health regulation varies widely among manufacturing industries due to the differences in materials, capital equipment, and processes employed. A simple measure of regulatory coverage, distinguishing those industries which fall within the purview of a particular standard from those that do not, would not be able to capture the differences in productivity impacts within the covered industries. This study distinguishes conceptually between the direct economic cost of regulatory compliance and the indirect cost of regulation operating through changes in multifactor productivity. The first step is to obtain published data on direct compliance costs as the index of regulatory intensity among covered industries and across years. The second step entails examining the statistical association between this measure of direct compliance expenditure and measures of productivity and productivity growth.

Two principal sources of information exist on the expenditures made by manufacturing industries to comply with EPA and OSHA regulations. The Census Bureau conducts an annual survey of manufacturing establishments to identify new capital expenditures for pollution abatement equipment and the labor, materials, and other expenditures to operate the equipment. Data from this survey cover the entire manufacturing sector from 1974 to the present. They do not include capital or operating expenditures for compliance with OSHA's occupational health regulations. Several different sources contain information on the economic impact of occupational health regulation. Prior to promulgating a major standard, OSHA contracts for an economic impact assessment, which provides some insight into the direct cost of compliance as anticipated at the time the standard is considered. During the course of the regulatory debate, other groups, including industry organizations, governmental oversight bodies, and labor unions, may submit their own cost projections. In some cases, follow-up studies have been conducted to evaluate the actual costs incurred. All these data sources were examined for this study.

A. *Pollution Abatement Expenditures*

Since 1973 the Bureau of the Census of the U.S. Department of Commerce has surveyed a large random sample of manufacturing establishments to obtain information on capital expenditures and operating costs required for pollution abatement.[28] These data provide the nation's principal source of information on the direct economic cost of reducing discharges to air, water, and land disposal. Data are aggregated to the four digit SIC level and published on an annual basis.[29] For this study, capital expenditures are amortized over a ten year period at a ten percent interest rate, added to the annual operating costs, and then the aggregate expenditure figure is divided by the value of shipments. Compliance costs are measured relative to value of shipments to control for the wide differences in size among four digit industries. This also controls for the effects of price inflation on measures of compliance expenditures, since the numerator and denominator are valued in the same year's prices.

In addition to the exclusion of OSHA compliance expenditures, two limitations in the Census data should be noted. First, these are self-reported figures and cannot be independently verified. Respondents have an incentive to exaggerate compliance costs as part of their effort to discourage further regulation. However, this exaggeration will only bias the subsequent productivity analyses if firms in different industries exaggerate to different degrees and if the degree of exaggeration varies systematically with productivity growth rates. Secondly, these data cannot clearly distinguish between capital expenditures made for pollution abatement and capital expenditures made for market-driven reasons, as in response to international competition. When forced to reduce their pollution discharges, establishments may purchase new equipment that is more efficient as well as less polluting. It is inappropriate to assign the full cost of these capital expenditures to EPA regulation. The difficulty in assigning costs separately to economic and environmental purposes is less of a problem in productivity studies than in evaluations of the direct cost of regulatory compliance, however. The economic value of new efficiency-enhancing equipment impacts industry shipments as well as pollution abatement capital expenditures, and hence is in the denominator

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28. BUREAU OF THE CENSUS, U.S. DEP'T OF COMMERCE, CURRENT INDUSTRIAL REPORTS: POLLUTION ABATEMENT COSTS AND EXPENDITURES, 1986 (1989).

29. For industries with low pollution abatement expenditures, data are provided only at the more aggregate three and two digit SIC levels to maintain confidentiality. Where four digit data are not provided, this study allocated expenditures within each two or three digit industry to its component four digit industries in proportion to each industry's share in the larger sector's aggregate value of shipments. Once divided by the value of shipments for the four digit industry in question, this implies that all four digit industries within a particular two or three digit industry have the same proportional direct regulatory cost. Generally, the Census publishes disaggregated four digit data for industries with substantial pollution abatement expenditures and aggregated two and three digit data for industries with few such expenditures.

as well as the numerator of the ultimate measure of EPA regulatory impact.

Table III.A.1 provides an overview of pollution abatement expenditures as a fraction of the value of shipments for the twenty major (two digit SIC) industry sectors in 1974, 1980, and 1986. These figures are calculated as the average of expenditures for each detailed (four digit) industry within each sector, weighted by the detailed industry's value of shipments to adjust for the differences in scale. Considerable differences exist in direct regulatory compliance expenditures across the manufacturing sector, with the range growing over time. Pollution abatement expenditures are highest in the paper, petroleum, chemical, and primary metal industries, where expenditures totaled approximately one percent of the total value of shipments in 1974 and approached or exceeded three percent by 1986. At the low end are the apparel and printing industries, where expenditures amounted to less than one fifth of one percent of industry shipments throughout this period. The uneven distribution of pollution abatement expenditures is expected, given the very uneven distribution of pollution emissions among industries. The EPA Toxic Release Inventory data report that the paper, petroleum, chemical, and primary metal industries discharged 2.8 billion, 0.8 billion, 12.1 billion, and 2.6 billion pounds of toxic substances to air, water, and land disposal in 1987, even after fifteen years of EPA regulation. In contrast, the apparel and printing industries discharged 0.005 billion and 0.062 billion pounds in 1987.[30]

B. *Occupational Health Expenditures*

The Census survey excludes expenditures made to comply with occupational health regulations and no comparable data exist for OSHA standards in any other survey. As a substitute, this study analyzed and compiled information from a wide variety of sources on anticipated and actual expenditures for occupational health protection for four digit manufacturing industries. This necessitated a separate analysis of each OSHA regulation, which required criteria for selecting among OSHA regulatory activities. OSHA mandates span a wide range of regulations from requiring personal protective equipment to setting Permissible Exposure Limits (PELs) to mandating disclosure of information.[31] This

30. U.S. ENVTL. PROTECTION AGENCY, THE TOXICS RELEASE INVENTORY: A NATIONAL PERSPECTIVE (1989).

31. *See generally* JAMES C. ROBINSON, TOIL AND TOXICS: WORKPLACE STRUGGLES AND POLITICAL STRATEGIES FOR OCCUPATIONAL HEALTH (1989); Sidney A. Shapiro & Thomas O. McGarity, *Reorienting OSHA: Regulatory Alternatives and Legislative Reform*,

study focused on the major regulations promulgated to directly reduce exposure to toxic substances. It therefore excludes cost of compliance with safety standards, industrial relations rules such as the Hazard Communication Standard, and the minor PELs adopted from voluntary industry guidelines in the early years of OSHA. This is necessary for pragmatic reasons, since credible data on the other OSHA rules are not available. It provides the advantage, moreover, of focusing on that aspect of OSHA regulation which received the most attention and of facilitating comparison with the EPA regulations. The study thus covers the OSHA regulations for asbestos, vinyl chloride, coke oven emissions, cotton dust, acrylonitrile, inorganic arsenic, lead, and ethylene oxide.[32]

The quality of the data on direct compliance costs varied widely among OSHA standards. Where possible, this study relied on evaluations made of actual expenditures subsequent to implementation of the rule. These evaluations are available for asbestos, vinyl chloride, and cotton dust. Alternatively, the study relied on the principal economic impact study contracted for by OSHA itself, in conjunction with subsequent OSHA comments published in the *Federal Register* based on industry testimony and submissions. This approach was used for coke oven emissions, acrylonitrile, inorganic arsenic, lead, and ethylene oxide.[33] Compliance costs were treated in a manner analogous to EPA regulatory compliance costs. Capital expenditures were amortized[34] and added to annual operating costs[35] and then divided by the industry's value of shipments for each year. The occupational health compliance cost data suffer from some of the same limitations as the pollution abatement data. Even the post-regulatory follow-up studies rely ultimately on industry statements concerning expenditures, which raise the same difficulty in

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6 YALE J. ON REG. 1 (1989).

32. The benzene standard is not included, since the 1978 version was overturned by the U.S. Supreme Court and a revised version was not promulgated until 1987.

33. Detailed case studies of each major OSHA health regulation are included as Appendices I-VIII in JAMES C. ROBINSON, OSHA REGULATION AND MANUFACTURING PRODUCTIVITY (1994).

34. Where the underlying data sources amortize capital expenditures, the amortized capital figures are used directly. While this results in a range of amortization periods and interest rates, it was judged to be preferable than to impose a single period and rate since true amortization periods and interest rates vary and are captured at least to some extent in the impact evaluations. In some cases, only amortized capital expenditures are available, with no information on either the amortization period or the interest rate used.

35. The economic impact studies typically estimate annual operating costs but do not indicate how long operating costs will continue at the first year's level. Generally, one expects that annual operating costs should decline as new capital is installed and exposures are reduced. In this analysis it is assumed that annual operating costs decline by 10% each year.

allocating capital expenditures between protective equipment and efficiency enhancement goals.

Table III.B.1 provides an overview of OSHA compliance expenditures relative to industry shipments for the twenty two digit SIC manufacturing sectors. Only one sector, chemical and allied products, incurred any costs complying with OSHA health regulations in 1974. By 1980, the high point in OSHA compliance expenditures, half of the sectors incurred compliance costs, but in every case these fell below one-fifth of one percent of industry shipments. The most heavily affected sectors were primary metals, textile mills, and stone, clay, and glass products. Compliance expenditures declined after 1980 as industries adjusted to the regulatory mandates of the 1970s and as the pace of new regulation declined.

C. *Trends in EPA and OSHA Compliance Costs*

Figure III.C.1 presents the trend in EPA and OSHA compliance costs as a fraction of the value of shipments for the entire manufacturing sector from 1974 to 1986. The contrast between the two regulatory agency impacts is striking. Most obviously, expenditures on compliance with environmental regulations dwarf those on compliance with regulations promulgated to protect worker health. Pollution abatement expenditures rose steadily throughout the period, with only a slight dip in 1984, while expenditures for occupational health protection peaked in 1980 and declined thereafter. The decline in OSHA compliance costs reflects the wane of regulatory enthusiasm at OSHA after the inauguration of President Reagan in 1981. The continued rise in pollution abatement expenditures relative to industry output value is due to the compliance initiatives required by the major environmental protection statutes legislated in the 1970s. Compliance costs for EPA and OSHA regulations combined grew from 0.46% of value of shipments for the entire manufacturing sector in 1974 to 1.14% in 1986.

Figure III.C.2 presents the year-to-year rate of change in pollution abatement and occupational health expenditures over the 1974-86 period to highlight the variability across years and its sensitivity to the general cycle of economic activity. While pollution abatement expenditures exhibit positive growth relative to industry output in all years except 1984, the rate of growth fluctuates significantly due to both changes in pollution control expenditures (the numerator) and industry value of shipments (the denominator). The almost linear time trend of pollution abatement expenditures relative to industry shipments presented in Figure III.C.1 indicates that pollution abatement expenditures (the numerator) fluctuate in the same cyclical pattern as do industry shipments (the denominator).

However, the amplitude of fluctuation for pollution abatement expenditures is smaller than that for industry output. As a consequence, as Figure III.C.2 indicates, pollution abatement expenditures as a fraction of industry expenditures rise during a business recession and fall during a business expansion. Major peaks in pollution abatement expenditures relative to total costs and revenues thus occurred during the OPEC-related recession of 1974-75 and in the more serious recession of 1981-82, while major declines are observed during the business recoveries of 1976-80 and 1983-84. The one striking exception to this inverse cyclical relationship between pollution abatement expenditures and business expansion occurred in 1984-86, where pollution abatement expenditures rose sharply relative to value of industry shipments despite a relatively good economic climate.

In order to measure the variation among manufacturing industries in the combined impact of environmental and occupational health regulation, EPA and OSHA compliance expenditures were summed. Table III.C.1 presents descriptive statistics on this combined measure of regulation for the 445 manufacturing industries during the 1974 to 1986 period. While some industries made no compliance expenditures during these years, others shouldered a significant burden. The typical (median) industry invested 0.15% of the value of its output on pollution abatement and occupational health in 1974, 0.28% in 1980, and 0.44% in 1986. The distribution of expenditures among industries is highly skewed, however, with some industries making substantially larger commitments. As evident in Table III.C.1, the upper quartile of industries invests at a rate four times that of the bottom quartile. The top five percent of industries devoted more than 1.5% of total production costs to regulatory compliance in 1974, more than 3.0% in 1980, and more than 4.5% in 1986. This skewed distribution of pollution abatement expenditures is consistent with the very skewed distribution of pollution emissions among manufacturing industries.

Table III.C.2 presents analogous descriptive statistics for the variation among manufacturing industries in the year-to-year changes in regulatory compliance expenditures relative to total costs and revenues over the 1974-75 through 1985-86 period. The median industry generally tracks the experience of the manufacturing sector as whole, depicted in Figure III.C.2, though with less pronounced cyclical fluctuations. The most heavily impacted quarter of industries experienced higher annual rates of growth in regulatory compliance expenditures, often by a substantial margin. The five percent of industries most heavily impacted consistently reported annual rates of growth between 30% and 70% in compliance expenditures relative to shipments. On the other hand, however, some industries reported significant declines in the burden of regulation in particular years. The most favored five percent of industries reported declines in compliance costs relative to total costs exceeding 15% in many years.

IV. Econometric Models and Results

A. *Specification of the Statistical Models*

In order to quantify the incremental impact of environmental and occupational health regulation on productivity and productivity growth, a series of multivariate statistical analyses were performed combining the measures of productivity developed in Section II and the measures of EPA and OSHA regulation developed in Section III. Four basic specifications were adopted, corresponding to the four measures of productivity: the multifactor productivity index, the growth rate in multifactor productivity, the translog production function, and the first-differenced (rate of growth) production function. Two sets of regulation measures were used with each of these specifications. In the first set of regressions, EPA and OSHA compliance expenditures relative to total costs were included individually to examine their relative importance. In the second, the effects of EPA and OSHA were combined into a single measure of regulatory compliance expenditures. These eight regression models were estimated for the pooled 1975-86 data and for each year individually. A set of nineteen variables for the major (two digit SIC) manufacturing sector was included to control for differences among detailed industries in basic technological and market factors.

The multifactor productivity index model includes both outputs and inputs in the dependent variable and so is the simplest to present.

$$(4.1)\ I_{it} = A_0 + S_{it} A_1 + R_{it} A_2 + U_{it}$$

Productivity for industry i in year t (I_{it}) is a function of a year effect (A_0), the two digit manufacturing sector of which it is a part (S_{it}), regulatory compliance expenditures relative to total production costs (R_{it}), and unmeasured factors captured in the error term (U_{it}). When this model is applied using data from only one year, the year effect takes the form of a conventional intercept term. When the pooled 1975-86 data are used, it takes the form of year-specific intercepts.

The growth rate in multifactor productivity is the year-to-year change in (4.1), which from (1.6) equals G_{it}.

$$(4.2)\ G_{it} = A_0 + (R_{it} - R_{it-1}) A_2 + (U_{it} - U_{it-1})$$

The rate of growth in multifactor productivity, i.e., the change in output minus the change in inputs, weighted by cost shares, is a function of the year effect (A_0), the change in regulatory expenditures relative to total costs ($R_{it} - R_{it-1}$), and the change in unmeasured influences captured in the error term. The year effect corresponds to the annual rate of change in productivity, portrayed in Figure II.2, in contrast to the annual level of productivity, portrayed in Figure II.1. The time-invariant effects of the two digit manufacturing sector (S_{it}) are differenced away, since they affect output equally in year t-1 and year t ($S_{it} = S_{it-1}$ for all i).

The translog production function uses industry output as the dependent variable and the various inputs as independent variables, in addition to the year, two digit sector, and regulatory effects:

$$(4.3)\ Q_{it} = A_0 + S_{it} A_1 + R_{it} A_2 + F(X_{it}) B + U_{it}$$

Q_{it} is the value of shipments of industry i in year t (in logarithmic units), X_{it} is the vector of capital, labor, and material inputs (also in logarithmic units), and the other variables are as defined in the productivity index equation. The input vector is used in the translog functional form defined in (2.3), and is indicated as $F(X_{it})$.

The rate of growth version of the translog model, described in (2.4), is specified as the first-differences of (4.3), where ($Q_{it} - Q_{it-1}$) is the rate of growth (logarithmic change) in output:

$$(4.4)\ (Q_{it} - Q_{it-1}) = A_0 + (R_{it} - R_{it-1}) A_2 + F(X_{it} - X_{it-1})B + (U_{it} - U_{it-1})$$

B. *Parameter Estimates*

Table IV.1 presents parameter estimates for the pooled 1974-86 data using the productivity index (4.1), translog production function (4.3), productivity index growth (4.2), and first differences production function (4.4) models. Here the data from all twelve years are combined into one analysis. In order to simplify the exposition, only the coefficients on the EPA and OSHA regulatory variables (compliance costs as a fraction of total expenditures) are presented. Industries with high pollution abatement compliance expenditures relative to total production costs experience significantly lower levels and rates of growth in multifactor productivity than industries with low compliance expenditures. The parameter estimates for pollution abatement expenditures are all negative and statistically significant. In contrast, the coefficients on occupational health expenditures are very small, of mixed signs, and not statistically different from zero. This quantitative importance of EPA relative to OSHA is not surprising, given the magnitude of difference in the direct compliance costs ascribed to pollution abatement and occupational health in Figure III.C.1.

Table IV.2 presents parameter estimates for the combined EPA and OSHA regulatory variables from the annual productivity and productivity growth regressions for 1974-75 through 1985-86. In contrast to the models described in Table IV.1, each year's regulatory compliance costs and productivity data are analyzed individually. The figures in the first column thus reflect twelve separate regressions of the productivity index model (4.1), those in the second column reflect twelve separate regressions of the production function model (4.3), those in the third column reflect twelve separate regressions of the productivity growth model (4.2), and those in the fourth column reflect twelve separate regressions of the first-differenced production function model (4.4). There is some variation among years in the incremental impact of regulatory compliance expenditures on productivity and productivity growth, but the overall pattern is quite consistent with the estimates derived from the pooled analyses presented in Table IV.I. In every case the sign of the association is negative, and in forty-three out of forty-eight cases it is statistically significant at the $p < .10$ level. The subsequent discussion will use these year-specific parameter estimates when calculating the cumulative impact of regulation on productivity.

V. The Impact of Regulation on Productivity

The impact of EPA and OSHA regulation on productivity (M_{it}) depends on both the extent of direct compliance costs in each industry (R_{it}), summarized in Section III, and the incremental impact of direct compliance costs on productivity (A_2), presented in Section IV. The impact on industry i in year t is calculated by multiplying compliance costs as a fraction of total costs by the parameter estimate, where the year-specific parameters A_2 are taken from column 1 of Table IV.2.

(5.1) $M_{it} = R_{it} A_2$

Table V.1 provides an overview of annual reductions in multifactor productivity (M_{it}) for the twenty major manufacturing sectors for 1975, 1980, and 1986. The combination of rising compliance costs (R_{it}) and relatively constant productivity parameters (A_2) ensures that the annual impact of environmental regulation on manufacturing productivity (M_{it}) grew throughout this period. The greatest one-year impacts occurred for the primary metals, petroleum products, chemicals, and paper sectors, which suffered productivity losses in 1985-86 of 0.055, 0.045, 0.042, and 0.039 points, respectively, against the manufacturing-wide index of 1.000. Again, these are the manufacturing industries responsible for the greatest volume of toxic discharges. The smallest one-year impacts in 1985-86 occurred in the apparel (0.000 points), industrial machinery (0.004), tobacco (0.005), and printing and publishing (0.003) sectors. The manufacturing sector as a whole suffered a 0.017 point reduction in the multifactor productivity index in 1985-86 due to environmental regulation, a doubling of the 0.009 point reduction experienced in 1974-75.

However, the full impact of environmental and occupational health regulation must be conceptualized in terms of the cumulative impact over multiple years rather than simply as the incremental impact in any one year. Productivity losses in one year lower the base upon which efforts to increase productivity in the next year must build. This requires one to estimate the rate of growth over time in productivity in the counterfactual situation of no regulation, as a standard against which to compare the rate of growth in productivity that actually occurred. The multifactor potential productivity index PI_{it} can be defined in a fashion analogous to the actual productivity index I_{it}, based on (1.6) and (5.1).

(5.2) $$PI_{it} = 1.0 \qquad \text{for } t=1974$$

$$PI_{it} = I_{it-1}\,(1 + G_{it})\,(1 - M_{it}) \qquad \text{for } t > 1974$$

Intuitively, the multifactor potential productivity index for industry i in year t is the actual index in the previous year (I_{it-1}) multiplied by a factor accounting for overall growth in productivity ($1 + G_{it}$) and a factor replacing the productivity lost due to regulation ($1 - M_{it}$). Here ($1 - M_{it}$) > 1 since M_{it} is negative.

The cumulative percentage impact of regulation from 1974 to year t, Z_{it}, can be calculated as the difference between actual and potential productivity, divided by potential productivity, and multiplied by 100:

(5.3) $$Z_{it} = [(PI_{it} - I_{it}) / PI_{it}]\ 100$$

Table V.2 presents the cumulative loss in multifactor productivity (Z_{it}) in 1975, 1980, and 1986 for the twenty major manufacturing sectors. As expected, the cumulative impacts are substantially larger than the incremental impacts documented in Table V.1. By 1986, the cumulative reduction in actual productivity compared to potential productivity was 31.5% in primary metals, 25.3% in petroleum products, 28.0% in chemicals, and 27.4% in paper products. These reductions in economic productivity should be evaluated in light of the reductions in pollution achieved through regulation. Between 1970 and 1984, for example, carbon dioxide emissions were reduced by 43% in primary metals, 79% in petroleum products, and 39% in the chemical industry.[36] Emissions of nitrous oxides in those three industries were reduced by 30%, 71%, and 41% respectively. Emissions of volatile organic compounds decreased by 54% in primary metals but increased by 5% in petroleum products and by 21% in the chemical industry. Emissions of lead decreased by 92% in primary metals (which accounted for the vast majority of total manufacturing emissions). Emissions of particulate matter (PM10) declined by 68% in primary metals, 57% in petroleum products, and 39% in the chemical industry. Needless to say, the expenditures for pollution abatement and occupational health were not confined to controlling air emissions, but extended to water discharges, worker health risks, and other targets.

There is substantial variability among the 445 detailed manufacturing industries in the cumulative impact of regulation on multifactor productivity. Table V.3 presents descriptive statistics on Z_{it} for the 1975-86 period. The typical (median) industry suffered losses that grew from 0.3% in 1975 to 5.2% in 1986. The impacts were highly skewed, however, consistent with the data in Table III.C.1 highlighting the very skewed distribution of direct regulatory compliance expenditures. The most heavily impacted quarter of the industries registered losses in actual compared to potential productivity greater than 10.7% by 1986, while the most heavily impacted five percent of industries suffered losses exceeding 45.4%. The cumulative impact for the manufacturing sector as a whole can be derived from these figures by weighting each detailed industry by its share in value of output for all manufacturing. Weighting in this manner highlights the fact that larger industries tended to suffer greater losses in productivity growth than their smaller counterparts. Overall, the U.S. manufacturing sector attained a level of multifactor productivity in 1986 that was 11.4% lower than it would have attained, absent the growth in environmental and occupational health regulation since 1974.

Figure V.1 plots the index of potential productivity (PI_{it}) for the 1974-86 period along with the index of productivity actually achieved (I_{it}) from Figure II.1. By construction, both indexes equal 1.0 in 1974. They diverge thereafter, with the shortfall of actual compared to potential productivity growing each year.

36. U.S. ENVTL. PROTECTION AGENCY, NATIONAL AIR POLLUTANT EMISSION TRENDS, 1900-1992 (1993).

VI. Discussion of Econometric Results

In the long run, the economic impact of environmental and occupational health regulation depends primarily on their influence on the rate of innovation and the growth in multifactor productivity. This, in turn, depends on three factors: the trend in direct compliance expenditures, the impact of these compliance costs on innovation and productivity growth in each individual year, and the cumulative impact of the innovation and productivity effects over multiple years. This study has presented evidence on the direction and magnitude of each of these factors.

The trend in direct expenditures due to EPA and OSHA regulation depends on the number of new regulatory initiatives and on management's ability to comply with these mandates in an efficient manner. The published case studies of regulation have documented management's ability to develop methods of compliance that are cheaper than initially envisioned, precisely because they have an economic incentive to do so. Cost-reducing management responses to regulation appear to have been overwhelmed, however, by the increased number and complexity of new regulations. Regulatory compliance costs in manufacturing industries grew during the 1974-1986 period both in absolute terms and, more importantly, relative to overall manufacturing costs and revenues. As presented in Figure III.C.1, direct compliance expenditures as a fraction of value of shipments more than doubled during this twelve year period, from 0.46% in 1974 to 1.14% in 1986. This trend is due primarily to environmental regulation; as a fraction of industry costs and revenues, compliance expenditures for occupational health regulation peaked in 1980 and declined thereafter.

Whatever the trend in direct compliance expenditures, it is important to focus on the indirect economic impact of environmental and occupational health regulation on innovation and productivity growth. The data analyzed in this study reveal no "technology-forcing" impact of environmental and occupational health regulation for the manufacturing sector as a whole. Expenditures by management to comply with EPA and OSHA mandates appear to have retarded rather than promoted the growth in multifactor productivity during the 1974-86 period. The incremental impact of compliance expenditures on productivity is significantly negative regardless of whether one uses an index of multifactor productivity, an econometric production function, year-to-year changes in multifactor productivity, or a first-differenced specification of the production function. Similar point estimates are obtained from the pooled 1974-86 data and for each year individually. This does not imply that individual regulations have not spurred productivity-enhancing innovation in some instances; on the contrary, the case study literature documents numerous examples.[37] However, these productivity-increasing instances are outweighed by the productivity-decreasing instances, and the net effect on productivity growth is negative.

The incremental impact of EPA and OSHA regulation on the manufacturing sector as a whole, calculated as the weighted average of annual impacts for the 445 detailed industries, grew from a 1.1% annual reduction in multifactor productivity in 1974-75 to a 2.5% annual reduction in 1985-86. However, the most important findings of this study concern the cumulative impact of environmental and occupational health regulation over time, as distinct from the incremental effect in any one year. The productivity-reducing effect of one year's regulatory compliance lowers the base upon which the next year must build. Small annual effects snowball into more substantial productivity deficits. The cumulative impact of regulation is analogous to the cumulative impact of compound rates of interest, but with the opposite effect on economic assets. The cumulative effect through 1986 on the manufacturing sector as a whole, computed as the weighted mean of impacts on the 445 detailed industries, was to reduce multifactor productivity by 11.4% from the level it would have achieved absent EPA and OSHA regulation.

The productivity effects obtained using these detailed industry data from one major sector of the economy, manufacturing, are consistent with results reported in other studies that use more aggregated industry data from the economy as a whole. Hazilla and Kopp model the adjustments in prices, output, and employment that occurred in thirty-six major (two digit SIC) manufacturing and nonmanufacturing industries between 1974 and 1990 due to environmental regulation.[38] They note that the engineering estimates of regulatory compliance developed by EPA significantly overstate the direct costs of compliance while ignoring the indirect costs. As firms incur pollution control costs, they raise prices to consumers, who then reduce purchases. This decline in demand leads firms to reduce output, which reduces direct pollution abatement costs (and all other production costs) and, in turn, employment. Employment falls more slowly than output in regulated industries, however, and this results in a decline in productivity. Analogous impacts of environmental regulation are reported by Jorgenson and Wilcoxon, who analyze thirty-

37. *See generally* Nicholas A. Ashford & George R. Heaton, Jr., *Regulation and Technological Innovation in the Chemical Industry*, 46 L. & CONTEMP. PROBS. 109 (1983).

38. Michael Hazilla & Raymond J. Kopp, *Social Costs of Environmental Quality Regulations: A General Equilibrium Analysis*, 98 J. POL. ECON. 853 (1990).

five major manufacturing and nonmanufacturing industries within a general equilibrium model.[39] They conclude that the cumulative impact of environmental regulation between 1973 and 1985 was to reduce output in the economy as a whole by 2.6% in 1985, compared to what it would have been without regulation.

Conclusion

The productivity-reducing burden of past regulation haunts the future of environmental and occupational health policy. A significant fraction of American legislators now apparently believe that EPA and OSHA are imposing costs on society out of proportion to the benefits they generate. The regulatory agencies are besieged with demands for more formalized risk assessments and cost-benefit studies, which proponents assume will conclude that less rather than more regulation is needed.[40] This revolt against regulation is emerging now partly due to special political circumstances. In part, however, the current challenge to environmental and occupational health policy indicates the cumulative effects of regulation on economic performance over many years.

It is customary for discussions of the economic impact of environmental and occupational health regulation to conclude with a plea for more cost-effective policies. Cost-effective regulation mandates ends but not means, establishes incentives but does not dictate methods of compliance.[41] Choice-preserving rather than choice-constraining initiatives encourage management to develop new and cheaper methods for achieving the desired goal. These principles have enjoyed increasing acceptance in policy circles in recent years, as witnessed by the plethora of emissions trading, pollution tax, information disclosure, and related initiatives.[42]

The indirect impact of EPA and OSHA regulation on productivity growth has received less prominence in political debates. In part this may have been due to an artificial separation between short run and long run economic performance, the former being ascribed to visible direct

39. *See* Dale W. Jorgenson & Peter J. Wilcoxen, *Environmental Regulation and U.S. Economic Growth*, 21 RAND J. ECON. 314 (1990).

40. *Special Analysis of Contracting for Regulatory Relief*, 18 CHEMICAL REG. REP. (BNA) S3-22 (1995).

41. Bruce A. Ackerman & Richard B. Stewart, *Reforming Environmental Law: The Democratic Case for Market Incentives*, 13 COLUM. J. ENVTL. L. 171 (1988); Breger et al., *supra* note 14; Richard B. Stewart, *Regulation, Innovation, and Administrative Law: A Conceptual Framework*, 69 CAL. L. REV. 1259 (1981).

42. R.W. Hahn, *Economic Prescriptions for Environmental Problems: How the Patient Followed the Doctor's Orders*, 3 J. ECON. PERSP. 95 (1989).

expenditures and the latter to less visible determinants of technological change. A common thread, however, ties together the policy implications of the direct cost of regulatory compliance and the indirect productivity impacts. In both cases the solution lies in innovation. Public policy demands incentives and institutions that encourage management to design environmental and occupational health concerns in from the beginning and to maintain those concerns throughout the cycle of production and distribution.

In their first two decades, EPA and OSHA pursued command and control policies in hopes of forcing technological innovation. Despite important gains in environmental quality and occupational health protection, their economic impact was significantly negative. The challenge today is to pursue incentive-conscious policies that stimulate technological innovation and facilitate continuous organizational adaptation to changing environmental and economic opportunities.

TABLE II.1

INDEX OF MULTIFACTOR PRODUCTIVITY FOR 445 MANUFACTURING INDUSTRIES, 1974-86.

YEAR	5TH PERCENTILE	FIRST QUARTILE	MEDIAN	THIRD QUARTILE	95TH PERCENTILE
1974	1.000	1.000	1.000	1.000	1.000
1975	0.873	0.949	0.982	1.017	1.069
1976	0.877	0.953	1.000	1.040	1.106
1977	0.868	0.956	1.002	1.053	1.149
1978	0.863	0.957	1.008	1.058	1.167
1979	0.848	0.945	1.001	1.056	1.165
1980	0.824	0.924	0.980	1.047	1.172
1981	0.818	0.913	0.979	1.043	1.171
1982	0.796	0.903	0.978	1.055	1.212
1983	0.799	0.914	0.994	1.081	1.245
1984	0.823	0.929	1.007	1.096	1.264
1985	0.807	0.944	1.013	1.104	1.318
1986	0.814	0.944	1.024	1.117	1.334

FIGURE II.1

MULTIFACTOR PRODUCTIVITY IN US MANUFACTURING, 1974-86.

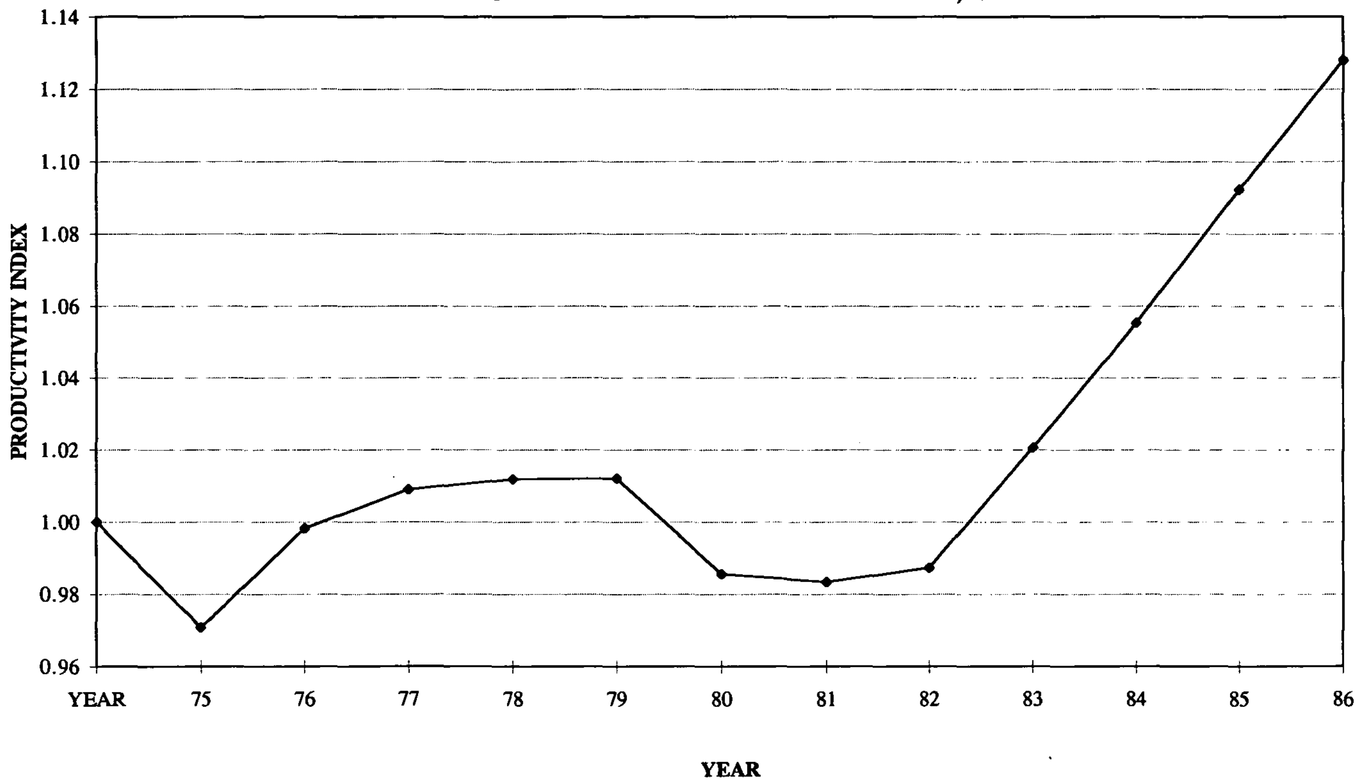

TABLE II.2

ANNUAL CHANGES IN MULTIFACTOR PRODUCTIVITY FOR 445 MANUFACTURING INDUSTRIES, 1974-86.

YEAR	5TH PERCENTILE	FIRST QUARTILE	MEDIAN	THIRD QUARTILE	95TH PERCENTILE
1974-75	-0.127	-0.051	- 0.018	0.017	0.069
1975-76	-0.050	-0.003	0.018	0.042	0.094
1976-77	-0.084	-0.018	0.009	0.035	0.094
1977-78	-0.065	-0.017	0.005	0.024	0.073
1978-79	-0.077	-0.029	- 0.005	0.021	0.071
1979-80	-0.094	-0.043	- 0.014	0.013	0.071
1980-81	-0.067	-0.025	- 0.003	0.022	0.085
1981-82	-0.100	-0.032	0.005	0.033	0.093
1982-83	-0.060	-0.013	0.022	0.049	0.108
1983-84	-0.060	-0.005	0.019	0.046	0.102
1984-85	-0.060	-0.015	0.008	0.033	0.086
1985-86	-0.067	-0.014	0.011	0.038	0.084

FIGURE II.2
ANNUAL CHANGES IN MULTIFACTOR PRODUCTIVITY IN US MANUFACTURING, 1974-86.

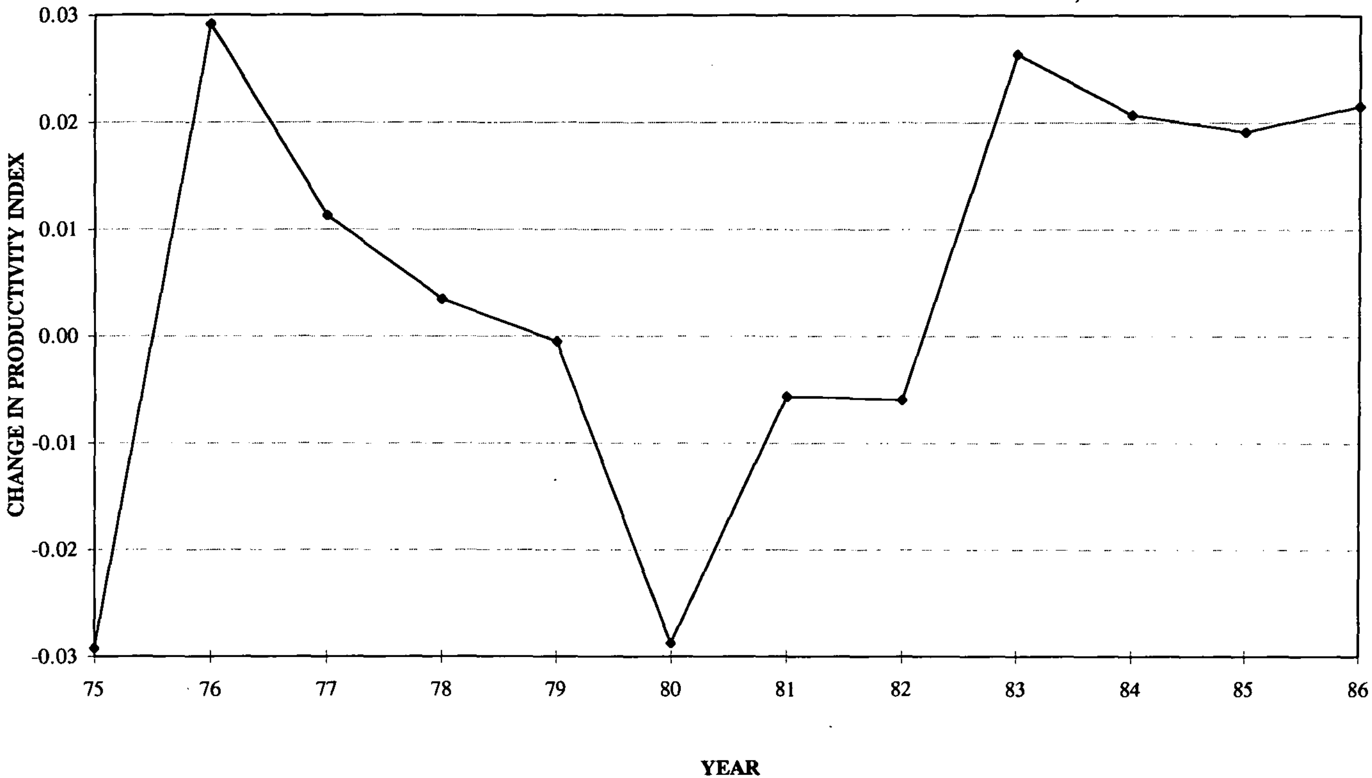

TABLE III.A.1

POLLUTION ABATEMENT EXPENDITURES AS A PERCENT OF VALUE OF SHIPMENTS FOR MAJOR MANUFACTURING SECTORS, 1974-86.

SIC	INDUSTRY SECTOR	1974	1980	1986
20	FOOD AND KINDRED PRODUCTS	0.178	0.351	0.516
21	TOBACCO PRODUCTS	0.135	0.214	0.327
22	TEXTILE MILL PRODUCTS	0.171	0.437	0.527
23	APPAREL & OTHER TEXTILE PRODUCTS	0.000	0.000	0.000
24	LUMBER & WOOD PRODUCTS	0.362	0.594	0.683
25	FURNITURE & FIXTURES	0.217	0.314	0.455
26	PAPER & ALLIED PRODUCTS	1.112	2.223	2.575
27	PRINTING & PUBLISHING	0.074	0.112	0.185
28	CHEMICALS & ALLIED PRODUCTS	1.089	2.051	2.776
29	PETROLEUM & COAL PRODUCTS	1.056	1.149	2.978
30	RUBBER & MISCELLANEOUS PLASTICS PRODUCTS	0.247	0.363	0.459
31	LEATHER & LEATHER PRODUCTS	0.165	0.413	1.007
32	STONE, CLAY & GLASS PRODUCTS	0.932	1.319	1.600
33	PRIMARY METAL INDUSTRIES	0.874	2.448	3.671
34	FABRICATED METAL PRODUCTS	0.201	0.322	0.572
35	INDUSTRIAL MACHINERY & EQUIPMENT	0.126	0.211	0.260
36	ELECTRONIC & OTHER ELECTRIC EQUIPMENT	0.159	0.272	0.431
37	TRANSPORTATION EQUIPMENT	0.178	0.362	0.485
38	INSTRUMENTS & RELATED PRODUCTS	0.179	0.270	0.418
39	MISCELLANEOUS MANUFACTURING INDUSTRIES	0.166	0.191	0.436

TABLE III.B.1

OCCUPATIONAL HEALTH EXPENDITURES AS A PERCENT OF VALUE OF SHIPMENTS FOR MAJOR MANUFACTURING SECTORS, 1974-86.

SIC	INDUSTRY SECTOR	1974	1980	1986
20	FOOD AND KINDRED PRODUCTS	0.000	0.000	0.000
21	TOBACCO PRODUCTS	0.000	0.000	0.000
22	TEXTILE MILL PRODUCTS	0.000	0.153	0.032
23	APPAREL & OTHER TEXTILE PRODUCTS	0.000	0.000	0.000
24	LUMBER & WOOD PRODUCTS	0.000	0.000	0.000
25	FURNITURE & FIXTURES	0.000	0.000	0.000
26	PAPER & ALLIED PRODUCTS	0.000	0.008	0.002
27	PRINTING & PUBLISHING	0.000	0.000	0.000
28	CHEMICALS & ALLIED PRODUCTS	0.027	0.050	0.019
29	PETROLEUM & COAL PRODUCTS	0.000	0.003	0.000
30	RUBBER & MISCELLANEOUS PLASTICS PRODUCTS	0.000	0.008	0.001
31	LEATHER & LEATHER PRODUCTS	0.000	0.000	0.000
32	STONE, CLAY & GLASS PRODUCTS	0.000	0.105	0.028
33	PRIMARY METAL INDUSTRIES	0.000	0.197	0.028
34	FABRICATED METAL PRODUCTS	0.000	0.000	0.000
35	INDUSTRIAL MACHINERY & EQUIPMENT	0.000	0.000	0.000
36	ELECTRONIC & OTHER ELECTRIC EQUIPMENT	0.000	0.099	0.039
37	TRANSPORTATION EQUIPMENT	0.000	0.002	0.000
38	INSTRUMENTS & RELATED PRODUCTS	0.000	0.000	0.029
39	MISCELLANEOUS MANUFACTURING INDUSTRIES	0.000	0.001	0.000

TABLE III.C.1

POLLUTION ABATEMENT AND OCCUPATIONAL HEALTH EXPENDITURES AS A PERCENT OF VALUE OF SHIPMENTS FOR 445 MANUFACTURING INDUSTRIES, 1974-86.

YEAR	5TH PERCENTILE	FIRST QUARTILE	MEDIAN	THIRD QUARTILE	95TH PERCENTILE
1974	0.000	0.070	0.153	0.317	1.580
1975	0.000	0.079	0.172	0.386	2.069
1976	0.000	0.087	0.196	0.418	2.550
1977	0.000	0.096	0.209	0.425	2.847
1978	0.000	0.119	0.218	0.465	2.765
1979	0.000	0.160	0.266	0.629	3.428
1980	0.000	0.165	0.282	0.573	3.269
1981	0.000	0.169	0.276	0.641	3.278
1982	0.000	0.144	0.286	0.611	3.808
1983	0.000	0.198	0.364	0.732	3.878
1984	0.000	0.175	0.328	0.751	3.557
1985	0.000	0.193	0.380	0.806	3.866
1986	0.000	0.220	0.442	0.912	4.487

FIGURE III.C.1

POLLUTION ABATEMENT AND OCCUPATIONAL HEALTH EXPENDITURES AS A PERCENT OF VALUE OF SHIPMENTS IN US MANUFACTURING, 1974-86.

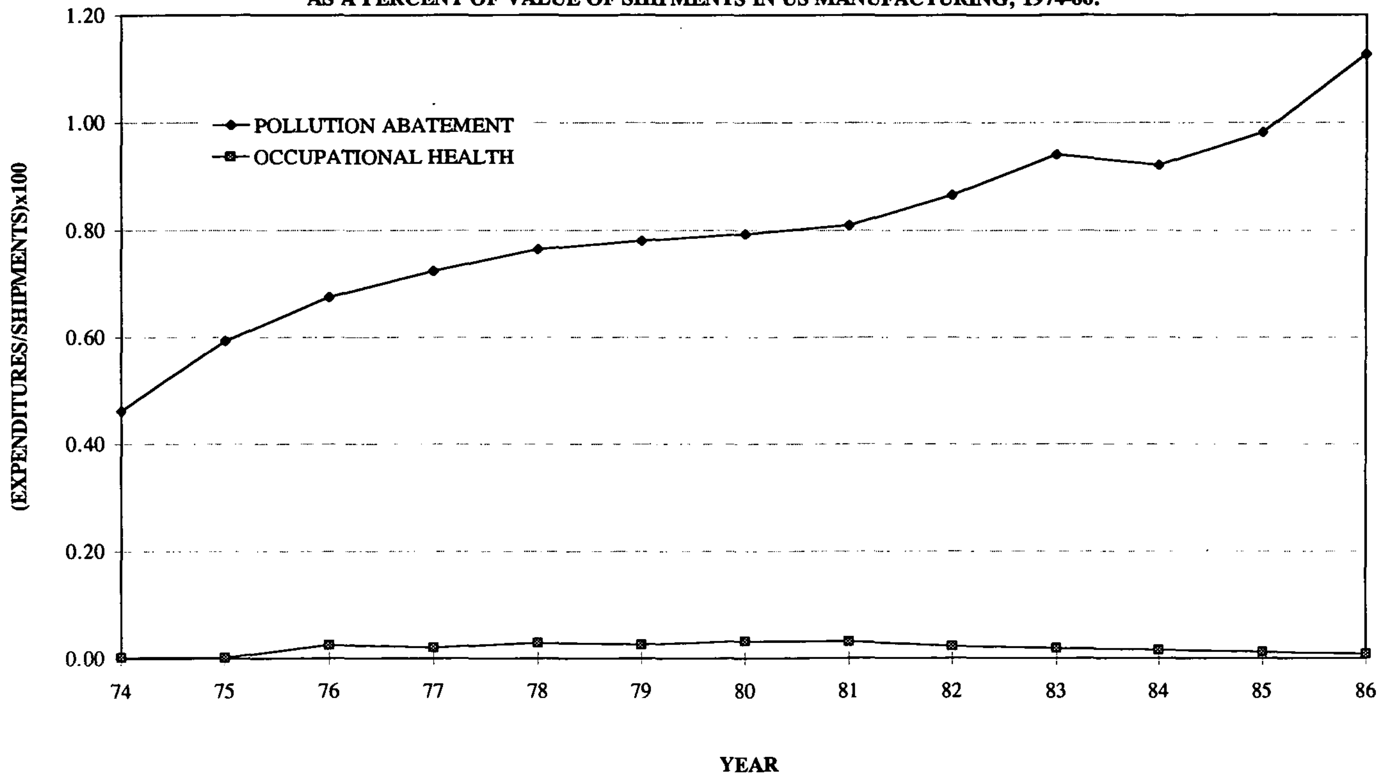

TABLE III.C.2

ANNUAL CHANGES IN POLLUTION ABATEMENT AND OCCUPATIONAL HEALTH EXPENDITURES AS A FRACTION OF VALUE OF SHIPMENTS FOR 445 MANUFACTURING INDUSTRIES, 1974-86.

YEAR	5TH PERCENTILE	FIRST QUARTILE	MEDIAN	THIRD QUARTILE	95TH PERCENTILE
1974-75	-0.071	0.000	0.018	0.074	0.637
1975-76	-0.112	-0.006	0.007	0.047	0.368
1976-77	-0.221	-0.026	0.001	0.046	0.322
1977-78	-0.165	-0.015	0.007	0.055	0.327
1978-79	-0.197	-0.010	0.031	0.114	0.694
1979-80	-0.626	-0.035	0.007	0.089	0.341
1980-81	-0.180	-0.023	0.002	0.028	0.330
1981-82	-0.414	-0.060	0.000	0.066	0.654
1982-83	-0.200	0.000	0.041	0.122	0.474
1983-84	-0.535	-0.088	-0.012	0.058	0.404
1984-85	-0.169	0.000	0.028	0.091	0.590
1985-86	-0.135	-0.003	0.033	0.106	0.641

FIGURE III.C.2

ANNUAL CHANGES IN POLLUTION ABATEMENT AND OCCUPATIONAL HEALTH EXPENDITURES AS A PERCENT OF VALUE OF SHIPMENTS IN US MANUFACTURING, 1974-86.

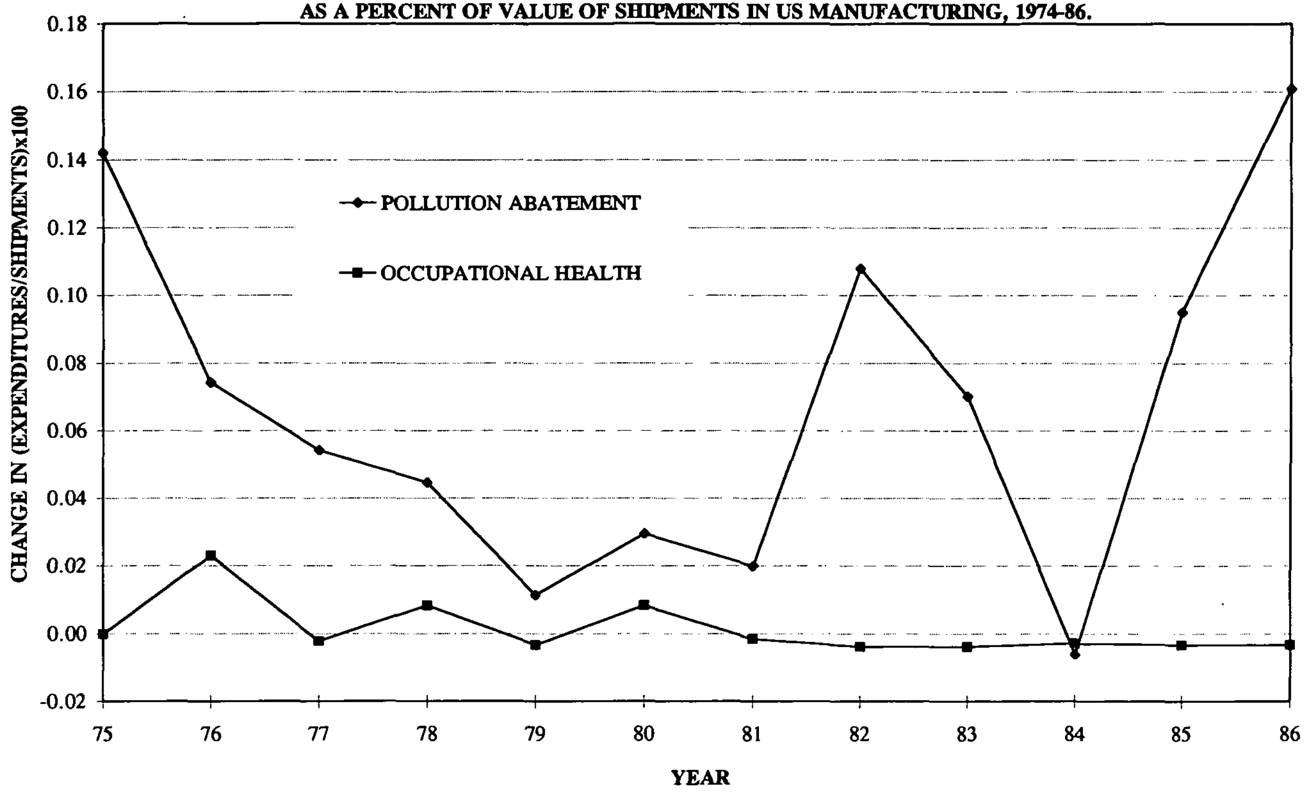

TABLE IV.1

THE SEPARATE IMPACTS OF EPA AND OSHA REGULATION: PARAMETER ESTIMATES FOR ALL YEARS 1974-86 (N=5340)

	PRODUCTIVITY INDEX (1974=1.00)	LOG OF INDUSTRY OUTPUT	PRODUCTIVITY GROWTH RATE	CHANGE IN INDUSTRY OUTPUT
EPA ONLY	-0.016 ***	-0.022 ***	-0.026 ***	-0.021 ***
OSHA ONLY	-0.001	0.005	-0.001	-0.001
ADJUSTED R2	0.17	0.99	0.08	0.86

NOTE: All regressions include 11 year variables.
Regressions in columns 1 and 2 also include 19 two-digit SIC industry sector variables.

* $p < .10$
** $p < .05$
*** $p < .01$

TABLE IV.2

THE COMBINED IMPACT OF EPA AND OSHA REGULATION: PARAMETER ESTIMATES FOR INDIVIDUAL YEARS, 1975-86 (N=445)

YEAR	PRODUCTIVITY INDEX (1974=1.00)	LOG OF INDUSTRY OUTPUT	PRODUCTIVITY GROWTH RATE	CHANGE IN INDUSTRY OUTPUT
1975	-0.016 ***	-0.021 *	-0.054 ***	-0.035 ***
1976	-0.017 ***	-0.024 **	-0.030 ***	-0.035 ***
1977	-0.016 ***	-0.028 ***	-0.009	-0.011
1978	-0.016 ***	-0.027 ***	-0.010	-0.008
1979	-0.017 ***	-0.034 ***	-0.015 ***	-0.013 ***
1980	-0.016 ***	-0.023 ***	-0.013 ***	-0.002
1981	-0.016 ***	-0.025 ***	-0.025 ***	-0.025 ***
1982	-0.018 ***	-0.019 ***	-0.047 ***	-0.039 ***
1983	-0.019 ***	-0.019 ***	-0.030 ***	-0.024 ***
1984	-0.012 **	-0.016 ***	-0.015 **	-0.012 **
1985	-0.007	-0.022 ***	-0.012 *	-0.040 ***
1986	-0.015 ***	-0.018 ***	-0.046 ***	-0.023 ***
1975-86 (N=5340)	-0.015 ***	-0.021 ***	-0.025 ***	-0.020 ***

NOTE: * $p<.10$
** $p<.05$
*** $p<.01$

TABLE V.1

ANNUAL REDUCTION IN THE INDEX OF MULTIFACTOR PRODUCTIVITY (1974=1.00) DUE TO EPA AND OSHA REGULATION FOR MAJOR MANUFACTURING SECTORS, 1975-86.

SIC	INDUSTRY	1975	1980	1986
20	FOOD AND KINDRED PRODUCTS	0.003	0.006	0.008
21	TOBACCO PRODUCTS	0.003	0.003	0.005
22	TEXTILE MILL PRODUCTS	0.003	0.009	0.008
23	APPAREL & OTHER TEXTILE PRODUCTS	0.000	0.000	0.000
24	LUMBER & WOOD PRODUCTS	0.007	0.010	0.010
25	FURNITURE & FIXTURES	0.005	0.005	0.007
26	PAPER & ALLIED PRODUCTS	0.025	0.036	0.039
27	PRINTING & PUBLISHING	0.001	0.002	0.003
28	CHEMICALS & ALLIED PRODUCTS	0.022	0.034	0.042
29	PETROLEUM & COAL PRODUCTS	0.021	0.018	0.045
30	RUBBER & MISCELLANEOUS PLASTICS PRODUCTS	0.005	0.006	0.007
31	LEATHER & LEATHER PRODUCTS	0.003	0.007	0.015
32	STONE, CLAY & GLASS PRODUCTS	0.018	0.023	0.024
33	PRIMARY METAL INDUSTRIES	0.023	0.042	0.055
34	FABRICATED METAL PRODUCTS	0.004	0.005	0.009
35	INDUSTRIAL MACHINERY & EQUIPMENT	0.002	0.003	0.004
36	ELECTRONIC & OTHER ELECTRIC EQUIPMENT	0.003	0.006	0.007
37	TRANSPORTATION EQUIPMENT	0.003	0.006	0.007
38	INSTRUMENTS & RELATED PRODUCTS	0.003	0.004	0.007
39	MISCELLANEOUS MANUFACTURING INDUSTRIES	0.003	0.003	0.007

FIGURE V.1
REGULATION AND MULTIFACTOR PRODUCTIVITY IN US MANUFACTURING, 1974-86.

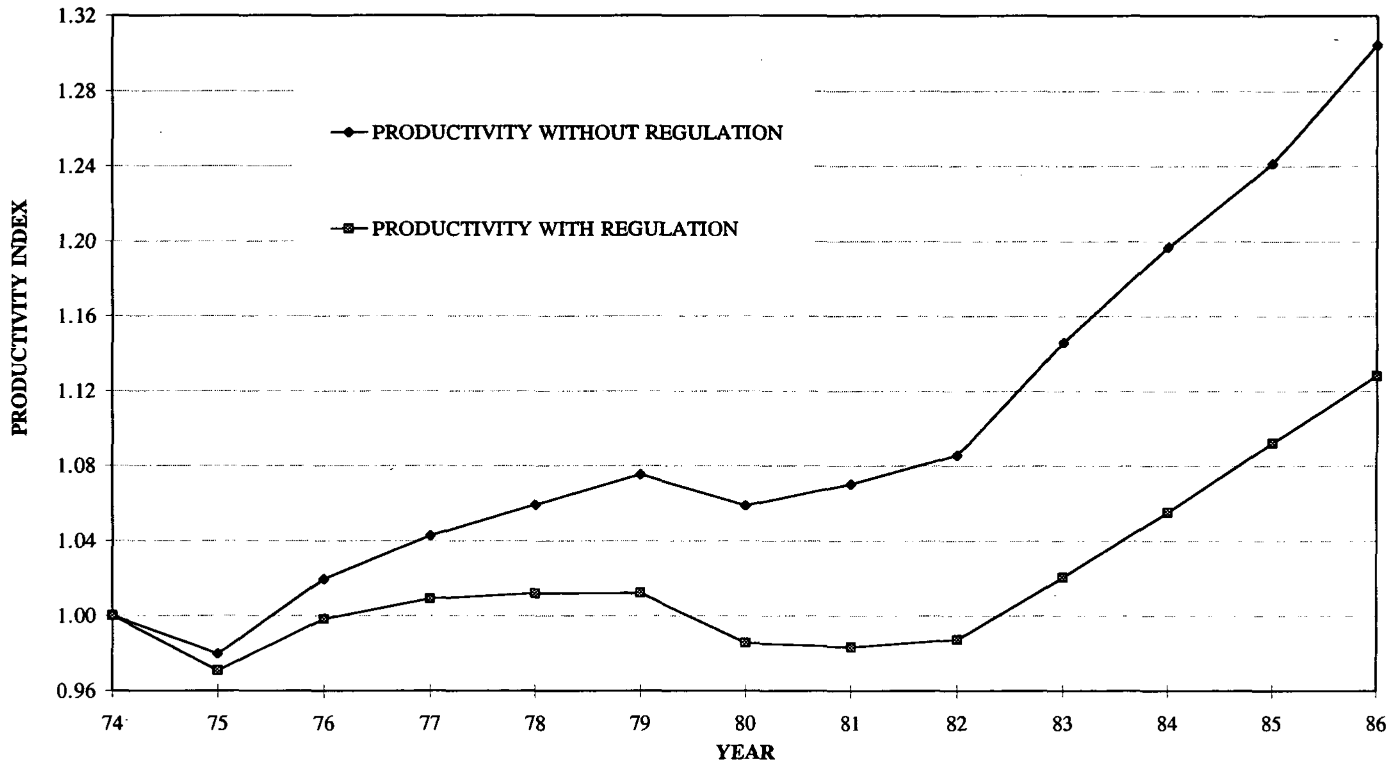

TABLE V.2

CUMULATIVE PERCENTAGE REDUCTION IN PRODUCTIVITY DUE TO EPA AND OSHA REGULATION FOR MAJOR MANUFACTURING SECTORS, 1975-86.

SIC	INDUSTRY	1975	1980	1986
20	FOOD AND KINDRED PRODUCTS	0.333	2.707	6.132
21	TOBACCO PRODUCTS	0.252	1.909	4.081
22	TEXTILE MILL PRODUCTS	0.331	3.688	7.528
23	APPAREL & OTHER TEXTILE PRODUCTS	0.000	0.000	0.000
24	LUMBER & WOOD PRODUCTS	0.737	4.390	9.447
25	FURNITURE & FIXTURES	0.465	2.845	5.721
26	PAPER & ALLIED PRODUCTS	2.371	16.070	27.396
27	PRINTING & PUBLISHING	0.132	0.918	2.119
28	CHEMICALS & ALLIED PRODUCTS	2.152	15.411	28.037
29	PETROLEUM & COAL PRODUCTS	2.037	12.667	25.267
30	RUBBER & MISCELLANEOUS PLASTICS PRODUCTS	0.487	3.197	6.359
31	LEATHER & LEATHER PRODUCTS	0.316	2.751	6.327
32	STONE, CLAY & GLASS PRODUCTS	1.712	10.469	19.412
33	PRIMARY METAL INDUSTRIES	2.225	17.400	31.527
34	FABRICATED METAL PRODUCTS	0.363	2.554	6.227
35	INDUSTRIAL MACHINERY & EQUIPMENT	0.239	1.692	3.209
36	ELECTRONIC & OTHER ELECTRIC EQUIPMENT	0.308	2.265	5.294
37	TRANSPORTATION EQUIPMENT	0.314	2.254	5.667
38	INSTRUMENTS & RELATED PRODUCTS	0.348	2.395	5.486
39	MISCELLANEOUS MANUFACTURING INDUSTRIES	0.268	1.607	4.164

TABLE V.3

CUMULATIVE PERCENTAGE REDUCTION IN PRODUCTIVITY
DUE TO EPA AND OSHA REGULATION
FOR 445 MANUFACTURING INDUSTRIES, 1975-86.

YEAR	5TH PERCENTILE	FIRST QUARTILE	MEDIAN	THIRD QUARTILE	95TH PERCENTILE
1975	0.000	0.127	0.275	0.613	3.204
1976	0.000	0.280	0.626	1.323	7.260
1977	0.000	0.442	0.941	1.984	11.479
1978	0.000	0.629	1.305	2.650	15.297
1979	0.000	0.918	1.793	4.025	19.992
1980	0.000	1.242	2.219	4.999	24.194
1981	0.000	1.546	2.659	5.945	27.433
1982	0.000	1.795	3.197	7.036	33.090
1983	0.000	2.321	3.874	8.081	38.495
1984	0.000	2.545	4.324	8.907	40.940
1985	0.000	2.694	4.569	9.428	42.263
1986	0.000	3.097	5.225	10.699	45.382