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THE MACROECONOMIC IMPACTS OF FEDERAL ENVIRONMENTAL REGULATION

PAUL R. PORTNEY*

As the introduction to this volume points out, environmental and other "social" regulation is suspected of being partly responsible for current economic problems in the United States.[1] This article discusses the expenditures necessitated by federal environmental regulations and the effects of these expenditures on prices, employment, real output, foreign trade, and other measures of economic performance. Because of the breadth of this subject, however, and the great number of studies addressing one or another aspect of it, attention here is focused on the use of large-scale, quarterly econometric models of the United States to examine these effects.[2] While these macroeconomic analyses perforce devote less attention to specific effects–say, those of regulation on trade–than do studies concentrating on single issues, they are comprehensive and integrated, and are of value for that reason.

The first part of this article discusses estimates of expenditures by households, industry, and governmental units that are required in order to comply with federal environmental regulation. The difference between these expenditures and the broader notion of the social

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1. "Social" regulation is usually taken to mean that practiced by the Environmental Protection Agency, the Occupational Safety and Health Administration, the Consumer Product Safety Commission, the Food and Drug Administration, and the National Highway Transportation and Safety Administration. It is sometimes contrasted with what is now called "economic" regulation–that governing price and entry, as exemplified by the Interstate Commerce Commission, the Civil Aeronautics Board, and the Federal Communications Commission.

This distinction between social and economic regulation is an artificial and misleading one, however. Just as economic regulation is intended to correct one kind of market failure –natural monopoly–social regulation is intended to address another–that arising from externalities or imperfect information. Therefore, there is nothing inherently "uneconomic" about social regulation.

2. Other authors have considered a wide range of different methods of determining the economic impact of environmental regulations. *See, e.g.*, G. Christainsen, F. Gollop, & R. Haveman, Environmental and Health-Safety Regulations, Productivity Growth, and Economic Performance: an Assessment (1980) (report prepared for the Office of Technology Assessment of the Joint Economic Committee of the United States Congress). For a comprehensive analysis of the effects of air pollution controls, *see* A. Rose, Assessing the Economic Impact of Air Pollution Abatement (March 1981) (working paper no. 53, Department of Economics, University of California at Riverside).

costs of regulation is also discussed. Because of the importance of expenditure estimates for macroeconomic simulation studies–what goes in, after all, in large part determines what comes out–special attention is given to the difficulties inherent in making such estimates. The second part of the paper, "Models and Results," reviews the methodology employed and results obtained in prior studies of the macroeconomic effects of regulation. The last section discusses the limitations of these macroeconomic studies, the care with which the results should be interpreted, and the ways in which future studies can be improved.

The final section of the paper, as well as the two that precede it, should impart a clear message to readers: while they are valuable if interpreted carefully, the macroeconomic simulation studies discussed are limited in what they can tell us. This is due to the limitations of econometric models and the unavoidably flawed expenditure estimates that drive them. Both these problems receive considerable attention in this article, but it is useful to highlight them here.

SPENDING FOR POLLUTION CONTROL

The econometric models discussed in the second section are defined in terms of the aggregates recorded in the national income and product accounts.[3] That is, the models are driven in large part by the expenditure decisions of households, private businesses, and federal, state, and local governments. Therefore, before these models can be used to evaluate the effects of environmental regulation, the "input" to the models must first be specified. In other words, it must be determined which commercial and industrial establishments, households, and governmental units will be affected by the regulations in question; how much, if anything, they will have to spend to comply with the regulations, and over what period of time; and how they will go about meeting these expenditures.[4]

Expenditures and Costs

To this point I have been careful to refer to the data which drive the simulation studies as pollution control *expenditures* rather than pollution control *costs.* To the layman, this distinction may seem unnecessary. Nevertheless, pollution control expenditures may be

3. For a discussion of these accounts, *see* Peskin's paper in this volume.

4. For example, will government finance pollution control expenditures by increasing taxes or by reducing other expenditures? Will business pay for pollution control by additional borrowing, out of retained earnings, or through the issuance of stock?

greater than or less than pollution control costs as economists define them.[5] The size of both is important.

To illustrate the difference between these two concepts, suppose a firm purchases pollution control equipment mandated by law and hires people to operate and maintain it. Part of the expenditures the firm makes includes the sales taxes on the equipment it purchases as well as the payroll taxes it pays for its employees. However, while properly counted as pollution control expenditures, these tax payments are not social or opportunity costs of pollution control because they do not preclude other uses. Rather, these tax payments are transfers from the firm to the government, which uses them for other purposes. In some cases, then, observed pollution control expenditures can exceed the social cost of pollution control.

However, the opportunity cost of pollution control can also be greater than expenditures on pollution control. For example, when firms devote land they already own to pollution control, they do not make an expenditure but they certainly do incur a cost–the forgone use of the land.[6] The social cost of pollution control is equal to observed direct expenditures plus the forgone opportunities from the use of the land.

The social or economic cost of pollution control can diverge from direct expenditures in other important ways. For instance, when a firm installs pollution control equipment, it must generally increase its prices to offset at least part of the increased capital and operating cost.[7] When this increase is reflected in higher final product prices, some consumers will postpone or forgo purchases they would have made at the earlier, lower prices. When this happens, another "hidden" social cost arises that is nowhere reflected in pollution control expenditures–this is the loss in what economists call "consumers' surplus," a loss properly counted in the social costs of pollution control. This loss arises because consumers are generally willing to pay somewhat more for the goods they buy than the prices they are ac-

5. To economists, costs are opportunities forgone. Thus, the true economic cost of pollution control is measured by what might have been done with the resources had they been put to their highest and best use.

6. For discussion and analysis of the use of tax-exempt bonds for pollution control, *see* G. Peterson & H. Galper, *Tax Exempt Financing of Private Industry's Pollution Control Investment,* 23 PUB. POL'Y (1975). This provision does not drive a wedge between expenditures and costs, but it does create a disparity between the private and social costs of pollution control.

7. If the firm faces foreign or domestic competition that does not also incur such costs, it may have to pay for pollution control out of reduced factor payments or profits. Generally, however, most producers will face cost increases, hence prices will rise to cover at least part of these higher costs.

tually charged—this excess is consumers' surplus. When high prices choke off demand, those no longer buying the product lose any consumers' surplus they would have enjoyed on the units they would have bought. This forgone opportunity for gain, then, is an economic or social cost of pollution control. The appendix to this article attempts to estimate for a particular case how large this forgone consumers' surplus may be in relation to recorded expenditures on pollution control in one industry.

While it is important to distinguish between expenditures and costs, each concept has its uses. As suggested above, expenditure data are used in both macro- and microeconomic analyses of the effects of regulation on inflation, unemployment, economic growth, and other aggregates. Data on expenditures can also be used to modify the conventional national income and product accounts to reflect the role of environmental protection on gross national product (GNP).[8] Also, estimates of the size and timing of future pollution control expenditures can help indicate where and when difficulties might arise in financing these expenditures. They might indicate whether, for example, public and private borrowing for pollution control will "crowd out" other potential borrowing.

Estimates of the social or resource costs of pollution control, on the other hand, are used in evaluating the welfare effects of environmental regulation. It is the resource or opportunity cost of pollution control that is compared with individuals' willingness to pay for resulting environmental quality in properly done cost-benefit analyses. As indicated in the introduction to this volume, it is this comparison of benefits and costs that indicates the desirability of a regulation or set of regulations from the standpoint of economic efficiency. Macroeconomic studies like those to be discussed later help to understand the way some of the costs of regulation are manifested in the economy. By determining whether unemployment, higher prices, or some combination of these and other effects will result from regulation, we can assess its distributional as well as its allocative effects.

Before turning to the available evidence on pollution control expenditures, one other distinction is worth drawing—that between incremental and total expenditures. Here, incremental expenditures are those that are made in response to federal environmental regulations.[9] Coupled with voluntary spending for pollution control and spending

8. *See* note 3, *supra.*

9. Of course, expenditures can be incremental to whatever baseline one desires. Since we are interested here in the effects of federal environmental regulation, that is the increment we consider.

necessitated by state and local rules and regulations, these incremental expenditures combine to form total pollution abatement expenditures. When econometric models are used to determine the impact of federal environmental regulations, incremental expenditures are the appropriate data to consider. If total expenditures were to be used, they might overstate considerably the effect of federal regulation.

Survey Estimates of Expenditures

Considering their importance, there are surprisingly few comprehensive estimates available of either past or future expenditures for pollution control. Sometimes the information that is available is conflicting or disparate. For example, both the Bureau of Economic Analysis (BEA) and the Bureau of the Census within the Department of Commerce conduct annual surveys to determine expenditures on pollution control. Similarly, McGraw-Hill Incorporated also surveys businesses annually to determine pollution abatement expenditures. Table 1 compares estimates from these three sources of actual capital investment in pollution abatement or control for 1978, and estimates from McGraw-Hill and BEA of planned capital expenditures for 1980.

As columns 1, 2, and 3 of the table indicate, there are considerable differences between estimates, even with respect to actual or historical capital expenditures. For example, McGraw-Hill's estimate of pollution control investment in the machinery industry in 1978 is three times that of the Census Bureau, and more than twice that of BEA. On the other hand, the Census estimate for investment in pollution control by the chemical industry is about 50 percent greater than the estimates of either McGraw-Hill or BEA. BEA's estimate for petroleum refining is more than three times that of the Census Bureau, and is 50 percent higher than McGraw-Hill's reported total. Other differences in both individual industry and total estimates are clear.

Given the discrepancies among estimates of historical expenditures for pollution abatement capital, one might expect even more divergent estimates of planned future expenditures. Columns 4 and 5 of Table 1 confirm this suspicion. According to McGraw-Hill, total planned capital expenditures for pollution abatement for all business in 1980 were $10.5 billion. This was 37 percent more than BEA projected based on its survey of manufacturing and nonmanufacturing firms. For the electric utility industry alone, the McGraw-Hill and BEA estimates of 1980 investment in pollution control differed by nearly a billion dollars. Differences like these can influence results of macroeconomic simulation studies, especially when the industry and

TABLE 1

ESTIMATED CAPITAL EXPENDITURES FOR POLLUTION CONTROL
(millions of dollars)

Industry	1978 ACTUAL (1) McG-Hill[a]	1978 ACTUAL (2) BEA[b]	1978 ACTUAL (3) Census[c]	1980 PLANNED (4) McG-Hill[d]	1980 PLANNED (5) BEA[b]
Iron and steel	$425	$441	$793	$1069	$638
Nonferrous metals	293	247		285	285
Other primary metals	–	64		–	87
Electric machinery	134	130	75	238	126
Machinery	243	111	82	196	97
Autos, trucks, parts	193	198	140	162	311
Aerospace	45	23		30	34
Fabricated metals	137	–		189	–
Instruments	58	–		146	–
Stone	207	164	127	126	176
Other durables	190	181	186	116	199
Total durables	1935	1561	1402	2559	1956
Chemicals	547	565	842	762	476
Paper/pulp	274	239	342	473	300
Rubber	100	58	28	201	58
Petroleum	834	1294	420	1625	1536
Food/Beverage	309	172	185	181	150
Textiles	81	29	60	110	36
Other nondurables	67	32	37	97	27
Total nondurables	2212	2389	1914	3450	2583
Total manufacturing	4147	3950	3316	6009	4540
Mining	511	206		109	171
Railroads	54	36		53	32
Airlines	20	15		97	13
Electric utilities	2791	2472		3615	2658
Gas utilities	60	35		61	44
Commercial	423	210		512	243
Commercial & other trans.				93	
	3859	2974		4539	3161
ALL BUSINESS	8006	6924		10,548	7699

Note: Dashes indicate no separate entry.

[a] 12th Annual McGraw-Hill Survey of Pollution Control Expenditures, May 14, 1979.

[b] Gary Rutledge and Betsy O'Connor, "Capital Expenditures by Business for Pollution Abatement, 1978, 1979, and Planned 1980," *Survey of Current Business*, June 1980.

[c] *Pollution Abatement Costs and Expenditures, 1978,* U.S. Bureau of the Census, MA-200(78)-2, U.S. G.P.O., Washington, D.C., 1980.

[d] 13th Annual McGraw-Hill Survey.

product in question is, like electricity, an important factor in the production of other goods.

There are two major reasons why these three sets of estimates diverge so. First, the Census Bureau surveys establishments or plants, while the BEA survey goes to firms. Hence, if a multidivision firm has operations in several different industries, *all* of its pollution control expenditures across all operations are attributed by BEA to its primary product. Thus, expenditures for pollution control in U.S. Steel's paintmaking operations are recorded under "steel works" in the BEA survey. This accounts for some of the differences between BEA and Census. Second, the sample sizes used by BEA, Census, and McGraw-Hill differ. The Census Bureau surveys 20,000 plants to estimate pollution control investment in the manufacturing sector. The Bureau of Economic Analysis surveys about 15,000 firms to prepare its estimate. McGraw-Hill, like BEA, bases its estimates on a sample of firms, yet they sample only 346—less than 3 percent of BEA's sample size. Hence, all three sources are trying to estimate national totals based on different sample sizes, composition, and definitions.

Several factors point toward possible upward bias of all three sets of estimates. Although the response rates for the McGraw-Hill and Census surveys are unknown, it is about 60 percent for BEA, of which at least some responses no doubt prove unusable. It is not unreasonable to expect that the firms that do respond to the survey are those that are spending considerable amounts on pollution abatement. If their experience is generalized to all firms in an industry, the resulting estimates will be high. This will be particularly true in industries with both large firms and small firms. Since many regulations exempt firms below a certain size, the effect of environmental rules on all small firms taken together could be negligible. Yet, if a number of small firms are treated as one big firm, estimates of their expenditures may be large.

Second, some respondents can be expected to have difficulty determining which portion of capital and operating expenditures is due to pollution abatement and which portion is made to improve normal operations and increase profitability. This joint cost problem is especially difficult when new facilities are constructed or existing ones are modified. The temptation in such cases is to err in the direction of large pollution control expenditures, creating a possible further upward bias to the estimates. Finally, although there is little evidence to support such a supposition, some firms may deliberately report erroneously high numbers in an attempt to cast regulation in a bad light.[10]

Engineering Estimates of Expenditures

In its annual report to the President, the Council on Environmental Quality (CEQ) also makes an estimate of total spending in the previous year on pollution abatement and control. Unlike that of the Bureau of Economic Analysis, CEQ's estimate is not based on survey data, although it has made some use of BEA analyses in preparing its estimates. Rather, the CEQ estimates are known as engineering estimates. They are based on assumptions about the type of equipment that will be required to comply with regulations, the cost of that equipment, and the number of sources that will have to install it. For example, the CEQ estimates assume that scrubbers will be required to meet new source performance standards governing sulfur dioxide emissions from coal-fired electric utilities. Similarly, it is assumed that certain existing utilities and other industrial sources will be forced to burn more expensive low-sulfur fuel oil and coal. With respect to land reclamation, the estimates assume that certain equipment will be required in order to restore strip-mined land to its approximate original contour. The cost of this equipment and its operation, then, more or less determine the resulting cost estimates.

Table 2 compares CEQ and BEA estimates of total spending between 1973 and 1978 for air and water pollution control and solid waste disposal. As the table indicates, in recent years the CEQ and BEA estimates have not differed by more than 10 percent and the cumulative totals over the six-year period 1973–78 are within 3 percent of each other.

Because BEA's estimates do not differentiate between incremental and total expenditures, they are not useful for determining the macroeconomic consequences of federal regulation. However, CEQ estimates not only total pollution control expenditures in each year, but also those expenditures which arose because of federal environmental regulations. Moreover, each year CEQ estimates incremental and total environmental quality expenditures over the next decade. These include, not only expenditures for air and water pollution control and solid waste disposal, but also those for the control of noise, pesticides, and toxic substances; for the protection of drinking water; and for land reclamation following surface and underground mining.

10. For an analysis of possible ways to elicit accurate and honest cost information from firms, *see* J. Sonstelie, Economic Incentives and the Revelation of Compliance Costs (1981) (report prepared for the Council on Environmental Quality, Washington, D.C.).

TABLE 2

ESTIMATED TOTAL EXPENDITURES ON POLLUTION CONTROL: AIR, WATER, AND SOLID WASTE*
(billions of current dollars)

Year	BEA[a]	CEQ[b]
1973	$22.3	$14.8
1974	26.2	21.6
1975	30.6	31.7
1976	34.2	34.2
1977	37.5	39.8
1978	42.3	45.9
Total	$193.1	$188.0

*Includes voluntary pollution abatement expenditures, those necessitated by state and local regulation, and those necessitated by federal environmental regulation.

[a]Gary Rutledge and Susan Trevathan, "Pollution Abatement and Control Expenditures, 1972–78," *Survey of Current Business,* February 1980, pp. 27–33.

[b]*Environmental Quality,* 1974, p. 221; *EQ,* 1975, p. 564; *EQ,* 1976, p. 167; *EQ,* 1977, p. 334; *EQ,* 1978, p. 447; *EQ,* 1979, p. 667.

In addition to these efforts, EPA is directed in the Clean Air Act and the Clean Water Act to make an annual reporting of the expenditures necessary to carry out those acts. This requirement has resulted in the publication of several such reports, the most recent of which appeared in 1979.[11] These reports deal only with air and water pollution control, although by definition they do report incremental rather than total expenditures. One major difficulty with the EPA estimates (which also are based on the engineering approach) is that they are generally out of date by the time they appear. For example, the August 1979 report did not include the effects on future incremental expenditures of the 1977 amendments to either the Clean Air Act or the Clean Water Act. Hence, the EPA estimates would have to be supplemented with additional information if they were to be used to determine the effect on the economy of current federal air or water pollution control efforts.

In fact, the estimates of air and water pollution control expenditures that CEQ reports in its most recent annual report are based in part on EPA's 1979 *Cost of Clean Air and Water,* but are augmented to take account of changes in the law and the promulgation of new

11. *See* U.S. ENVT'L PROTECTION AGENCY, THE COST OF CLEAN AIR AND WATER: A REPORT TO CONGRESS (1979).

rules and regulations between 1977 and 1979. Because CEQ's annual estimate of incremental expenditures is more current with respect to air and water pollution control than EPA's, and includes additional information as well, it is presented in Table 3. Note that expenditures are estimated for 1979, 1988, and cumulatively for the decade in between.

Several observations about the CEQ estimates are in order. First, in absolute terms, estimated expenditures on pollution abatement and environmental quality are quite substantial. The $37 billion that CEQ estimates was spent to comply with all federal environmental regulation in 1979 was about three-fourths of all federal spending on health care in the United States in that year and 62 percent of total U.S. payments for imported oil in 1979. Thus, environmental regulation requires considerably more than slight changes in the operating practices of households, businesses, and governments.

This trend is likely to continue, according to CEQ. By 1988, expenditures for pollution abatement and other environmental quality programs will grow to nearly $70 billion in constant (1979) dollars. This represents an estimated annual real rate of growth of 6.6 percent, at least twice and perhaps three times the rate of growth expected for the economy as a whole during this period. This comparison between overall economic growth on the one hand and expenditures necessitated by federal environmental regulation on the other, helps put these expenditures in a somewhat different light. For while clearly large in absolute terms, environmental control expenditures still account for a fairly small fraction of gross national product–less than 1.6 percent in 1979. If real GNP grows at a rate of 2 percent until 1988, the ratio of federally induced environmental spending to real gross national product will still be less than 2.5 percent.

For the purposes of this discussion, these ratios have additional significance. Because macroeconomic models are driven by expenditures for all purposes, and because the ratio of incremental expenditures for pollution control to GNP is small, we should not expect pollution control expenditures to have a very large direct effect on the macroeconomic aggregates of interest. That is, since expenditures induced by regulation are still small in comparison to the size of the economy, they cannot have a large effect in modeling exercises. This helps explain the results discussed in the next section.

Finally, because the CEQ estimates (and those of EPA upon which they are partially based) are engineering estimates, they, too, must be interpreted cautiously. First, the engineering approach has its own inherent bias toward overestimation. Over time, it is inevitable that

ESTIMATED INCREMENTAL POLLUTION ABATEMENT EXPENDITURES,[a] 1979–88*
(billions of 1979 dollars)

Program	1979			1988			Cumulative (1979–88)		
	Operation and maintenance	Annual capital costs[b]	Total annual costs	Operation and maintenance	Annual capital costs[b]	Total annual costs	Operation and maintenance	Capital costs[b]	Total costs
Air pollution									
Public	1.2	.3	1.5	2.0	.5	2.5	15.7	3.7	19.5
Private									
Mobile	3.2	4.9	8.1	3.7	11.0	14.7	32.1	83.7	115.8
Industrial	2.0	2.3	4.3	3.0	4.1	7.1	25.8	33.0	58.8
Electric utilities	5.5	2.9	8.4	7.6	5.7	13.3	62.3	42.7	105.0
Subtotal	11.9	10.4	22.3	16.3	21.3	37.6	136.0	163.1	299.1
Water pollution									
Public	1.7	4.3	6.0	3.3	10.0	13.3	25.1	59.2	84.3
Private									
Industrial	3.4	2.6	6.0	5.4	4.5	9.9	42.0	34.0	76.0
Electric utilities	.3	.4	.7	.3	.9	1.2	2.9	6.5	9.4
Subtotal	5.4	7.3	12.7	9.0	15.4	24.4	70.0	99.7	169.7
Solid waste									
Public	<.05	<.05	<.05	.4	.3	.7	2.6	2.0	4.6
Private	<.05	<.05	<.05	.9	.7	1.6	6.4	4.4	10.8
Subtotal	<.05	<.05	<.05	1.3	1.0	2.3	9.0	6.4	15.4
Toxic substances	.1	.2	.3	.5	.6	1.1	3.6	4.6	8.2
Drinking water	<.05	<.05	<.05	.1	.3	.4	1.3	1.4	2.7
Noise	<.05	.1	.1	.6	1.0	1.6	2.6	4.3	6.9
Pesticides	.1	<.05	.1	.1	<.05	.1	1.2	<.05	1.2
Land reclamation	.3	1.1	1.4	.3	1.2	1.5	3.8	11.5	15.3
Total	17.8	19.1	36.9	28.2	40.8	69.0	227.5	291.0	518.5

*Source: COUNCIL ON ENVT'L QUALITY, ELEVENTH ANNUAL REPORT 394 (1980).

[a]Incremental costs are those made in response to federal environmental legislation beyond those that would have been made in the absence of the legislation.

[b]Interest and depreciation.

new, less expensive means will be developed to meet environmental standards (for example, dry scrubbers and fluidized bed combustion for sulfur dioxide removal, as opposed to the wet scrubbers assumed in the estimates). Hence, actual pollution control expenditures should fall over time relative to engineering estimates of expenditures, as a result of technological innovation.

Second, actual expenditures (and costs) may fall short of engineering estimates as a result of what might be called regulatory innovation. By this I mean the redesign or reform of regulation to allow for greater flexibility in compliance.[12] EPA's "bubble" and "offset" policies are examples of this increased flexibility. Respectively, they allow individual firms to reduce pollution in the least expensive ways, and permit reductions in emissions in geographic areas to take place in locations where pollution control can be most easily accommodated. In this way, regulatory innovation can act to spur technological innovation. As more and better use is made of economic incentives and other innovative approaches to regulation, actual expenditures and costs can be expected to fall short of ex ante, engineering estimates.

A third reason why engineering estimates can be regarded as no more than broadly suggestive has to do with the open-endedness of many rules and the discretion they give to EPA. For example, Section 112 of the Clean Air Act authorizes EPA to identify and establish emissions limitations for hazardous air pollutants. Similarly, the Toxic Substances Control Act empowers EPA to establish testing requirements for many new or existing chemicals and to ban certain substances found to pose hazards to human health. Neither in these nor in other cases can we be sure of the eventual number of substances that will be controlled, the stringency of these controls, the ease with which they can be met, and their subsequent economic effects. Yet such information is necessary to determine, for simulation or other purposes, the expenditures likely to arise as a result of regulation. For these three reasons, then, the CEQ/EPA expenditure estimates should be viewed with the same caution as those based on surveys of firms or industrial plants.

Summary

What are we to conclude from all this? What is the relationship between expenditures on pollution control and the economic or social costs arising from regulation? Do existing estimates understate pollution control costs and expenditures? Can the expenditure estimates be used in macroeconomic simulations to identify aggregate impacts?

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12. *See* the paper by Harrington and Krupnick in this volume.

The following inferences seem warranted. First, the social cost of environmental regulation is probably greater, and perhaps significantly so, than actual direct expenditures for pollution control. This follows from the important costs of pollution control that are omitted from expenditure estimates (see the appendix for a rough calculation of some of these costs). These omissions probably offset the occasional divergence between private and social costs that can cause expenditures to exceed resource costs.

Second, although costs probably exceed actual direct expenditures, both are likely to fall short of most estimates of expenditures, quite possibly by a considerable margin. Existing survey estimates are based on responses from those firms or plants likely to be the most severely affected by regulations. These respondents also have incentives to err on the high side when reporting their expenditures for pollution control. Engineering cost estimates can also be expected to frequently overstate pollution control expenditures because it is difficult to foresee the technological changes that will reduce compliance costs and expenditures over time. Neither can the possible regulatory innovations that will arise be foreseen.

Still, existing expenditure estimates are not without value. They do provide the information necessary to run the macroeconomic models. They do enable us, in this way, to determine roughly how the costs of regulation may manifest themselves in the economy. This does enable us to draw some inferences about the distributional effects of these regulations. Nevertheless, for the reasons outlined above, expenditure estimates are inevitably flawed and must be recognized as such. They can be viewed as no more than suggestive, and at times they may fall short of even this modest goal.

MODELS AND RESULTS

In addition to helping identify the macroeconomic effects of regulation, the large quarterly models of the U.S. economy have been used to analyze the effects of changes in government tax and expenditure policies, perturbations in the price and availability of energy and other natural resources, changes in consumer and producer behavior, and natural occurrences such as droughts or prolonged periods of hot or cold weather. Econometric models offer two advantages in these and other kinds of studies. The first is their comprehensiveness. That is, they identify effects on many important aggregate measures, such as the inflation rate, the unemployment rate, the trade balance, and new investment, as well as price and output effects for at least some individual economic sectors (the pulp and paper industry, electric utilities, food processing, and so on).

The second attractive feature of the econometric models is that the predictions they generate are integrated and simultaneously determined. The equations of the models are linked so that price increases in one sector are translated into cost and price increases in other sectors. These secondary effects may influence employment in affected industries, which in turn may influence aggregate demand. Similarly, the many other feedbacks inherent in econometric models ensure at least a crude approximation to the simultaneous and interdependent decision-making characterizing a market economy. These feedbacks are missing when piecemeal or partial equilibrium approaches are used to examine the response of a particular industry or sector to a policy or other change. While piecemeal approaches often allow the inclusion of more detail (when one worries about sugar beet processing, for example, one can specify production at the individual process level), they often ignore induced changes in other industries or input markets that might eventually produce results very different from those that emerge from an industry-specific or microanalytic approach.

Design of the Macro Studies

The general approach taken in the macroeconomic simulation studies is easy enough to describe. Beginning with estimates of the expenditures necessitated by regulation, it is first determined how these expenditures will manifest themselves in the economy (or how their absence would be felt). By adjusting the appropriate equations in the model, one can characterize an economy without regulation and the spending it entails. For example, any jobs related to the manufacturing of mandated pollution control equipment must be deleted in the "without controls" case. Similarly, investment in pollution control equipment must be removed, as must state and local spending for pollution abatement. State and local taxes must be reduced by the amount of expenditures in the "without" case, as well. Finally, a basic set of assumptions must be made about the future values of the variables determined outside the model, the so-called exogenous variables. For example, how much will the three levels of government spend for goods and services in the years to come? At what rates will income be taxed? How fast will the money supply expand? What will be the rate of population growth?

Once appropriate adjustments have been made to the model and the exogenous variables have been specified, the model can be solved to produce a picture of the economy operating over some period of time first in the presence, and then in the absence of environmental regulation. The only difference between the two simulations is that one includes spending and other changes induced by regulation, while the other does not. The difference between the time paths of the important variables is then taken to be the measure of the effect of regulation. This is the basic approach that has been used in all the simulation studies to date.

The Chase and DRI Studies

The first such study was conducted in 1972 by Chase Econometric Associates for CEQ, EPA, and the Department of Commerce. There were a number of steps to the Chase methodology, which began with CEQ and EPA estimates of the incremental expenditures in 15 major industries for annualized capital and operations and maintenance expenses. No attempt was made in the study to include estimates of municipal spending on waste treatment.

Chase calculated the initial effects of these expenditures on production costs in the industries considered. These cost increases were then translated into price increases using industry markup factors. Then it was determined how these initial increases would affect costs and prices in other industries through their effects on the prices of inputs to these industries. (For example, the cost of producing automobiles went up not only because of air and water pollution control expenditures by automakers, but also because steelmakers were forced to invest in pollution control.) Next, these direct and indirect increases in the prices of intermediate products were translated into changes in the prices of final products. After adjusting the investment equations of the model as well as the user cost of capital (to reflect the added investment in "unproductive" plants and equipment), the Chase macro model was solved to determine the general equilibrium effects of industrial expenditures on pollution control.

Some of the important results of this study are presented in Table 4. Chase predicted that industrial pollution control expenditures would have a somewhat restrictive effect on the economy over the nine-year period 1972–80. For example, the unemployment rate was predicted to be higher in the presence of environmental controls than without them, averaging about 0.13 of one percentage point per year higher over the eight-year period. During the same period, Chase predicted the inflation rate to be higher in the "with-controls" case for the first four years (by about 0.35 of one percentage point) but then lower than in the baseline (or no-controls case) for the five years 1976

TABLE 4
EFFECTS OF POLLUTION CONTROL ON MACROECONOMIC VARIABLES

	1972	1973	1974	1975	1976	1977	1978	1979	1980
Unemployment rate, percent									
Baseline projection	5.41	4.93	4.70	4.73	4.38	4.37	4.44	4.44	4.47
With pollution control costs	5.39	4.99	4.81	4.90	4.52	4.55	4.61	4.59	4.62
Difference	.02	.06	.11	.17	.14	.18	.17	.15	.15
Percentage growth rate of consumer price index									
Baseline projection	2.97	4.13	4.39	4.48	3.98	4.17	3.96	3.56	3.21
With pollution control costs	3.17	4.47	4.88	4.83	3.87	3.80	3.61	3.29	2.99
Difference	.20	.34	.49	.35	–.11	–.37	–.35	–.27	–.22
Gross national product, constant dollars									
Baseline projection	786.4	836.6	875.7	907.8	954.3	997.3	1038.8	1083.6	1131.5
With pollution control costs	788.4	835.7	872.4	899.4	941.2	984.8	1029.0	1075.0	1123.2
Difference	2.0	–0.9	–3.3	–8.4	–13.1	–12.5	–9.8	–8.6	–8.3
Net foreign balance									
Baseline projection	3.5	3.5	1.6	1.0	0.2	–1.1	–1.1	0.7	3.3
With pollution control costs	2.9	2.7	0.1	–.9	–.8	–1.3	–1.2	.6	3.1
Difference	–.6	–.8	–1.5	–1.9	–1.0	–0.2	–0.1	–0.1	–0.2
Fixed business investment, constant dollars									
Baseline projection	83.6	93.0	101.4	105.7	112.4	118.3	123.3	129.2	135.1
With pollution control costs	85.4	95.0	104.5	108.5	112.3	116.5	121.5	127.7	133.9
Difference	1.8	2.0	3.1	2.8	–0.1	–1.8	–1.8	–1.5	–1.2

Source: Chase Econometric Associates, Inc., "The General Economy," pp. 323–324 in *The Economic Impact of Pollution Control: A Summary of Recent Studies,* prepared for the Council on Environmental Quality, the Department of Commerce, and the Environmental Protection Agency, March 1972.

through 1980. According to Chase, after 1972 real gross national product was expected to be lower throughout the simulation period as a result of pollution control. The difference was expected to be the largest in 1976, when pollution control spending was seen as reducing real GNP by $13.1 billion, or 1.4 percent. As the table indicates, both the balance of trade (net foreign balance) and fixed business investment were predicted to be adversely affected by pollution control spending, although Chase expected the latter to be simulated initially by the pollution control investments firms had to make.

In a number of respects, the 1972 Chase study is quite dated. First, new regulations have imposed added costs on the industries considered. For example, according to the inputs supplied to Chase in 1972, by 1977 the petroleum refining industry would be bearing annual incremental pollution control expenditures of $304 million (in 1978 dollars). However, according to EPA's more recent 1977 *Cost of Clean Air and Water* report, annual incremental expenditures in petroleum refining in 1977 were $682 million, and this excluded any costs associated with the 1977 amendments to the Clean Air and Clean Water acts.

Second, the municipal waste treatment expenditures excluded from the 1972 Chase analysis are significant. According to CEQ, for example, such expenditures amounted to nearly half of all incremental water pollution control spending in 1979 (see Table 3). Hence, by excluding such spending, the Chase study understated the effect of environmental regulation on economic performance. Finally, changes in the structure of the U.S. and world economies since 1972 also help render obsolete Chase's 1972 prediction of the impacts environmental regulation would have on the economy in 1980.

Of course, the best estimates of the current or future effects of environmental regulation will come from those models which are based on the most recent data and representation of the economy. While Chase has continuously updated its model, and used it to reexamine periodically the effects of environmental control expenditures,[13] the most recent econometric study was conducted for CEQ and EPA by Data Resources Incorporated (DRI) in 1978.[14]

In several respects, the 1978 DRI study represents the state of the art for such efforts. First, and perhaps most important, the DRI

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13. The 1976 Chase study is described and analyzed in some detail in R. Haveman & V. Kerry Smith, *Investment, Inflation, Unemployment, and the Environment*, in CURRENT ISSUES IN U.S. ENVIRONMENTAL POLICY 164 (P. Portney ed. 1978).

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

study used the most comprehensive and recent estimates of pollution control expenditures. For example, the study was based on CEQ and EPA estimates of incremental air and water pollution control spending between 1970 and 1986. Table 5 presents the EPA/CEQ estimates of incremental investment in pollution control between 1970 and 1986 used in the study, including expenditures for mobile source pollution control and expenditures by states and municipalities for water pollution control. These latter governmental expenditures had never before been included in macro simulation studies.

It is important to note, however, that DRI did not take into account expenditures expected to arise from the 1977 amendments to the Clean Air and Clean Water acts. Hence, the results do not include any of the direct effects on the economy of regulations protecting visibility or air quality in clean areas, or the effects of new controls on industries discharging toxic substances into water bodies. Neither did the inputs to the DRI study include any of the effects of existing regulations governing hazardous wastes, toxic substances, land reclamation, noise control, or drinking water protection. While expenditures for these programs currently are small relative to those made for air and water pollution control, they will grow in time, as Table 3 shows.

The obvious additional advantage of the DRI study is its relatively recent completion. This means that the model used to perform the study reflects at least some of the recent experience with diminished rates of productivity growth, high and unstable energy prices, expansions in labor force participation, and other changes in economic conditions and structural relationships. Data Resources faces the same problems in predicting future economic behavior and relationships as plagued the 1972 Chase effort, of course, but their results do give us the best picture of current effects associated with regulation.

The methodology of the DRI study was similar to that used by Chase.[15] To simulate the absence of air and water pollution control, DRI reduced aggregate investment in durable equipment and in new plant construction and apportioned these reductions across individual industrial sectors. The rental price of capital was also reduced to reflect the fact that no "unproductive" pollution control investment need accompany "productive" investment in the absence of controls.[16] These cost reductions in the no-controls case were then translated into lower final product prices. Personal consumption ex-

15. For a more thorough description of the methodology of Data Resources, Inc., *see id.* (Technical Appendix–submitted to EPA and CEQ March 30, 1979).

16. For a discussion of the national income accounts and what they measure and exclude as productive outputs, *see* Peskin's paper in this volume.

TABLE 5

ESTIMATED INCREMENTAL INVESTMENT FOR POLLUTION CONTROL, 1970–1986
(millions of 1977 dollars)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
All industries	2,458	3,258	4,690	4,848	4,640	5,181	4,946	4,770	4,405	6,643	7,338	6,849	7,402	8,208	8,413	7,216	6,659
Manufacturing industries	1,450	1,931	2,800	2,897	3,092	3,671	3,195	3,013	2,755	3,582	4,095	4,373	4,503	4,907	4,740	4,493	4,337
Primary Metals	269	361	556	587	661	892	753	719	654	804	979	968	950	1,057	572	520	481
Electrical Machinery	14	22	35	36	34	23	25	22	18	37	44	45	51	50	48	45	37
Non-electrical Machinery	10	19	35	37	39	30	34	31	25	45	41	38	32	32	26	19	17
Transportation Equipment	59	75	103	106	94	54	56	53	49	97	137	178	213	252	287	206	219
Stone, Clay & Glass	76	101	157	167	213	157	75	70	62	97	154	217	280	316	378	274	170
Other Durables	47	72	119	125	163	130	91	82	70	99	90	84	82	75	69	62	61
Food Incl. Beverage	117	149	197	200	176	139	168	161	149	400	554	674	749	716	788	796	806
Textiles	16	21	27	27	26	36	43	41	38	94	156	219	241	254	266	270	248
Paper	208	265	356	363	487	572	359	339	317	492	640	638	635	631	629	626	623
Chemicals	251	318	415	420	536	733	847	809	764	931	793	794	798	1,048	1,351	1,852	1,357
Petroleum	373	512	773	800	616	864	702	648	574	415	414	410	348	342	174	194	214
Rubber	2	5	11	12	27	15	18	17	14	34	40	47	54	61	67	53	39
Other Nondurables	9	11	16	17	22	26	24	23	21	37	53	61	69	73	84	75	64
Nonmanufacturing	1,008	1,327	1,889	1,951	1,548	1,510	1,751	1,757	1,649	3,061	3,243	2,476	2,899	3,301	3,674	2,724	2,322
Mining	59	75	98	98	24	63	71	49	47	119	85	54	72	88	102	70	58
Public Utilities	750	999	1,444	1,492	1,398	1,297	1,532	1,569	1,473	2,845	3,061	2,269	2,675	3,060	3,418	2,500	2,109
Commercial	200	253	348	361	126	150	147	140	129	97	97	153	152	154	154	154	155
State and local government	−38	490	310	143	1,378	1,548	2,635	2,310	2,434	2,960	3,190	2,902	2,442	1,888	1,542	1,705	1,778
Mobile source emission control	505	599	581	1,499	1,011	2,123	2,622	2,755	2,728	2,679	3,633	5,430	5,288	5,475	5,667	5,756	5,756

Source: Data Resources Inc., "The Macroeconomic Impact of Federal Pollution Control Programs: 1978 Assessment," p. 9, a report submitted to the Environmental Protection Agency and the Council on Environmental Quality, January 29, 1979.

penditures on automobiles were reduced, since there would be no fuel economy penalty without controls, and new car prices were reduced. Federal grants-in-aid to municipalities (which cover 75 percent of the capital cost of waste treatment plants) were reduced, as were state and local expenditures for waste treatment.

Finally, the share of annual operations and maintenance expenditures devoted to labor—assumed to be 50 percent by DRI[17]—was divided by the average wage in manufacturing. This provided an estimate of the annual increase in jobs resulting from pollution control expenditures. Appropriate adjustments were made to the unemployment rate in the without-controls case (initially raising it above its level in the "with-controls" case).

Table 6 presents some of the major results of the DRI study for the entire seventeen-year simulation period. Consider first the inflation rate, measured by the percentage rate of growth of the consumer price index for urban areas. According to DRI, the effect of air and water pollution controls was to increase the expected inflation rate over the seventeen-year period by an average of 0.25 of one percentage point a year. Between 1970 and 1978, the period over which one can expect the DRI model to be the most accurate (because it was estimated using data from that period), the environmental regulations were seen as adding nearly one-third of one percentage point to the average annual inflation rate. In 1977, for example, the inflation rate in the "with-controls" case was predicted to be 6.5 percent as opposed to 6.2 percent in the absence of controls. Between 1979 and 1986, DRI predicted, air and water pollution controls would add an average of 0.13 of one percentage point to the annual rate of price increases.

According to DRI, air and water pollution control expenditures stimulated employment in the past and will continue to do so through 1986. Between 1970 and 1986, DRI found the average unemployment rate to be lower by 0.25 of a percentage point annually in the with-controls case than in the absence of controls. This difference is about the same in both the estimation period and the 1979-86 forecast period. For 1980 and 1981, DRI estimated that pollution control spending would reduce the unemployment rate by 0.4 of one percentage point.

The effects on unemployment that DRI identified are net effects. That is, DRI predicted that the jobs created by pollution control (in the production, installation, operation, and maintenance of pollution

17. This is less than labor's average share in value added of 70 percent because of the high capital intensity of pollution control.

TABLE 6

ESTIMATED IMPACT OF POLLUTION CONTROL EXPENDITURES ON THE ECONOMY, 1970–86

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Percentage growth rate of CPIU																	
Without	5.8	4.1	3.0	5.8	10.5	8.7	5.4	6.2	7.3	7.0	6.8	6.6	6.0	5.9	5.8	5.8	5.7
With	5.9	4.3	3.3	6.2	11.0	9.1	5.8	6.5	7.5	7.1	6.9	6.8	6.3	6.1	5.9	5.8	5.7
Diff	0.1	0.2	0.3	0.5	0.5	0.4	0.4	0.3	0.2	0.1	0.1	0.3	0.3	0.2	0.1	0.1	0.1
Unemployment rate, percent																	
Without	5.2	6.3	6.0	5.2	5.8	8.6	7.9	7.2	6.2	6.4	6.4	6.2	6.4	6.0	5.4	5.2	5.2
With	5.0	5.9	5.6	4.8	5.6	8.5	7.7	7.0	6.1	6.3	6.0	5.7	6.1	5.7	5.2	5.0	5.0
Diff	−0.2	−0.3	−0.4	−0.3	−0.2	−0.2	−0.2	−0.2	−0.1	−0.2	−0.4	−0.4	−0.3	−0.2	−0.2	−0.2	−0.2
Gross national product, 1977 dollars																	
Without	1515.3	1555.1	1643.8	1737.7	1718.8	1698.2	1793.8	1884.2	1963.6	2021.9	2109.5	2183.5	2252.6	2362.1	2473.7	2563.5	2646.7
With	1522.5	1568.2	1658.3	1748.7	1724.6	1702.6	1799.6	1806.8	1959.9	2023.0	2118.8	2189.7	2250.9	2351.9	2457.0	2543.5	2622.3
Diff	7.2	13.1	14.4	11.0	5.8	4.4	5.8	2.5	−3.7	1.1	9.3	6.2	−1.8	−10.2	−16.7	−20.0	−24.5
Imports, 1977 dollars																	
Without	137.1	141.2	155.3	162.5	157.2	137.5	164.0	180.8	199.9	205.4	215.2	226.2	233.1	245.8	262.4	278.3	292.9
With	138.2	144.1	159.8	167.9	162.2	142.0	169.3	186.6	204.8	210.3	221.6	233.2	239.3	251.2	267.0	282.1	295.6
Diff	1.1	2.9	4.5	5.4	5.0	4.5	5.4	5.8	4.9	5.0	6.4	7.0	6.2	5.4	4.6	3.8	2.7
Exports, 1977 dollars																	
Without	119.8	121.1	129.5	156.0	166.2	161.0	171.6	175.7	189.6	200.6	210.7	222.6	233.0	244.1	255.8	267.9	280.4
With	119.9	121.3	129.9	156.2	166.2	160.9	171.4	175.5	189.0	199.9	210.2	222.0	232.1	242.7	254.0	265.9	278.1
Diff	0.1	0.3	0.3	0.2	0.0	−0.2	−0.2	−0.2	−0.6	−0.7	−0.6	−0.6	−1.0	−1.4	−1.8	−2.0	−2.3

Source: Data Resources Inc., "The Macroeconomic Impact of Federal Pollution Control Programs, 1978 Assessment," submitted to the Environmental Protection Agency and the Council on Environmental Quality, Washington, D.C., January 29, 1979.

control equipment) would more than offset any job losses resulting from regulation-induced slowdowns in economic activity.

Pollution control expenditures were predicted by DRI to have a mixed effect on real GNP between 1970 and 1986. Between 1970 and 1978, according to DRI, real GNP was higher than it would have been without environmental controls. This was due to the stimulating effect of added spending for pollution control, which outweighed the restrictive effects that higher prices and reduced productivity had on the growth of real output. In six of the nine years between 1978 and 1986, however, real GNP was predicted to be lower in the presence of pollution control spending than in its absence. By 1986, in fact, DRI predicted this difference to be $24.5 billion, or nearly 1 percent of predicted real GNP in that year. Over the entire seventeen-year period, according to DRI, pollution control expenditures would produce a cumulative net gain in real GNP of $3.9 billion. Had the simulation period been extended one more year, however, the cumulative net effect on real output would no doubt have been negative, given the large gaps between the two scenarios toward the end of the period.

According to DRI, the balance of trade has been and is likely to be adversely affected by expenditures on pollution control. Imports are predicted to be higher throughout the seventeen-year period on account of controls, the average annual difference being on the order of $4.7 billion. Exports initially increased in the "with-controls" case (from sales of pollution control equipment), although the increase was small and disappeared by 1974. From 1975 on, exports are lower in the with-controls case, the average annual difference amounting to about $1 billion.

While the adverse trade effects of pollution control may be fairly small in absolute terms, they can be a large percentage of the annual trade balance, according to DRI. For example, DRI predicted that the 1980 trade deficit in the "with-controls" case would be $11.4 billion, as opposed to $4.5 billion in the absence of air and water quality legislation. Hence, DRI found that environmental control expenditures would be responsible for about 60 percent of the predicted U.S. trade deficit in 1980.

Since real GNP was generally lower after 1978 in the "with controls" case, even though employment was found to be higher, it follows directly that productivity (or output per person employed) must be less in the "with controls" case. The DRI results, and others bearing on regulation and productivity, are discussed in the paper by Robert Haveman and Gregory Christainsen in this volume.

CONCLUSIONS AND RECOMMENDATIONS

There are a number of observations that can be drawn about the methodologies of the macro studies, the results obtained, and the care with which these results should be interpreted.

First, although the Chase and DRI studies obtain somewhat conflicting results,[18] the studies are in agreement as to the apparent size of the impacts of pollution control. Both find the direct price, output, employment, and other macroeconomic effects of pollution control to be relatively small. This is not to dismiss a contribution to the inflation rate of 0.2 to 0.6 of one percentage point as trivial. It is not. But with inflation rates in excess of 10 percent per year, neither can it be argued that even drastic cutbacks in regulation would make an immediate and substantial contribution to lower prices. The same can be said of the effects of environmental controls on employment or unemployment, the rate of growth of the economy, and so on. To reemphasize, this conclusion follows quite directly from the relatively small size of environmental control expenditures *when compared with GNP.* Given this ratio (currently about 1.5 to 2.0 percent), it would be surprising if environmental regulations were found to have a large direct effect.

Nevertheless, we must still be guarded in drawing conclusions about the total macroeconomic impacts of federal environmental regulations. There are at least two (and perhaps more) ways in which regulation can affect the economy that are not reflected in the studies discussed here and that may never adequately be incorporated in such studies.

The first concerns the potentially inflationary effects of environmental regulation. As discussed above, the models generate these effects as the higher operating costs resulting from regulation are passed on in the form of higher prices for intermediate and final products. But if the "catch-up" phenomenon Barry Bosworth describes is pervasive—if workers are successful in recouping in higher wages the price increases resulting from regulation—then environmental regulation will have indirect effects not adequately reflected in most models.

There is another, even more important, indirect macroeconomic

18. For example, Chase found unemployment higher throughout its simulation period in the "with-controls" case, while DRI found pollution control spending reduced the unemployment rate in its study. This may be because DRI took into account the jobs created in operating and maintaining pollution control equipment, while Chase appears to have ignored these employment effects in its 1972 study.

effect of environmental regulation that conventional models seem to be unable to capture. It, too, diminishes considerably any confidence we can place in the results of simulation studies. Regulation not only increases the costs of the governmental and industrial activities that are undertaken in the economy, it can also influence the decision whether or not to undertake them. Thus, applying stricter discharge standards to new sources than to existing ones may not only increase environmental expenditures by any new sources, it may also affect the number of new sources. Complicated environmental permitting procedures or requirements for preconstruction modeling of air quality may not only delay the construction of new plants, but also tip the balance against building certain of them at all.[19] The possibility that current regulations will be tightened or reinterpreted in the future may also inhibit new economic development.

These and other possible indirect effects of regulation share a common characteristic: it is virtually impossible to reflect them in a model of macroeconomic activity in any but a crude and ad hoc way. That is, no simple adjustments in parameter values will capture these effects, nor will shifts in any of the variables exogenous to the models. We suspect that such indirect effects will influence the level and location of industrial production, the rate at which new technologies are introduced (and, hence, productivity is augmented), the competitiveness of certain domestic markets, and other important characteristics of the economy as well. But we must be left to speculate as to the magnitude and timing of these effects. In view of this, it is wrong to vest too much importance in the quantitative results of the current vintage of macroeconomic simulation studies.

There is another reason to avoid literal interpretation of the results of macroeconomic analyses. Even if regulations that are gradually introduced could influence the level as well as the composition of employment and output, offsetting fiscal and monetary policy might negate these effects and produce others. Suppose, in other words, that any increase in unemployment automatically triggered increased government spending or other economic stimulation. Unless this response is incorporated in the simulation experiments,[20] the model-

19. The possibly deleterious consequences of new source performance standards and permitting delays are discussed by Harrington and Krupnick in this volume.

20. This has been attempted in the past. In the 1972 Chase study, for example, an additional simulation was run in which fiscal and monetary policy were used to keep real output and employment at the levels that would have existed in the no-controls case. Predictably, inflation was forecast to be somewhat higher when government policy was used to offset job loss. The 1978 DRI study also examined possible policy offsets. Included were runs in which policy attempted to hold interest rates constant, keep inflation to its level in the no-controls case, or keep real GNP constant.

ing results may indicate increased unemployment, even though the compensating policies triggered by such increases would lead to different effects altogether. The very real possibility of discretionary responses adds to the difficulty of the task described in this paper.

In view of the limitations discussed here, and those related to the expenditure data on which the macro studies are based, should we pay any attention to them at all? The answer is probably yes, if only because such studies will continue to be used to advance one side or another in the debate over environmental and other regulation. Several steps might be taken that could increase the usefulness of the resulting studies.

First, it would be preferable in future macroeconomic studies to enter a range of values for each of the expenditure estimates, rather than a point estimate. The range could vary from sector to sector, depending on the uncertainty of the estimate. For example, it could be specified that environmental expenditures in the petroleum refining industry in 1982 will be between $350 million and $600 million. If upper and lower bounds were entered for each value, the resulting output would give a broader but more honest picture of what we know of the likely effects of regulation. There is nothing unhelpful about a conclusion that current air and water pollution controls will add between 0.2 to 0.4 of 1 percentage point to the annual rate of inflation in 1984. Of course, a "most likely" or "average" value could be chosen where a range will not do, but the range should always be presented as a reminder of the uncertainty surrounding expenditure (and benefit) estimates, as well as the uncertainty inherent in macroeconomic modeling.

Second, an attempt should be made to incorporate at least some of the indirect effects of regulation in the modeling exercises. While difficult, at least one approach merits some consideration. The DRI model now includes a "sentiment" variable in the equations explaining consumer spending, which is designed to reflect optimism or pessimism about future economic conditions. It might be possible to construct a similar variable for "producer sentiment" that reflects in part expectations about additional future regulation or changes in existing rules. Such a variable might prove useful in helping explain business investment in new plant and equipment. If so, it could also help measure any potentially adverse effects of regulation on the economy, effects which have little or nothing to do with direct increases in production costs.

A final recommendation has to do with the benefits of environmental regulation. All the attention given to expenditure estimates (and, occasionally, cost estimates) has tended to obscure an important fact: while they are very difficult to estimate, the benefits of air and water pollution control are no doubt considerable. Moreover, while certain of these benefits are not reflected in the national income accounts,[21] other benefits might well influence gross national product. Thus, although the beneficial effects of regulation have not been included in past studies, they should be included in future efforts to determine the macroeconomic effects of environmental regulation.

This is not the place to review the benefits of environmental regulation. Freeman has recently done that elsewhere.[22] He has also suggested which portions of the likely benefits of air and water pollution control will affect gross national product and which will not.[23] According to Freeman, of the $21.4 billion in benefits that may have arisen in 1978 as a result of air quality improvements in the United States since 1970, $19.8 billion could be considered "utility-increasing" benefits, while $1.6 billion could be termed "cost-reducing or output-increasing." The utility-increasing benefits include outputs of regulation for which people would be willing but do not have to pay—and which, therefore, do not show up in market transactions. These include enhanced amenities arising from improved air quality and reductions in the risk of illness or death related to air pollution. The cost-reducing or output-increasing benefits take the form of enhanced agricultural yields, reduced medical costs, reductions in household cleaning costs, and reductions in materials damage caused by pollution. With respect to water pollution control, utility-increasing benefits include enhanced recreational opportunities and increased amenity values; cost-reducing benefits include lower treatment costs to municipalities and industries using intake waters; and output-increasing benefits include those from commercial fisheries.

At the very least, the cost-reducing and output-increasing benefits of air and water pollution control should be included in future simulation studies. This should not be too difficult to do. For example, reduced spending on health care or household cleaning could easily be accommodated in an econometric model, as could reductions in industrial costs resulting from cleaner water or air.

One such adjustment could significantly affect the results of the

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21. For a discussion of omissions from the national income and product accounts, *see* Peskin's paper in this volume.

22. *See* A. Freeman, The Benefits of Air and Water Pollution Control: A Review and Synthesis of Recent Evidence (December 1979) (report prepared for the U.S. Council on Environmental Quality, Washington, D.C.).

23. *See* A. Freeman, Benefits of Pollution Control: Review and Synthesis (1979) (unpublished manuscript based on A. Freeman, *supra* note 22).

simulation studies. If air pollution does have the effect on sickness and lost productivity that some have estimated it might,[24] improved air quality could be reflected in the econometric models by increases in labor productivity. This might substantially affect the inflation and unemployment rates predicted by the models, as well as future trends in real output and other important variables. Even if adjustments like these are made, the models will still not be able to reflect the utility-increasing benefits of pollution control. Some of them will never be reflected in market transactions, and hence will not be amenable to simulation.

An observation is in order about including regulatory benefits in future simulations: the results may be surprising to some. Suppose, for example, as a result of regulation and improved environmental quality, less money is spent on health, cleaning, and other "defensive" expenditures. Then the unemployment rate predicted by an econometric model may be higher during part or all of the simulation period than if these beneficial effects had not been included. Similarly, increased labor productivity resulting from clean air might mean that fewer workers are required to produce a given output than before. This, too, might manifest itself in the form of increased unemployment.

On the other hand, the inflation rate may be lower in the "with-benefits" scenario than without. Less spending, coupled with decreased costs to manufacturers, would probably mean lower prices. Depending on the way that benefits are entered into the simulation models, other effects will no doubt appear. While it is difficult to guess their direction, some will influence certain variables in the "wrong" way—e.g., more inflation, higher unemployment, a less favorable balance of trade, and so on. Just because benefits are the favorable result of regulation, it does not follow that their macroeconomic manifestation will be favorable. This should not be surprising since the expenditures (or costs) associated with regulation appear to have some favorable macroeconomic effects.

AUTHOR'S NOTE

As this volume went to press, EPA announced the results of a 1981 update of DRI's 1978 macroeconomic analysis.[25] This update dif-

24. T. Crocker, et al., *Methods Development for Assessing Air Pollution Control Benefits,* in U.S. ENVT'L PROTECTION AGENCY, 1 EXPERIMENTS IN THE ECONOMICS OF EPIDEMIOLOGY (1979).

25. Data Resources Incorporated, "The Macroeconomic Impact of Federal Pollution Control Programs: 1981 Assessment," prepared for the Environmental Protection Agency, July 1981.

fered from the 1978 DRI study in several respects. First, the cost estimates upon which the 1981 simulations were based were higher than those used in the 1978 study. For the first time the estimates included projected spending in response to solid and hazardous waste regulations and regulations governing toxic substance control, as well as expenditures expected to arise as a result of the 1977 amendments to the Clean Air Act and Clean Water Act. In addition, the 1981 update used a newer version of the DRI model.

In spite of these differences, there were no major qualitative changes in the results. According to DRI, compliance with environmental regulation is still predicted to exacerbate inflation, reduce the rate of growth of productivity and real income, and stimulate employment throughout the simulation period (1970–87). Because the 1981 update assumed higher compliance costs, however, the size of these effects has changed from the 1978 study. For instance, in the 1981 study DRI predicted that environmental regulation would increase the average annual inflation rate between 1970 and 1987 by 0.4 percentage points (as opposed to 0.25 in the 1978 study). Between 1981 and 1987, according to the 1981 DRI study, environmental regulation will add nearly 0.6 percentage points to the annual inflation rate. This is a substantially higher effect than predicted in the 1978 analysis.

DRI estimated that the average annual rate of growth of real GNP would be slowed by about 0.1 of a percentage point, as a result of environmental regulation, as would the annual rate of productivity growth. DRI predicted in their 1981 update that environmental regulation would reduce the unemployment rate by 0.4 percentage points, a finding consistent with their 1978 analysis.

APPENDIX
ESTIMATING FORGONE CONSUMERS' SURPLUS

It was noted earlier that expenditures on pollution control are not necessarily the same as the social or opportunity costs of pollution control. In general, the latter will exceed the former because expenditure data do not reflect the forgone surpluses resulting from regulation or any costs arising from delay, uncertainty, locational, or other effects of environmental regulation on economic activity.[26]

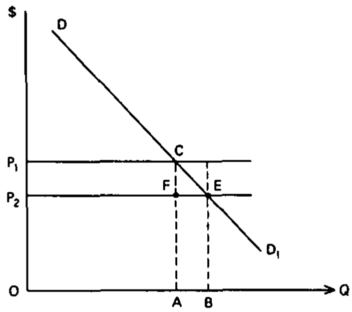
It is possible to make a very rough estimate for a particular industry of the forgone consumers' surplus that may result from environ-

26. Other authors have made similar points. *See* R. Crandall, A Review of EPA Industry Cost Studies (paper presented for the National Commission on Air Quality) and R. Leone & D. Garvin, Regulatory Cost Analysis: An Overview (1980) (paper prepared for the National Commission on Air Quality).

mental regulation. This cost of regulation can be illustrated diagrammatically as in Figure 1. There the demand for a product is represented by the downward sloping line DD^1. For simplicity, assume the product can be produced at constant cost OP_1, so that supply is assumed to be perfectly elastic at this price. As the figure indicates, at price P_1, OA units of the product are sold.

FIGURE 1

Welfare cost of regulation



However, the cost of production of the good—and hence its price, OP_1—includes the effects of environmental regulation on the producer. Without these regulations and the expenditures they necessitate, a lower price—say OP_2—could be charged for the product in question. This would not only eliminate direct pollution control expenditures equal to P_1P_2DC (which would be included in expenditure surveys), it would also reduce another cost. This is represented by the triangle *CDE.* It is the consumers' surplus that would be enjoyed on the additional units that would be purchased at price OP_2 (or that is forgone because of regulation). If we let ϵ represent the elasticity of demand for the good in question, the lost consumers' surplus associated with regulation, which we call ΔW, may be approximated by:

$$\Delta W = \frac{\epsilon(OP_1 - OP_2)^2 OA}{2OP_1} \qquad (1)$$

Now, suppose the units in question are new automobiles. According to EPA, the cumulative effect of all proposed vehicle emissions controls for carbon monoxide, hydrocarbons, and nitrogen oxides would add slightly more than $500 to the average sticker price of a 1981 model year car.[27] This is the expression $(OP_1 - OP_2)$ in Equa-

27. According to Putnam, Hayes and Bartlett, Inc., the cumulative effect of all controls on sticker prices of 1981 cars is $435 in 1977 dollars ("Comparisons of Estimated and Actual Pollution Control Cost for Selected Industries," prepared for the Office of Planning

tion (1). If the average sticker price of a 1981 model year car is \$8,000, and if 9 million new 1981 cars are sold, the welfare loss associated with emissions controls can be calculated by substituting these numbers and a value for ϵ, the elasticity of demand and solving (1). According to Burright and Enns,[28] the elasticity of demand for new cars is approximately 0.7. Hence,

$$\Delta W = \frac{(0.7)(\$500)^2 (9 \times 10)^6}{\$16,000}$$

or about \$98 million in 1979 dollars.

Two observations are in order. First, this very rough estimate of forgone consumer surplus is small in comparison with the direct expenditures on vehicle emissions controls that would show up in surveys. For example, in the illustrative case considered here, direct expenditures would be equal to \$4.5 billion (9 million cars times \$500 in expenditures for emission control per car).[29] In this case, then, one part of the cost of pollution control that goes unmeasured by pollution control expenditures is only slightly more than 2 percent of measured expenditures. Moreover, this estimate may be high because of the emissions control waivers that EPA has granted several of the automakers. These waivers have reduced the actual cost of complying with the emission standards below the figure used here.

Of course, this very rough estimate of \$98 million represents an unmeasured cost of regulation for a single, although admittedly important, product. If similar calculations of consumer surplus loss could be made for all final products, the total would surely run into the billions. Moreover, the \$500 price differential represents only the cost of the vehicle emissions controls. It does not include the effect of the other expenditures automakers must make to ensure that car production takes place in an environmentally sound way. Nor does the differential include the cost of the safety features and equipment required by federal regulations.[30]

and Evaluation, U.S. Environmental Protection Agency, February 1980, Table 13, Column 7). This was converted to 1979 dollars using the implicit price deflator for new plant and equipment for air pollution control.

28. B. Burright & J. Enns, *Econometric Models of the Demand for Motor Fuel* (April 1975) (Rand Corporation Report No. R-1561-NSF/FEA).

29. As Table 3 indicates, CEQ's estimate of 1979 expenditures on mobile source pollution control is considerably higher than this. This is because the CEQ estimate also includes a fuel economy penalty resulting from emission control devices, as well as expenditures for maintenance and replacement of the catalyst in some pollution control equipment.

30. The estimate may be low for another reason, too. If autos cannot be produced at constant marginal cost as assumed in the example, there will also be a producers' surplus generated in production. Thus, by increasing production cost, environmental regulation reduces not only consumers' but also producers' surpluses. *See* R. Leone & D. Garvin, *supra* note 25, at 9–13.