CONCEPTUAL AMD STATISTICAL ISSUES IN DEVELOPING ENVIRONMENTAL MEASURES— RECENT U.S. EXPERIENCE

BY JOHN E. CREMEANS*

The purpose of this paper is to describe the conceptual and statistical basis of the estimates of United States public and private spending for pollution abatement and control (PAC) prepared by the Bureau of Economic Analysis, U.S. Department of Commerce. The concepts and definitions were designed to ensure comparability with the national economic accounts since much of the analysis of the effects of environmental programs on the economy is conducted with the aid of the accounts. The work to date has been limited to pollution associated with harmful "foreign" substances and forms of energy discharged in the course of production, distribution and consumption. The conceptual base includes evaluation of benefits, but estimates completed thus far are limited to the cost of pollution abatement and control.

Definitions are given for pollution, pollution abatement, direct pollution abatement cost, indirect pollution abatement cost and indirect benefits. A framework for the estimation and presentation of PAC expenditures is developed and the estimate of U.S. PAC expenditures for 1972 and 1973 is presented. A brief chronological summary of the BEA project is also provided.

INTRODUCTION

Because of the widespread concern for the environment and the significant levels of public and private spending for pollution abatement and control (PAC), the United States Government is engaged in a comprehensive program to estimate these expenditures and, in the future, to estimate the resulting benefits as well. An important milestone was passed in 1975 with the publication of a comprehensive estimate of spending in the United States for PAC by consumers, business and government within the framework of the national economic accounts.[1] This work began in the summer of 1972 and has been carried out by the Bureau of Economic Analysis with assistance in data collection from the Bureau of the census.

Many problems of concept, definition, data collection and estimation had to be resolved in the preparation of this estimate. A brief chronological summary of the project is given in the next section of the paper. In addition, other papers are available which cover the results obtained and the data collection and estimation techniques used.[2] The purpose of this paper, however, is to describe the concep-

*Chief Statistician, Bureau of Economic Analysis, U.S. Department of Commerce. The author wishes to acknowledge the assistance given by his associates at BEA, but especially by Frederick Dreiling, Gary Rutledge, and William Sullivan who made many significant contributions. The paper was prepared for the IARIW 14th General conference, Aulanko, Finland, August, 1975.

[1]John E. Cremeans and Frank W. Segal, "National Expenditures for Pollution Abatement and Control, 1972", *Survey of Current Business*, February 1975, p. 8.

[2]John E. Cremeans, "Capital Expenditures by Business for Air and Water Abatement, 1973 and Planned 1974," *Survey of Current Business*, July, 1974, p. 58. John E. Cremeans, Frank W. Segal and Gary L. Rutledge, "Capital Expenditures by Business for Air, Water and Solid Waste Pollution Abatement, 1974 and Planned 1975," *Survey of Current Business*, p. 15. Frank W. Segel and Gary L. Rutledge, "National Expenditures for Pollution Abatement and Control, 1973," *Survey of Current Business*, February, 1976, p. 30.

tual and statistical basis of the work. These are most important problems and their resolution is a prerequisite to effective data collection and estimation.

A Summary of the Environmental Studies Project

A brief chronological summary of the Environmental Studies Project is given in this section. It is divided into parts on organization, concepts and definitions, data collection, and estimation.

Organization

Discussions of the importance of pollution abatement expenditures to the U.S. economy and to the national economic accounts began with BEA in 1969. It was apparent then that both legally mandated and voluntary programs for pollution abatement would involve significant spending. In addition, authorities on national accounting principles had focused attention on the accounts as a tool for analyzing the social and economic implications of pollution abatement and some had identified what they believed were deficiencies in the accounts for this purpose.

This attention and the clear lack of adequate data for analysis of environmental problems led to a joint BEA-Census proposal which was presented to the Office of Management and Budget in January 1971. By October 1972 an Environmental Studies Staff was established within the Office of the Director consisting of five professionals.

Concepts and Definitions

It is not possible to separate fully the work on concepts and definitions from the other tasks. From the beginning it was recognized that useful statistics would have to fit within the framework of the national economic accounts and would have to be based on a thorough understanding of the physical processes of pollution and pollution abatement. Conceptual problems were the subject of the earliest informal discussions and the results of this work affect every step of data collection, estimation and analysis. A milestone was reached, nevertheless, when a discussion paper was prepared and circulated within BEA in the spring of 1973.

Data Collection

It was thought early in the program that the most difficult data to obtain would be business spending for pollution abatement. A very large number of firms is involved and there is little standardization in abatement or in accounting for it. For that reason BEA and the Census Bureau jointly interviewed about twenty-five business organizations including both corporations and trade associations. A proposed questionnaire was developed simultaneously and the organizations visited were asked to comment. None of these organizations predicted success and a few suggested that important questions could not be answered. Nevertheless, this questionnaire with some modification was mailed on a pilot basis to approximately 1,100 manufacturing establishments in January 1974. The response rate

was one of the highest experienced in a pilot survey and the quality of individual answers appeared to be excellent. The questions were difficult and time consuming, but apparently the responding firms felt the survey to be important and so were motivated to make the effort necessary. A full scale sample survey of approximately twenty thousand establishments was mailed in September of the same year.

The same concepts and definitions were used to modify two long-standing Census Bureau surveys to incorporate questions concerning pollution abatement spending. The Water Use in Mining and Manufacturing surveys were changed to incorporate sections on the cost of water pollution abatement and on the quality of water at both intake and discharge. In addition, BEA's Plant and Equipment Survey, conducted since 1947 to estimate actual and planned business capital spending, was modified to determine the amount of business capital spending for pollution abatement. The Plant and Equipment Survey is mailed to the company headquarters of a sample of nonagricultural businesses. The results of the survey are available much more quickly than for the establishment surveys and they include planned as well as completed spending. The first P & E survey with pollution abatement questions was mailed in November 1973 and the first revised water use survey was mailed in March 1974. These surveys are now established as a part of the continuing program.

In our early ignorance, we had assumed that the collection of data on government spending would be straightforward. In practice, we have found as much difficulty in defining terms and almost as much in collecting the data as was experienced in the business sector. Many of the problems were solved by persuading the Office of Management and Budget that our definitions of pollution abatement spending were the most useful for their purposes as well as ours. The most difficult collection problem, however, turned out to be spending by local governments. This spending is mostly for sewer construction and there are few reliable sources.

Estimation

The estimation of spending for Pollution Abatement and Control was the first objective of the program. The conceptual framework provided the basis for the estimate and, most importantly, for determining what data were available from existing sources and what data had to be collected from new sources. BEA's first estimate of PAC expenditures was for the calendar year 1972 and was published in the February 1975 issue of the *Survey of Current Business*. It is believed to be the first comprehensive estimate of PAC expenditures conceptually and statistically consistent with the national accounting aggregates. This series is now published annually.

Scope of the Program

Current Treatment in the Accounts

A brief summary of the current treatment of environmental costs and benefits in the national economic accounts will be useful. The treatment of PAC expendi-

tures is identical to that of corresponding expenditures for other purposes: consumer expenditures for pollution abatement materials or services are included in personal consumption expenditures, and government PAC expenditures are included in government purchases of goods and services. However, neither can be separately identified.

Although the treatment of business PAC expenditures is also the same as that of other business expenditures, it requires special note. Even though they represent purchases of goods and services used directly to reduce the emission of pollutants, current operating expenses for abatement are netted out of GNP because they are not final products. They may, of course, increase the costs of these products and lead to price increases, but GNP in constant dollars will fall as PAC expenditures rise unless additional resources are employed or productivity increases.

Business expenditures for capital goods for abatement are counted as gross private domestic investment in the year in which they occur. However, the effect on GNP in the years that an abatement good is in service differs from that of an ordinary capital good. In its years of service, an ordinary capital good produces a stream of services whose dollar value enters into the calculation of GNP. The stream of services produced by an abatement good does not, because it has no market value.

The treatment of environmental benefits in the national economic accounts is more difficult to describe. The benefits of an improved environment affect all sectors of the economy and would be reflected indirectly in the accounts in so far as they were tangible economic benefits.[3] Tangible benefits will, for the most part, appear as lower costs in all sectors. Maintenance costs will decrease, certain types of health care costs will decrease, and some so-called defensive expenditure may decrease. Such lowered costs may increase real GNP as resources are released for other purposes and could change the composition of goods and services produced.

Examples of Important Issues

While an exhaustive catalogue of the issues will not be presented here, a few examples will provide a useful introduction to the problem.[4]

The baseline problem. It has been suggested that expenditures for PAC should be measured from a baseline that is defined by zero expenditure for environmental protection. Some forms of pollution abatement have been practiced for many decades—long before the current surge in interest and legislation. If a "zero pollution abatement" accounting base were desired, many long-standing production methods would have to be excluded from the base (and included in PAC expenditures) even though some of them have production advantages.

The problem of joint costs. Joint costs arise because many abatement techniques also increase production or have valuable by-products. They also arise when a new process is designed to achieve specified emission standards. It is difficult to estimate how much of the total cost should be charged to abatement

[3]Some would not. For example, a capital gain on property which becomes more valuable as a result of an environmental improvement would not be included.

[4]Some of the major conceptual issues were discussed by George Jaszi, "An Economic Accountant's Ledger," *Survey of Current Business*, July 1971, Part II, pp. 221–25.

and how much to ordinary expenditures. This problem is expected to become more significant as new plants are built and new equipment is designed that incorporate abatement techniques and devices.

The "unconscious cost" problem. Some expenditures made as a result of pollution abatement decisions are not recognized by those who make them. For example, if strip mining were to be banned for environmental reasons, the incremental costs of opening and operating deep mines or of providing substitute fuels would generally not be recognized as PAC expenditures by those incurring the actual expenditures.

Unconscious benefits are perhaps even more prevalent and difficult. Few of us have the technical skill to recognize or measure a slowly improving environment and, if we did, we would find if very difficult to attribute these improvements to specific causes or to estimate their economic value.

Each of these issues (and many others) is addressed in the sections below. The issues are not discussed individually, but are covered in the development of the concepts and definitions.

Key Early Decisions

Before addressing the conceptual problems, it will be useful to review several key decisions that defined the scope of the program. The first decision was that useful economic measures of environmental change must be consistent with the national economic accounts. These accounts provide a conceptual and statistical framework for estimating both the costs and benefits of pollution abatement and control. Also, the use of this framework ensures comparability between these measures and other components of the accounts. Such compatability is essential to the analysis of the effects of environmental programs on the economy, much of which is conducted with the aid of the accounts.

The second decision was to avoid an immediate fundamental reexamination of the accounts as has been suggested by some.[5] While it is possible that the structure of the accounts may be changed to accommodate environmental factors in the future, proposed changes cannot be fully evaluated until the process of environmental change is better understood, useful measures of the change are defined, and a data base is available for experimentation. Such a reexamination is being undertaken by others and the advantages and disadvantages of the proposed restructuring may not be clear for some time. Also, the development of a reliable estimate of actual expenditures will contribute to such examinations and will be very useful whatever their outcome.

The third decision was to concentrate on pollution associated with harmful "foreign" substances and forms of energy discharged in the course of production, distribution, and consumption. There are two additional areas of concern often voiced: the need for conservation of natural resources and the need to preserve "the quality of life". These last two concerns, while important, are far less tractable in that they involve judgment and taste to an extent not found in the first.[6]

[5]See for example, Milton Moss (Ed.), *The Measurement of Economic and Social Performance*, Studies in Income and Wealth, XXXVIII, (New York, 1973).

[6]cf. Edwin S. Mills and Frederick M. Peterson, "Environmental Quality: the first five years," *American Economic Review*, June 1975, p. 261.

The fourth decision, and a very important one, was to set for ourselves the goal of developing a theoretical base with sound concepts and definitions before proceeding to collect new data or to develop estimating techniques. In the light of our experience, we believe even more firmly that this sequence is essential.

Basic Definitions

Method of Approach

The word "pollution," while less broadly defined than the word "environment," is subject to a wide variety of interpretations. Pollution can be interpreted to cover many areas and the task of the definitions that follow is to focus our attention on those areas that are properly included in economic statistical data for the analysis of the environment and its relation to the economy. Thus, the definitions contain many restrictions that are designed to remove areas that are not properly included or belong in other categories; for example, consumer or industrial safety.

The definitions are first stated in concise language in which some words or phrases have particular meanings or are themselves subject to more precise definition. A discussion of the definition then follows, often with these words or phrases discussed in detail.

Pollution and Pollution Abatement

A Definition of Pollution:

> Pollutants are all the classes of measurable agents (forms of matter or energy) that are discharged to common-property media from a government or market-related activity so as to cause loss of welfare to a human receptor.
>
> Pollution is the discharge and harmful impact of these pollutants.

Under this definition, a harmful impact of polutants occurs if and only if all of the following conditions are fulfilled concurrently:

1. *The agent is a measurable form of matter or energy.*

a. *agent*: The agent is a physical substance such as sulfur dioxide or a form of energy such as heat or sound. We are concerned with classes of such agents and not with each specific discharge. The agent impacting upon persons and property need not and often will not be the originally discharged substance. For example, oxides of nitrogen and hydrocarbons react chemically in the presence of sunlight to produce photochemical smog. The discharged agents reacting chemically are called primary pollutants, and the agents produced are called secondary pollutants.

b. *measurable*: Agents are measurable if there is no reason why they cannot be measured presently or sometime in the future. The smog in early nineteenth century England was pollution even though the people did not measure it or even know its chemical composition.

The agent must be measured (or identified) by means of instruments or laboratory procedures and not through human judgment. Thus a work of art and a city dump may both reflect light, but the relative beauty of the two is not discernable by instruments. This restriction removes "eyes-ores" as a source of pollutants.

2. *The agents are discharged to common-property media.*

a. *discharges*: Discharges include waste discharges, accidental spillage, and the escape of valuable process inputs or products.

b. *common-property media*: These media are the valuable resources that all members of society share. The distinguishing characteristic of these media is the lack of individual property rights and their associated enforcement. These media include air, surface water, and public lands. An exception to this rule for public lands is land specifically designated for waste disposal. For the purpose of this definition, private property owned and used by many persons is considered private, even if as in large apartment buildings, the passageways are used by numerous residents and guests. This restriction removes many cases properly included in the category of industrial safety. Emission of toxic substances within a chemical plant so as to endanger employees is thus considered a matter of industrial safety, whereas the emission of the same substance into the air of the surrounding community is considered to be pollution.

3. *The agent originates in a government or market-related activity.* Market-related activities are the production of goods and services, their distribution, and their expected consumption.

a. *market-related pollution*: The activities of production and distribution are considered market-related even if they are performed within government or a nonprofit institution. For example, the generation of electricity is included as production when it occurs within a governmental entity. Some consumer products generate pollutants in the course of their normal, expected use. Phosphates from detergents and exhaust emissions from automobiles are important examples. The market-related act of their production and sale implies the discharge of pollutants even if the product is used in nonmarket activities.

Market-related activities include the production, distribution, and consumption of goods and services. The act of driving to the beach on Sunday afternoon generates pollution and seems not to be directly related to market activities. But there was implied in the purchase of the automobile and the purchase of the gasoline burned in it the generation of a stream of hydrocarbons, carbon monoxide and oxides of nitrogen as a result of its normal and expected use. Thus, the manufacture and sale of an automobile virtually guarantees the emission of pollutants as a function of its design—regardless of the purpose of its use. In contrast, sulfur dioxide could be generated by the open burning (oxidation) of elemental sulfur; but this is not the normal expected use of the chemical and hence is not implied by its manufacture and sale.

b. *natural cause pollution*: An agent generated by a natural cause is not considered market-related even though the agent may be the same harmful substance released by a market-related activity. For example, sulfure dioxide from plant decay or the carbon monoxide in swamp gas is not included. Agents generated by natural causes are logically excluded from the category of pollutant because they are not amenable to economic analysis or control.

4. *The agent causes the loss of welfare to a human receptor.*

a. *losses in welfare*: Losses in welfare may take many forms, adversely affecting public health, vegetation, and materials. The losses include physical damages to persons or property whether a person is aware of the damage or not. For example, slowly-developing emphysema from breathing polluted air may go unnoticed for years, but the results nevertheless represent losses in welfare.

b. *losses of welfare to a human receptor*: Most damages to the environment do impact upon man, but the definition requires that the impact upon man be made explicit. Thus it is not sufficient for "nature" to be changed. Virtually all activities in agriculture and mining involve changing the natural environment. The way in which change in the natural environment impacts upon human beings must be made explicit.

A Definition of Pollution Abatement

> Pollution abatement is the reduction or elimination of emissions of pollutants brought about by human activity directed to this purpose.

The word abatement is used in its dictionary sense of "the destruction or removal of a nuisance." The present forms of pollution abatement include prevention, treatment, and recycling. Thus, any human activity that was consciously chosen because it results in less pollutants being discharged than its alternatives is considered to be a pollution abatement activity.

There are "end-of-line" techniques that treat pollutants after they are generated, but before they are discharged to the common property media. There are also "changes-in-production-processes" that reduce or eliminate the generation of pollutants by employing material substitutions, catalysts, reuse of waste products or complete change in production methods. Both types of abatement techniques are included although the latter has both production and abatement functions that are difficult to separate.

An important consideration is that a project or process change designed to abate one pollutant may have as a by-product the generation and emission of other pollutants. For example, activated sludge may be incinerated to avoid its discharge to water. The result is a decrease in water pollution and an increase in air pollution. This is a difficult point because almost all pollution abatement methods include the generation of some new pollutants however small in quantity. For the purpose of these definitions, a process designed to reduce one pollutant significantly at the expense of a small increase in others is considered to be "pollution abatement" so long as the net new emissions do not violate existing standards or regulations.

Tangible Costs and Benefits of Pollution Abatement and Control

It is the purpose of this section to identify the categories of costs and benefits resulting from pollution abatement. This will be done by considering the effect of environmental changes within an abstract model. In this model the costs and benefits of pollution abatement are considered from the point of view of the whole of society. The cost of PAC is that which is sacrificed (i.e., opportunities foregone) by society in order to achieve a desired level of pollution control. The benefit, analogously, is that which is gained by society. Tangible costs and benefits are sometimes defined as those that are priced by the market. However, a slightly different definition will be used in this paper; tangible costs and benefits are those that are reflected in the Gross and Net National Product.[7]

A Definition of Pollution Abatement and Control Cost:

> Pollution abatement and control cost is the tangible value of final goods and services available when there are no restrictions on the discharge of pollutants less the market value of such goods and services available when restrictions on the discharge of pollutants are imposed.[8]

If it were possible to conduct a controlled experiment in the economy, the entire economy might be operated for n years without pollution controls and, then returning to the starting point, again for n years with no exogeneous change except for the imposition of pollution controls. All tastes and preferences (including the desire for leisure) would be held constant, and so the differences in result would be due to the imposition of the pollution controls only. The cost of the program to society would then be the value of the final goods and services available in each year without controls less the value of final goods and services produced in the corresponding years with controls.[9]

[7]To ascertain the tangible and intangible costs and benefits one would have to define and measure welfare; a task far beyond the scope of this study. By limiting consideration to those transactions affecting GNP/NNP, consistency with established data collection systems and the national accounts is maintained. GNP/NNP include some inputations which are artificially priced with reference to commensurate market prices, but exclude other market transactions (or portions thereof) such as capital gains. An example of a benefit priced by the market but not included in GNP/NNP is the capital gain on real estate near a body of water improved by pollution abatement.

[8]The Keynesian consumption function is assumed to be the same for both cases. That is, it is assumed that consumers will not change their rates of saving when pollution is reduced. If city dwellers no longer have to spend weekends in the country to avoid pollution, perhaps they will continue to spend the same amount on other things.

[9]The "value of final goods and services available" is related to real net national product. This concept is essentially one of constrained maximization and may be considered as a mathematical program in which NNP is maximized subject to constraints of resource availability, etc. The comparison is made with and without constraints on the emission of pollutants. It is difficult to imagine a situation in which literally no controls exist. In practice, one usually considers "present controls" in contrast with "proposed controls."

Not all of our problems of evaluation would be solved even if such an experiment could be conducted. The experiment offers no new tool for the evaluation of the change in the distribution of income that would occur. Also, there is an "index number" problem in making the comparison. One would have to choose to value the two outputs using the respective prices, the prices prevailing before the experiment or some other set of prices. Even if this problem is solved there remains the problem of evaluating the intangible benefits. These problems are ignored in the discussion as its purpose is to develop conceptual categories of costs and benefits.

Four Categories of Tangible Costs and Benefits

The difference in final goods and services available may occur in four ways. First, productive resources such as land, labor, and capital may be diverted from conventional uses to supply the current account input requirements for polution abatement. Second, productive resources may be diverted to the production of pollution abatement plant and equipment on capital account. Third, conventional goods and services may not be produced because productive resources are idled or are diverted to less productive uses as a result of pollution restrictions. Fourth, production of conventional goods and services may increase after controls are instituted because of the indirect benefits (e.g., better health of workers, reduced corrosion, etc.) leading to increased productivity.

In the first category, productive resources are diverted from the production of (or use as) final goods and services and are used up in pollution abatement processes. These goods and services are on current account and hence appear immediately in the current year as a reduction in final goods produced. They include those used up in the operation and maintenance of retrofit pollution abatement devices and those required incrementally by process changes designed to reduce or eliminate pollutants. These costs are offset in part by the tangible benefits of by-products or recovered materials.

In the second category, productive resources are diverted to the production of new pollution abatement plant and equipment on capital account. In the year of their manufacture, the value of final goods and services available is not reduced because abatement capital goods are themselves classed and counted as final goods. There are, however, reductions in the years following. Capital goods (both conventional and those designed for pollution abatement) generate a stream of future goods and services. A dynamo produces a stream of electricity in the years following its manufacture, whereas an electrostatic precipitator produces a stream of cleaner air. Electricity is sold to consumers and is included as a final good: cleaner air is not. Thus, when pollution abatement equipment is produced on capital account, there is no reduction associated with the production of the capital good itself, but there is a reduction in the potential for production of conventional goods and services both in year of installation and in the years following.

In the third category, resources that would have been used to produce final goods and services will be idled or diverted to less productive uses as a result of pollution restrictions. Coal mines and coal mining machinery may be idled as a result of restriction on the emission of sulfur dioxide. Coal miners may be unemployed or may accept alternative employment in less productive occupations. There may be secondary and tertiary affects if, for example, the manufacturers of mining equipment lay off workers. In this category, there are no expenditures made to abate pollution. The resources, or techniques, required to bring formerly productive processes into compliance with pollution abatement regulations are not available or projected profits after modification are too low to keep the establishment in business. The final goods that would have been produced by these resources had pollution controls not been imposed are lost to the economy.

In the fourth category, we have the tangible benefits of pollution control. The reduction of pollution will, for example, improve workers' health and productiv-

ity, reduce the cost of treating intake water, reduce damage to materials, and will bring such other benefits that will result in increases in the production of conventional goods and services. In addition, pollution controls may stimulate the development of technology in such a way that productivity will be increased. Not all the benefits are included, because the intangible benefits of cleaner air, water, and land are not counted.

Taken together, the costs in the first three categories and the benefits in the fourth category may generate either a net loss or gain in final goods and services available. However, because of the existence of unpriced and unincluded benefits, the presence of a net loss or gain in final goods and services available is only a partial measure of the effect of pollution control. A tangible net cost may be offset by the intangible benefits.

Direct and Indirect Costs and Benefits

On the one hand, the costs in categories one and two are incurred by ongoing establishments with abatement activities and they are directly traceable to specific abatement programs. These costs will be called direct costs because they are associated with outlays for equipment, materials and labor for pollution abatement projects and are net of direct benefits such as valuable materials recovered as a by-product of abatement.

On the other hand, the costs and benefits of categories three and four do not accrue directly from expenditures. They are called indirect because they fall on individuals and organizations remote from the abatement activity. The costs result from the loss of production that would otherwise have taken place, the gains from additional or less costly production.[10] Most importantly, they fall on those who cannot answer direct questions about the extent or value of the losses or gains. That is, they are largely "unconscious."

The relation between pollution abatement costs and pollution abatement expenditures enables us to adopt methods of estimating direct costs in the ongoing economy. The first category of costs, losses in final goods and services available due to the current account costs of pollution control, may be assumed to equal the pollution abatement expenditures on current account. The second category of costs, losses in final goods and services on capital account, equal the capital goods used up in the abatement process. These latter costs may be estimated by calculating capital consumption allowances for pollution abatement plant and equipment. As in the experiment, these costs do not occur immediately but are distributed over the useful lifetime of the piece of capital.[11]

The indirect costs and benefits, categories three and four, are not related to specific expenditure (or sales) and hence must be estimated by other means.

[10]There is no separate category for direct benefits. Direct tangible benefits accrue to the abator and hence are offset against the cost of abatement. Categories one and two contain *net* costs. If the direct benefits exceed the direct cost for any project then it is profitable and need not concern us because it would be put into effect without external controls.

[11]Interest on the capital pollution abatement equipment is also a cost. As a practical matter of estimation, it may not be wise to collect such data by asking the owner of the capital for his interest costs since this is often a function of his financial condition and other variable factors. Abators will often have differing average and marginal costs of capital and hence reporting may not be consistent.

Category three costs might be approximated by estimating the value of the product of the idled or diverted resources prior to controls less the value of their product in alternative uses with controls. The indirect tangible benefits of pollution control (Category four) might be determined by estimating the cost of pollution damage without controls. In both of these cases, we must identify and estimate the effect even though we do not always have straightforward relationships with specific causes.

A Definition of Direct Pollution Abatement Cost:

> Pollution abatement cost is the value of resources (factors and intermediate inputs) that are used up by a pollution abatement project or productive unit less the value of resources that would be used up in the least cost alternative designed without constraint with respect to pollutant emission.

Pollution abatement cost is the value of resources used up to abate pollution and hence not available for use in production or distribution of conventional goods and services. These costs are direct costs because they are directly attributable to abatement projects and are associated with expenditures for labor and materials. Cost data is derived from expenditure data and expenditure data is itself valuable for many analyses. A definition of Pollution Abatement Expenditure is necessary and it will be used most often in actual data collection.

A Definition of Pollution Abatement Expenditure (PAE):

> Pollution abatement expenditures are outlays for equipment, materials, labor and/or services for a pollution abatement project (or productive unit) less the necessary outlays for the least cost alternative designed without constraint with respect to pollutant emission.

There are "end-of-line" abatement techniques that treat potential pollutants after they are generated, but before they are discharged to common property media. There are also "changes-in-production-process" that reduce or eliminate the generation of pollutants by employing material substitutions, catalysts, by reuse of waste materials or by a complete change in production methods. Estimating the pollution abatement expenditures for "end-of-line" abatement projects will be relatively straightforward since the least cost alternative designed without constraint with respect to pollutant emission will be no project at all. In most cases the pollution abatement expenditure for an "end-of-line" project will include all the expenditures associated with it.

When pollution abatement is accomplished through a "change-in-production-process," the pollution abatement function may be inseparable from the productive functions. That is, pollution abatement and the production of goods and services may be joint products of the same expenditure. If the physical equipment, the material inputs, or the services of input labor cannot be separated into pollution abatement functions on the one hand and productive functions on the other, pollution abatement expenditure must be estimated as the difference between the actual expenditures for the project and the expenditures that would

have been necessary for the least cost alternative designed without constraint with respect to the emission of pollutants. This is, of course, the "joint cost" problem referred to earlier.

The procedure must be applied to the same well-defined project, device, or productive unit with the same quality and quantity of output. The difference to be considered is the addition of a pollutation abatement component. The pollution abatement component may involve the recovery of inputs or the generation of a saleable (or otherwise usable) by-product. If new by-products are sold, their value must be deducted from the total expenditures for the project. In general, one would select the smallest project or productive unit for which expenditure records are maintained.[12]

This definition can be modified for use in more limited analyses where, for example, we wish to determine the net expenditures made to comply with a particular regulation or specific legislation. In this case, we determine the "gross" pollution abatement expenditure in order to comply with the regulation in question and deduct the expenditure for the least cost alternative that would satisfy previously existing regulations. This is referred to as the "compliance" expenditure.

Pollution abatement expenditures may include both capital and current account expenditures. The definition does not imply that these two categories are merged or that the expenditure may not be further subdivided. In fact, capital and current account expenditures must be segregated so that they can be used as a basis for estimating Direct Pollution Abatement Cost.

A Definition of Indirect Pollution Abatement Cost:

> The indirect cost associated with the termination or curtailment of production is the sum of: the value added by labor and capital that is prematurely retired because of pollution constraints, less the value added by these factor inputs in any subsequent use including salvage, plus the incremental cost of producing the substitute product under the new less polluting conditions.

Indirect costs result because capital and labor are not perfectly interchangeable. If productive resources were perfectly interchangeable, they would be reallocated immediately from environmentally-unfavorable to environmentally-favorable processes, and no resources would be idled. In reality, productive resources are at best imperfectly reallocable. Some capital goods have no profitable alternative use; some workers cannot be reassigned to new jobs. Even when reallocation is possible, there are significant conversion costs. Machines must be retooled and transported; workers must be retrained and relocated. Those resources that are successfully reallocated often have lower productivity in their

[12]The "gross" pollution abatement expenditure is not compared to the expenditure in which the enterprise has the dirtiest productive process possible, but with the expenditure in which the enterprise is perfectly indifferent to pollution control. The two situations are often not equivalent. For example, before pollution abatement was a major concern, a large segment of the paper industry shifted from the sulfite to the sulfate process to increase its productive efficiency. The change, incidentally, reduced the pollution they generated by about 80 percent. To have the dirtiest possible process in this industry, an enterprise would have had to increase its long-run costs. This is the "baseline" problem. cf. Jaszi, *op.cit.*

new use than they had in their old. Thus, we have the possibility of losses in production due to idled resources; expenditures for retooling, retraining, and relocation; and losses in production due to lower productivity in alternative uses.

In all these cases, the indirect costs associated with the termination or curtailment of production is the value added by labor and capital in the old (polluting) process less the value added in any subsequent use, including salvage. The value added in subsequent use is, of course, net of conversion, retraining, or relocation costs.

An additional complication is introduced if a production technique is banned completely for reasons of environmental protection. For example, it has been proposed that surface mining be outlawed entirely because of its destructive effects on the land and thus that mineral extraction be limited to deep mining. In such a case there would be formerly productive resources that could not be reallocated (as discussed above) and, in addition, there would be increased costs due to the required use of less efficient deep mining sites and techniques.[13]

The calculation of these incremental costs would be particularly difficult because they would involve "unconscious expenditures" for pollution abatement. Referring to the strip mine/deep mine example, a large part of the expenditures involved would be made by the operators of new deep mines who are responding to the higher price of minerals and not to regulations or voluntary efforts to reduce pollution. There would be no survey question that could catch these incremental expenditures even though they would be a real cost of pollution abatement.

A Definition of Indirect Benefits:

> The indirect tangible benefits of pollution abatement are all those positive results of pollution abatement that are external to the individual or organization controlling the abatement and lead to increases in the conventional goods and services available to society.

Examples of indirect tangible benefits are the increased productivity of workers due to better health; the increased purity and usefulness of inputs of air, water, and land; the reduction of corrosion; and healthier, more abundant vegetation. There are many other tangible improvements brought about by pollution abatement that result in the increased production of goods and services or the greater durability of them.

Costs Versus Benefits

A distinction has been made between *direct* costs and benefits and *indirect* costs and benefits. The direct benefits of pollution abatement—since they are enjoyed by those who initiate and control the corresponding abatement activities—are offset against the direct costs to yield *net* direct costs. The indirect costs and benefits are distinguished by the fact that they are not associated with expenditures and, as a rule, fall on individuals and organizations that may or may not be involved in abatement activities. More importantly, most of these indirect

[13]Care must be taken to avoid double counting. The incremental costs referred to here are ordinary production costs and not new PAC costs which would be counted as direct costs.

costs and benefits are not measured by the recipients (and would not be under the most idealized conditions) nor can they easily be calculated by comparing the beneficiaries' circumstances with those of others. This should not be surprising. Since Pigou, economists have recognized that the problem stems directly from the fact that damage caused by pollutants is excluded from the transactions of the market. It will never be easy to determine a market price for such things.

Economists—particularly government economists—are often accused of restricting their analysis of pollution problems to the *cost* of pollution abatement to the detriment of the benefits of the abatement itself.[14] This is certainly true of studies that are based on reasonably detailed and reliable data. Reliable cost data, while not abundant, is more available than data on either benefits or damages.

Why are benefits/damages data so scarce? It would not seem to be for lack of trying. If the number of published articles bears any relationship to the effort expended, then the measurement of the benefits of abatement (and analogously the damages of unabated pollution) has received the lion's share of research effort.[15] Reliable estimates of benefits have not been made because the benefits are indirect and are, therefore, significantly more difficult to estimate. Reliable estimates of indirect costs are not available either.[16]

For these reasons, BEA began its work in estimating the *cost* of abatement. We have not given up on the estimation of benefits, but we know that different methods—perhaps some not now known—will have to be used. The remainder of this paper will be restricted to the measurement and presentation of the net direct costs of abatement. Perhaps the companion piece on indirect costs and benefits can be presented at a time in the future.

A Framework for the Estimation and Presentation of Pollution Abatement and Control Expenditures

Potential Uses of the Data

Economists and others will be asking the same sorts of questions about the economy in the next ten years that they have asked in the last. They will attempt to explain and predict changes in employment, inflation, the balance of payments, productivity, and growth of real gross national product. Interest in these aspects of the economy will not be changed by the existence of an environmental improvement program, but details of the analysis and the data will change.

Because of the magnitude and unconventional nature of environmental expenditures, an environmental program will affect all of the measures of economic activity listed above. Pollution abatement expenditures do not produce

[14]For example, Mills and Peterson, *op. cit.*, p. 126.

[15]See Thomas E. Waddell, "The Economic Damages of Air Pollution," U.S. Environmental Protection Agency, May 1974, for both estimates of air pollution damage and an extensive bibliography.

[16]"Capital Expenditures by Business for Air, Water, and Solid Waste Pollution Abatement, 1974 and Planned 1975," *Survey of Current Business*, July 1975. BEA's most recent P & E survey that covered capital PAE included a question on production facilities closings where pollution restrictions were a factor. This has not permitted estimates of cost or of the total number of such facilities closed. It has, however, provided a picture of the characteristics of such closed facilities.

goods and services of the type now included in the GNP. They produce cleaner air, water and land—products not now counted in corporate accounts, in household accounts, or in the GNP. Thus, such expenditures will appear as additional costs without being offset identifiable additional aggregate production, final output, or earnings. Productivity and the growth of real GNP will tend to fall; prices of affected goods and services will tend to rise. The costs of goods and services sold in international trade will be affected, resulting in an adverse effect upon the balance of payments if other countries do not initiate similar programs. Of course, there will be positive economic impacts as well. The required investment in pollution abatement equipment may stimulate technological improvements, economic activity, and employment. Improved pollution abatement controls and equipment may find new export markets as other nations embark on pollution abatement programs. It is clear that the impact of these forces must be incorporated into forecasts and analyses supporting national economic policy.

While traditional analyses of the economy will continue to be made, they will require new inputs of pollution abatement expenditure and cost. Such data are essential to the detailed examination, understanding, and prediction of the economy and of the impact of the environmental improvement program. Keynesian models of employment and inflation will require pollution abatement expenditure data. Analysis of the balance of payments will require pollution abatement cost data by product line. Studies of productivity and growth will require pollution abatement cost data by industry. Thus, the old questions will continue to be asked, but accurate answers will require new inputs of pollution abatement expenditure and cost data.

The examination of these areas of national economic policy will be best served if the environmental statistics are conceptually and statistically consistent with the national economic accounts as has been discussed before. It should be recognized, however, that there are other analytical problems that will require a greater level of detail and a different method of organization. For example, we will wish to appraise the cost effectiveness of pollution abatement programs and projects. This requires data in much greater detail and requires marginal costs as well as annual costs and expenditures.

The remainder of this paper concerns PAC expenditures at the national level of aggregation. This level of detail and this concentration on cost (in contrast to benefits) seems an essential first step.

Details of the Framework

Table 1 is a framework for the estimation and presentation of PAC expenditure estimates.[17] Expenditures are subdivided into the main body of pollution abatement expenditure (line 2), government expenditure for regulation and monitoring (line 16), and expenditures for research and development of pollution abatement devices and techniques (line 19). Within each of these broad subdivisions, expenditures are divided into the major domestic final purchase categories in which abatement occurs. Within each of the purchase categories, expenditures

[17]Table 1 shows the estimated PAC expenditures in the U.S. in 1972 and 1973. (Estimates for later years available (e.g. *Survey of Current Business*, February, 1977)).

TABLE 1

NATIONAL EXPENDITURES FOR POLLUTION ABATEMENT AND CONTROL, 1972 AND 1973[1]

(Millions of dollars)

Line	1972					1973				
	Total	Air	Water	Solid Waste	Other and Unallocated[2]	Total	Air	Water	Solid Waste	Other and Unallocated[2]
1 National expenditure for pollution abatement and control (2+16+19)	19,513	7,097	8,547	4,079	−210	23,020	9,194	9,627	4,396	−197
2 Pollution abatement[2] (3+6+12)	18,334	6,424	8,270	4,032	−398	21,635	8,447	9,277	4,347	−435
3 Personal consumption	1,804	1,804	—	—	—	2,818	2,818	—	—	—
4 Durable goods	452	452	—	—	—	676	676	—	—	—
6 Nondurable goods and services	1,352	1,352	—	—	—	2,142	2,142	—	—	—
6 Business	10,743	4,438	4,300	2,407	−401	12,673	5,468	5,115	2,527	−437
7 On capital account	5.281	2,539	2,444	298	—	6,598	3,318	2,920	360	—
8 On current account	5,463	1,899	1,856	2,108	−401	6,075	2,150	2,195	2,167	−437
9 Private purchases	4,674	1,824	728	2,108	14	5.120	2,052	883	2,167	18
10 Government enterprise purchases	1,204	76	1,128	—	—	1,410	98	1,313	—	—
11 Costs recovered	−415	—	—	—	−415	−455	—	—	—	−455
12 Government	5,787	182	3,970	1,632	3	6,144	161	4,161	1,819	2
13 Federal purchasers	153	61	85	5	2	212	49	146	16	2
14 State and local purchases	2,043	(*)	415	1,628	1	2,206	(*)	402	1,803	1
15 Government enterprise purchases of fixed capital	3,591	121	3,470	—	—	3,726	112	3,614	—	—
16 Regulation and monitoring	357	142	136	18	66	483	164	186	16	117
17 Federal purchases	200	48	79	9	64	278	50	99	14	115
18 state and local purchases	157	94	58	8	2	205	115	88	2	2
19 Research and development	822	531	141	27	122	902	583	164	33	122
20 Private purchases	518	410	63	12	32	568	451	69	13	35
21 Federal purchases	205	104	34	5	62	269	126	62	11	69
22 State and local purchases	99	17	44	10	28	65	6	33	9	18
22 Addendum: Business capital consumption allowances[4]	580	—	—	—	—	809	—	—	—	—

*Less than $500,000.

[1]Excludes agricultural business; real estate operators; private medical, legal, educational, and cultural services; and nonprofit organizations.

[2]"Other" includes expenditures for abatement and control of noise, radiation, and pesticide pollution. "Unallocated" includes business expenditures not assigned to media.

[3]Pollution abatement expenditures are attributed to the sector that performs the abatement activity.

[4]Based on conventional (historical cost) depreciation reported to the PAE survey for 1973.

NOTE.—Revised 1972 and preliminary 1973. Details may not add to totals because of rounding.

Source: Bureau of Economic Analysis, U.S. Department of Commerce.

are further subdivided into types of expenditure based on the definitions and categories used in the national accounts.

In some respects, the framework for PAC expenditures resembles the gross national product table of the national income and product accounts. Its terms have been designed to be consistent with the GNP definitions, but the similarities may be misleading. There are fundamental differences that must be understood if the data are to be used properly.

An apparent difference between Table 1 and the GNP framework is the inclusion of the subdivision, "Business expenditures for pollution abatement on current account." Within the GNP table, the final purchase category for business contains only gross private domestic investment. All other business purchases are intermediate goods and services that are netted out in the calculation of final purchases.

When the transactions of only one industry or set of activities instead of the total economy are being considered, it is not possible to allocate the value of intermediate inputs to the value of final output produced by other industries. Rather, all the inputs of an industry must be considered to determine the requirements of the activity involved, and any complete accounting of inputs must have a category for "Business expenditures on current account" (line 8).

The inclusion of current business expenditures highlights a complication in the treatment of government enterprises in the national accounts. Government enterprises are "those agencies of the government whose operating costs are at least to a substantial extent covered by the sale of goods and services in contrast to the general activities of government which are financed mainly by tax revenues and debt creation."[18] Very substantial sums are spent by state and local governments for sewerage and sewage treatment and, since these activities are predominantly financed by the sale of services, all such operations are classified as government enterprises.

Following the definitions of the national accounts, fixed capital formation (purchase of structures and equipment) is classified as a part of government purchases (line 15), while purchases on current account are treated in a way similar to business purchases (line 10). Table 1 thus includes the purchases of government enterprises on current account under business and their purchases of structures and equipment under government.

It should be noted that there is an element of double counting in Table 1. The manufacturers of capital equipment for pollution abatement will make expenditures for production-oriented pollution abatement which will appear as current account spending. Some part of this cost will be passed on and will be a component of the capital equipment spending appearing in the category, "Business expenditures on capital account for pollution abatement." Thus, the same expenditure will appear more than once in different forms.

Those secondary effects will not be limited to simple cases. The copper, aluminium and lead used to build the precipitator included in business capital will have associated production-oriented PAE and so on back into the many stages of production. There will be few PAE that are unaffected by other PAE in the

[18]U.S. Department of Commerce, Office of Business Economics, *National Income*, 1954 Edition, p. 49.

previous stages of production. A pure figure may only be determined by calculation of value added through a modified input–output model.

Additional Rules

1. A distinction is made between pollution abatement and pollution control. Pollution abatement is direct action to reduce the emission of pollutants. Pollution control includes two activities that reduce pollution indirectly. (a) Regulation and monitoring is a governmental activity that is indirect in the sense that it insures that others take action to reduce pollutant emissions. Regulation and monitoring includes monitoring point discharges, testing ambient levels of pollution, developing and reviewing standards, issuing permits, and enforcing standards. (b) Research and development is conducted by public and private organizations for the purpose of finding and demonstrating new and better pollution abatement techniques. Research and development is indirect because it contributes to reducing pollutant emissions in the future.

2. PAC expenditures (Table 1) include all purchases[19] of goods and services for the direct reduction of the emission of pollutants and purchases of goods and services for regulation and monitoring and for research and development for abatement. Capital consumption allowances are not included in the total, although they are shown as an addendum. Those who wish to estimate the annual cost of PAC may do so be removing expenditures on capital account and adding capital consumption allowances.[20]

3. PAC expenditures are for controlling pollution in the United States and do not include spending by U.S. companies for reducing emissions from their foreign facilities. Thus the estimate does not include a separate entry for exports.

Conclusion

The objective of the program described in this paper is to develop national estimates of the costs and benefits of pollution abatement that are consistent with the national economic accounts. This objective has not yet been reached. A number of intermediate steps have been taken. A conceptual basis for the estimation of pollution abatement costs and benefits has been developed, although much additional work is required before it can be put into practice with respect to indirect costs and benefits. A data collection program has been established and a significant body of new and useful data is being collected, but it is restricted to direct spending. A national estimate of direct PAC expenditures has been prepared which is consistent with the national economic accounts. We believe that this is the first such estimate ever prepared anywhere in the world, but this work must be labeled as incomplete until the corresponding figures for the indirect costs and benefits are available. In summary, significant progress has been made, but there are many problems still to be solved and much work still to be done.

[19]In many cases goods for abatement are not identifiable as such until they are used for abatement purposes. Purchases of general purpose goods used for abatement are estimated as the value of such good used, including those drawn from inventory. Thus the estimate is not a true measure of abatement goods sold in a particular year.

[20]Business expenditures on current account are defined as current expenses less capital consumption allowances and general overhead charges.