Review of Income and Wealth
Series 41, Number 3, September 1995

ENVIRONMENT-ECONOMIC ACCOUNTING AND INDICATORS OF THE ECONOMIC IMPORTANCE OF ENVIRONMENTAL PROTECTION ACTIVITIES

BY DEBORAH VAUGHN NESTOR
AND
CARL A. PASURKA, JR.
U.S. Environmental Protection Agency

In this paper, we define environmental protection (EP) activities in the context of an input–output (I–O) framework. The U.S. I–O table is adjusted to separate inputs purchased by various economic sectors to abate pollution. We use I–O concepts and the I–O matrix adjusted for EP activities to derive a matrix of inputs to EP activities, which is independent of the matrix of inputs to traditional economic activities. This matrix is the basis for deriving measures of the economic importance of EP activities, including the size of EP activities relative to GNP and direct employment and indirect employment attributable to EP activities.

1. INTRODUCTION

The use of Gross National Product (GNP) as an index for a nation's aggregate economic welfare has come under heavy criticism. The failure to incorporate environmental linkages into the System of National Accounts (SNA) has been a topic of discussion for the international community, the United Nations in particular. Discussions of environmentally sound and sustainable development dominated the 1992 United Nations Conference on Environment and Development in Rio de Janeiro. The UN has also taken action, proposing revision of the current SNA to account for environment-economic linkages. The UN's proposed System for integrated Environment and Economic Accounting (SEEA) is based heavily on the core SNA. In a related vein, GNP often serves as a frame of reference when measuring the economic importance of environmental protection (EP) activities. As articulated by Schäfer and Stahmer (1989) in an assessment of the economic importance of EP activities in the German economy, total expenditures for EP are typically compared to GNP. To the extent that total expenditures for environmental regulation include purchases of intermediate goods and services, such comparisons are misleading. GNP covers only those purchases for *final* demand and hence, comparing *total* environmental expenditures overstates the size of EP activities relative to the national economy.[1]

Note: All views expressed in this paper are the authors' and do not reflect the official position of the U.S. Environmental Protection Agency. The authors thank Randy Wigle, Richard Schmalensee, and Anton Steurer for comments on an earlier version and Arnold Katz, Anne Lawson, Gary Rutledge, and Allan Young as well as the Interindustry Economics and Environmental Economics Divisions of the Bureau of Economic Analysis for many helpful discussions and assistance with the data. This work also has benefitted from insightful conversations with Anne Grambsch and comments from two anonymous referees.

[1] If pollution abatement processes are highly intermediate input-intensive, then it is a theoretical possibility for total pollution abatement expenditures to be larger than GNP.

In this paper, we apply one aspect of the UN's proposed SEEA. More specifically, we define environmental protection (EP) activities in the context of an input–output (I–O) framework. The U.S. I–O table is adjusted to separate inputs purchased by various economic sectors to abate pollution. Our disaggregation of the U.S. I–O table builds upon previous attempts to incorporate pollution abatement processes into an I–O framework.[2] More specifically, we adopt, with a few modifications, the methodology applied by Schäfer and Stahmer (1989) in adjusting the 1980 I–O table for the Federal Republic of Germany. Schäfer and Stahmer combine two common approaches for incorporating pollution abatement processes into the I–O framework. First, Leontief's Extended System distinguishes purification industries that eliminate the pollution produced by conventional economic sectors (Leontief, 1970). Second, the technique of input coefficients adjustment has been used to distinguish the direct input requirements for pollution abatement incurred by polluting industries (Ketkar, 1980, 1983a, b, 1984). As illustrated below, full characterization of EP activities in the U.S. economy requires combining the two approaches.

The focus of this paper differs from previous applications of I–O analysis to environmental issues. We do not attempt to assess the economic impacts of environmental regulation. The primary contribution of this paper lies in the application of integrated environmental and economic accounting concepts and a more accurate characterization of the costs of complying with environmental regulations.[3] The framework directly feeds into improved modelling of the economic impacts of environmental regulations, and we discuss these applications and extensions below.

The remainder of this paper is organized as follows. Section 2 reviews the relationship between the I–O structure of an economy and the UN's SEEA. In section 3, we present the framework for defining EP activities applied in this study and briefly describe the types of economic activities that constitute EP activities. Section 4 presents the 1982 benchmark U.S. I–O table, adjusted to disaggregate EP activities. Section 5 uses I–O concepts and the I–O matrix adjusted for EP activities to derive a matrix of inputs to EP activities, which is independent of the matrix of inputs to traditional economic activities. This matrix is the basis for measuring the economic importance of EP activities. Section 6 presents the computations for the size of EP activities relative to GNP and direct employment and direct plus indirect employment attributable to EP activities. Finally, section 7 summarizes the findings of this study and directions for future research.

2. Background: The UN System for Integrated Environmental and Economic Accounting (SEEA)

The UN has proposed the System for Integrated Environmental and Economic Accounting (SEEA) as a special satellite system that is closely

[2]For recent surveys on other applications of input–output analysis to environmental issues, see Pearson (1989) and Førsund (1985).

[3]Discussions of environmental accounting are often tied to GNP/GDP adjustments (to make it more reflective of welfare changes) and measurement of sustainable income or development. We refrain from discussion of these issues. For good summaries of the various approaches to environmental accounting and the related concepts of GNP/GDP adjustment and sustainability see Ahmad, El Serafy, and Lutz (eds.), 1989 and Lutz (ed.), 1993.

related to the core System of National Accounts (SNA). Figure 1 provides a schematic representation of the SEEA, and illustrates its relationship with the core SNA and the development of methods to measure environmental impacts.[4] The SEEA are comprised of four parts, labelled I, II, III, and IV in the figure. Part I describes production and consumption activities and the accounts of nonfinancial assets. This includes the I–O table from which EP activities are separated from the rest of the production activities in the economy. In addition, Part I contains information regarding changes in the stocks of natural assets. Part II describes the physical relationships between the natural environment and the producing sectors of the economy. Part III represents economic cost of actual or potential deterioration of environmental and natural resource assets associated with economic activities. Constructing Part III of the SEEA requires that a monetary value is placed on the use of the environment. Part IV represents information derived from extending the nation's production boundary to incorporate the economic functions of the natural environment. For example, a nation's production boundary might be extended to include the growth of wild animals that are hunted for meat.

The UN's SEEA framework represents a modification of rather than a radical change to the existing SNA. By relying heavily on the core SNA, the SEEA represents a conceptually straightforward approach to environmental accounting. However, developing the full set of integrated environmental and economic accounts still is no easy task. Describing physical environment-economic relationships, valuing the use of environmental resources, and defining the production boundary are all conceptually and analytically difficult problems, which are only beginning to be resolved (see UN, 1993). In contrast, disaggregation of the economy's I–O table into environmental and nonenvironmental activities, while still difficult, represents a comparatively simpler task.

3. Environmental Protection Activities in an I–O Framework

Conceptual Framework

Disaggregation of the I–O tables into EP and non-EP components requires developing a scheme for classifying the various types of EP activities. The UN (1993) provides some guidance, proposing that environmental protection activities be classified into the following five categories: external EP activities, internal EP activities, fixed capital formation for EP, household EP activities, and government EP activities. Assuming that all environmental control costs can be traced to an EP activity, we apply a version of the UN classification scheme. Our scheme is also similar to the framework Schäfer and Stahmer (1989) used to adjust the 1980 I–O table for the Federal Republic of Germany.

Within the UN framework, external EP activities are represented as separate rows and columns in an I–O matrix. External EP activities include, for example, the services of solid waste disposal and sewage treatment. Internal EP activities are ancillary activities (analogous to administration or research and development)

[4]For an in-depth description of the SEEA, see UN, 1993.

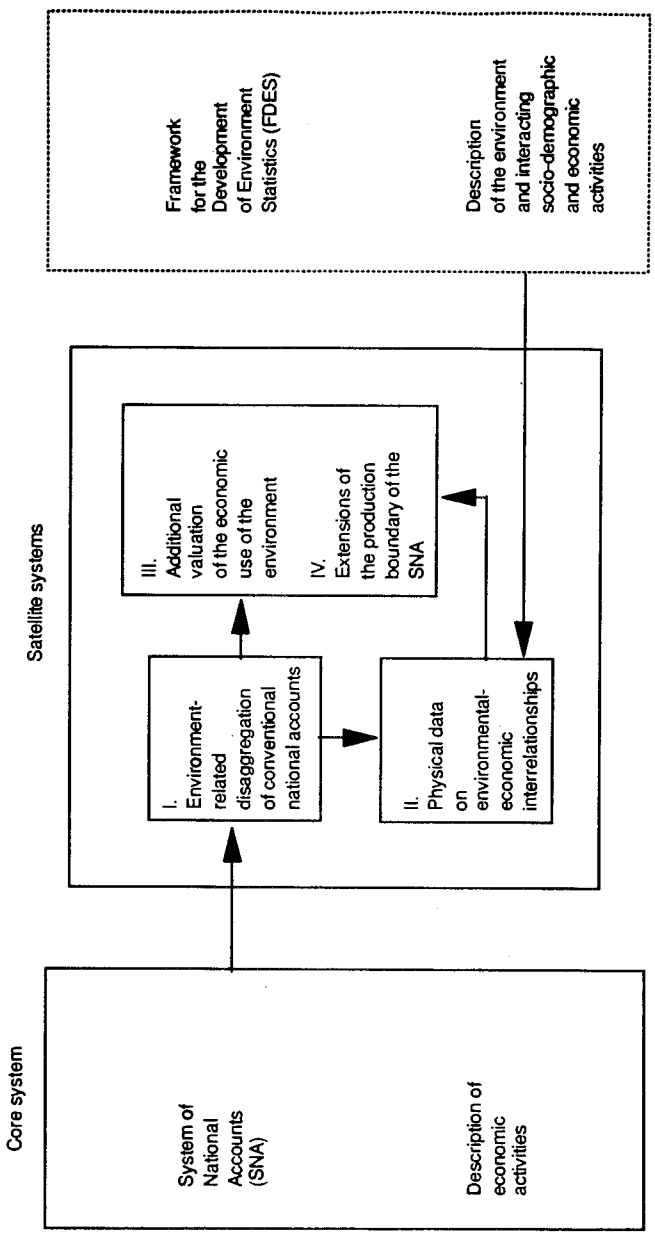


Figure 1. System for Integrated Environmental and Economic Accounting
Source: UN, 1993

and are measured by the inputs purchased for and combined as pollution abatement activity by the polluting industry. Internal EP activities are not separated from the main activities of an establishment, and in the I–O framework, are accounted for by separating out that portion of total inputs used by polluting industries for pollution abatement. The category fixed capital formation for EP represents the accumulation of fixed assets for EP and corresponds to gross private domestic investment in the I–O format. As an example, the purchase of a scrubber represents the accumulation of capital for air pollution abatement.

In addition, of EP activities are performed by households and government. Household and government EP activities are like EP investment activities in that they are represented by an adjustment to final demand in the I–O framework.

For illustrative purposes, the five categories of EP activities are now described in the context of the I–O accounting framework. In Figure 2, the entries depicted by the column vector $\mathbf{X}_{(n+1)}$ represent the dollar value of the products purchased as intermediate inputs from other sectors in the economy by the external EP activities sector. The corresponding row vector $\mathbf{X}'_{(n+1)}$ represents the dollar value of the external EP activities that other industries purchase for use as an intermediate input. The cells $\mathbf{X}_{(n+1)(n+1)}$, $\mathbf{Y}_{(n+1)}$, and $\mathbf{q}_{(n+1)}$ represent purchases of external EP activities by the external EP sector, purchases of external EP activities for

$\mathbf{X}_{ne}+\mathbf{X}_e$	$\mathbf{X}_{(n+1)}$	$\mathbf{Y}_{ne}+\mathbf{Y}_e^*$	$\mathbf{q}_{ne}+\mathbf{q}_e$
$\mathbf{X}'_{(n+1)}$	$\mathbf{X}_{(n+1)(n+1)}$	$\mathbf{Y}_{(n+1)}$	$\mathbf{q}_{(n+1)}$
$\mathbf{V}_{ne}+\mathbf{V}_e$	$\mathbf{V}_{(n+1)}$		
$\mathbf{q}'_{ne}+\mathbf{q}'_e$	$\mathbf{q}_{(n+1)}$		

Figure 2. Input–Output Matrix Adjusted for Environmental Protection Activities

final demand, and output of external EP activities, respectively. In Figure 2, the internal EP activities appear as an $n \times n$ matrix of environmental intermediate inputs, $\mathbf{X}_e$, and the $1 \times n$ vector representing environmental value added, $\mathbf{V}_e$. Nonenvironmental activities are reflected by $\mathbf{X}_{ne}$ and $\mathbf{V}_{ne}$, respectively. Finally, household, investment, and government EP activities (excluding purchases of external EP activities) are embodied in final demand, depicted by the $n \times 1$ vector $\mathbf{Y}_e^*$ in Figure 2. $\mathbf{Y}_{ne}$, of course, represents the $n \times 1$ vector of nonenvironmental final demand. The row vector $\mathbf{q}'_e$ represents the total costs of pollution abatement while the corresponding column vector $\mathbf{q}_e$ represents total demand (intermediate and final) for inputs used in pollution abatement processes. The individual cells for $\mathbf{q}'_e$ and $\mathbf{q}_e$ are not necessarily identical.

EP Activities Included

External EP Activities

External EP activities constitute the component of total EP activities that is best defined by existing data sources. Sectors that provide external EP activities are included in the benchmark (540 sector) I–O tables. The primary difficulty in

identifying external EP activities is that the 540 sector I-O tables are not sufficiently disaggregated. External EP activities consists of the following three activities: water supply (that portion of water supply that is for water treatment), sewerage services, and solid waste management.[5] Water treatment, which EPA has determined to constitute 12.4 percent of water supply expenditures, is included because EPA includes water treatment expenditures when measuring the costs of EP.

Internal EP Activities

The first component of internal EP activities consists of expenditures on intermediate inputs used for purposes of pollution abatement. For manufacturing sectors, the U.S. Department of Commerce (Bureau of the Census), *Current Industrial Reports* (MA-200), reports data on labor, depreciation, "materials and supplies" and "services and other costs" used for pollution abatement at the four-digit SIC industry. Data on labor and depreciation levels for manufacturing sectors are used directly. For air and water pollution abatement, "services and other costs" are assigned to the non-EP services sector; for solid waste pollution abatement, "services and other costs" are assigned to solid waste management services, part of external EP activities mentioned above. To allocate the broad category of "materials" expenditures to specific I-O categories, we used engineering studies and computed the percentage of total operating costs associated with various inputs, including: chemicals, electricity, etc. The data are less detailed for non-manufacturing sectors and data from manufacturing industries are used.[6]

Second, the EPA (1990) reports durable goods and nondurable goods and services (current account) expenditures for abating the pollution from motor vehicles.[7] The expenditures on autos and trucks are first allocated between business and households based upon purchases of autos and trucks for personal consumption and gross private fixed investment. The nondurable component (which consists of a fuel economy penalty, a fuel price penalty, and maintenance cost) allocated to business is classified as intermediate input expenditures. EP expenditures for motorcycles are classified as household EP activities while EP expenditures for aircraft are classified as internal EP activities.

Finally, indirect business taxes associated with EP, another component of value-added are included in internal EP activities. The 1980 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) introduced environmental excise taxes on the petro-chemical, inorganic chemical and petroleum industries to provide a source of funds for the Superfund. After its

[5]In isolating external EP activities from the I-O tables, we assumed that all inputs to EP activities are purchased from domestic sources. This should result in only a slight overestimation of EP value-added and employment since a substantial portion of EP inputs are non-traded or are seldom traded (e.g. electricity and construction). This assumption was also used in isolating internal, household, investment, and government activities, discussed below.

[6]Details are provided in an appendix available upon request from the authors.

[7]Throughout this paper, "BEA data" will refer to data reported in *Survey of Current Business* (see Rutledge and Vogan, 1994) while "MA-200 data" will refer to data reported by the U.S. Department of Commerce (Bureau of the Census) in "Pollution Abatement Costs and Expenditures" *Current Industrial Reports*, unless otherwise noted. Also, unless otherwise noted, "EPA data" will refer to data reported in *Environmental Investments: The Cost of a Clean Environment*. Farber and Rutledge (1989) discuss the *Survey of Current Business* data.

expiration, the Superfund Amendment and Reauthorization Act of 1986 (SARA) reimposed the excise taxes. The environmental excise tax is paid by the petroleum and the chemical industries (see Belal, 1987). In addition, an additional tax on fuel is imposed for the Leaking Underground Storage Tank Trust Fund. These are classified as internal EP expenditures as well.

Household EP Activities

Households perform two types of EP activities. The first type is associated with household expenditures on motor vehicle air pollution abatement.[8] These include expenditures on emission devices (e.g. catalytic converters) and the costs of operating these devices such as: fuel economy penalty, fuel price penalty, and a maintenance cost (see EPA, 1990). EP expenditures for motorcycles, noted above, are assigned to households. The second type of household EP activity is related to the expenditures associated with the repair and maintenance of septic systems.

Investment Activities for Environmental Protection

Investment activities for EP are represented as the accumulation of fixed assets for EP. For households, initial purchase of septic tanks, septic systems, and connectors to public sewer systems are classified as investment. These are classified as investment expenditures since the purchase of housing is classified as investment. Business investment expenditures for pollution abatement include the initial expenditures for motor vehicle pollution abatement devices. BEA reports capital expenditures for air, water, and solid waste pollution abatement in total for each four-digit SIC industry. We disaggregate capital expenditures into specific I–O categories (e.g. construction, installation, equipment, etc.) using engineering studies, as in the case for intermediate materials inputs.[9]

Government EP Activities

The final component is EP activities performed by governments. Five categories of activities in the U.S. I–O tables embody government EP purchases: state and local government purchases for sewerage (capital expenditures only), state and local government purchases for sanitation, state and local government purchases for highways, state and local government purchases for water (capital expenditures only), state and local government purchases for natural and agricultural resources and recreation. All state and local government purchases for sewage and sanitation reported in the published U.S. I–O tables are counted as EP expenditures. We include only the percentage of state and local expenditures for highways which pertains to highway erosion abatement (0.83 percent). The BEA reports government highway expenditures related to EP (see Rutledge and Vogan,

[8]As noted above, the EPA (1990) reports durable goods and nondurable goods and services expenditures for abating the pollution from motor vehicles. These expenditures are allocated between business and households based upon purchases of autos and trucks for personal consumption and gross private fixed investment. Nondurable EP expenditures for motor vehicles by business are classified as internal EP activities. Both durable and nondurable EP expenditures for motor vehicles by households are classified as household EP activities.

[9]Details are provided in an appendix available upon request from the authors.

1994). Following EPA, the portion of expenditures by state and local government purchases for water that are for water treatment are classified as EP expenditures.[10] Also following EPA, 20 percent of natural resource expenditures are included as EP expenditures.

4. Presentation of the U.S. Environmental Protection I–O Tables

To apply this framework, we start with the 1982 benchmark I–O table published by BEA (U.S. Department of Commerce, BEA, 1991). We aggregate the

TABLE 1

List of I–O Sectors

Sector	Description
1	Agriculture, forestry, fisheries
2	Utilities and mining
3	Construction
4	Food, beverages and tobacco
5	Textiles, leather, wood, paper and products
6	Chemicals and allied products
7	Petroleum refining
8	Rubber, plastic, stone, clay and glass products
9	Primary metals
10	Manufacturing products
11	Machinery and transport equipment
12	Non-EP services
13	External EP services
14	Other industry
PCE	Personal Consumption Expenditures
GPFI	Gross Private Fixed Investment
Inv.	Change in inventories
Exp.	Exports
Imp.	Imports
IBT	Indirect Business Taxes

540 sector table to 13 producing sectors and one external EP sector. Table 1 lists the I–O sectors while Table 2 is the EP I–O table.

The above presentation of EP activities in an I–O framework is useful because it represents only a modification to BEA's benchmark I–O tables. However, this representation of EP activities is cumbersome. To simplify the presentation of EP activities in the I–O tables, Schäfer and Stahmer propose "externalizing" internal EP activities. The process involves transferring the inputs associated with EP to the column in the I–O table that represents external EP activities. Figure 3 provides a schematic representation of the externalization procedure. $\mathbf{X}_{e^{**}}$ is the $n \times 1$ column vector in which each element is the row sum of the matrix $\mathbf{X}_e$ (see Figure 2) and $\mathbf{X}_{e^*}$ is the $1 \times n$ row vector in which each element is the column sum of the matrix $\mathbf{X}_e$. Reading down column $(n+1)$ in Figure 3 gives the dollar value of the intermediate inputs used in internal EP activities plus the intermediate inputs purchased by the external EP services sector. As shown by row $(n+1)$, the inputs

[10]The EPA has calculated that 18.4 percent of capital expenditures for water supply are for water treatment.

$\mathbf{X}_{ne}$	$\mathbf{X}_{(n+1)}+\mathbf{X}_{e^{**}}$	$\mathbf{Y}_{ne}+\mathbf{Y}_{e}^{*}$	$\mathbf{q}_{ne}+\mathbf{q}_{e}$
$\mathbf{X}'_{(n+1)}+\mathbf{X}_{e^{*}}+\mathbf{V}_{e}$	$\mathbf{X}_{(n+1)(n+1)}$	$\mathbf{Y}_{(n+1)}$	$\Sigma\mathbf{X}_{e^{*}}+\Sigma\mathbf{V}_{e}$ $+\mathbf{q}_{(n+1)}$
$\mathbf{V}_{ne}$	$\mathbf{V}_{(n+1)}+\Sigma\mathbf{V}_{e}$		
$\mathbf{q}'_{ne}+\mathbf{q}'_{e}$	$\Sigma\mathbf{X}_{e^{**}}+\Sigma\mathbf{V}_{e}$ $+\mathbf{q}_{(n+1)}$		

Figure 3. Externalization of Internal Environmental Protection Activities

used for pollution abatement in each sector are aggregated with purchases of external EP activities. The individual entries in row $(n+1)$ become total operation and maintenance costs for environmental protection undertaken by business sectors. Table 3 shows the total U.S. I–O table with internal EP activities externalized.

5. The I–O Model in the Presence of EP Activities and the Decomposition of Gross Output in the Economy

Using I–O concepts and the I–O matrix adjusted for environmental protection activities, it is possible to derive a matrix of inputs to EP activities, which is independent of the matrix of inputs to traditional economic activities. The derivations that follow closely parallel the derivations presented in Schäfer and Stahmer (1989). These derivations serve as the basis for developing measures of the economic importance of EP activities and estimating employment attributable to EP activities.

Temporarily ignoring the distinction between EP and non-EP activities, the basic I–O model is described by

$$q = Aq + Y \tag{1}$$

where

$$A = X\hat{q}^{-1}. \tag{2}$$

q is the vector of gross output, **X** is the matrix of inter-industry flows, and **Y** is the vector of final demand. **A** is the matrix of direct intermediate input requirements. The $\hat{\mathbf{q}}^{-1}$ matrix is a diagonal matrix whose elements consist of the reciprocal of industry gross output.

The vector of gross output requirements for producing any vector of final demand is obtained by solving (1) for **q**,

$$q = [I - A]^{-1} Y = BY. \tag{3}$$

I is, of course, the identity matrix.

For later reference, it is useful to note

$$B = [I - A]^{-1} = I + A + A^2 + A^3 + \ldots . \tag{4}$$

TABLE 2

1982 Environmental Protection Activities I-O Table
(millions of dollars)

	01	02	03	04	05	06	07
01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02	0.4	1,802.2	11.8	28.5	92.7	165.7	301.7
03	0.2	243.1	6.6	22.0	82.8	144.5	143.5
04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
05	0.0	11.4	0.6	1.2	3.1	5.6	17.6
06	0.1	177.3	3.7	14.6	58.2	102.2	65.0
07	55.0	72.7	68.9	8.4	34.6	21.2	119.1
08	0.1	111.8	4.3	12.4	44.5	75.9	105.8
09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	9.7	0.5	1.0	2.7	4.8	15.0
12	0.6	489.3	19.9	54.8	151.7	358.7	483.9
13	275.4	366.9	154.1	252.8	234.7	297.8	103.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Int. Inputs	331.9	3,284.4	270.4	395.5	705.0	1,176.5	1,354.6
Labor	0.6	803.8	19.8	75.5	163.6	323.1	357.5
IBTs	0.0	0.0	0.0	0.0	0.0	194.6	37.7
Other	0.3	545.5	10.5	74.6	221.3	282.0	215.7
Total value added	0.9	1,349.2	30.3	150.1	384.9	799.7	610.9
Total output	332.9	4,633.6	300.8	545.6	1,089.9	1,976.2	1,965.5

TABLE 2—continued

	08	09	10	11	12	13	14	Total Int. Input Use
01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02	66.5	150.0	37.8	42.2	107.9	0.0	0.0	2,807.5
03	46.0	82.6	31.0	28.2	77.5	0.0	0.0	908.1
04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
05	2.9	8.1	1.4	1.8	4.5	0.0	0.0	58.1
06	29.8	43.5	21.5	18.5	51.2	0.0	0.0	585.6
07	8.4	7.1	12.5	13.1	335.0	0.0	0.0	755.9
08	26.0	56.0	16.5	15.2	42.9	0.0	0.0	511.4
09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	2.5	6.9	1.2	1.5	3.8	0.0	0.0	49.5
12	117.8	361.7	69.3	57.3	188.5	0.0	0.0	2,353.5
13	127.2	167.8	174.6	180.2	2,440.5	163.0	0.0	4,938.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	426.9	883.7	365.9	358.0	3,251.9	163.0	0.0	12,967.5
Labor	156.5	297.3	123.3	166.6	224.8	0.0	0.0	2,712.4
IBTs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	232.3
Other	145.8	375.7	74.4	106.9	106.3	0.0	0.0	2,159.0
Total VA	302.3	673.0	197.7	273.5	331.1	0.0	0.0	5,103.7
Output	729.2	1,556.7	563.6	631.5	3,583.0	163.0	0.0	18,071.3

Note: The purchase of $3.4 million of I-O 7 by I-O 13 represents that portion of increased business costs due to the fuel price penalty and fuel economy penalty which is assigned to External EP Services (I-O 13). To avoid double counting of expenditures, these internal EP activities of the external EP Services sector are excluded from the estimates of EP activities.

TABLE 2—continued

	Non-EP PCE	EP PCE	Non-EP GPFI + Inv.	EP GPFI	Exp − Imp	Non-EP Gov't.	EP Gov't.	Total Final Demand	Total Commodity Output
01		0.0		0.0			17.6	17.6	17.6
02		0.0		0.0			19.5	19.5	2,827.0
03		0.0		6,764.8		470.4	6,822.8	14,058.3	14,966.5
04		0.0		0.0			1.5	1.5	1.5
05		0.0		81.8			56.2	138.0	196.1
06		0.0		43.6			50.8	94.4	680.1
07		1,149.9		0.0			433.7	1,583.6	2,339.5
08		0.0		222.1			5.6	227.6	739.0
09		0.0		0.0			0.1	0.1	0.1
10		0.0		863.8			85.2	948.9	948.9
11		2,525.9		3,602.4			403.7	6,532.0	6,581.6
12		440.0		201.7			373.2	1,015.0	3,368.4
13		5,657.8	0.0	0.0	2.2	133.6	2.2	5,795.8	10,733.7
14		0.0		0.0			2,834.8	2,834.8	2,834.8
Total									
Labor									2,712.4
IBTs									232.3
Other									2,159.0
Total VA									
Output		9,773.7	0.0	11,780.1	2.2	604.3	11,107.0	33,267.3	51,338.5

TABLE 3

1982 I-O TABLE (EXTERNALIZED INTERNAL ENVIRONMENTAL PROTECTION ACTIVITIES)
(millions of dollars)

	01	02	03	04	05	06	07
01	55,652.3	27.1	486.0	79,859.8	6,279.1	280.8	1.9
02	2,707.0	128,131.2	3,857.8	4,973.8	8,971.4	12,180.6	136,906.7
03	1,811.7	13,521.9	445.2	501.9	1,063.2	397.4	345.8
04	11,954.8	8.0	1.7	52,410.7	959.6	921.4	25.8
05	1,584.9	514.4	19,988.3	10,506.7	105,316.8	2,733.2	453.7
06	9,937.7	1,551.8	5,482.5	3,632.4	9,460.4	27,690.4	3,054.7
07	8,239.0	11,057.6	16,013.7	1,352.8	5,427.6	3,246.4	17,374.7
08	487.2	667.1	25,699.9	8,452.6	16,266.0	5,013.6	626.4
09	0.0	281.1	13,959.7	8.0	1,822.5	698.3	47.8
10	701.8	3,128.7	49,145.3	10,214.9	5,556.3	3,181.7	524.0
11	2,253.7	5,762.5	10,199.6	523.2	2,200.8	951.4	85.1
12	27,616.7	48,237.1	87,224.9	38,768.4	48,857.7	22,321.9	16,670.1
13	332.9	4,633.6	300.8	545.6	1,089.9	1,976.2	1,965.5
14	18.8	449.5	8.4	4,194.0	1,180.2	920.6	310.0
Total Int. Input	123,298.3	217,971.7	232,813.7	215,944.9	214,451.5	82,513.9	178,392.1
Labor	14,248.2	46,474.5	144,455.5	39,894.7	95,766.4	27,823.2	7,759.4
IBTs	3,680.8	35,942.6	2,076.4	9,243.2	2,821.7	1,582.7	4,729.3
Other	54,163.0	124,219.7	59,445.5	31,967.9	31,116.3	22,510.8	15,825.0
Total value added	72,092.0	206,636.8	205,977.4	81,105.8	129,704.4	51,916.7	28,313.7
Total Output	195,390.3	424,608.5	438,791.1	297,050.7	344,155.9	134,430.6	206,705.8

TABLE 3—continued

	08	09	10	11	12	13	14	Total Int. Input Use
01	5.3	3.2	48.4	15.8	9,130.0	10.9	0.0	151,800.6
02	9,778.3	14,640.9	5,584.5	5,138.5	38,367.1	4,052.2	0.0	375,289.9
03	575.6	1,386.5	2,202.2	2,570.0	57,012.1	4,778.5	0.0	86,611.8
04	67.9	8.2	118.4	21.2	45,998.8	1.1	0.0	112,497.6
05	5,128.6	456.1	7,492.3	6,224.3	36,770.3	159.1	0.0	197,328.8
06	17,133.7	3,505.6	6,082.4	2,016.1	12,964.1	883.1	0.0	103,394.9
07	1,465.2	1,548.4	2,178.0	2,245.4	49,556.9	1,194.9	0.0	120,900.7
08	19,683.2	1,757.3	12,819.5	12,057.9	12,875.8	571.9	0.0	116,978.4
09	506.2	28,741.4	42,401.1	32,033.6	358.2	0.1	0.0	120,857.9
10	1,563.9	2,075.5	48,371.4	37,596.8	30,943.4	279.1	0.0	193,282.8
11	1,051.9	2,681.4	5,328.2	74,521.7	24,175.6	375.6	0.0	130,110.9
12	18,358.4	16,849.2	51,622.7	54,551.7	553,301.7	3,698.6	0.0	988,079.0
13	729.2	1,556.7	563.6	631.5	3,583.0	163.0	0.0	18,071.3
14	1,188.1	5,202.4	1,693.5	1,617.4	13,300.1	14.8	0.0	30,097.8
Total	77,235.6	80,412.8	186,506.1	231,241.9	888,337.0	16,182.8	0.0	2,745,302.4
Labor	36,137.9	31,383.4	115,084.1	128,174.9	879,852.0	4,636.0	345,009.8	1,916,700.0
IBTs	2,255.3	1,183.7	3,092.5	4,174.4	181,338.9	378.6	0.0	252,500.0
Other	11,746.6	−6,848.1	22,499.2	29,678.6	601,658.0	2,669.7	37,745.0	1,038,397.1
Total VA	50,139.8	25,719.0	140,675.8	162,027.9	1,662,848.9	7,684.2	382,754.8	3,207,597.1
Output	127,375.4	106,131.8	327,181.9	393,269.8	2,551,185.9	23,867.0	382,754.8	5,952,899.5

TABLE 3—*continued*

	Non-EP PCE	EP PCE	Non-EP GPFI + Inv.	EP GPFI	Exp − Imp	Non-EP Govt't.	EP Gov't.	Total Final Demand	Total Commodity Output
01	15,998.0	0.0	−1,513.0	0.0	15,295.3	8,505.7	17.6	38,303.6	190,104.2
02	72,885.1	0.0	2,080.9	0.0	−43,440.8	11,951.9	19.5	43,496.6	418,786.5
03	0.0	0.0	263,320.8	6,764.8	82.3	75,188.6	6,822.8	352,179.3	438,791.1
04	180,650.5	0.0	1,229.0	0.0	210.3	6,332.0	1.5	188,423.3	300,920.9
05	110,696.2	0.0	9,101.3	81.8	−17,100.8	9,628.4	56.2	112,463.1	309,791.9
06	31,960.1	0.0	429.7	43.6	4,740.1	6,502.9	50.8	43,727.2	147,122.1
07	77,319.5	1,149.9	−2,310.1	0.0	−10,100.7	14,550.9	433.7	81,043.2	201,943.9
08	11,650.1	0.0	−1,001.9	222.1	514.2	2,165.1	5.6	13,555.2	130,533.6
09	50.0	0.0	−4,821.8	0.0	−12,743.5	981.8	0.1	−16,533.4	104,324.5
10	54,030.4	0.0	60,992.3	863.8	−9,077.4	28,636.7	85.2	135,531.0	328,813.8
11	60,737.9	2,525.9	129,006.4	3,602.4	10,656.1	53,103.8	403.7	260,036.2	390,147.1
12	1,393,194.5	440.0	55,654.7	201.7	67,747.4	76,884.1	373.2	1,594,495.7	2,582,574.8
13	0.0	5,657.8	0.0	0.0	2.2	133.6	2.2	5,795.8	23,867.0
14	17,243.5	0.0	−27,037.2	0.0	18,830.4	343,208.8	2,834.8	355,080.3	385,178.1
Total									
Labor									1,916,700.0
IBTs									252,500.0
Other									1,038,397.1
Total VA									3,207,597.1
Output	2,026,415.8	9,773.7	485,131.2	11,780.1	25,615.1	637,774.2	11,107.0	3,207,597.1	

The vector of total primary factor demands is

$$P = \Pi q \tag{5}$$

where

$$\Pi = V\hat{q}^{-1}. \tag{6}$$

V is the matrix of primary inputs and **Π** is the matrix of primary input coefficients.

Now, let **IO** represent the I-O table depicted by Figure 2 written in matrix form

$$\mathrm{IO} = \begin{bmatrix} X_{ne} + X_e & X_{(n+1)} & Y_{ne} + Y_e^* \\ X'_{(n+1)} & X_{(n+1)(n+1)} & Y_{(n+1)} \\ V_{ne} + V_e & V_{(n+1)} & 0 \end{bmatrix} \tag{7}$$

The table **IO** consists of two parts: the elements which are directly related to EP and the elements which are not directly related to EP. That is, we can decompose **IO** into the following two tables

$$\begin{aligned} \mathrm{IO} &= \mathrm{IO}_e + \mathrm{IO}_{ne} \\ &= \begin{bmatrix} X_e & 0 & Y_e^* \\ X'_{(n+1)} & X_{(n+1)(n+1)} & Y_{(n+1)} \\ V_e & 0 & 0 \end{bmatrix} + \begin{bmatrix} X_{ne} & X_{(n+1)} & Y_{ne} \\ 0 & 0 & 0 \\ V_{ne} & V_{(n+1)} & 0 \end{bmatrix}. \end{aligned} \tag{8}$$

$\mathbf{IO}_e$ is the table whose elements directly represent EP activities while $\mathbf{IO}_{ne}$ is the table whose elements do not. Note that $\mathbf{IO}_{ne}$ includes purchases of inputs by the external EP activities sector, since these do not represent direct purchases for EP. More specifically, the external EP sector purchases these inputs to produce its output, *not* to comply with environmental standards. The output of external EP sector is, in turn, purchased as an intermediate input by other sectors for EP purposes, and it is at this point we count external EP activities as EP expenditures.[11] The primary inputs to external EP activities are captured in $\mathbf{IO}_e$ as the primary inputs required to support final demand and intermediate input

[11]Schäfer and Stahmer also represent the external EP activities sector in the EP I-O table by its row entries. It is also possible to achieve identical results by representing the external EP activities sector by its column entries. In this case the table **IO** is correctly partitioned as:

$$\begin{aligned} \mathrm{IO} &= \mathrm{IO}_e + \mathrm{IO}_{ne} \\ &= \begin{bmatrix} X_e & X_{(n+1)} & Y_e^* \\ 0 & X_{(n+1)(n+1)} & 0 \\ V_e & V_{(n+1)} & 0 \end{bmatrix} + \begin{bmatrix} X_{ne} & 0 & Y_{ne} \\ X'_{(n+1)} & 0 & Y_{(n+1)} \\ V_{ne} & 0 & 0 \end{bmatrix}. \end{aligned}$$

Final demand ($\mathbf{Y}_{(n+1)}$) and intermediate input purchases ($\mathbf{X}_{(n+1)}$) of external EP activities are included in $\mathbf{IO}_{ne}$ since $\mathbf{IO}_e$ covers total production of external EP activities, and hence, accounts for $\mathbf{Y}_{(n+1)}$ and $\mathbf{X}_{(n+1)}$. Including $\mathbf{Y}_{(n+1)}$ and $\mathbf{X}_{(n+1)}$ in $\mathbf{IO}_e$ would lead to double counting when computing the direct value-added associated with EP activities. This representation has the advantage that it highlights the intuition behind using direct EP value-added to measure the size of EP activities, since this is analogous to using value-added for a specific industry to compute its contribution to GNP. However, it has the disadvantage that the link between environmental protection expenditures and $\mathbf{IO}_e$ is no longer apparent, and this creates a conceptual inconsistency since external EP activities are represented by production while all other EP activities are represented by use.

purchases of external EP activities. This is equal to primary inputs used by the external EP sector. Thus, including the primary inputs to external EP activities in $\mathbf{IO}_e$ would lead to double counting in the amount of value-added associated with external EP activities.

From $\mathbf{IO}_e$ and $\mathbf{IO}_{ne}$, we can derive the following

$$A_e = \begin{bmatrix} X_e & 0 \\ X'_{(n+1)} & X_{(n+1)(n+1)} \end{bmatrix} \cdot \hat{q}^{-1} \tag{9}$$

$$\mathrm{A}_{ne} = \begin{bmatrix} X_{ne} & X_{(n+1)} \\ 0 & 0 \end{bmatrix} \cdot \hat{q}^{-1}$$

$$\Pi_e = [V_e \quad 0] \cdot \hat{q}^{-1}$$

$$\Pi_{ne} = [V_{ne} \quad V_{(n+1)}] \cdot \hat{q}^{-1}.$$

$\mathbf{A}_e$ represents the matrix of intermediate input requirements associated directly with EP while $\mathbf{A}_{ne}$ represents the matrix of intermediate input requirements associated with other (i.e. non-EP) economic activities. $\mathbf{\Pi}_e$ is the matrix of primary input requirements for EP activities and $\mathbf{\Pi}_{ne}$ is the matrix of primary input requirements for other economic activities.

Furthermore, the following relationships hold

$$A = A_e + A_{ne} \tag{10}$$

$$\Pi = \Pi_e + \Pi_{ne}$$

$$Y = Y_e + Y_{ne}.$$

$\mathbf{Y}_e$ represents household, investment, and government EP activities while $\mathbf{Y}_{ne}$ represents non-EP final demand. Both $\mathbf{A}_e$ and $\mathbf{Y}_e$ can be further partitioned to present elements pertaining to external EP activities independently of other EP activities, or

$$A_e = A_e^{\mathrm{ext}} + A_e^{\mathrm{int}} \tag{11}$$

$$Y_e = Y_{(n+1)} + Y_e^*$$

$\mathbf{A}_e^{\mathrm{ext}}$ and $\mathbf{A}_e^{\mathrm{int}}$ represent the matrix of direct intermediate input requirements relevant to the external and internal EP sectors, respectively. $\mathbf{Y}_e^*$ is defined above and denotes EP final demand, excluding purchases of external EP activities.

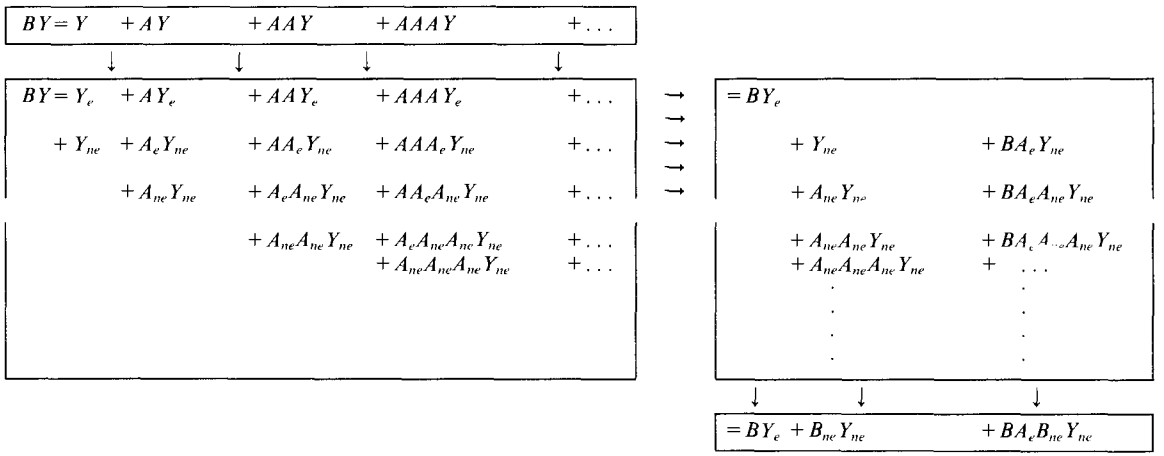
Using (4), introduce the notation

$$B_{ne} = [I - A_{ne}]^{-1} = I + A_{ne} + A_{ne}^2 + A_{ne}^3 + \ldots . \tag{12}$$

Referring to (3), the objective is to decompose gross output in the economy ($\mathbf{q}$) into output required to support EP activities and gross output that is not relevant to EP. The decomposition of $\mathbf{q}$ into EP and non-EP components is shown in Figure 4. In sum, Figure 4 shows

$$q = [I - A]^{-1} Y = BY = BY_e + B_{ne} Y_{ne} + BA_e B_{ne} Y_{ne}. \tag{13}$$

Figure 4. Decomposition of Gross Output in the Economy



Equation (13) indicates that gross output ($\mathbf{q}=\mathbf{BY}$) has three components. The first component, $\mathbf{BY}_e$, is the gross output required to support final demand associated with EP activities. This output is produced with intermediate inputs used for both EP and non-EP activities. The second component, $\mathbf{B}_{ne}\mathbf{Y}_{ne}$, consists of the gross output required to support non-EP final demand. The output is produced with intermediate inputs used for non-environmental protection activities. The third component, $\mathbf{BA}_e\mathbf{B}_{ne}\mathbf{Y}_{ne}$, measures the output required to support intermediate inputs used for environmental protection activities. This output includes EP inputs required indirectly to support non-EP intermediate inputs and final demand.

6. Indicators of the Importance of Environmental Protection in the U.S. Economy

As mentioned in the introduction, total expenditures for EP are typically compared to GNP. Such comparisons may be inappropriate since GNP covers only purchases for final demand. A more appropriate comparison might be between value-added associated with EP activities and value-added for the economy (which is equal to GNP). This comparison is analogous to using value-added for a specific industry to compute its contribution to GNP or measure its size relative to the national economy. The value-added for EP activities is simply the sum of value-added for external, internal, household, investment, and government EP activities. In matrix notation, this is

$$P_e^d=[\Pi Y_{(n+1)}+\Pi A_e^{\text{ext}}BY] + [\Pi_e Y_e^*+\Pi_e Y_{ne}+\Pi_e A_e^{\text{int}}BY+\Pi_e A_{ne}BY]+\Pi_{ne}Y_e^*. \tag{14}$$

Note that (14) is composed of seven components. The sum of the first two components is equal to $\mathbf{V}_{(n+1)}$, and thus comprise the value-added associated with external EP activities. The first component represents final demand purchases of external EP activities. The second component represents the use of external EP activities as an intermediate input. The sum of the third through sixth components are the value-added associated with internal EP activities, and this sum is equal to $\mathbf{V}_e$. The third and fourth components represent EP value-added associated with EP and non-EP final demand. The fifth and sixth components represent EP value-added associated with intermediate inputs used for internal EP activities and non-EP activities.[12] The seventh component is the non-EP value-added required to support household, investment and government EP activities, excluding purchases of external EP activities.

Additionally, one might want to compute the total share of GNP required to support EP activities. Such a measure is given by the expression for primary

[12]If **IO** is partitioned so that the external EP activities sector is represented by its column entries (see endnote 11), the sum of the first two components of (14) will equal $\mathbf{V}_{(n+1)}$ as well. The sum of the third through sixth (which equals $\mathbf{V}_e$) and the seventh components are also independent of partitioning strategy.

inputs (value-added) used directly and indirectly in EP activities.[13] Using (13), the vector of total primary factor demands is

$$P = \Pi q = \Pi B Y = \Pi B Y_e + \Pi B A_e B_{ne} Y_{ne} + \Pi B_{ne} Y_{ne}. \tag{15}$$

In (15), $\mathbf{\Pi B Y}_e$ and $\mathbf{\Pi B A}_e\mathbf{B}_{ne}\mathbf{Y}_{ne}$ are primary inputs related to EP activities. $\Pi \mathbf{B}_{ne}\mathbf{Y}_{ne}$ contains primary inputs for both EP and non-EP activities, and thus, needs further disaggregation as follows

$$\Pi B_{ne} Y_{ne} = \Pi_e B_{ne} Y_{ne} + \Pi_{ne} B_{ne} Y_{ne} \tag{16}$$

so that

$$P = \Pi B Y_e + \Pi B A_e B_{ne} Y_{ne} + \Pi_e B_{ne} Y_{ne} + \Pi_{ne} B_{ne} Y_{ne}. \tag{17}$$

It follows that the vector of primary inputs relevant to EP ($\mathbf{P}_e^{(d+i)}$) is

$$P_e^{(d+i)} = \Pi B Y_e + \Pi B A_e B_{ne} Y_{ne} + \Pi_e B_{ne} Y_{ne}. \tag{18}$$

Finally, it is possible to measure the economic importance of EP activities in terms of the number of individuals employed in EP activities. Using (14), the formula for computing direct employment associated with EP activities ($\mathbf{L}_e^d$) is

$$\begin{aligned} L_e^d = {} & [l' Y_{(n+1)} + l' A_e^{\text{ext}} B Y] \\ & + [l_e' Y_e^* + l_e' Y_{ne} + l_e' A_e^{\text{int}} B Y + l_e' A_{ne} B Y] + l_{ne}' Y_e^*. \end{aligned} \tag{19}$$

$\mathbf{l}$ denotes the vector of labor-output ratios, with $\mathbf{l}_e$ being for EP activities and $\mathbf{l}_{ne}$ being for non-EP activities.

Using (18), the formula for computing direct plus indirect employment associated with EP activities ($\mathbf{L}_e^{(d+i)}$) is

$$L_e^{(d+i)} = l' B Y_e + l' B A_e B_{ne} Y_{ne} + l_e' B_{ne} Y_{ne}. \tag{20}$$

Equations (14), (18), (19), and (20) are used to measure EP activities relative to GNP as well as compute direct employment and direct plus indirect employment.[14,15] These computations were performed using the 1982 EP I–O

[13]Schäfer and Stahmer (1989) interpret direct plus indirect value-added associated with EP as a measure of defensive expenditure on EP that is comparable to GNP. Further, they suggest that GNP be reduced by this number to make changes in GNP more reflective of changes in economic welfare. This suggestion stems from the criticism of current national income accounting practices that measures taken to reverse or protect from the environmental side-effects of production are treated as income generating.

[14]Due to the problem of secondary production (i.e. most industries produce more than one commodity) and because we isolate EP activities from BEA's "The Use of Commodities by Industry" table, it is necessary to adjust the total requirements matrix (**B**). In this study, we use the commodity by industry direct requirements table, $\mathbf{B} = \mathbf{W}[\mathbf{I} - \mathbf{AW}]^{-1}$, where **W** is BEA's "The Make of Commodities by Industry" table. When calculating (14), (18), (19), and (20), both **B** and $\mathbf{B}_{ne}$ are adjusted in this manner. Further details are available in an appendix available upon request from the authors.

[15]To accommodate labor costs associated with government employees, "Government Industry" is introduced as a special industry into the U.S. I–O table. The gross output of this sector equals the labor costs associated with government employment. We include employment associated with government EP activities in the EP "Government Industry," which is part of the "Other Industry" sector (I–O 14) in this study. Since data on government employment are available in *Public Employment in 1982* (U.S. Department of Commerce, 1983), it is possible to calculate labor-output ratios for "Government Industry" in the same manner as for other sectors.

TABLE 4

INDICATORS OF THE ECONOMIC IMPORTANCE OF EP ACTIVITIES (1982)

Indicator	Total	As a Percent of National Aggregate
EP Value-Added (Direct)	$20,593.1 million	0.64
EP Value-Added (Direct + Indirect)	$50,802.5 million	1.58
Employment (Direct)	640,181 individuals	0.69
Employment (Direct + Indirect)	1,433,502 individuals	1.54

Notes: BEA (see Rutledge and Vogan, 1994) report U.S. expenditures for pollution abatement and control of $55,359 million in 1982. Since GNP was $3,170.2 billion in 1982 (U.S. President, 1992, p. 299) the EP expenditure–GNP ratio was 1.75. For the values in the table, we use GNP as calculated from the 1982 I–O table (3,207.6 billion).

Due to the problem of secondary production (i.e. most industries produce more than one commodity), we use a modified form of the total requirements matrix, derived from "The Make of Commodities by Industry" table, to perform the above computations. Details are provided in an appendix available upon request from the authors.

tables and appear in Table 4. Table 4 shows that, in 1982, value-added associated with EP activities was about $20.5 billion or 0.64 percent of GNP. Alternatively, this value can be interpreted as EP activities or the EP "industry" contributed $20.5 billion to GNP. EP activities employed 640,181 individuals, or accounted for 0.69 percent of total U.S. employment.[16] The reason that EP value-added as a percentage of GNP is lower than EP employment as a percentage of total U.S. employment is that payments to labor in the external and government EP sectors is lower than for the economy as a whole. When multiplier effects are included, $50.8 billion (1.58 percent of GNP) and 1.43 million individuals (1.54 percent of total U.S. employment) were required to support EP activities. In this case, the EP employment percentage is lower. One possible explanation is that the relative influence of employment in the external and government EP sectors declines when indirect effects are included.

7. SUMMARY AND POSSIBLE EXTENSIONS

This study has applied the UN's proposed System for integrated Environmental and Economic Accounting and disaggregated the U.S. I–O table into EP and non-EP components. It is possible to build upon the framework set forth in

[16] *Employment, Hours, and Earnings, United States, 1909–1990* (U.S. Department of Labor, 1991), supplemented by *County Business Patterns: 1982* (U.S. Department of Commerce, 1984), is the data source for employment by SIC sector. Agricultural employment is from the *Statistical Abstract of the United States: 1985* (U.S. Department of Commerce, 1984) and public employment is from *Public Employment in 1982* (U.S. Department of Commerce, 1983).

this study and develop the other parts of the SEEA. Besides serving as the foundation for integrated environmental and economic accounts, the EP I–O tables serve other useful functions.

First, we illustrated the use of the EP I–O tables for deriving various indicators of the economic importance of environmental protection activities in the U.S. economy. This application is important from a policy perspective because of recent interest in quantifying the impacts of environmental regulation on sectors providing EP goods and services and more generally, in defining an environmental protection "industry" (Brown, O'Leary, and Browner, 1993). The I–O approach applied in this study is a consistent framework for defining an environmental protection "industry" as well as for estimating its size and the number of individuals employed in environment protection activities.

Another important application is in the area of general equilibrium (GE) modelling of environmental policy. The prime difficulty in applying GE models to environmental policy has been in the lack of detail in published data. Specifically, environmental compliance cost data are organized by the industries that bear the cost of environmental regulation, and data on the exact inputs purchased to perform pollution abatement are not reported. Without information on the inputs to pollution abatement processes, modelers have made simplifying assumptions about which goods and services are purchased to comply with environmental regulation, and these assumptions could influence the accuracy of model results. The I–O framework, if institutionalized, would provide information necessary for accurate modelling of pollution abatement processes.

References

Ahmad, Y. J., El Serafy, S., and Lutz, E. (eds.), *Environmental Accounting for Sustainable Development*, The International Bank for Reconstruction and Development, The World Bank, Washington, DC, 1989.

Belal, R., Environmental Taxes, 1981–1985, *Statistics of Income Bulletin*, Vol. 6, 51–58, Spring, 1987.

Brown, R. H., O'Leary, H., and Browner, C., *Environmental Technology Exports: Strategic Framework for U.S. Leadership*, Report of the Interagency Environmental Technologies Exports Working Group, 1993.

Farber, K. D. and Rutledge, G., Pollution Abatement and Control Expenditures: Methods and Sources for Current-Dollar Estimates, mimeograph, 1989.

Førsund, F., Input–Output Models, National Economic Models, and the Environment, in Kneese, A. V. and Sweeney, J. L. (eds.), *Handbook of Natural Resource and Energy Economics*, Vol. 1, 325–341, Elsevier Science Pub., New York, 1985.

Ketkar, K., Some Allocation and Distribution Effects of Pollution Abatement Expenditures in the United States, Ph.D. dissertation, Vanderbilt University, 1980.

———, Pollution Control and Inputs to Production, *Journal of Environmental Economics and Management*, Vol. 10, 50–59, March, 1983a.

———, The Allocation and Distribution Effects of Pollution Abatement Expenditures on the U.S. Economy, *Resources and Energy*, Vol. 5, 261–283, 1983b.

———, Pollution Control Policies and the Structure of the U.S. Economy, *Applied Economics*, Vol. 16, 237–256, No. 2, 1984.

Leontief, W., Environmental Repercussions and the Economic Structure: An Input–Output Approach, *Review of Economics and Statistics*, Vol. 52, 262–271, 1970.

Lutz, E. (ed.), *Toward Improved Accounting for the Environment*, The International Bank for Reconstruction and Development, The World Bank, Washington, DC, 1993.

Pearson, P., Proactive Energy-Environment Policy Strategies: A Role for Input–Output Analysis? *Environment and Planning A*, Vol. 21, 1329–1348, October, 1989.

Rutledge, G. and Vogan, C., Pollution Abatement and Control Expenditures, 1972–1992, *Survey of Current Business*, Vol. 74, 36–49, May, 1994.

Schäfer, D. and Stahmer, C., Input-Output Model for the Analysis of Environmental Protection Activities, *Economic Systems Research*, Vol. 1, 203–228, No. 2, 1989.

U.S. Department of Commerce, *Statistical Abstract of the United States: 1985*, U.S. Government Printing Office, Washington, DC, 1984.

U.S. Department of Commerce, Bureau of Economic Analysis, Benchmark Input-Output Accounts for the U.S. Economy, 1982, *Survey of Current Business*, Vol. 71, 30–71, August, 1991.

U.S. Department of Commerce, Bureau of the Census, *County Business Patterns: 1982*, U.S. Government Printing Office, Washington, DC, 1984.

———, *Public Employment in 1982*, U.S. Government Printing Office, Washington, DC, 1983.

———, Pollution Abatement and Control Expenditures, 1982, *Current Industrial Reports*, MA200, U.S. Government Printing Office, Washington, DC, 1984.

U.S. Department of Labor, Bureau of Labor Statistics, *Employment, Hours, and Earnings, United States, 1909–1990*, U.S. Government Printing Office, Washington, DC, 1991.

U.S. Environmental Protection Agency, *Environmental Investments: The Cost of a Clean Environment*, Report of the Administrator of the Environmental Protection Agency to the Congress of the United States, EPA-230-11-90-083, 1990.

U.S. President, *Economic Report of the President*, Washington, DC, U.S. Government Printing Office, 1992.

United Nations, Department of Economic and Social Information and Policy Analysis, Statistical Division, *Handbook of National Accounting: Integrated Environmental and Economic Accounting*, Interim Version, Studies in Methods, Series F, No. 61, 1993.