ARTIKLER 50

NATIONAL ACCOUNTING AND THE ENVIRONMENT

By Henry M. Peskin

NASJONALREGNSKAP OG MILJØVERDIER

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STATISTISK SENTRALBYRÅ

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FORORD

Statistisk Sentralbyrå har hittil bare i liten grad vært i stand til å utrede hvordan og i hvilken utstrekning den offisielle statistikk bør beskrive tilstand og forandringer i miljøforholdene. Men et skritt på veien er tatt gjennom et samarbeid med det amerikanske forskningsinstituttet "Resources for the Future, Inc.". Med direkte finansiering fra dette instituttet arbeidde dr. Henry M. Peskin et halvt år i Statistisk Sentralbyrå med problemene omkring utbyggingen av en begrepsmessig ramme for registrering av endringer i miljø-verdiene. Dr. Peskin brukte norsk produksjonsstatistikk og nasjonalregnskap som utgangspunkt for en del av sine studier og samarbeidde dessuten med andre norske institusjoner som har tatt opp miljøvernproblemer.

Statistisk Sentralbyrå er glad for å kunne legge fram resultatet av dr. Peskins arbeid i serien Artikler fra Statistisk Sentralbyrå, og ser dette arbeidet som et utgangspunkt for videre framstøt. De synspunkter som hevdes i artikkelen, står likevel for forfatterens egen regning.

Statistisk Sentralbyrå, Oslo, 3. august 1972

Petter Jakob Bjerve

PREFACE

The Central Bureau of Statistics has so far only to a limited extent been able to investigate how, and to what extent official statistics should register the status and changes in environmental conditions. A step in that direction has, however, been taken in co-operation with the American research institution "Resources for the Future, Inc.". With direct financial support from that institution Dr. Henry M. Peskin worked for half a year in the Central Bureau of Statistics with the problems of establishing a conceptual framework for registration of changes in environmental factors. Dr. Peskin used statistics of production and national accounts for Norway as a basis for some of his investigations and also had consultations with other Norwegian institutions engaged in the study of environmental problems.

The Central Bureau of Statistics is happy to be able to present the results of Dr. Peskin's research in the series "Artikler fra Statistisk Sentralbyrå" (Articles from the Central Bureau of Statistics), and considers this research a basis for further efforts. Nevertheless, the author alone is responsible for the opinions given in the article.

Central Bureau of Statistics, Oslo, 3 August 1972

Petter Jakob Bjerve

FORFATTERENS MERKNADER

Denne artikkelen er utarbeidd mens forfatteren studerte mulighetene for å tilpasse nasjonalregnskapssystemet til å kunne omfatte visse miljøfaktorer. Forskningen ble finansiert av "Resources for the Future, Inc." og gjennomført i Statistisk Sentralbyrå, Oslo.

Jeg vil takke dr. Allen Kneese, direktør for "Quality of the Environment Program, Resources for the Future, Inc.", som tok initiativet til undersøkelsen. Videre vil jeg spesielt takke forskningssjef dr. Odd Aukrust i Statistisk Sentralbyrå og hans stab, ikke bare for teknisk og kontormessig hjelp, men også fordi de stilte sin store erfaring når det gjelder nasjonalregnskap til min disposisjon. Dr. Aukrusts innsikt i de spesielle synspunkter som gjør seg gjeldende for behandling av miljøfaktorer i nasjonalregnskapet, hjalp meg å velge de problemstillinger som er tatt opp i denne artikkelen.

Arbeidet er gjennomført i en fem-måneders periode, mens jeg hadde permisjon fra the Institute of Defense Analyses, Arlington, Virginia. En del av tankegangene i artikkelen var imidlertid utviklet på forhånd, mens mitt forskningsarbeid ble finansiert av dette institutts Independent Research Program.

Oslo, juni 1972

Henry M. Peskin

AUTHOR'S NOTE

This paper was prepared while the author was investigating the general question of how national accounting systems may be altered to include certain environmental factors. This research was financed by "Resources for the Future, Inc.," and was performed at the Central Bureau of Statistics in Oslo, Norway.

I wish to thank Dr. Allen Kneese, Director, "Quality of the Environment Program, Resources for the Future, Inc.," who initiated the project. I am especially grateful to Dr. Odd Aukrust, Chief of the Research Division, Central Bureau of Statistics of Norway and his staff for not only providing me with technical and clerical assistance but also for sharing their vast experience in the field of national accounting. Dr. Aukrust's knowledge of the specific concerns of national income accountants with respect to the possible treatment of environmental matters helped me to select the issues that are discussed in this paper.

The work was accomplished over a five-month period while I was on a leave of absence from the Institute for Defense Analyses, Arlington, Virginia. However, some of the concepts in this paper were developed earlier when my research on the environment was supported by the Institute's Independent Research Program.

Oslo, June 1972

Henry M. Peskin

INNHOLD

CONTENTS

INTRODUCTION

The purpose of this paper is to discuss some of the problems of expanding a system of national accounts in order to include certain factors that affect the environment. The factors to be considered will be limited to the generation of residuals and the consumption of common property resources. "Residuals" refers to those products, generated either by industry or households, that have no positive market value. These, of course, include commonly accepted pollutants; but they may also include items that, at least at present, are not considered polluting or especially dangerous. "Common property resources" refers to those natural resources that have no positive market value because the rights of ownership have not been established or exercised. Examples will differ in different nations and localities; but everywhere ordinary air qualifies for the definition and in many places the same will be true for water and space.

This paper consists of four sections. Section I attempts to show where the themes discussed in this paper fit into the more general debate concerning alleged deficiencies in the national accounts. Section II discusses the role of the national accounts as a part of a more general information system for environmental analysis and policy. Section III presents a strategy for expanding the accounts. Section IV discusses data deficiencies and needs based on some experience in attempting to implement the strategy.

While the paper is purposely informal, a more detailed discussion of certain of the issues raised in the main body of the paper can be found in the Appendices.

CHAPTER I. NATIONAL INCOME, NATIONAL ACCOUNTS, AND WELFARE

Simultaneously with the recent surge in the public's concern with environmental problems was a flood of articles in the popular press attacking the national accounts for their inability to reflect environmental deterioration. Attackers and defenders of the national accounts are now beginning to express their views in more academic publications[1)].

Unfortunately, the debate has been marred by a failure to distinguish between national account aggregates and the national accounts themselves. These

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1) Examples are the already published papers by Denison [7] and Juster [19] and the, as yet, unpublished papers by Herfindahl and Kneese [11], Jaszi [17], Juster [18], and Olson [38].

aggregates, which include a variety of indexes made up of account data such as gross national product, net national product, national income, etc., are indeed an output of the national accounting process. Yet, forming account aggregates is but one of several uses of the accounts. Criticizing the aggregates and the accounts as if they were the same things fails to appreciate the broader purposes of a national accounting system.

It is true, however, that both the accounts and the account aggregates are deficient in the treatment of various factors that affect the physical environment[1]. The principal objective of this paper is to suggest methods for correcting deficiencies in the former concept. However, since current discussions have confused the two issues, it might help to clarify matters by briefly discussing deficiencies in the account aggregates, if for no other purpose than to indicate those problems not to be treated.

Deficiencies in the aggregates are often illustrated by pointing out "paradoxes". It is, for example, a paradox to many that an increase in output accompanied by pollution and an equal increase in output not accompanied by pollution will yield the same increase in the GNP. Others find it a paradox that "defensive" expenditures against environmental deterioration by households (for example, the purchase of an air conditioner)[2] will be counted as an increase in the net national product even though the household's welfare may be unchanged as compared to what it was prior to the environmental deterioration. Still others find it a paradox that efforts by business to clean up the environment may actually lead to a decrease in GNP if the clean-up activity requires a substitution of intermediate products and labor services for previously produced final products.

These paradoxes illustrate two principal criticisms that can be levelled against an account aggregate. On the one hand, the aggregate may be felt to be deficient because it measures only those outputs that have market values. If the "negative value" of pollution were included, then the first and final paradox would disappear. On the other hand, the aggregate may also be felt to be deficient because it includes too many items that make only an intermediate contribution to welfare. Thus, if the air conditioner were recognized as gross investment outlay with no net investment or consumptive value, the second paradox would disappear.

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1) The term "physical environment" will be left loosely defined as encompassing any material things that affect human well-being. A tighter definition is not necessary for the paper. There is some question in the author's mind whether a tighter definition would ever be necessary. In any event, attempts at a precise definition (see, for example, [53]) have not been too successful since they rely on equally vague concepts such as "eco-system".

2) Other familiar examples of "defensive" expenditures include outlays for house painting and health to the extent that these outlays are a result of environmental deterioration. The concept of "defensive" expenditures is similar to the concept of "regretable necessities", i.e., those expenditures that are necessary in modern society but yield no net welfare such as the outlays for travel to work, police, and national defense.

Because of both deficiencies the account aggregates are criticized for their failure to accomplish their supposed function of measuring changes in welfare and growth.

Actually these criticisms of the account aggregates have a long history, dating back far before the current concern with the environment. Most, if not all, of the issues in the current debate have their parallels in an important series of articles written in the 1940's by Hicks [12], [13], Kuznets [25], and Little [29]. The basic issue now is as it was then. In what sense can a national account aggregate measure changes in welfare and growth? All the current ingredients were in the former debate too, including the proper valuation of non-market outputs and externalities and the definition of intermediate vs. final goods. It is difficult to see how the current revival adds very much to the former debate or to its principal outcome: namely, that a national account aggregate will reflect true changes in welfare and growth only if the changes are very substantial and only if any changes in income distribution and product mix have been minor.

Nevertheless, several economists, such as Nordhaus and Tobin [36] and Juster [18], have proposed modifications to the aggregates (such as subtracting out "defensive" expenditures from currently measured net national product) that supposedly will make them better indicators of welfare and growth[1]. However, these proponents have not provided an objective standard by which their changed indexes can be compared with the conventional indexes. Thus, for example, whether Tobin's index is indeed a better welfare measure than ordinary GNP is a matter of subjective opinion.

One might feel, nevertheless, that a subjective standard is quite adequate because the changes suggested seem rather "obvious". Yet even the most non-controversial-appearing suggestion can suddenly appear controversial upon closer examination. Consider Juster's proposed treatment of defensive expenditures by enterprises and households. Given that the government wishes to maintain environmental quality at a fixed level, he suggests that while no adjustment in net national product (NNP) be made for the outlays by business, household outlays should be subtracted from NNP. To Juster, the rationale for this

> ".... seems unambiguous and straight forward. Emission filters on automobiles, tall stacks on factories, and water treatment facilities at industrial plants add nothing to the flow of economic or social benefits produced by the system. They simply represent costs of maintaining the constant level of environmental benefits from which society is presumed to have started. To the extent that these costs are incurred by business enterprises who have larger capital stocks and depreciation allowances to show for it, the lower-than potential rate of growth of real output which these control measures impose is

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1) There seems to be common agreement that current aggregate concepts are adequate indexes of cyclical movements.

> appropriately measured and no adjustment needs to be made. To the extent that these costs are incurred directly by households, adjustment of price indexes to record emission control devices as a quality improvement clearly gives the wrong answer - the car does not run any better or more efficiently, and it simply costs more to get the same combination of vehicle services plus constant environmental benefits. Thus it is not appropriate to count consumer defensive outlays as part of net output, nor is it desirable to add back in industrial defensive outlays as a part of net output"[1)].

While this argument may appear reasonable and clear, the concept of a "defensive outlay" is not clear. Certainly it could be applied to more than antipollution expenditures. As Jaszi points out, "... food expenditures defend against hunger, ... clothing and housing expenditures defend against cold and rain, ... medical expenditures defend against sickness, and religious outlays against the fires of hell"[2)]. Should such expenditures also be excluded from NNP?

As Jaszi points out, the basic difficulty with Juster's suggestion is that it requires the national accountant to know the motivation for all expenditures - to know what expenditures add to net welfare and what expenditures merely maintain welfare. In other words, the accountant would have to decide what portion of the air conditioner expenditure represented an addition to enjoyment and what portion represented only a maintenance of enjoyment. To make this distinction would require the accountant to have an unrealistic familiarity with both individual and social welfare functions[3)].

Does this mean that there should not be attempts at improving the conventional national income aggregates? Not necessarily. However, the approach should be made more scientific. To this end, it must be realized that individual and social welfare functions (and, consequently, their variables) are not and will never be directly observable. However, it may be possible to hypothesize what these functions should be like and then devise observable tests of these hypotheses. Thus, for example, if the issue is whether air conditioners should or should not be included in the final product (that is, in the social welfare function), the issue should not be finally decided until a test is devised that would yield unambiguously different results depending on whether air conditioners add or fail to add to net welfare.

This paper, by dealing with deficiencies in national accounts rather than in the account aggregates, handles a much easier problem. Rather than worrying about whether a particular account aggregate measures output or welfare -- a difficult issue since both concepts are not observable independently of the income aggregate, the only concern here is the simpler issue of whether the accounts provide adequate information. With this issue there is far less controversy.

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1) Juster [18], p. 50-51.

2) Jaszi [17], p. 11.

3) Similar problems would arise regarding educational expenditure. How much represents a capital-type outlay designed to improve or maintain "human capital" and how much represents a final-consumption outlay -- the amount of education the consumer finds enjoyable?

CHAPTER II. THE OBJECTIVE OF AN EXPANDED NATIONAL ACCOUNTING SYSTEM

a. The concept of national accounting

There is wide agreement that there should be some changes in national accounting systems in order that they can provide more information on the environment. Even defenders of current procedures, such as George Jaszi, will admit to the desirability of some modification[1].

There is, however, a vast gulf between, say, the recommendations of Jaszi on the one hand and those implicit (if not directly proposed) in the works of Richard Stone, on the other. Jaszi sees benefit in establishing capital accounts for tangible capital held by consumers and government and, further, he is sympathetic towards Denison's suggestion that a measure of anti-pollution expenditures by business somehow be used to modify current measures of output. Yet these suggestions are trivial compared to the concepts in Stone's monograph, "An Integrated System of Demographic, Manpower and Social Statistics and Its Links With the System of National Economic Accounts"[2]. Stone shows that a wide variety of social and demographic data can be placed in an accounting framework and that this framework can be displayed in a matrix form completely analogous to the accounting framework recommended in the United Nations of National Accounts (SNA).

A more direct plea for a comprehensive extension of the national accounts was made by Nancy and Richard Ruggles. They make a strong case:

> "It is now being realized that the extension of the economic accounts to make them more relevant cannot stop with the adjustment of the economic accounting framework to cover imputed transactions or social costs in the deterioration of the environment, and other monetary measures. The extended accounts must by their very nature grapple with demographic and social characteristics of the population. Problems relating to health care, education, income of the aged, and discrimination require the introduction of non-transactions information rather than merely more comprehensive coverage of actual and imputed transactions. Furthermore those who are concerned with the development of social indicators and social accounts recognize the importance and relevance of related economic information. Thus poverty as a social condition is directly related to income received. The level and change in government expenditures on education and health and the distribution of these benefits over the population are relevant to social as well as economic analysis. It thus becomes obvious that social accounts cannot be conceived of as sets of information distinct from the economic accounts, but must be highly intertwined with the economic accounts. (Emphasis added.)"[3]

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1) Jaszi, [16] and [17].

2) Stone [46].

3) Ruggles & Ruggles, [43], p. 1-2.

This seems to be a strong argument, so strong in fact that one may wonder, if matters are so "obvious", how there could be any disagreement.

Yet a divergence of views among well-known specialists exists, with the result that very little clear guidance has been provided to the community of professional statisticians whose job it will be to implement any changes. Perhaps one of the reasons for the lack of agreement on how much the national accounts should be altered is a lack of agreement on what the concept of national accounts actually implies. It is evident that the concept of a national accounting system can have both a broad and narrow interpretation. In the broadest sense, a national accounting system consists of the entire data collection and assembly activity, from the processing of industrial census questionnaires to the final publication of summary tables. In the narrow sense, on the other hand, a national accounting system can be construed to consist of the final set of accounts including any supporting sub-accounts.

If we interpret national accounting in the broader sense, then "expanding the accounts" to include a variety of environmental factor such as measures of the flows of non-market commodities does not present any special conceptual problems, although there may be practical difficulties. All that is called for is the collection of more information. Of course, this new information may be presented, measured, and classified in a variety of ways within the accounting system; and, in fact, it probably should be presented, measured, and classified in a variety of ways at least until the information needs for environmental policy are more firmly established.

On the other hand, if the concept of an accounting system is understood in the narrow sense, then "expanding the accounts" can present both conceptual and practical difficulties. Consider, for example, the United Nation's SNA. The principal feature of the SNA is the integration of production, consumption, and accumulation accounts through the device of including them all in a single large matrix, with "outgoings" shown along the rows and "incomings" along the columns[1]. Thus row i and column i are the credit and debit sides of account i. The intersection of row i and column j shows the relation between the debits and credits of the two accounts i and j. Displaying the accounts in this manner helps assure the consistency among all the sub-accounts in the system.

A sub-group of the production accounts is a group of commodity accounts, whose "outgoings" go to industries, consumption, government, investment, and exports and whose "incomings" come from industries, value added, and imports. One possible way of "expanding" the SNA would be to expand the number of commodity accounts to include non-market commodities. Unfortunately, there are two features of the matrix presentation that preclude this possibility. In the first place all entries must be measured in common units. Otherwise consistency checks, which

1) See [49] for a complete description.

require the ability to make row and column sums, are impossible and thus one of the advantages of the matrix presentation would be negated. In the second place, the matrix presentation admits to only one classification scheme per matrix (although aggregations within a classification are possible). For example, capital goods could be classified by the institution that has ownership or they could be classified by type of capital good (say, plant vs. equipment). If both schemes are attempted in the same matrix, a given "outgoing" (e.g., the value of a machine from the machine-commodity sector) will have to be delivered to two different accounts (e.g., the equipment account and the enterprise account). Row and column sums again become meaningless[1].

As is pointed out below, alternative valuation schemes and alternative classification schemes (process classifications as well as non-market commodity classifications) will characterize initial efforts to expand the accounts. Designing a rigid presentation system such as the SNA does not seem to be worthwhile. Any effort in this direction would be better redirected towards obtaining enough data to permit several presentation schemes, as the need arises. Consistent with this point of view, this paper interprets the concept of national accounting in the broader sense.

b. Guidelines for expanding the accounts

Given the desirability of some alteration to the accounts, two arguments have been made for caution[2]. One is based on the feeling that environmental problems are immediate and that the associated immediate information needs should be provided by simple alterations that can be implemented in the short run. The other reason is that the "users' needs" are not well-defined. Research into these "needs" has been recommended[3].

In view of this justifiable caution, any major action towards changing the accounting system should be guided by principles that would serve to define an appropriate scope and direction for these efforts. If the governmental

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1) Apparently the SNA meets this problem by using the ownership classification for the matrix, saving type of capital classification for a supplementary table.

2) These were expressed in the notes accompanying the Agenda of the Conference of European Statisticians held in Geneva, January 24-25, 1972.

3) Such research is underway. In Norway, for example, the Chr. Michelsens Institute has in the Spring of 1972 completed a preliminary report outlining a possible information and management system for environmental policy. However, while many pages are devoted to who might need information, who might provide the information, how the information might be classified, and how the information might flow through the management system, the extent of the "need" - the amount of information - has not been analyzed, perhaps a matter to be left for further research.

statistical bureau is viewed as a manager of a large inventory of data, then the theory of optimal inventory control perhaps can suggest these principles. One important implication of this theory is that the mere fact that a piece of datum may be potentially useful, does not alone justify its inclusion in the government's information system. Thus, while all the statements about the benefits of information in the Ruggles quote may be accurate, it is by no means "obvious" that statistical offices should store this information any more than it would be "obvious" for a pharmacy to store every possibly beneficial drug on its shelves.

The analogy with the pharmacy's inventory problem should be carried further for it points out the central problem of constructing an information system, the contribution to the problem by Stone and Ruggles, and the appropriate strategy for further research. Like the pharmacy, the governmental statistical service must decide which pieces of information to store on its shelves, i.e., in its information system. An attempt to store all pieces of information is prohibitively expensive; yet there is some risk in not doing so since there is a finite probability that information on a particular subject might suddenly be deemed critical, just as there is a finite probability that the pharmacy might not have a drug required to treat a rare disease.

Thus both the pharmacy and governmental statistical service face a classical inventory problem: what to store given uncertain demand, non-zero storage costs, and a penalty for not being prepared. Of course, once the pharmacist decides what to store, he should sensibly arrange his shelves. And the Stone accounting system might provide a sensible shelf arrangement for the governmental statistical bureau[1]. The pharmacist must also worry about where he should get his stock. The proposal of Ruggles & Ruggles to set up synthetic data sets and the similar literature on data development probe the analogous question for the governmental statistical bureau.

What has not been sufficiently investigated, however, are the basic inventory questions of what to order, how much, and how often. These, of course, are difficult problems. However, the governmental statistical office's inventory problem is perhaps more complicated because the demanders of information do not have their demands tempered by relative prices reflecting the marginal costs of producing the information. Consequently, the often "unreasonable" data demands by government bureaucrats may simply reflect the fact that they are treating information as a free good when it is in fact not. (The demands would not seem "unreasonable" if the data were, in fact, a free good.)

The statistical office must therefore design an inventory system by assuming "hypothetical" data demand functions - that is, the statistical office must estimate the demand conditions that would exist were they to "sell" the data to its governmental customers at prices that reflect real relative costs.

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1) The author, however, is not of this opinion.

While finding a general and optimal solution to this design problem may be rather difficult, approximate solutions are possible. Specifically, guidance as to the appropriate content of an information system can result from an analysis of (1) the probable functions of the data, (2) the relative marginal importance of individual types of data in accomplishing the functions, (3) the likely frequency of demand for these data, and (4) the relative marginal cost of providing the data. It should be noted that analysis of data functions requires asking the question "What is the data needed for?" and not simply the questions "Who needs the data?" or "Who might provide the data?", questions that have already been raised in previous studies of environmental information systems.

Moreover, the often discussed issue of whether environmental data should be placed in the national accounting framework or in some other framework should be subsumed under the analysis of cost. That is, data should be put into the accounting framework only if this framework means cheaper collection and control costs. The fact that an accounting framework can be contrived through the creation of "dummy accounts" or by the introduction of new concepts of capital (i.e., "environmental assets") should not, in itself, argue for an accounting framework. Nor, in fact, should we accept Thomas Juster's argument that the potential usefulness of the accounting framework "for understanding and explaining the behaviour and performance of the system"[1] justifies its implementation. One-sided benefit-cost analysis (heavy emphasis on benefits; little on costs) is luxury for those who do not have to make the hard decisions about actual implementation.

c. The uses of environmental data

When undertaking that part of the cost-benefit analysis that concerns the probable uses of environmental data to be included in an information system, one should be careful not to confuse his academic interests with what he feels is or should be the community interest. All who have suggested expansion of the accounting system or have otherwise recommended the collection of new data have pointed out a multitude of problems that require such data for their solution. However, some of these problems deal mainly with questions of analysis or understanding (e.g., How does the system work?) while others deal mainly with questions of policy (e.g., What should be done?). Admittedly, the line between these two types of questions is fuzzy since many policy issues cannot be decided without some understanding of the system. The key word, however, is "some". A complete understanding of all aspects of the environment is no more essential for

1) Juster [18].

good environmental policy than is a complete knowledge of chemistry necessary for good cooking[1].

If data for policy are given a higher priority than data for analysis, it is quite likely that the total amount of information needed for the information system would be smaller than if the reverse were true. Several theoretical investigations of optimal environmental policy seem to arrive at the same basic conclusion: a well-designed policy can operate with knowledge of only a small subset of the relevant variables that characterize the complete physical environmental system[2]. For example, given taxing power, a regional environmental commission could control air and water pollution by taxing pollutors in proportion to residuals generated, raising and lowering the tax rates until a desired environmental standard was reached. Information needed for such a policy includes data on the production of residuals, data on the harmful effects of pollutants, and some information on the public's willingness to "pay for" a cleaner environment in terms of possible higher prices, lower production or lower employment[3]. While even these data needs may seem extensive, they are far less than the data required for some of the more sophisticated environmental models. These models, for example, require all the above policy data plus data on production processes and data describing the transmission and diffusion of residual through the media of air and water.

Of course, more sophisticated policies -- usually those policies directed at a number of specific targets -- will require more sophisticated data; and one can imagine a set of policy objectives that would necessitate exactly the same data as would be required for the most sophisticated of the analytical models. Nevertheless, it is well to recognize that, in principle, the data needs for the two objectives -- policy and analysis -- will differ. To make the distinction more concrete, each objective will be looked at in more detail below.

d. The analytical objective

It is difficult to list all the data required for analyzing environmental problems since the number of specific problems and the number of possible models for dealing with these problems is almost limitless. However, we can recognize

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1) This essential point was made many years ago by Fritz Machlup [30]. He argued that an automobile driver does not need an engineering analysis in order to know whether it was safe to pass another vehicle even though an analysis of his action would require such technical information.

2) Examples are [23] and [32].

3) In other words, the regional environmental commission would have to be democratic enough to reflect the public's constrained demand function for a cleaner environment. This demand function depends, as all demand functions do, on the public's utility function and resources.

three main areas of analysis that encompass most of the specific problems that have been raised[1]. The first area encompasses problems of residual generation; the second, problems of transmission; and the third, problems of the effects of residuals.

Analysis of the generation of residuals requires a study of the relation between specific processes and the generation of pollutants, not only by industries but also by households and governments. Theoretical studies[2] have argued that the required process analysis must be complete enough to relate all outputs, whether or not they have market value, to all inputs. The latter include not only purchased inputs but also environmental resources, such as air and water, and any inputs that are the outputs of other processes. Since the concept of outputs includes residuals, analysis of pollution disposal activities are also included under this first heading. Data required for the analysis of residual generation are an extension of the usual data required for input-output and process analysis. These requirements will be discussed in more detail in Chapter III of this paper.

Analysis of the transmission of residuals means the analysis of the diffusion and movement of residuals through air, water, and ground. In principle, transmission depends on the location of the source of the generation, the rate of generation, and physical characteristics of the transmission media - the flow of river currents, the density of the ground, weather conditions, etc. Not only are the data requirements for this analysis extensive in their own right, but because of the need to specify the source of the pollutants, it means that the data required for the generation analysis must be specified in geographical detail.

Probably the most difficult issues fall under the third area of analysis - the analysis of the effects of pollutants. This area encompasses analyses of all reasons why pollutants may be considered undesirable. While knowledge in this area is still rather sparce, it is fairly certain that large amounts of biological data, both cross sections and time series, will be required. A vast amount of data on the physical effects of pollutants (e.g., on house paints, on meteorological conditions, etc.) will also be required. Moreover, the physical and biological effects are most likely dependent on the concentration of pollutants. Thus, it would be useful to have data on the accumulated stock of pollutants as well as their generated flows. Finally, data on social preferences are needed - specifically, data on people's willingness to trade material goods for environmental improvement.

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1) These three areas parallel the three main sections of the comprehensive Russel-Spofford model as described by Kneese and Herfindahl [11].

2) For example, Kneese, Ayres, and d'Arge [23] and Ayres and Kneese [2].

e. The policy objective

As with the analytical objective, it is difficult to list the data requirements in specific detail since the set of possible policies is quite large. However, following the proposal of Herfindahl and Kneese[1], two groups of policy data can be identified: (1) Monitoring or "base line" data and (2) data needed for policy action.

The first category includes data that describe the "state" of the environment while the second category includes data needed by the policymaker in order to bring about appropriate changes. Kneese and Herfindahl further suggest that the latter type of data can be grouped into three categories: (1) "materials balance data", (2) "production function information, i.e., what types of action are possible", and (3) "information on the benefits associated with the possible courses of action". They further argue that these three types of data are "essential" for policy action.

With respect to this last point Kneese and Herfindahl have perhaps either confused analytical needs and policy needs or they envision a policy so sophisticated in design that the analytical needs and policy needs become identical. In any event, many useful courses of action are possible without detailed knowledge of the information that falls into the above three categories -- at least in the detail recommended by Kneese and Herfindahl.

Consider, for example, information falling under the second category. Kneese and Herfindahl write "... we need to know what the possibilities are for processing an effluent containing pollutants or for changing processes so as to alter the composition of effluents together with the costs associated with these different options"[2]. They then procede to illustrate their point by displaying the results of an analysis of the beet sugar industry. In that industry, a shift of processes can bring about a substantial reduction in organic wastes with a "comparatively small increase in potentially harmful gas and inert solids"[3].

The weakness of this argument, however, is that the "we" in the phase "we need to know" is not identified. If it is "we, the analyst", their arguments are valid, but if they mean "we, the policymaker", their arguments are more questionable. Suppose, for example, the policymaker knew nothing about beet sugar but did know that his constituency did not like organic wastes. Accordingly he proceeded to outlaw or tax the dumping of organic wastes. This policy should be effective in accomplishing the objective of reducing organic wastes regardless of the technical conditions in the industries affected.

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1) See [11], p. 53 f.

2) Herfindahl and Kneese [11], p. 73.

3) Analyses of the paper and pulp industry have similarly demonstrated a relation between process alternatives and residuals. See [3].

One might argue that such a naive policy is hardly socially optimal. But such a response is irrelevant to the essential message of the preceeding discussion: namely, that the marginal benefit of any piece of data for policy is dependent on what the policy is. In no sense are data "essential", if that term is to imply that the data have infinite marginal benefit independently of the policy chosen.

There are, however, good reasons why more sophisticated policies may be better policies, and, accordingly, there are good reasons why data on material balance, technical possibilities, costs, benefits, etc., may be worth the cost of their collection. These are:

(1) To insure that environmental policy objectives do not overly conflict with other policy objectives. We say "overly" because conflicts are quite likely. Action directed against a particular industry may hinder the attainment of employment and growth targets, income distribution objectives, balance of payments goals, etc. Information on relative benefits (the third category of policy data in Herfindahl and Kneese's scheme) increases in importance as the probability for conflict increases.

(2) To insure that the environmental objectives are attained at the least social cost. For example the simple policy of taxing or otherwise restricting pollution is efficient only if the private (industrial or household) response, whether it be by process change, the purchase of anti-pollution devices, or by reduction in activity, is the least costly response. Communal central disposal facilities, because of scale economies, may be less costly in real terms. Data falling in the second category above is required to analyse this issue[1].

(3) To insure that the public is aware of the environmental implications of private and public investment decisions, consumption decisions, and non-environmental public policy. Because of the complex interrelationships in the economy, those making private investment or consumption decisions may not be aware that they may be causing an environmental problem. Similarly, a social policy directed towards one sector of the economy (say, for example, a policy to construct highways) may have environmental implications quite unknown to the individual policymaker who is responsible. Data of the inter-industry type, falling in the first category above, would serve an important policyfunction of educating the public and accordingly increasing the probability that privately viewed benefits will also be social benefits.

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1) Perhaps it is obvious that this issue should be analyzed. Unfortunately, however, there are many public officials who have assumed that constructing more central disposal facilities is the best response.

As policymakers place increasing emphasis on these three objectives, data of the type needed for analytical purposes will begin to appear equally as "essential" for policy as for analysis. While ideally final decisions on the scope of an environmental data bank -- and consequently of any expansion in the national accounts -- can not be made without knowing the relative priorities placed on data for analytical purposes vs. data for policy purposes and the relative priorities placed on various policy objectives, it may be desirable to begin construction of the data bank and expansion of the accounts in anticipation of future data demands. For this purpose, a conservative planning assumption would be that as time goes on policy will tend to become more sophisticated.

Of all the data suggested by Herfindahl and Kneese as useful for both analysis and policy, there seems to be two types that will be of high importance regardless of the ultimate decisions on priorities. These are: (1) data that measure current environmental conditions and (2) data that relate industrial and household activity to the generation of residuals. The first type comprises both Herfindahl and Kneese's "base-line" data and data on the effects of residuals[1)], while the second type comprises data falling under Herfindahl and Kneese's first and second categories of policy action data - data on material balances and production possibilities.

f. Considerations of cost

Given that both types of data should be included in an environmental data bank in anticipation of future policy and analytical demands, a decision should be made concerning appropriate collection procedures and form of storage. This decision cannot be based merely on technical considerations, but also must be based on considerations of cost. As noted earlier, analysis of cost should be placed on the same footing as analysis of benefit, both being necessary for the design of an efficient data system.

While it is well beyond the scope of this paper to provide an analysis of the real costs of collecting and assembling data measuring current environmental conditions, we can safely assert that it would not be prudent to attempt to collect such data as part of an expanded national accounts system. While one can imagine that such data could be assembled in an accounting framework (perhaps based on physical mass and energy conservation principles), it is difficult to see that much would be gained by so doing. On the other hand, as will be argued in the next chapter, data of the second type - relating residuals to industrial and household activities - can be appended to many existing national accounting systems at a relatively low marginal cost. Because of the necessity to conserve

1) The mere measure of the quantity of a residual without some measure of its disutility or effects provides no basis for policy action.

mass, much of the data on residual generation is intimately related to already collected data on industrial and household inter-sector flows of materials. This intimate relation allows a technical check not only on the validity of any new data that will be assembled on residuals but also on the validity of previously collected data on inter-sector purchases of materials. Experience has already shown that the process of developing residuals "accounts" has uncovered previously undisclosed errors in the regular accounts[1]. Thus the "net" marginal cost of collecting residuals data is, in a sense, lower than the "gross" marginal cost - if one counts improvements in the regular accounts as an ancillary benefit.

The procedure for expanding the national accounting system will be the subject of the next chapter.

CHAPTER III. PROBLEMS OF EXPANDING THE NATIONAL ACCOUNTS

In this chapter a strategy is discussed for expanding the national accounting system by including certain information on the generation of residuals and the consumption of common property resources. This strategy, if followed, should greatly increase the usefulness of the national accounting system as a component of an environmental information system regardless of whether this system is to serve the interests of policymakers or analysts. Specifically, the suggested modification in the accounts will help illuminate the important relation between the size and composition of industrial activity and residual generation as well as the relationship between alternative industrial processes and residual generation. The accounts thus will provide much of the information on material balance relationships and technical possibilities that were considered essential by Herfindahl and Kneese. Moreover, since the modification relies to a large extent on existing information sources, the information cost should be reasonable.

National accounting systems describe the flows of goods and services between "sectors", defined by a variety of criteria such as geography (e.g. foreign vs. domestic account), type of ownership (e.g. public vs. private enterprises), type of product produced (e.g. manufacturing vs. agriculture), etc. Generally, the goods and service flows are measured in market-determined value units; and, indeed, the existence of a defined market is often an important criterion for inclusion. An important exception, however, is government services, which are valued at cost of production[2].

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1) See below, pp. 32, 33.
2) Other exceptions include the value of owner-occupied housing services and the value of banking services.

The basic strategy for expanding the accounts is (a) to expand the list of commodity and service flows to include all physical non-market inputs and outputs (regardless of whether they are conventionally considered as pollutants) and (b) to emphasize process distinction as the basic criterion of sector definition.

In pursuing this strategy, several issues must be faced at the outset, among them sector definition, product definition, regional accounting, etc. These will be discussed below:

a. Sector definition

Decisions on sector definition can be based on convenience, historical accident, or even purely arbitrary criteria if the accounts are primarily to serve as a mere "library" of data. However, analytical and policy objectives require more specific criteria. Unfortunately, policy objectives may dictate a set of criteria that are different from those required for analysis. This is certainly the case with the simple policy discussed earlier where a pollution tax is applied to residuals regardless of their source. Such a policy does not require the detailed industrial sectoring common to many national accounting systems and, as suggested before, the policy may not require any accounting system at all. Even if the policies are more sophisticated and thus more dependent on an accounting system the policies may require sector definitions based on political, social, or even racial distinction[1)] and these may be quite irrelevant criteria for most analytical purposes.

Theoretical models of optimal environmental policy suggest that the sectoring for the expanded accounting system should meet one basic criterion: that sectors however defined and regardless of their degree of aggregation should be distinguished by how they transform physical inputs into physical outputs (where the concept of inputs and outputs is comprehensive - including all physical entities regardless of whether they have conventional market value). This criterion implies that if a sector is an aggregate, the components of the aggregate should be similar (ideally, the same) in the inputs and outputs, i.e., they should have both process homogeneity and product homogeneity.

1) Policymakers may be interested in applying the pollution tax differently depending on whether a firm is black- or white-owned.

It is well known that these objectives, which are also desired when sectoring input-output tables[1], are very difficult to attain in practice[2]. However, the objective is more closely approached in low levels of aggregation than at higher levels. The reason for this is that as products (or processes) get defined in more detail, processes necessary to produce products tend to become unique. Thus, while there are a large number of processes associated with an aggregate product such as "transportation equipment", there are fewer associated with the product "automobiles", even fewer associated with the product "Ford automobiles", and so on.

While this argument suggests that aggregation should be avoided if possible, much aggregation is of course an inevitable consequence of the way the basic data are collected. If, as is usual, the establishment is the basic reporting unit, the most detailed disaggregation possible would be to define each sector as a separate establishment. However, since establishments often produce several products with several processes under the same roof, a large amount of aggregation would remain. Given that some aggregation is inevitable, it is unrealistic to expect to attain the ideal goal of homogeneity in both process and product, and consequently some choice must be made between defining sectors according to process.

From the standpoint of using the expanded accounts for the analysis of pollution problems, it seems that the best choice would be to distinguish sectors by process within product rather than by product alone. For example, instead of a "paper" sector, there would be "paper made by sulfate process" and "paper made by sulfite process". In certain cases, however, the alternative processes within product group are so numerous, especially in the chemical industry, that this procedure may be cumbersome.

An alternative approach of choosing process criteria without regard to product may have some appeal. For example, a sector might be defined to include all sulfur burning and sulfur dioxide producing industrial processes. Of course, such a sectoring criteria would be far removed from standard national accounting practice. And while such a radical change in the accounts might be justified for the analysis of pollution problems a rigid adherence to such a radical sectoring

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1) Thus in Norway where there is a close relationship between the activity of constructing national accounts and the activity of constructing policy models of the input-output type, the following sectoring guidelines are used:
   (1) The activities included within a sector should have similar inputs and outputs;
   (2) If the activities produce different outputs, the outputs should remain in approximate fixed proportion to each other;
   (3) Vertically integrated activities should be included within the same sector.

2) They may be even more difficult to attain when the input and output list is expanded to include "non-market" inputs and outputs.

rule would make the accounts practically useless for the analysis of anything else. As mentioned before, it is questionable whether any rigid sectoring rule should be built into an accounting system, especially when the concept of national accounting is broadly construed to include the entire accounting process[1].

b. Accounting for waste disposal processes

Waste treatment that is the exclusive activity of an establishment, regardless of whether the establishment is privately or publicly owned, presents no special accounting problem. There is no reason why such an activity cannot be accounted for in the same manner as any other industrial process. However, waste treatment that takes place within an establishment does present a problem, one that is probably quite familiar to input-output analysts: how to account for two or more jointly-performed activities that take place within a single sector. The specific issue here is whether such "in-house" waste disposal activities should be accounted for as if they were part of the sector's principal production process or whether these activities should be assigned to one or more separate "dummy" sectors.

The latter alternative may appear attractive since it would highlight the importance of disposal activities and would permit the accounting to show how these activities respond to policy. However, one major difficulty in treating jointly-performed processes as if they were performed separately is that there is no way to accurately account for separate input and output flows. If processes are truly jointly-performed, separate commodity and service flows are not observable even conceptually, let alone in practice.

However, the above remark exaggerates the problem somewhat since in reality the degree of "jointness" and the consequent problem of separate accounting of waste-disposal differs from establishment to establishment. For example, a particular factory may have very distinct disposal equipment. In that case, a separate accounting will be relatively easy, with the major problem being how to allocate overhead expenditures. On the other hand, another factory (perhaps in the same industry) might be accomplishing the same disposal objectives without any explicit disposal equipment but instead by a complex mixture of process change and recycling of materials. In this situation, a separate accounting of the "disposal activity" is practically impossible.

One way to account for intra-establishment waste disposal activity regardless of the degree of "jointness" is to do the following. Account for intra-establishment waste disposal as if it were part of the establishment's principal process, but maintain a level of disaggregation high enough to assure that those

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1) See above, p. 14.

establishments within a product classification that had explicit waste treatment facilities would be lumped into one accounting sector, those that employed recycling process would be in another sector, those that did nothing about wastes would be in a third sector, etc.[1)]

Offsetting one obvious drawback of this procedure - a substantial increase in the number of accounting sectors - is the fact that such an accounting system will show clearly the variety of likely responses to waste management policies: the installation of waste-disposal equipment, shifts in processing, effects of recycling, etc. These alternative responses could be totally obscured in a more aggregated accounting system.

c. Defining "non-market" commodities

Presently there exists no standard list of "non-market" inputs and outputs (residuals) that can be appended to standard commodity lists (such as the Brussels Nomenclature). This situation raises problems that are far more serious than may appear at first. There is, of course, the familiar problem of lack of comparability between nations or regions that would arise if each region or nation devised its own list. An obvious approach towards solving this problem is to attempt to account for all possible non-market inputs and outputs in the greatest detail possible. One argument for doing this is that it will permit future aggregations that will be in agreement with a standard list and classification scheme once they are decided upon.

Unfortunately, there are two problems with this suggestion. First, a detailed list of all possible non-market inputs and outputs will be very large indeed, and may, in fact, expand the size of the accounting system beyond what can be conveniently handled, even by electronic computers.[2)] A more fundamental problem, however, is that a residual that is a combination of other residuals may have properties that in no way represent the properties of the individual inputs. The property of the aggregated residual, in terms of its harmful effects or in terms of how it can be further processed, is a function of the amounts of the components and their physical and chemical properties. However, this "function" may be difficult to calculate or completely unknown.

An example of this aggregation problem is readily available. The OECD is

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1) It should be noted that this procedure is at odds with the implicit accounting framework required by the model suggested by Leontief where waste disposal is always treated as a separate activity.

2) In the pilot study of an expansion of the accounts for the paper pulp industry (see Appendix III) the list of non-market inputs and outputs exceeded 50 items. Since many of these are unique to the industry, a similar detailed accounting for other industries, could be expanded to produce a list very much larger.

conducting an investigation of paper and pulp residuals in its member countries. It is possible (using methods described in Appendix III) to estimate paper and pulp residuals in considerable detail. The OECD, however, has requested BOD_5 (biological oxygen demand over 5 days measured in kilograms oxygen) be used as a pollution measure. Unfortunately, there is no practical way to convert the detailed list of residuals to BOD_5.[1)]

The "correct" classification scheme can not be determined until more is known about the effects of residuals (and their aggregates) and the technical possibilities for further processing. Only then will it be known which residuals in which classifications should be the objects of policy. Until that time, however, the accounting of residuals may have to rely on several alternative classification schemes. As with decisions on sector classification, "non-market" commodity classification should perhaps be kept free from rigid, inflexible rules.

d. Valuation and measurement

The existence of markets serves the national accountant in two important ways. First, market valuations provide a natural way to compare heterogeneous commodities. Moreover, if the markets are not too imperfect -- that is, if prices tend to approximate relative social demands and real social costs -- relative market values are useful bases of comparison for they provide information on the relative social preferences for different commodities as well as their relative worth as factors of production.

Secondly, market valuations permit the accountant to make and compare input and output totals. These totals not only have meaning in themselves. Since the accountant defines inputs and outputs to assure that the value of their totals are equal, they also provide a way for controlling for errors and for approximating missing data. To some extent, this second virtue of market valuations can be duplicated by using weight as a unit of measurement. However, the monetary unit of measure is certainly very convenient since it can be applied to items having very different physical characteristics.

Whether it is possible to duplicate these two features with respect to the measurement of non-market commodities is an important problem. Two possible approaches have been suggested, more or less explicitly, in the recent literature on environmental externalities. The first approach is to impute monetary values. Unfortunately, those who promote this procedure have been rather vague on how the imputations are to be made. As discussed in Appendix II, the value of a given amount of pollution is one thing for the producer of the residual, another thing

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1) Estimates of BOD_5 for paper pulping residuals are usually based on experiments conducted on the waste liquor.

for the recipient of the residual, and the value that would be observed were the level of pollution market-determined is different again. Indeed, as the Appendix shows, even if the national accountant could observe the functions measuring the benefits and dis-benefits of pollution to the producers and damaged parties respectively, he still could choose among several "reasonable" ways to value a given amount of pollution. The fact that he can not directly observe these functions (or any points on these functions) make the imputation problem doubly difficult[1]. The remarks by Juster that these imputation problems merely place a "greater burden" on the national accountant rather understates the difficulty[2].

The other approach, advocated by Kneese and his associates[3], is to measure all physical inputs and outputs, whether purchased or not, in units of weight. Laws of conservation of mass assure that an input-output weight accounting can be set up corresponding to the usual input-output value accounting. Thus, using weight measures permits the second virtue of market valuation to be duplicated and extended to non-market inputs and outputs. However, the first virtue -- the fact that market valuations permit a meaningful comparison of heterogeneous items -- is not duplicated. A pound of SO_2 is not half as bad as two pounds of H_2S.[4]

Nevertheless, of the two measurement approaches, Kneese's appears to be the most practical. Yet data limitations make it difficult to apply the approach to the complete list of inputs and outputs. Many items are not reported by weight. This is especially true of commodities flowing into the household sector. Therefore, it will be necessary in the first attempts at material balance accounting to measure inputs and outputs in whatever physical units of measure that are reported, leaving the conversion to unit of weight for later analysis. While this compromise makes a complete comparison of the total weight of inputs and outputs impossible, physical and chemical laws permit a partial balancing of inputs and outputs for selected items. For example, an estimate of the production of the residual SO_2 can be checked by comparing the weight of its sulphur atoms to the weight of the sulphur atoms entering the process as inputs.

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1) All imputation problems are, at least, "singly" difficult since benefit functions cannot be directly observed. But the problem of multiple valuation is usually avoided by assuming economic equilibrium. For example, conventionally, imputed rent to the services of capital is the rent the capital stock would earn if the size of the capital stock were optimal. However, the basic reason why pollution is a problem, is that its "market" is not in equilibrium and its amount is, thus, not optimal.

2) See Juster [18].

3) In several publications. See [2] and [23].

4) This obvious point was apparently the basis of a criticism of Ayres and Kneese by Noll and Trijonis [35].

e. Other issues

The following issues can be treated more briefly:

(1) Final consumption

While conventional accounting for the most part neglects production activities of the household, the importance of households as a major producer of residuals is too significant to be ignored. Household consumption (as well as the consumption of government) should be treated as another processing activity. However, the concept of a final recipient of materials can be usefully preserved by introducing a "dummy" environmental sector. This sector can be imagined to "produce" as outputs non-market input commodities as well as natural resources with residuals and the depletion of the stock of natural resources viewed as the environmental sector's balancing input items.[1)]

(2) Accumulation

Since the adverse effects of many residuals are thought to be more related to their accumulated stocks than to their flows, it would be useful to have a stock or "capital" account corresponding to the flow or "current" account. In principle, this is not difficult. Take the stock of a particular residual at the beginning of the period, add the gross generation of the residual, and subtract out the deterioration ("depreciation") of the stock during the accounting period. The result is the stock at the end of the accounting period. Unfortunately, for most "non-market" commodities little is known about two crucial elements of the equation: the beginning stock and the deterioration rate. Accumulation accounting must await further scientific investigation.[2)]

(3) Geographical accounting

There is no doubt that geographical considerations have played a significant role in the past analysis of residuals problems and geography can be expected to play a future role in policymaking even though there are numerous examples of policies that have neglected geographical considerations. These considerations include questions concerning the location of pollution sources, the characteristics of the media that are the primary recipients of the residuals, the location of populated areas, weather conditions, etc. As important as these data are, it does not appear likely that they can be included within a formal accounting framework. Even a system of interlocking regional input-output accounts will only partially

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1) This approach is similar to that adopted by Kneese, Ayres, and d'Arge in their Walras-Cassel general equilibrium model. See [23], p. 76 f.

2) Of course, it is possible and may be worthwhile to account for the stock of those non-market (and market) commodities for which the beginning stock and deterioration rate is known, e.g., certain natural resources.

handle the geographical information. Moreover, there has been little success in building such accounts with the available data on the flows of marketed commodities, let alone with data on residuals. However, two pieces of geographical information can be collected almost as a byproduct of the usual effect in collecting data for the accounts: data on the geographical location of producers of residuals and data on where the residuals are initially deposited, that is into land, air, rivers, lakes, etc. The first information is already available while the second could be obtained at low marginal cost.

CHAPTER IV. DATA DEFICIENCIES AND NEEDS

The author has made a very modest attempt to implement some of the ideas discussed in this paper. Specifically, two sectors of the national accounts of Norway were "expanded": Sectors 2721 and 2722, sulfite and sulfate paper pulp respectively. In addition, a small effort was made to estimate the "production" of residuals in the household sector.

In the process of doing this empirical work, certain problems arose. This section discusses these problems and the recommendations they suggest.

a. The collection of pollution data on residuals

In Norway, as in the United States, the official census bureau up to now has not been given prime responsibility for the assembly of data on residuals and non-market inputs. In Norway, for example, the Ministry of Finance has assumed responsibility for organizing the data, a large portion of which is to be collected by the Norwegian Association of Industries under contract with the Finance Ministry.[1)] The data forthcoming from the Association will be based on a survey of its members; however, the responses will be reviewed by technical specialists.

This procedure in principle - and, so far, in practice - is a poor one for obtaining the process information needed to do a full accounting of all material inputs and outputs. For the approach to be fully successful, the reporting establishments would have to reveal process information that they presently reveal only to official census bureaus under the strictest confidentiality safeguards. It is unlikely that firms will be willing to permit access to detailed process information by governmental agencies without these confidentiality safeguards. At best they may be willing to reveal their production and

1) The data has not been fully transmitted to the Finance Ministry as of the date this is being written.

use of non-market commodities to a non-census agency providing their reports are not checked against the reported market material inputs and outputs found on the industrial census forms. To permit such a check by a non-census agency, such as the Finance Ministry, would again raise the confidentiality issue. But, as suggested earlier, such a check is highly desirable as a method to control the quality of the reported data.

The experience in Norway substantiates the views expressed in the previous paragraph. The Industry Association has, up to now, provided only summary data in, at best, 2-digit industry detail. It is, of course, impossible with such data to associate processes with pollutants, let alone associate particular establishments with the generation of residuals.

An obvious recommendation suggested by the foregoing is that the data on non-market commodities be collected by the same agencies that collect data on market commodities: the official census bureaus. The bureaus are experienced in preserving confidentiality, while at the same time, providing policy-makers with necessary information on a "need to know" basis.[1] Furthermore, it seems better public policy to let an official census agency, rather than industry, decide what data should be suppressed from public scrutiny through aggregation -- especially when the data in question concern the use for disposal purposes of such public resources such as air, land, and water.[2]

b. Data generation and quality control

In Norway, and perhaps elsewhere, it seems to be a foregone conclusion that inter-industry data are to be developed solely through the questionnaire process. This has been the case with normal industrial input-output data and currently is the case with pollution data.

Unfortunately, such a singular reliance on questionnaires creates a serious quality control problem. Indeed, one could say that the system assumes a reasonably high level of data quality, for the current procedures to check quality are rather weak. Basically the check is one of temporal consistency: an establishment's response is compared to the response of earlier years. As long as reporting establishments are reasonably honest and efficient, one might argue that these temporal consistency checks are all that are required. However, in the process of analyzing the chemical pulp industry, with the purpose of laying

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1) All this should not imply that total confidentiality be preserved at all costs. Certain policy may require the publication of certain establishment data, e.g., the amount of residuals generated.

2) One other argument for census bureau collection is efficiency. Much of the information sought by the Industry Association questionnaire was already available in the files of the Norwegian Central Bureau of Statistics.

out a typical set of "expanded" accounts[1], several examples were found where inputs had been mis-classified (e.g., in one case sodium cloride was reported as sodium sulfate). There were also other instances of questionable entries. The temporal consistency check did no good as these errors were duplicated on earlier forms.[2]

It is quite possible that problems of quality control will be even more severe with respect to data on residuals. In the first place establishments are being asked to report on items that are normally far removed from the information needed for every day business operations. Many managers may have no idea what residuals are generated and, thus, they may be unable to provide accurate data. In the second place, if they believe that they may be penalized or taxed in proportion to residuals generated, they may be unwilling to provide accurate data. Laws and social pressure may force firms to fill out the forms, but these incentives can not assure accurate responses.

Data on both market and non-market inputs can be checked for internal consistency by qualified specialists who have knowledge of industrial process. Moreover, a process analysis can provide information that may otherwise be missing from the forms. Indeed, it was possible by using process analysis to estimate the use and generation of non-market inputs and outputs for the Norwegian pulp industry without having access to the Industry Association's pollution questionnaire. However, questionnaires on pollution are still required to provide information on the establishment's treatment of residuals as well as information on any process techniques that may be peculiar to the reporting establishment.

It would be, of course, prohibitively expensive for census bureaus to have every questionnaire analyzed by an engineer. However, census bureaus should consider such analyses on a sample basis. Also, an industry specialist could develop "typical" input-output ratios for a select group of market and non-market inputs and outputs; and the responses of establishments could be compared to these ratios informally[3] or formally through such techniques as statistical discrimination analysis. In cases where an establishment's reported ratios differ greatly from the "typical" ones, representatives of the reporting firm can be invited to defend their responses or make any necessary corrections.

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1) See Appendix III.

2) In one case the liquor from a calcium sulfite pulping operation was reported as being delivered as input to a kraft pulping operation. This is technically very unlikely. Most likely the liquor was fermented to produce alcohol; but this is not reported by the kraft firm as one of its secondary products.

3) The errors discussed above were discovered through such an informal comparison of reported ratios with the ratios that were "typical" for the process used.

c. Efficient data retrieval

A frequent complaint of those engaged in empirical work is the lack of data. To this complaint can be added another: the lack of an efficient procedure for retrieving and processing data that has already been collected. Many hours were spent hand copying data that existed in machine-readible form but were otherwise unavailable because of lack of computer programs that could readily access the data.

The reason for this state of affairs seems to be that computer data processing has been specialized towards producing a standard version of the national accounts. In order to produce a modification of the standard version, fairly expensive re-programming becomes necessary.

What is needed is a change in data-processing philosophy. A better objective for the computer programmer would be to prepare general data retrieval systems that would permit the assembly of basic data in a variety of ways. Each item of data should be "subscripted" or coded to identify the piece of information according to various criteria: by reporting establishment, by process, by main produced product, whether the item is an input or output, by geographical location of establishment, by the unit of measure, by commodity code, etc. The program should permit rapid sorting and aggregating along any of the dimensions or subscript codes.

As long as computer programming is directed towards a single rigid accounting framework, any expansion of the accounts will look unattractive from a cost-benefit point of view.

d. Data by weight

Finally, there is a need to measure more of the inputs and outputs in units of weight, even in those cases where other units of measure are more commonly used in market transactions.

The lack of weight data seems to be most severe for commodities consumed by the household sector, with the exception of unprocessed food products, meats, and fish. Without this information, it will be impossible to develop complete material balance accounts for the household sector, and consequently it will not be possible to improve upon the presently crude estimates of household waste generation.[1] Given the probable importance of this sector as a generator of residuals, this data gap is quite serious.

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1) The bases of the existing estimates are generally unknown to the author. In Norway, one estimate was based on a very small sample of garbage trucks. In general, where ranges for these estimates are reported, they are quite large, often larger than the reported mean values.

CHAPTER V. CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the principal recommendations of this paper.

1. The problem of how environmental factors can be included within the national accounts cannot be analyzed without first making a clear distinction between the concept of national account aggregates and the process of national accounting -- the latter being the main concern of this paper.

2. Since the national accounts can be viewed as part of the government's inventory of statistical information, principles of optimal inventory policy may suggest the appropriate scope of the system including the amount of environmental information. These principles require an analysis of the costs of storing data, the likely demands for the data, and the social costs of not being able to satisfy demands.

3. In anticipating data demands, a distinction should be made between those data that are required for policy and those data required for analysis. In general, the inventory of environmental data required for analysis will be larger than that required for policy. However, as policies become more sophisticated in an attempt to meet several policy targets, the demand for data can be expected to grow.

4. Considerations of cost suggest that data that measure current environmental conditions are best left out of the accounting system.

5. Considerations of likely demands (for either policy or analytical purposes) as well as costs suggest the desirability of expanding the accounts by including a measure of the inter-sectoral flows of "non-market" commodities along with the already accounted for flows of marketed commodities. These "non-market" commodities include air and water as inputs and pollutants and other residuals as outputs.

6. Accounting sectors should be defined with an emphasis on grouping similar technical processes rather than similar products or type of ownership. To assure process homogeneity within any defined sector, the level of disaggregation will likely be higher than presently employed.

7. Since waste disposal and waste destruction activities are often highly intertwined with ordinary production activities, these activities should not be assigned to separate sectors, but, rather, included as part of the principal processing activity. An exception, obviously, is in those cases where the exclusive processing activity of a sector is waste disposal.

8. The appropriate definition and classification of residuals cannot be determined until more is known about their undesirable effects. The accounting system should be flexible enough to permit alternative definitions and aggregations.

9. At first, residuals should be measured in conventional units. However, the consistency checks of double-entry accounting can be preserved if all physical inputs and outputs can be measured by weight. Value or monetary imputations, while very desirable, are extremely difficult and may, in fact, be theoretically impossible.

10. The conventional concept of "final" consumption, while valuable for many policy purposes, should not obscure the fact that many consumption avtivities are residual-generating processes. Such activities should be treated similarly to industrial processes.

11. While it would be desirable for the expanded accounts to contain information on both the geographical generation and distribution of residual flows, the latter will probably have to be neglected in initial accounting efforts for reasons of cost.

12. Accounting for changes in the stock of residuals must await better scientific information on existing stocks of residuals and their natural rate of "deterioration".

13. Data on the generation of residuals and the consumption of non-market inputs should be assembled by the same statistical agencies that collect ordinary marketed-commodity input-output data. One important reason for this centralization is the fact that these two types of data should be technically consistent. These properties of technical consistency provide a useful check on the quality of both types of data.

14. Data storage and retrieval procedures should be improved so that it would be possible to construct alternative summary accounts from the same detailed set of micro-account data. In this way, aggregation and classification rules can be easily altered as the need arises.

15. A greater effort should be made to measure commodity flows by weight -- even for those commodities that are conventionally measured in other physical units.

APPENDIX I. SOME NOTES ON THE DEFICIENCIES IN ACCOUNT AGGREGATES

The following is a brief contribution to what has become a huge literature on the subject of whether national income aggregates provide a good measure of a nation's welfare. Given the already large number of pages on this subject, it is realized that the marginal product of this contribution may be quite small. Indeed, the purpose of this Appendix is to show that recent articles on this issue have similarly added little to earlier discussions of the inadequacies of account aggregates as welfare measures.

A basic philosophical distinction between national accounts and national account aggregates is that the former measures quantities while the latter attempts to describe quantities. Because of this qualitative aspect, aggregate concepts were open to criticism from their earliest history, on the grounds that they described the wrong thing or that they did not describe what they claimed to describe. Adam Smith, for example, criticized Quesnay's measure of national income because he felt that all commodities were "productive", not simply agricultural commodities as Quesnay claimed; and, later, economists were to criticize Smith for his failure to include services in his income-concept.[1] Obviously, these criticisms arose not because Quesnay and Smith made outright errors, but rather because they and their modern critics had different ideas of what the income aggregate should describe. To argue that Smith's concept of national income was "wrong" while the modern concept is "right" presupposes acceptance of the modern view that national income should describe both productive potential and economic welfare.

The other ground for criticism of account aggregates -- that they do not describe what they claim to describe -- is amply illustrated by much of the current debate over whether GNP or NNP provides an adequate description of welfare.[2] Actually the recent discussion is, in its essentials, a repeat of an earlier debate over the meaning of account aggregates among Hicks [12] [13], Kuznets [25], and Little [29]. Many of the points made by these writers involve theoretical points that can be directly applied to the current issue of whether the inclusion of environmental factors will make GNP a better welfare measure. Thus, it is worthwhile to review these points.

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1) For a brief history of national accounting, see Kendrick [22].

2) However, some of the modern criticism of environmentalists is on the first grounds. They assume GNP was intended to describe national productive ability and that for this purpose the GNP is quite adequate. Their criticism is rather that production potential is the wrong measure of the nation's well-being.

Hicks set the ground rules for the discussion by carefully distinguishing the concept of economic welfare from the concept of general welfare. His dichotomy and definition of changes in economic welfare were not questioned in the subsequent debate. The principal issues discussed by Hicks were: (1) whether account aggregates could be constructed to display unambiguous changes in economic welfare; and (2) whether account aggregates could be constructed to measure changes in "productivity" or, to use Little's more accurate phrase, "production potential". Unfortunately, Hicks' basic distinctions between economic and general welfare and his careful statement of the problem, are missing in much of the current debate.

To Hicks and to others who have seriously reflected on the problem, it was a foregone conclusion that the national account aggregates could not reflect general well-being or welfare. The debate instead centered on whether these aggregates could be used to indicate changes in economic welfare, meaning changes in general welfare "under an assumption of unchanged tastes". In other words, the ground rules for the debate presumed the existence and stability of a social preference function. Modern economic welfare theory emphasizes the restrictiveness of not only the assumption of such a function being stable over time, but also the restrictiveness of the assumption that such a social preference even exists.

A large portion of these articles of Hicks and Kuznets were concerned with the following problem: Assuming the existence and stability of a social preference function, can an index number describing aggregate income be constructed such that an increase in this index implies an unambiguous increase in welfare? The problem is especially difficult since the assumed social preference function is unobservable and its behaviour with respect to changes in income distribution is unknown. While both Hicks and Kuznets attempted to solve this problem by establishing criteria that permitted the comparison of the potential incomes that could be available to individual members of society[1)], Little pointed out that no "scientific" criterion was possible since the welfare implications of income distribution was a matter of ethics, not science. About all one can conclude is that if income redistributions are not too severe, the larger the increase in the income aggregate, the larger the probability of an actual welfare increase.

Another portion of these articles raised issues that are perhaps more pertinent to the current debate over the treatment of environmental factors in the accounts. Of special importance is the discussion of whether national income

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1) Hicks' criterion asks the question: Could people to-day be made worse off than yesterday by some appropriate redistribution of past income? and Kuznet's criterion asks the question: Could people be made better off to-day than yesterday by some appropriate redistribution of present income?

was equivalent looked at, on the one hand, as the value of output or, on the other hand, as the value of factor input. The answer to this question depends on several ancillary issues: (1) the extent to which government services are intermediate rather than final goods; (2) whether excise taxes imply higher output values than factor input values; and (3) the approximate valuation of "public" or "collective" goods.

Any attempt to include pollution and similar externalities in either the national accounts or national account aggregates must face a similar set of issues.

The problem of excise taxes, for example, is analogous to the problem of having a different value for pollution depending on whether it is valued from the producer's side or from the consumer's side.[1)] An excise tax on a product serves to drive a similar wedge between the producer's value and the consumer's value. Admittedly, the excise tax problem is simpler because the value of the tax provides an estimate of the discrepancy between the producer's and consumer's value. The discrepancy is far harder to observe with respect to pollution.

However, the solution to the excise tax problem, common to most accounting systems, suggests a possible solution to the pollution valuation problem: namely, leave the differences in valuation explicit. In the U.S. system, for example, indirect business taxes are included in the output aggregate (net national product) but they are excluded from the factor input aggregate (national income). If the value of pollution were added to the accounts a similar practice could be followed: namely, value output from the consumer's point of view and value input from the producer's point of view.

Kuznets suggested another solution to the problem: namely, maintain the equality of the output and input valuations by counting the value of the excise tax as implicit factor income. The argument was that the government provides indirect services to factors of production, the value of which equals the value of the indirect tax. In dismissing this approach, Hicks recognized that certain government services provide "invisible" or "unallocable" benefit upon the community in general (Hicks [13], p. 169) and that equating the costs of these unallocable benefits with implicit wages of factors of production seemed "hopelessly far-fetched". Hicks was alluding, in more modern terminology, to the problem of "public goods"; goods that provide benefit to the community as a whole, regardless of whether or not every member of the community pays in proportion to the benefits received or pays for them at all. Because of these characteristics, the marginal cost of the services of a lighthouse (to use the classic example of a public good), may be near zero for an incremental amount of service provided to a ship, while the marginal benefit of this service can be

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1) See Appendix II.

quite high. There is no reason for equality of total cost and total benefit either; and, needless to say, this holds regardless of whether the lighthouse was financed with excise taxes or by some other means.

If public-goods effects cause problems for the evaluation of governmental services, these effects raise similar problems for the evaluation of pollution. The basic reason that institutions have not evolved to assure a Pareto-optimal level of pollution -- the one level where a unique valuation exists from both the producer's and consumer's view[1] -- is that the reduction of pollution is an activity that often shares the characteristics of a public good. If my neighbor would arrange a reduction in air pollution, I would benefit. Assuming he takes a symmetrical view of me[2], little effort at pollution reduction would take place.

The concern of Hicks, Kuznets, et al. of how to divide governmental expenditure between intermediate and final goods also has its counterpart in much of the current debate. The specific issue is not how to classify "defensive" expenditures designed to offset pollution. Under our current accounting system, expenditures of this sort made by households and government are counted as final consumption demand.[3] The suggestion that, alternatively, they should be counted as either gross investment or as current maintenance outlays designed to maintain the stock of "environmental capital" has proven to be a source of hot debate.[4]

It is not surprising that the debate on the classification of goods between intermediate and final has continued for so many years. On one side, we have those who feel that the present classification of goods is unsatisfactory. They argue that current procedures lead to account aggregates that overstate welfare gains. Their opponents in the debate may or may not agree, but argue that,

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1) See Appendix II.

2) Actually complete symmetry is not to be expected since my neighbor may have more at stake, if, for example, he lived closer to the polluting source or otherwise felt stronger about the problem than myself. Thus, in practice, a great deal of anti-pollution activity does take place through the voluntary (non-government imposed) efforts of individuals. This is because most pollution is a "quasi-public good" and not a "pure public good". For a discussion of the importance of this distinction, see Mohring and Boyd [31].

3) "Final goods" in the debate refers to final consumption goods and not the more broadly-defined concept of final demand of the open Leontief input-output model. In the I-O model, final demand includes any goods that are not included among the goods consumed by production sectors on current account.

4) Such a debate took place at a recent Conference on Income and Wealth of the National Bureau of Economic Research, held at Princeton, New Jersey, November 4-6, 1971. See, for example, Juster [18].

In a similar spirit to the Juster paper, the Netherlands Central Bureau of Statistics has proposed to quantitatively measure the amount of environmental deterioration by the amount of defensive outlays that would be necessary to maintain the services of the environment (presumably, at some base period level). See [34].

in any event, it is not, in many cases, practical to decide whether a particular item is intermediate or final. (Is an air conditioner only a defense against increased pollution or does it provide net utility in its own right?)

Indeed, this debate is likely to continue indefinitely since the basic issues involved cannot be resolved with theoretical economics. There is an important philosophic question of whether economists -- in their role as economists -- can, with the tools of economic analysis, specify what goods should or should not be included in society's welfare function. To argue that a list of goods should or should not be included as final consumption items is to argue that one particular group of items directly affects welfare and another only has indirect effects. Yet society's welfare function is unobservable directly. (It may not even exist.) Economic analysis does provide the means to hypothesize society's behavior under an assumption of a particular social welfare function; but to assume a function and to actually observe such a function are far different things. Until someone discovers a way of directly observing the welfare function, true final consumption will be what the national accountant says it is and the debate will continue.

In the meantime, it is the opinion of this writer that participants in the debate could better spend their time devising empirical tests that would support their positions. For example, if one believes that a particular item should be included, then one should suggest a testible hypothesis that clearly implies one observable result if the item were included and another if it were not. Only through such an empirical approach can the debate be freed from the quagmire of subjective opinion.

APPENDIX II. A THEORETICAL VIEW OF THE IMPUTATION PROBLEM

Imputing monetary values to externalities -- and thus measuring them with the same monetary yardstick as the one used for commodities traded in the market place -- would undoubtedly be very useful, no one has suggested a procedure that the national accountant could safely follow. It is the purpose of this Appendix to show that the problem is more than a practical one. Theoretical analysis suggests that there may be, in principle, no single monetary imputation that even approximately measures the value of an externality to all people affected by it.

The theory will be presented in terms of a familiar two-party model with a single polluter and a single injured party. This simple model is quite adequate for illustrating many of the problems that are of concern in this paper. No implication is to be drawn that this model is realistic or even adequate for the analysis of other pollution problems such as the design of appropriate anti-pollution policy.[1] (However, the model is misleading in one very important respect; and this will be discussed below.)

The model assumes that pollution has economic properties similar to other factor inputs. Its generation provides a valuable service to the polluter, measured by the hypothetical financial loss he would suffer were his pollution less than it actually is. Like other factor inputs, the model assumes diminishing returns: the incremental value of pollution declines with increased generation. This incremental value is shown diagrammatically as line a-a in Figure 1.

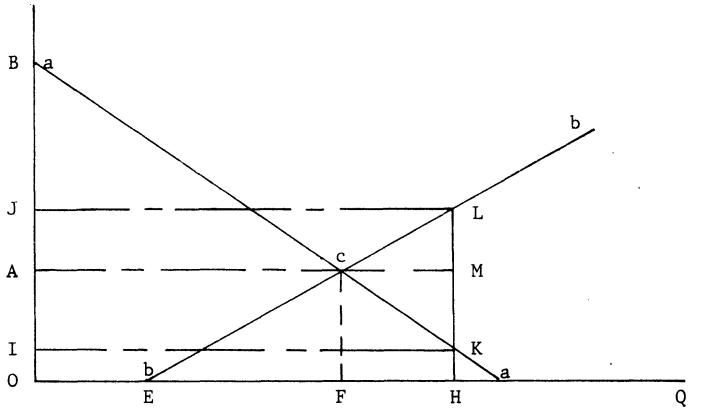

Figure 1

1) Kneese, for one, makes a convincing argument that for the analysis of optimal pollution management, a more general equilibrium model is required. See [23].

The model further assumes that the injured party views the same pollution as a source of negative value, either because the pollutant itself causes him actual or psychic harm or because its generation makes it more difficult for him to enjoy items or substances that give him positive benefit (such as fresh air or space).[1] In contrast to the polluter's view of the pollutant's incremental value, the model assumes, from the viewpoints of the injured party, increasing returns: the incremental harm or negative value of pollution increases with increased generation. This incremental value is shown as line b-b in Figure 1. (Its negative sign has been ignored in order that it can share the same verticle axis as line a-a.)

It is well known[2] that if the injured party could sell "rights" to pollute (in units of Q), or if the polluter could sell "rights" not to pollute, in the absence of any taxes a bargain would be struck at a unit price of OA with OF units of pollution generated. Furthermore, under the assumption that the welfare of the polluter and the injured party were weighted equally by society, the level OF would be socially and Pareto-optimal. Then if a national accountant wished to value pollution analogously to ordinary goods, he would value it at a figure equal to the rectangle OACF, although probably with a negative sign.[3] The reality is, however, that such a "rights market" does not exist and consequently, no market price can be observed.

Moreover, there is a fundamental reason why such "rights markets" do not exist and why Pareto-optimal levels of pollution are difficult to obtain. As mentioned in Appendix I, the reduction of pollution often has the characteristics of a public good. It is in this respect that the model described in Figure 1 is especially misleading. If, as the model assumes, there were only one polluter and one injured party, there would be no public good problem. Thus, it is possible and, in fact, often is the case that some accommodation between the parties could be arranged, perhaps with the assistance of the courts. Assuming rational behavior on both sides, this accommodation could be expected to result in a pollution level fairly close to the Pareto-optimal one.

In reality, however, the actual pollution level is likely to differ from OF. In this situation, there is no obviously correct unique price or pollution

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1) The source of the pollutant's dis-benefit, whether it is bad in itself or because it uses up common property resources, is not of importance in the model. But these possible alternatives are of importance in a complete analysis of the problem.

2) See Buchanan and Stubblebine [4] or Turvey [48].

3) This figure does not equal either the true value of the pollution to the polluter (equal to + OBCF) or to the injured party (equal to - ECF), but this discrepancy between "market" values and true values exists also with ordinary goods.

value available to the national income accountant, even if he knew the position of the marginal value curves a-a and b-b.

Suppose for example, the polluter produces what would be from his point of view a nearly optimal pollution level of OH. (He could not be expected to produce much more than that since the marginal value of so doing quickly approaches zero.) What is the value of the pollution?

Using the polluter's marginal value as the price, it would be (1) OIKH and positively valued; but using the injured party's marginal value, it would be (2) OJLH and negatively valued. Other valuation schemes may seem equally sensible:

(3) the difference between the above two values or a net negative marginal value of IAMK;

(4) the total value to the producer or OBKH;

(5) the total value to the injured party or minus ELH;

(6) the difference between the values in (4) and (5) or OBKH- ELH;

(7) the gain to the polluter by exceeding the optimal level OF or FCKH;

(8) the loss to the injured party by exceeding the optimal level or FCLH; and

(9) the net loss due to exceeding the optimal level or CLK.

Nearly all these alternatives have some desirable properties. Schemes (2) and (5), for example, imply a zero value when pollution is OE or less, i.e., when it is at a level low enough to be ignored by the injured party. Schemes (3), (7), (8), and (9) have the property that optimal pollution levels receive zero value, perhaps a desirable feature if the accounting value is to be used to monitor the effectiveness of an optimal management system. Finally schemes (1), (4), and (7) have certain practical advantages. Since it is largely a (admittedly complex) technical matter, the value of pollution to the polluter can be estimated by considering cost implications of adjusting to lower pollution levels.[1] Since it involves psychic, physical, and physiological factors, estimating the negative value of pollution to the injured party is far more difficult.[2]

This analysis serves to illustrate that accounting for environmental externalities involves a doubly-difficult imputation problem. The usual problem of imputing a price or value for non-market activities is compounded by the fact that conceptually a unique price or value does not exist for both producer and consumer unless pollution levels are Pareto-optimal, i.e., at a level equal to OF.

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1) Russel [44] has provided such estimates for a hypothetical petroleum refinery.

2) With respect to air pollution, attempts of such measurements, sometimes referred to as the formulation of "damage functions" have been made by Lave and Seskin [26] and Ridker [42].

APPENDIX III. AN EXAMPLE OF "EXPANDED" ACCOUNTING - THE NORWEGIAN CHEMICAL PULP INDUSTRY

This appendix describes an effort to "expand" the national accounts for two sectors in order to illustrate the accounting principles -- and the difficulties in applying these principles -- suggested in Chapter III of the paper.

The sectors selected were the Norwegian sulfite pulp industry (ISIC 2721) and the sulfate of "kraft" pulp industry (ISIC 2722). These industries were chosen for two reasons. In the first place a comparison of these two accounts after they have been expanded to include the flows of non-market inputs and outputs should serve to illustrate the gain in information resulting from defining sectors according to "process" rather than by "product". In the Norwegian accounts, a full accounting of even the market-transacted inputs and outputs is made only for the aggregation of these two sectors: chemical pulp.[1] While sulfite pulp and kraft pulp are similar and, depending on the amount of bleaching, can in fact be close substitutes for certain uses, they differ substantially in their use and generation of "non-market" inputs and outputs.[2]

The second reason for illustrating the accounting concepts with data for the chemical pulp industry is that available information permitted detailed estimation of the use and generation of "non-market" commodities in the absence of any survey data. While surveys of water use and the generation of residuals by chemical pulp establishments have been undertaken in Norway, the responses to the questionnaires were not available to the author.

In connection with their study of the generation of residuals in the paper industry, Bower, et al. [3] prepared flow charts describing typical processes used in the manufacture of chemical pulp including pulping, bleaching, and drying. Separate process charts were developed for the kraft process, for the various sulfite processes (magnifite-, ammonia-, calcium-based processes), and for the semi-chemical process (which, in Norway, is considered in the Industry Statistics as part of the sulfite-pulp industry). The various inputs and outputs are shown in great detail with their amounts measured in pounds per English ton of pulp (estimated to contain 1800 pounds of fiber). By dividing these numbers in half, one converts these figures to kilograms per metric ton pulp, the basic units used in the tables of the appendix.

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1) However, the supporting industry statistics and survey forms provide the data necessary for constructing a full input-output accounting for the two subsectors. The Official Industry Statistics [5] does recognize these two subsectors as distinct.

2) See Bower et al. [3] for a discussion of this point. Their paper is the basis of much of the technical material in this appendix.

These flow charts were used in the following manner. For our base year (1969), each of the 16 establishment survey questionnaires for the sulfite industry and the 6 questionnaires for the sulfate industry were examined first to determine (1) what process was employed[1] (by scanning the list of reported inputs), (2) how much pulp was produced, (3) what proportion of the pulp was bleached, and (4) what proportion was dried. Then the appropriate flow charts were applied to each establishment in order to estimate total use of air and water and total generation of a long list of residuals. As many as three flow charts would have to be applied if the establishment in question produced pulp of which some or all was bleached or dried (one chart for pulping, one for bleaching, and one for drying).

Generally these flow charts were applied without any modification for possible differences between Norwegian processes and the typical processes described in the charts.[2] There are, however, several reasons why these flow charts may not describe the Norwegian processes exactly. There may be process changes associated with the production of some secondary product such as alcohol; there may be differences in operational efficiency and, consequently, in the amount of chemicals required for replenishment of stocks circulating in the process; and, most important, there is the real possibility that the "wrong" process was being attributed to the reporting establishment. This last point is probably the case with respect to bleaching. A single sulfite bleaching process was attributed to all sulfite establishments. This is a probable source of error since many alternative bleaching techniques are possible.

Of special importance is the fact that the flow charts assume no residuals processing beyond that which is desirable for the most efficient production of the principal product, pulp. To a certain extent in Norway some of the residual waste "liquor" is fermented for the production of alcohol and this processing has been estimated to reduce soluable organic wastes about 15 per cent below the estimates presented below.[3] Moreover, some residuals processing such as waste-burning, while not materially affecting the total weight of the residuals will of course alter the relative amounts between solid, gas, and liquid forms from that which is implied by the flow charts.

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1) It was assumed that there was only one process used per reporting establishment, a good assumption considering the small size of the Norwegian establishments.

2) An exception, however, was made for the production of "kvistmasse" or "knot-pulp" produced in small quantities by most of the establishments. "Kvist-masse" is a pulp made from grinding up the knots, which are normally screened out in the pulping process. (It is used to make wall-board.) Since this screening and the associated generation of residuals were shown on the flows charts, it was a simple matter to account for the reduction in residuals associated with the production of "kvistmasse".

3) Private communication with chemical engineer Hans Peter Dahm.

The poorer these flow charts describe the Norwegian processes, the poorer the estimates of residuals are likely to be. Therefore, in order to get some idea of how well the charts described Norwegian processes, the amount of certain important purchased inputs computed by the charts were compared to the amounts actually reported in the establishment questionnaires.[1] While these comparisons were made for each establishment, for disclosure reasons only the results consolidated over all establishments are shown in Table 1.

Table 1. Comparison of reported use of chemicals with use computed from flow charts. (All figures in metric tons)

	(1) Computed	(2) Reported	(2) - (1) Difference	$\frac{(2)-(1)}{(2)} \times 100$ Per cent difference
CHEMICALS				
I. Sulfite process				
a. Pulping				
$CaCo_3$	71,888	59,024	-12,864	-21.8
S	69,556	72,105[2]	2,549	3.5
$Mg(OH)_2$	2,597	8,791	6,194	70.4
b. Bleaching				
Cl_2	23,648	25,407[3]	1,759	6.9
NaOH	2,366	18,659	16,293	87.3
CaO	10,880	9,749	-1,131	-11.6
II. Sulfate process				
a. Pulping				
CaO	2,448[1]	18,259	15,811	86.6
Na_2SO_4	6,528	13,986	7,458	53.3
b. Bleaching				
Cl_2	2,994	3,599	605	16.8
ClO_2	327	10,711	10,384	96.9
NaOH	1,685	6,142	4,457	72.6

1) Includes 155 used in bleaching.

2) Converted to sulfur equivalent.
Actually reported: S = 27,818
FeS_2 = 40,419
SO_2 = 45,729

3) Converted to Cl_2 equivalent.
Actually reported: Cl_2 = 23,573
NaCl = 6,112 (Cl_2 obtained by electrolysis)

1) Since sulfur is purchased in several forms (as pyrites, as SO_2, and as free sulfur), all reported sulfur inputs were converted to their equivalent value in metric tons of free sulfur.

The general conclusions that can be drawn from the establishment by establishment comparison and which is supported by the data shown in Table 1 is that the flow charts reflect the Norwegian sulfite processes better than they reflect the Norwegian sulfate processes.[1] Furthermore, there seems to be a general problem of fitting the bleaching charts to the Norwegian data, although the use of chlorine seems fairly well "predicted".

It seems safe to conclude that the subsequent estimates of residuals are fairly accurate with respect to those generated by the sulfite establishments. Since these establishments account for approximately three-fourths of total Norwegian chemical pulp production (by weight), estimates of total residuals generated by the chemical pulp sector also are probably reasonably accurate. It should be noted that the computations of chemicals used in the sulfate process and in bleaching greatly underestimate the reported use.[2] The laws of mass conservation suggest that the estimates of the residuals associated with these processes are similarly on the low side.

By the above methods, two accounts were constructed that identified as many as 100 market-transacted input items and about 50 non-market inputs and residuals for the sulfite and sulfate sectors. Items were measured both in physical and value terms except for the non-market items, which were measured only in physical units.

Tables 2 and 3 were derived from these detailed accounts. In order to perform a material balance, the input and output items consist of aggregations of only those commodities or factors that enter or exit the processes physically. (Thus, labor, electric power, and certain inputs clearly of a "capital" nature were excluded.) The total approximate weight of these inputs exceeded the total approximate weight of the outputs in both accounts by the amount shown under the category "Unallocated Excess". These amounts provide a measure of the accuracy of our accounting and are directly related to our inability to predict the amount of residuals accurately, the inaccuracy of the assumed density of the basic wood input, lack of knowledge of the true water content of the pulp, etc. The "Unallocated Excess" represents about 4 per cent of the total input or output weight in the sulfite account and about 9 per cent in the sulfate account. The lower percentage for the sulfite sector is consistent with the conclusions drawn

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1) The poor forecast of the use of $Mg(OH)_2$ is not of major importance since only three establishments, accounting for about 15 per cent of total Norwegian sulfite production, use the magnifite process.

2) Apparently much of the error in "predicting" the level of chemical use in the Norwegian kraft establishments is explained by the fact that operational efficiences can vary greatly plant to plant. The flow chart assumed a fairly efficient operation. "Efficiency" is used here in its technical or engineering sense. The Norwegian operations may be economically efficient depending on the costs of chemicals vs. the costs of other factor inputs.

from the analysis behind Table 1: namely, that the sulfite residuals were better estimated by the flow charts than were the sulfate residuals.

Comparison of the two detailed "expanded" accounts used to build Tables 2 and 3 reveals substantial differences between the sulfite and sulfate sectors with respect to their relative use and generation of non-market inputs and outputs. Also, the composition of these non-market items differs substantially from the composition implied for aggregate of these two sectors. Table 4 illustrates these points by comparing the absolute and per-ton levels of selected non-market inputs and outputs for the sulfite sector, the sulfate sector, and their aggregate.

Table 2. Sulfite pulp materials balance account (1969). (Metric tons)

Input		Output	
Wood ($3,532,570 M^3$)	2,119,542[1]	Pulp	612,635[2]
Chemicals	251,309	Residuals	
Fuel oil	200,415	Liquid	111,685,562
Water	116,849,890	Gas	2,788,637
		Solid[3]	662,380
Air	900,682	Unallocated excess ..	4,572,624
Total	120,321,838	Total	120,321,838

1) Estimated density = .6 T/M^3.

2) Estimated dry weight.

3) Includes substantial water content. Dry value for sulfite is approximately 30,600 tons and for sulfate, approximately 3,000 tons.

Table 3. Sulfate pulp materials balance account (1969). (Metric tons)

Input		Output	
Wood ($1,303,364 M^3$)	782,018[1]	Pulp	198,674[2]
Chemicals	60,877	Residuals	
Fuel oil	28,201	Liquid	17,930,788
Water	20,026,820	Gas	2,047,321
		Solid[3]	24,729
Air	1,320,210	Unallocated Excess ..	2,016,614
Total	22,218,126	Total	22,218,126

Notes: See Table 2 above.

Table 4. Comparison of selected estimates of "non-market" inputs and outputs.
Norwegian pulp industry (2721 and 2722) 1969

	Sulfite (2721)		Sulfate (2722)		Total (2721 + 2722)	
	Total (tons)	Per ton pulp	Total (tons)	Per ton pulp	Total (tons)	Per ton pulp
INPUT						
Water	116,849,890	190.73 t	20,026,820	100.802 t	136,576,710	**168.341 t**
Air	900,682	1.470 t	1,320,210	6.645 t	2,220,892	**2.737 t**
OUTPUT[1]						
Liquid						
Water	110,936,073	181.080 t	17,920,271	90.199 t	128,856,344	**158.825 t**
Total dissolved solids	626,939	1 023.348 kg	3,041	15.307 kg	629,980	**776.498 kg**
Organic	624,185	1 018.852 kg	514	2.587 kg	624,699	**769.989 kg**
Inorganic	2,754	4.496 kg	2,527	12.719 kg	5,281	**6.509 kg**
Fiber	1,804	2.945 kg	112	.564 kg	1,916	**2.362 kg**
Carbohydrates plus Clorine combined.	0	0	2,621	13.193 kg	2,621	**3.231 kg**
Gas						
Cl_2	238	.388 kg	23	.116 kg	261	**.322 kg**
Residual sulfides	5	.008 kg	1,940	9.764 kg	1,945	**2.397 kg**
SO_2 total	40,281	65.751 kg	1,482	7.460 kg	41,763	**51.476 kg**
From processing	32,249	52.640 kg	352	1.772 kg	32,601	**40.183 kg**
From fuel oil[2]	8,032	13.111 kg	1,130	5.688 kg	9,162	**11.293 kg**
Solids[3]	662,380	1 081.198 kg	24,729	124.470 kg	687,109	**846.914 kg**

TOTAL PULP PRODUCTION, 1969:
Sulfate pulp 198 674 metric tons est. dry weight
Sulfite pulp 612 635 " " " " "

1) Assumes no pollution control equipment or other residuals processing.
2) Assumes S content 2%.
3) Includes substantial water content. See note 3 to Table 2.

For example, the large generation of dissolved solids for the chemical pulp industry (776 kg per ton pulp) is dominated by the dissolved solids generated by sulfite processing where more than a ton of these dissolved solids per ton of pulp is produced. On the other hand, the sulfate sector generates per ton of pulp far more dissolved chlorine (negligible for the sulfite sector) reflecting the fact that sulfate pulps often require relatively more bleaching. Finally, sulfite processing dominates in the per-ton production of SO_2, although this estimate has been challenged by a Norwegian expert as being far too high.[1)]

The information provided by these detailed "expanded" accounts supports the view put forth by Kneese and his associates[2)], that significant alteration in the amounts and composition of residuals are possible by process changes, even without the installation of pollution control equipment.

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1) The American expert who prepared the sulfite flow charts does not, of course, share his Norwegian counterpart's opinion. The data in [20] also support the Norwegian position.

2) For example, see [23].

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