EVALUATION AND USE OF THE POLLUTION ABATEMENT COSTS AND EXPENDITURES SURVEY MICRO DATA

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CES 96-1 November 1995

Abstract

The Pollution Abatement Costs and Expenditures Survey (PACE) is an annual survey of manufacturing establishment's operating costs and capital investment expenditures for pollution abatement purposes. This paper provides a description and evaluation of the PACE micro data available at the Center for Economic Studies (CES). The paper provides an overview of the survey, how the sample is drawn, how the survey questionnaire has changed over time, an assessment of the data quality, and suggestions for the use of the data, as well as its limitations. Also included are suggestions for modifying the survey design and data processing procedures.

The PACE data series, linked to the economic data in CES' Longitudinal Research Database (LRD), covers the years 1979-1993, excluding 1983 and 1987.

Keywords: Pollution Abatement, survey data, survey design, survey methodology.

* I thank Stephen Andrews, and Robert McGuckin for comments on an earlier draft. I benefitted greatly from conversations with Elinor Champion and Gretchen Dickson, who provided extensive information on the historic design and processing of the MA 200 survey.

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I. INTRODUCTION

The Pollution Abatement Costs and Expenditures Survey (PACE) conducted by the U.S. Bureau of the Census (Bureau) is the principal source of data on pollution abatement expenditures by the manufacturing sector. Capital investment expenditures for pollution abatement purposes in the manufacturing sector reached 8.4 billion dollars in 1992. This amount represents 7.5 percent of the total manufacturing capital investment for that year, and 0.3 percent of manufacturing values of shipments. In addition to capital investment, pollution abatement operating costs for the manufacturing sector reached 19.2 billion dollars, or 0.7 percent of the value of shipments. While pollution abatement costs and expenditures are a relatively small portion of total manufacturing costs and expenditures at the aggregate level, this is not necessarily true at the micro, or plant level. In addition, the impact of pollution abatement expenditures on the behavior and performance of manufacturing plants is nontrivial.

This report on the use and evaluation of the PACE survey data is motivated by the Center for Economic Studies' (CES) twofold mandate. First, CES is responsible for enhancing the accuracy and usefulness of the Bureau's data measuring economic activity in the U.S. Second, CES is to make the micro data

available to internal and external researchers. [1] The demand for micro level pollution abatement data at CES has increased substantially in the last few years. Recent users include government agencies (EPA, DOE, and the Congressional Office of Technology Assessment), universities (Clark University, Columbia University, and Carnegie-Mellon University), and other facilities (Argonne Laboratory and the World Bank).

CES has compiled a longitudinal database suitable for micro analyses by linking the annual PACE with the CES Longitudinal Research Database (LRD). The LRD is a concatenation of the economic Census of Manufactures (CM) and the Annual Survey of Manufactures (ASM). Recent studies include the relationship between pollution abatement costs and productivity (Gray and Shadbegian, 1994 and 1993), the cost of air pollution abatement (Hartman, Wheeler, and Singh, 1994) environmental regulation and location choice (Levinson, 1992), the role of state and plant characteristics (Post, 1994), the role of community characteristics and toxic pollution (Singh, 1994), the dispersion and heterogeneity of toxic intensity (Streitwieser, 1994), and the cost of air pollution abatement (Hartman, Wheeler, and Singh, 1994). These studies have focused attention on the quality of the data and the structure of the survey itself.

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[1] Due to the confidential nature of the survey data, research based on Bureau plant level data can be conducted only at CES, or at the Boston Research Data Center, located in the Census Bureau's Boston Region Office.

The purpose of this paper is twofold. The first is to evaluate the PACE data quality and comparability over time, as well as, to suggest changes in the survey design and data processing procedures. This aspect of the paper will be of most interest to the survey analysts at the Census Bureau. The second purpose of the paper is to inform PACE data users of the data available at CES, and to provide an overview of the survey, including how the sample is drawn, how the survey questionnaire has changed over time, an assessment of the data quality, and suggestions for the use and limitations of the data. The audience for these topics is the outside researchers working with the data at CES.

The paper is organized as follows. Section II discusses the survey design and the changes over time. The longitudinal database created by linking the PACE survey to the LRD and the subsequent data file structure are presented in Sections III and IV, respectively. Data quality is addressed in Section V. Finally, recommendations for future survey design and data processing procedures are given in Section VI. Survey questionnaire forms are included in the Appendix.

II. PACE SURVEY DESIGN

The PACE survey has been conducted annually since 1973 by the Environment, Technology and Innovation Branch of the Bureau’s

Manufacturing and Construction Division. Plant level data for 1979-93 currently reside at CES in SAS® data sets, with two exceptions. The 1983 data has not been recovered and no survey was conducted in 1987. Historical data files for surveys conducted prior to 1979 cannot be retrieved. Aggregate tabulations are published annually by the Bureau in Pollution Abatement Costs, and Expenditures, 19XX. Details of the scope, methodology, and data limitations are contained in each year's report.

The PACE survey covers manufacturing establishments with 20 or more employees. [2] Early surveys indicated establishments with fewer than 20 employees accounted for only about 2 percent of pollution abatement costs. Establishments in Apparel and Other Textile Products (SIC 23) are also excluded from the PACE survey as these establishments operate primarily in rented quarters where abatement efforts generally default to the landlord. [3] In addition, establishments selected for the survey, but spending less than $500 on pollution abatement annually, are not required

[2] Establishments with fewer than 20 employees are exempt from the PACE survey in order to reduce the reporting burden for small establishments. These small establishments comprise about 10 percent of the manufacturing establishments.

[3] Each year's PACE data includes a number of establishments with nonmanufacturing or textile industry codes. However, the number is quite small, constituting less than 0.1 percent of any given year's observations.

to complete the detailed portion of the questionnaire. [4]

Figures 1 and 2 show the distribution of establishments by size and 2-digit industry for 1992, respectively. (The patterns is similar for all years.) While the distribution of manufacturing establishments is dominated by small (fewer than 50 employees) and medium sized establishments (50 to 500 employees), the reverse is true of the PACE sample. The PACE sample is predominately medium and large sized establishments. Thus, while the sample may be small in terms of number of establishments, employment and value of shipments in manufacturing are well covered.

The PACE sample selection methodology has evolved over time. Prior to 1994, the PACE survey was a probability proportionate to size (PPS) subsample of the ASM. [5] The ASM is itself a probability sample of approximately 55,000 establishments drawn from the CM. The CM is a complete enumeration of all manufacturing establishments, conducted every five years, in years ending in '2' and '7'. There are more than 375,000 establishments currently classified as manufacturing

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[4] Such establishments must indicate they spend less than $500 annually for pollution abatement and return the questionnaire. Thus, this data item can serve as a screening device for analysis.

[5] The measure of size used to determine sampling probabilities is weighted ASM total value of shipments. As value of shipments increases, the corresponding probability of selection increases. Thus, the PACE sample is biased towards larger establishments.

establishments. The ASM sample is drawn a few years after each census; the same panel of establishments, adjusted annually for births, deaths, and changes in status of establishments, is surveyed for five years. The PACE sample was then drawn from the ASM. The PACE sample weight for a given establishment is the inverse of its probability of selection. Sample selection was controlled at the 4-digit industry level, based on the designated level of expected error.

Prior to 1984, a new sample was selected from the ASM only as time and resources permitted. No attempt was made to incorporate births (new establishments) between sample selections. In addition, there was no replacement for establishments which exited from the sample due to closing or status changes. As a results, the sample size declined between 1979 and 1982.

Starting with the 1984 survey, the PACE sample was drawn concurrently with the new ASM sample (from the previous Census) and maintained for five years. Sample maintenance for establishment births was also instituted in the early 1980s. A sample of establishments from the ASM birth sample was added to the PACE sample to retain the sample at about 20,000. The variation from year to year was a function of the rate of establishments leaving the ASM panel compared to the rate of establishments entering. However, for several years, the ASM birth file passed to the PACE survey staff was incomplete. The

result was an apparent birth rate much slower than the exit rate. At the time this was discovered there was a backlog of thousands of births and insufficient resources to supplement the sample. This is why the survey sample declined in the years between new sample selection.

Beginning with the 1989 survey, the sample size was reduced to approximately 17,000 in order to reduce processing costs and reduce respondent reporting burden. At the same time, the sample was reallocated by industry. Pollution intensive industries were identified an over sampled in order to generate highly reliable estimates. Next, 3-digit industries, or balance of 3-digit industries that were of secondary concern were identified, where pollution was still an important concern. Finally, all other industries were pooled for representation as a group.

A caveat about the 1989-91 sample is necessary. The 1989 ASM file used as a frame for the 1989-91 PACE samples contained incorrect industry SIC codes for several thousand establishments. (The industry data in the 1989 ASM are correct; it was the transferred file which was affected). Thus, the industry representation in the 1989-91 PACE is not as accurate as designed. A new sample was drawn in 1992 to correctly stratify the industry representation.

Beginning with 1994, the PACE sample is no longer an ASM subsample. Rather, the 1994 sample was drawn from the 1992 Census, with the intent of keeping that sample for five years.

Because of respondent burden, smaller plants in the ASM may or may not be sampled. For example, if a plant is selected for another survey, it is excluded from sampling on the PACE survey. It is not known at this time how this will impact our ability to link PACE data with concurrent economic data from the ASM (or CM).

Geographic location has never been a consideration in the sampling process. Aggregate statistics at the 2-digit SIC level are published by state, after adjusting with a fixed-based difference. [6] This methodology yields unbiased statistics, but with a large sample error. Very careful consideration should be taken before results based on a micro analysis of PACE establishments in a particular locality are used for inferences about the universe of establishments in that locality.

III. LINKING PACE TO THE LRD

For most research, the full benefit of the micro data files on pollution abatement is attained by linking the PACE files with the LRD file. In so doing, we create a record of the establishment's production activity and pollution abatement activity. A synergy for potential research is achieved by merging the information in the two data sets that cannot be

[6] For a discussion on fixed-based difference adjustment to ASM and ASM based survey data, see Davis, Haltiwanger, and Schuh (1990).

realized by each in isolation. Examples of such work are the impact of pollution abatement expenditures on plant productivity (Grey and Shadbegian, 1993) and the relationships between state and plant characteristics and pollution abatement expenditures (Post, 1994).

A complete linkage between the PACE and LRD cannot be achieved for any year's data. Match rates of PACE establishments with same year's LRD establishment data are below 70 percent for 1979-81. However, recent match rates have greatly improved, averaging about 95 percent since 1989. There are several reasons for less than total matching. First, for early survey years establishments selected for the PACE survey may be from an earlier ASM panel, and therefore an earlier CM, than the concurrent ASM. This source of nonmatches probably affects small establishments disproportionately, due to the sample design for the ASM.

A second source of nonmatches is the lack of "permanent plant numbers" (PPN) in the PACE data files. [7] CES uses PPN to identify and link all establishments in the LRD. The PPN is considered "permanent" to the establishment and usually does not change over time, even when the establishment is sold. [8] In

[7] Only the 1991 and 1992 PACE name and address files have contained PPN's.

general, the PACE survey files identify establishments only by "Census file number" (CFN), which should be equivalent to the LRD's "identification number" (ID), designating ownership.

A third source of nonmatches is related to ownership changes. The processing of ownership changes for PACE and the ASM was entirely separate. Therefore the PACE CFN does not always match that in the concurrent ASM. Only recently, has the SSEL been used to update ownership status before preparing the year's mail file. Table 1 lists the ASM and CM from which each year's PACE sample is drawn, as well as the number of nonmatches and match rates between PACE and the LRD.

Table 2 shows the number of establishments which can be continuously linked to the LRD across time. By looking across a row, the size of the balanced panel of establishments which can be constructed is shown. For example, 12,557 establishments in the 1979 PACE survey can be linked to the 1979 ASM. There are 11,872 establishments covered in both the 1979 and 1980 PACE which can be linked to the 1979 and 1980 ASMs. The balanced panel size decreases substantially across time. Data on only 1,734 establishments are found in the PACE and LRD files for the

[8] The PPN is a 10-digit number, usually equal to the 1977 ID number. If the plant started operations after 1977, the PPN is equal to the most current ID number of the plant. A PPN can change if an establishment is split into multiple sites for survey purposes. The CFN, however, also changes with a change in ownership, when the establishment moves from being part of a single-unit firms to a multi-unit firm, and the reverse.

years 1979-93. Given the dynamics of establishment survival and the structure of the PACE survey sample, any balanced panel is likely to consist of large establishments and not be representative of the manufacturing sector.

IV. CES PACE-LRD DATA FILE STRUCTURE

The linked PACE-LRD data files are maintained at CES as SAS® data sets. PACE establishments not found in the LRD are maintained in the PACE data files; all LRD variables, including PPN, are blank values. All variables are labeled and the PACE survey questionnaire number is included in the variable's label. LRD variable labels are in uppercase letters; PACE variable labels are in upper and lowercase letters. There are potentially three types of data for each question in the PACE survey. *Reported data* are exactly as written on the survey form by the respondent. *Edited data* contain all analyst and computer edits, including imputes, and reported data where no changes are made. *Adjusted data* are the weighted edited data, which when tabulated, yield the published statistics. Reported data are not available for 1984-86 and adjusted data are not available for 1979-86, although adjusted data can be derived using the edited data and the survey weights. In general, the linked PACE-LRD files include the reported and edited data. The PACE survey weight and item edit flags are included, where available. Item edit flags

are discussed in Section V.

In addition, the PACE name and address files are maintained, when available. Name and address files are not available for the early years. PACE was initially part of the Current Industrial Report (CIR) system. Name and address files were housed separately from data files. Only in 1984 were name and addressed included in the database. Table 3 shows the information available at CES for each PACE survey since 1979.

V. DATA QUALITY

The PACE data files residing at CES are used occasionally to generate aggregate statistics. It is often the case that the micro files do not result in aggregate statistics equal to those in the published reports. This can occur for a variety of reasons, the most common being the late receipt or editing of data included in the CES files. Most often, these differences are so small as to be inconsequential. However, for some items, particularly at the 4-digit industry level, the differences can be substantial. Examination of the micro data usually reveals the difference can be attributed to a single (or few) late reporting small establishment(s), which, because of its large weight, results in a significant difference in the aggregate.

Figures 3A-5B present the published and CES micro data generated aggregate pollution abatement capital expenditures and

operating costs, for air, water, and solid waste, respectively.[9] The published statistics are represented with circles and micro data generated comparable statistics by squares. For capital expenditures there is very little difference between the two series, except for 1979 and 1982 expenditures for solid waste. Differences between the published statistics and the micro data-based statistics for operating costs are significant for solid waste in 1979 and all three media in 1985.

There are a number of issues which impact the quality of the PACE data and which set limits on the empirical analysis which can be conducted on the micro data. Issues to be considered include the following.

- 1983 data file,
- Comparability over time,
- Conflicting industry, location, summation information,
- Imputed data,
- Blank data, and
- Measurement error -- relationship to LRD data.

First, a comment about terminology is in order. The PACE survey uses the terms ***expenditures*** with capital investment and ***costs*** with operating and maintenance. This report will maintain the dichotomy of expenditures and costs referring to capital and operating and maintenance expense, respectively.

[9] Blank values are set equal to zero.

1983 Data File

The available 1983 data are not the file used to generate the published statistics. Historical data files for the PACE survey were obtained in a variety of formats. The only file located with 1983 data is one with 1983/1984 data. This file is for 1984 data. The establishments in the file are those for the 1984 survey. The 1983 data are on the file to establish the format for entering and editing the 1984 data. This creates three possible situations. First, for those 1984 establishments which were included in the 1983 survey, the 1983 data were used; data were imputed for all blank items. Second, for 1984 establishments not covered in the 1983 survey, a record was generated with imputed data based on industry average value. Lastly, for 1983 establishments not in the 1984 sample, there is no establishment record. There is no apparent methodology for determining which 1983 establishments are from the 1983 survey and which are fully imputed. Similarly, for the individual 1983 data items, we cannot distinguish reported/edited from imputed data as impute flags were not set when this editing file was created.

In most years, the prior year data should be close to the current data, except when a new sample is selected. As the 1983 and 1984 PACE samples were drawn from different universes, the 1980 ASM (1977 CM) and the 1984 ASM (1982 CM), respectively, the probability is substantial that many of the 1983 observations are

fully imputed. Nearly 9,000 establishments in the 1983 PACE file are not found in the 1980 ASM, from which it was drawn. This suggests these records are full imputes. Survey analyst estimate that as much as two-thirds of the establishment records are imputed. For this reason, CES recommends against using the 1983 data for any analysis.

Comparability of Survey Design Over Time

The survey questionnaire has also been modified over time, although the basic framework of data collection on new capital costs and operating expenditures by media has remained unaltered. In general, more detail has been collected over time and thus intertemporal comparisons can be made at an aggregate level by combining appropriate categories. Survey questionnaires are included in the Appendix.

Several differences between the 1992 and earlier surveys impact certain types of comparisons made across years, as detailed in Pollution Abatement Costs and Expenditures, 1992. Several changes affect the capital expenditures data. Pollution abatement capital expenditures by end-of-line and production process enhancements (formerly changes-in-production processes) now apply to solid/contained waste as well as for air and water. The trends in end-of-line and changes-in-production process for air and water are presented in Figures 6-7, respectively.

As of 1992, the split between hazardous and nonhazardous

capital expenditures is now reported for water, not just air and solid waste. Also, prior to 1992 capital expenditures for air pollution included a breakdown for seven types of pollutants. In 1992, these data are combined into three categories: 1) particulates, sulfur oxides, nitrogen oxides, carbon monoxide, hydrocarbons/ volatile organic compounds, and lead, 2) other hazardous, and 3) other nonhazardous air pollutants.

Finally, starting in 1992, the survey includes "nonmedia" and "other" pollution abatement capital expenditures. "Nonmedia" includes underground storage tanks and site cleanup; "other" capital expenditures are for noise abatement, radiation abatement, multimedia, and not elsewhere classified. Capital expenditures for abatement that crosses environmental medias are included in "multimedia."

Intertemporal comparisons of detained operating costs are more difficult than comparisons of capital expenditures. Prior to 1983, operating costs were broken down by media (air, water, and solid waste) or by category (depreciation, labor, materials, and other services), but no category data within media were collected. From 1983-1991, information on the four categories of operating costs were collected by media. Starting with the 1992 survey, modified the category definitions. The "fuel and electricity" operating costs are separated from "materials and supplies." "Equipment leasing and other costs" are separate from "contract work/services" and combined with "materials and

supplies." "Labor" is relabeled "salaries and wages." Intertemporal comparisons can be made from 1984-1992 can be made by media for depreciation, labor, and an aggregate "all else" category, as shown in Figures 8-10.

Finally, the split between hazardous and nonhazardous operating costs is now collected for air and water, not just solid/contained waste. [10]

Conflicting State and Industry Information

Industry and location are important selection and control characteristics for researchers using the PACE data. It is therefore important that these characteristics of establishments are correctly identified. The PACE data files include 4-digit industry for each establishment, and location information is available from the PACE name and address files. As shown in Table 4, comparison of these two characteristics from the PACE files with those on the LRD files reveals that the incidence of conflicting state location information is low -- less than 1 percent for all years except 1988.

Conflicting industry classification is more common, averaging less than 10 percent for all years except 1982 and 1988, where nearly 25 percent of the establishments have conflicting industry codes. The substantial industry differences

[10] Further clarification of “nonmedia” and “other” terminology will be included in the 1995 survey.

in these two years probably reflect the revision of the SIC codes in 1982 and 1987 and the processing practice of concentrating industry switches in a census year or the first year of an ASM panel.[11] Industry classification differences at the 4-digit level are probably not of great concern. However, the 2-6 percent with differing 2-digit industry codes may be of some concern for the researcher, depending on the sample and issue being examined. There appears to be an improvement in the consistency of industry codes after 1988, reflecting efforts to reconcile the PACE and ASM data.

Imputed Data

The 1984-93 PACE files contain flags which identify the status of the data entry. No flags are available for years prior to 1984. As a general rule, numeric values without a flag are either reported or edited, but not imputed. There are a number of possible flags which can appear in the data files as listed is Table 5. Data items with a flag set to 'IM', or 'M' are imputed. In principal, capital data are not to be imputed; however, we find some capital expenditures with the impute flag set in all years.

The prevalence of imputed data is of great importance to researchers, as imputed observations are frequently deleted from

[11] See McGuckin and Peck (1993) for a fuller discussion and measurement of industry reclassification.

micro data analysis. Two issues are of interest concerning imputed data. First, the time trend in the aggregate impute rate, and second, how impute rates vary across data items for any given year.

The aggregate rates for reported, edited, imputed, and blank data are given in Table 6. [12] The incidence of data with no flag is reported also. Aggregate impute rates range from a low of 2.2 percent in 1985 to a high of 17.1 percent in 1989. Prior to 1989 imputations were a part of the general edit program. Beginning in 1989, the imputation program was separated from the general edit program.

Little is known about the pre-1989 imputation programs, other than the fact that imputed data are not necessarily a processing correction for item nonresponses. For example, in processing the 1984-88 data, an impute flag was set for cases where the data are computer corrections for respondents' addition error. The researcher frequently will find that the data flag on the operating expenditure subcategories (depreciation, labor,

[12] Rates for reported, edited, imputed, and blank data are based on the number of data items which are reported (corrected, imputed, or blank) divided by the total number of data item. For example, there are 19,505 establishment records in the 1988 PACE survey. Eighty-six establishments did not complete the full survey due to the various questionnaire screening items, leaving 19,419 respondents. There are 42 items on the 1988 survey requesting numeric data. Thus, there are a total of 19,414 x 42 = 815,598 possible data items. The impute flag, 'M', is set on 17,982 of these items. The impute rate is calculated by: 17,982 / 815,598 = .022, or 2.2 percent.

materials, and other costs) indicates reported data, while the flag on the total indicates imputed data. The impute flag was set when the reported total did not equal the sum of the four subcategories and a corrected total was substituted (14,116 in 1984; and 12,597 in 1985). Therefore, researchers are cautioned against omitting all data based on the impute flag being set. [13]

Since 1989, imputation has been a two stage process and all imputed data are designated with the flag "M". In the first stage, establishment impute cases are identified based on the following definitions.

Full Impute - Any nonreporting active establishment with prior year data for media specific total pollution abatement operating costs, payments to government for pollution abatement, and costs recovered through abatement activities.

Partial Impute - Any reporting active establishment with prior year data for media specific total pollution abatement operating costs, payments to government for pollution abatement, and costs recovered through abatement activities, and did not respond for these items in the current period.

Imputation occurred only for key item codes, with each key item imputed on a separate basis. In general, the industry average rate of change between the prior and current year was applied to the prior year's data. In the second stage, balance checks are

[13] There may be other instances of this type of flag setting which are unknown at this time. Thus, it may be important for the researcher to examine the flags for the data items of interest to determine which data items are true imputes.

performed on detailed data items. [14] Capital expenditures are not imputed, even when prior expenditures were reported, in recognition of the lumpy nature of capital investment.

During the editing process prior year data were imputed for establishments new to the sample. This had the impact of using prior imputed data to generate current imputes. This practice was halted with the 1994 data.

Conditional impute rates by 2-digit industry and for specific data variables are reported in Tables 7 and 8. The impute rates in these two tables are conditioned on the questionnaire item field having numeric data present; e.g., the portion of the data being imputed, given there is numeric data present. [15] Tobacco products (21), paper (26), chemicals (28), and petroleum refining (29) exhibit the lowest conditional impute rates, averaging less than 10 percent, while lumber (24), furniture (25), printing (27), and miscellaneous manufacturing (39) show average conditional impute rates above 15 percent. The highest annual average conditional impute rates occur in 1989 and 1992: 35.2 percent and 20.4 percent, respectively.

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[14] Formulas for imputation are available at CES; contact the author.

[15] Conditional impute rates are the portion of the data having an impute flags, given that there is numeric data present. For example, using the 1988 survey data, as in footnote 8, there are a total of 815,598 possible data items. The item field is blank for 637,359 of these items; leaving 178,239 items with numeric data present. Thus, the conditional impute rate is 17,982 / 178,239 = .101, or 10.1 percent.

Finally, conditional impute rates vary significantly across data items. Table 8 lists the data items, by year, with conditional impute rates of 25 percent or greater for any year since 1984. [16] With few exceptions, impute rates are highest in 1989. The exceptions are those items which are new to the 1992 survey. These variables tend to have high impute rates in 1992, but they diminish significantly the next year. This suggests that as respondents become familiar with the new item, imputation is needed less. An additional factor influencing this trend is that the nonresponse rate for these items increased significantly between 1992 and 1993, thus reducing the denominator in the conditional impute rate calculations.

Blank Data Fields

The incidence of blank data fields is substantial, averaging 28.8 percent for 1984-86, and doubling, to 57.2 percent, for the 1988-92 period. This reflects the fact that in early years, blank items on an otherwise completed form were imputed. This practice was stopped in 1988. While it is not known with certainty whether a blank data item means the establishment had

[16] Conditional impute rates are the portion of the data having a flag indicating the numeric value is imputed, given that there is a numeric data present. For example, for 1988, 8,306 establishments have numeric values for total air operating costs. Of these, 2,480 establishments have a flag set to 'M', indicating imputed data. Thus, the conditional impute rate is 2,480 / 8,306 = 0.292, or 29.2 percent.

zero expenditures for the item in question, blanks are treated as zeros if the establishment reported and data. [17] Therefore, data values are no longer imputed for these blank data items during processing.

Blank data are treated as zero in generating the published statistics and in the calculation of the standard error of estimates. Whether these blank data are nonresponses or zero is of some importance to micro data users, as most econometrics packages (including SAS ®) delete blank data from the calculation of means and other summary statistics, as well as in the estimation of models, and zero values are not deleted.

Measurement Error

One aspect of measurement error centers around the fact that survey data do not always conform exactly to the variables the data user has in mind. Measurement error can occur for a variety of reasons. For example, respondents may deliberately report erroneous information, or fail to report, or miscalculate difficult to identify expenses, or misinterpret the questionnaire. Even carefully constructed survey questions do

[17] Survey analyst for the MA-200 indicate that respondents' attitude is an important characteristic of the data. Many respondents believe the data is turned over to the EPA, or that the survey is itself an EPA form. They tend to complete the survey correctly, or not at all. Large companies in heavily polluting industries tend to keep the best records of pollution abatement expenditures.

not always yield true measurements of their theoretical counterparts. A Bureau review of Economic Area surveys found misinterpretation of question or survey form was the most significant deficiency of the PACE survey. [18] The net effect of these measurements errors is not known; however, survey analysts feel this is a growing problem.

Measurement error is important to researchers as it causes biased and inconsistent results with many econometric model estimation techniques. In particular, attenuation, where the estimated coefficient is biased toward zero, has severe consequences if the motivation behind the analysis is to address policy issues, such as Gray and Shadbegian's (1994) work on pollution abatement costs and plant productivity.

> ... If a large part of the variation in abatement costs is due to mismeasurement, the coefficient on abatement costs in our regression will be biased toward zero. ... If we are interested in how plants would respond to increased regulation, it would be helpful to observe variation in regulation within plants over time. If most of our variability in regulation is across plants, with relatively small variation at a specific plant over time, it will be harder to generate precise estimates of regulation's impact on productivity, and our predictions about the impact of changing regulation will have to be more tentative.

A number of changes were made in the instructions for the 1992 PACE survey in order to clarify the definitions of several concepts, and the types of data collected. Many of these changes reflect input from the Bureau of Economic Analysis and other

[18] King and Kornbau (1994).

policy data users. For example, pollution abatement is redefined as follows.

> ... for the purposes of reducing or eliminating unwanted emissions or wastes that are created by the production process and harmful to the environment or the removal of pollution created by production in prior years. For this survey, only expenditures with the primary purpose of protecting the environment are included.

Prior surveys' reference to "pollutants" is replaced with "unwanted emissions or wastes." The definition of pollution is expanded by adding the phrase "harmful to the environment" to the qualification "created by the production process." In addition, techniques for pollution abatement are clarified, and additional definitions are included in the survey form.

Changes-in-production processes have been relabeled "production process enhancements" and new instructions detail how to report these enhancement expenditures if it is not feasible to report only the portion intended for environmental protection. Respondents are finding it difficult to allocate investment in end-of-line equipment versus changes in production processes as pollution abatement is increasingly built into equipment, rather than added on. New instructions for reporting capital expenditures clarify the treatment of "construction in progress intended for environmental protection."

As mentioned previously, in 1992 "labor" was relabeled "salaries and wages" to underscore that expenditures on environmental administration are now reported in this category.

The survey instructions also clarified the inclusion of the following types of expenses in 1992:

Incremental costs for consumption of environmentally preferable materials and fuels,
Conducting environmental studies for development or expansion,
Compliance and environmental auditing,
Developing pollution abatement operating procedures, and
Testing and monitoring procedures and equipment.

Taxes, fines, permits, legal fees, and superfund taxes and contributions are specified not to be included in pollution abatement expenditures. Finally, "cost recovered" is now termed "cost offsets" and the definition clarifies that cost offsets must be related to production and for environmental protection motives rather than economic motives.

While these changes may reduce the measurement error of some reported items, they have the unfortunate side effect for micro data users of making temporal comparisons across time of such data items more problematic, as discussed in earlier in this section.

One way of testing for measurement error is to calculate the ratio of pollution abatement costs to total costs. Although there is considerable variation in these ratios, both within and across industries, what is of interest here is when the ratio exceeds reasonable bounds. Tables 9-12 show the distribution of plants with data by the ratio of pollution abatement expenses to total LRD expenses for new capital investment, capital depreciation, labor, and materials, respectively. The incidence

of blank data varies considerably. [19] Blank data are more prevalent for capital expenditures than for the operating costs categories, averaging 56.3 percent for capital expenditures and about half that for depreciation, labor, and material costs. This trend is not surprising, as capital investment expenditures are lumpy in nature.

Establishments reporting expenditures for pollution abatement exceed total expenditures in the LRD are obvious cases of measurement error. Of establishments reporting investment in capital for pollution abatement, approximately 6 percent indicate that more than 100 percent of their capital expenditures are for pollution abatement. Either there is understatement of total capital investment in the LRD, and/or an overstatement of pollution abatement capital investment in the PACE. Some PACE survey respondents have indicated that they do not include pollution abatement capital expenditures in the capital investment reported on the ASM, thus understating total capital investment. Others indicate they report all their pollution abatement expenditures on the PACE survey, despite instructions to in count only that made specifically for pollution abatement

[19] For Tables 9-12, capital, depreciation, labor, and materials are aggregated across environmental media (unweighted). Only if data were blank for all medias was the establishment classified as “Blank Data”. If any of the media categories had a numeric value, then the establishment was considered to have data. Therefore, the incidence of blank data is understated on these tables.

purposes, and not expenditures made for production and profit reasons. In general, large establishments in heavily polluting industries track their expenditures very well. There is a problem of missing capital data for nonresponding large establishments. No data are imputed in these cases.

For 1979-82, the ratio of depreciation costs for pollution abatement capital to LRD total capital depreciation exceeds 100 percent for nearly 5 percent of the establishments with pollution abatement depreciation costs. In contrast, for 1984-88, 10 percent of the establishments exhibit this degree of measurement error. Capital depreciation data are not available in the LRD after 1988.

The labor and materials cost ratios are quite different; only a few establishments exhibit ratios exceeding 100 percent. This suggests that it is far more difficult to measure capital, and therefore depreciation, and to allocate the portion for pollution abatement, than it is to measure labor and material costs.

VI. RECOMMENDATIONS

To date the design and processing of the PACE survey (as with most economic surveys conducted by the Bureau) is conducted with the objective of producing cross-sectional aggregate statistics. Each year is treated in isolation. Such an

orientation permits the identification of interesting cross-sectional relationships in economic data, but does not produce the quality longitudinal data necessary to generate useful information about the behavior and performance of economic units. In this vein, the following suggestions are made for design and processing of the PACE survey to enhance its value to micro data. These recommendations may not be compatible with current Bureau resource limitations and such concerns as respondent burden.

Survey Design Recommendations

1) Return the PACE sample from the concurrent year's ASM. This would insure the availability of general economic data (from the ASM, or CM) to augment the PACE data, for every establishment in the PACE sample and would minimize industry code discrepancies. In addition, it would allow for a number of editing checks for consistency of the data, as discussed below.

2) Ask for total employment and total value of shipments on the PACE survey to aid in matching with ASM and CM data.

3) Maintain the PPN, as well as CFN on the data records to facilitate identification and linkage of PACE establishments with the LRD.

3) To the extent possible, the expenditure and cost categories should be similar between the CM, ASM, and PACE in order to facilitate comparison between pollution abatement expenses and total production expenses. The breakout of operating costs on the PACE survey since 1992, in conjunction with the revised definitions, is a welcomed move in this direction.

4) Instructions on the ASM and CM should indicate that costs and expenditures should be totals, including expenses for pollution abatement, health, and safety purposes.

Processing Recommendations

1) A flag should be set for every data item, including items left blank. Where there is a numeric value the flag should indicate if reported, imputed, corrected or adjusted.

2) Periodic (every two or three years) edit checks for data consistency should be implemented, checking PACE data against data from the concurrent ASM. For example, calculating the ratio between PACE reported capital investment and ASM reported total capital investment. Establishments with a derived ratio greater than 1.00 would be flagged for verification or correction. Similar ratio checks can be run on reported salary and wages, fuel and electricity, and materials.

3) As a routine matter, notify CES when final PACE data and name and address files are available. Also, CES should receive a copy of each year's publication, as it becomes available.

4) Include reported, adjusted, and edited data in data files transferred to CES, as well as the survey weights, data flags, and the name and address information (as is currently being done).

5) Establish a continuous working relationship between CES and ETI branch. CES could provide information on and examples of PACE data uses and needs. ETI could provide details on proposed changes in survey and sampling design, and data processing and review which affect the year's data. Details of the data processing specifications would be most beneficial to the data users in understanding the properties of the survey data.

REFERENCES

Davis, Steve J., John Haltiwanger, and Scott Schuh, "Published Versus Sample Statistics from the ASM: Implications for the LRD," Proceedings of the American Statistical Association Business and Economics Section , 1990.

Gray, Wayne B. and Ronald J. Shadbegian, "Environmental Regulation and Manufacturing Productivity at the Plant Level." CES Discussion Paper 93-6, March 1993.

Gray, Wayne B. and Ronald J. Shadbegian, "Pollution Abatement Costs, Regulation and Plant-Level Productivity." CES Discussion Paper 94-14, December 1994.

Hartman, Raymond S., David Wheeler, and Manjula Singh, "The Cost of Air Pollution Abatement." Unpublished paper, April 1994.

King, Carol and Michael Kornbau, "Inventory of Economic Area Statistical Practices," ESMD Report Series ESMD-9402, Washington, D.C.: Bureau of the Census, May 1994.

Levinson, Arik, "Environmental Regulations and Manufactures' Location Choices: Evidence from the Census of Manufactures." Unpublished paper, Columbia University, November 1992.

McGuckin, Robert H., and SuZanne Peck, "Manufacturing Establishments Reclassified into New Industries: the Effect of Survey Design Rules," Journal of Economic and social Measurement , 19, pages 121-139, 1993.

Post, Ellen S., "The Importance of State and Plant Characteristics in Determining the Environmental Compliance Costs of Chemical Manufacturing Plants: Evidence from the PACE Survey, 1979-1990." Unpublished paper, University of Maryland, October 1994.

Singh, Manjula, "Do Community Characteristics Affect Toxic Pollution? Analysis of Toxics Release Inventory Data." Unpublished paper, Boston University, November 1994.

Streitwieser, Mary L., "Cross Sectional Variation in the Toxic Waste Releases from the U.S. Chemical Industry." CES Discussion Paper 94-8, August 1994.

U.S. Bureau of the Census. Pollution Abatement Costs and Expenditures, MA-200 ( )-1 . Washington, D.C.: U.S.

Government Printing Office, various years.

TABLE 1
PACE-LRD Match

Year	From ASM	From CM	PACE Sample Size	No Match To LRD	% LRD Match
1979	1977	1972	20,123	7,566	62.4
1980	1977	1972	20,123	8,188	59.3
1981	1977	1972	20,002	8,704	56.3
1982	1980	1977	18,419	911	95.1
1983[1]	1980	1977			
1984	1984	1982	20,099	1,620	91.9
1985	1984	1982	20,099	2,886	85.6
1986	1984	1982	18,047	2,653	85.3
1987[2]					
1988	1984	1982	19,505	2,923	85.0
1989	1989	1987	16,775	622	96.3
1990	1989	1987	16,803	1,459	91.3
1991	1989	1987	16,523	59	99.6
1992	1989	1987	16,742	779	95.3
1993	1989	1987	16,680	1,296	92.2

[1] No data available.
[2] No survey conducted.

Table 2
PACE-LRD Data

YEAR	1979	1980	1981	1982	1983[1]	1984	1985	1986	1987[2]	1988	1989	1990	1991	1992	1993
1979	12,557	11,872	11,068	7,267	-	5,289	4,977	4,148	-	4,040	2,574	2,443	2,410	1,871	1,734
1980		11,935	11,104	7,277	-	5,298	4,986	4,156	-	4,046	2,577	2,446	2,413	1,874	1,737
1981			11,298	7,346	-	5,343	5,026	4,189	-	4,078	2,591	2,457	2,424	1,882	1,744
1982				17,508	-	7,718	7,188	5,943	-	5,757	3,270	3,106	3,064	2,258	2,080
1983[1]					-	-	-	-	-	-	-	-	-	-	-
1984						18,479	16,816	13,266	-	12,699	4,707	4,435	4,361	2,965	2,702
1985							17,213	13,500	-	12,910	4,758	4,482	4,407	2,991	2,721
1986								15,394	-	14,668	5,257	4,938	4,853	3,256	2,954
1987[2]									-	-	-	-	-	-	
1988										16,582	5,771	5,392	5,206	3,486	3,261
1989											16,153	14,539	13,758	6,764	6,234
1990												15,343	14,338	6,935	6,382
1991													15,732	7,626	6,952
1992														16,741	14,936
1993															16,680

[1] No data available.
[2] No MA-200 Survey conducted.

Table 3
Available PACE Information

YEAR	Reported Data	Edited Data	Adjusted Data	Flags	Weights	Name & Address
1979	X	X			X	
1980	X	X			X	
1981	X	X			X	
1982	X	X			X	
1983[1]						
1984		X		X	X	X
1985		X		X	X	X
1986		X		X	X	X
1987[2]						
1988	X	X	X	X	X	
1989	X	X	X	X	X	
1990	X	X	X	X	X	
1991	X	X	X	X	X	X
1992	X	X	X	X	X	X
1992	X	X	X	X	X	X

[1] No data available.
[2] No survey conducted.

Table 4
PACE-LRD State and Industry Matches

Year	N	% PACE St ≠ LRD St	% PACE Ind ≠ LRD Ind 2-Digit	% PACE Ind ≠ LRD Ind 4-Digit
1979	20,123	NA	1.6%	8.9%
1980	20,123	NA	1.8%	9.0%
1981	20,002	NA	1.9%	9.6%
1982	18,419	NA	6.1%	24.9%
1983[1]				
1984	20,099	0.2%	2.1%	5.7%
1985	20,099	0.2%	1.9%	6.1%
1986	18,047	0.9%	1.9%	5.8%
1987[2]				
1988	19,505	1.4%	6.0%	23.7%
1989	16,775	0.8%	0.1%	0.3%
1990	16,793	0.4%	0.6%	1.4%
1991	16,531	0.1%	0.2%	0.3%
1992	16,741	0.2%	2.3%	7.9%
1993	16,680			

[1] No data available.
[2] No survey conducted.

Table 5
PACE Data Item Flags

Flag	Year	Value
A	1989-93	Interactive correction, item added by analyst
AC	1983-86	Interactive correction, analyst correction based on response data
B	1989-93	Blank or reported zero
C	1989-93	Computer edit rejection of reported data, new data created
CC	1983-86	Compute edit rejection of reported data, new data created
D	1989-93	Computed item (derived/created by edit system)
E	1989-93	Computer edit rejection of a batch analyst correction, new data created
IM	1983-86	Imputed data
K	1988-93	Analyst correction, previously imputed, came in on next year’s form
L	1989-93	Late receipt of data, same as respondent reported
LI	1983-86	Late receipt of data, edited/raked
M	1988-93	Imputed data
MI	1983-86	Edited/raked data
R	1988-93	Reported data
RD	1983-86	Reported data
RP	1983-86	Reported data
T	1989-93	Interactive correction, analyst correction based on response data

Table 6
Percentage of PACE Data Imputed, Reported, Edited, or Blank

YEAR	Imputed Data	Reported Data	Edited Data	Missing Flag	Blank Data
1984	4.7	65.2	2.9	1.4	25.8
1985	2.2	65.9	0.5	2.9	28.5
1986	2.0	62.5	0.5	2.8	32.1
1987[1]					
1988	2.2	19.1	0.4	0.2	78.1
1989	17.1	29.7	1.9	0.0	51.4
1990	4.6	30.9	1.7	0.0	62.7
1991	3.5	31.9	1.9	0.0	44.5
1992	9.7	36.3	1.5	0.0	52.6
1993	4.4	37.6	1.7	0.0	56.2
Mean	5.6	42.1	1.4	0.8	48.0

[1] No survey conducted.

Table 7
PACE Survey Conditional Impute Rates[1], By Year and 2-Digit Industry

	2-Digit Industry																		
Year	20	21	22	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	Mean
1984	6.4	3.5	5.6	7.6	9.2	5.3	9.7	4.7	5.1	9.5	7.2	7.6	6.1	5.5	6.1	5.6	5.4	8.6	8.1	6.3
1985	2.7	1.7	3.0	2.2	2.8	2.4	2.5	2.8	2.5	2.6	2.5	3.8	4.3	3.4	3.4	2.9	3.5	4.3	4.2	3.1
1986	2.6	1.4	2.8	1.8	2.8	2.4	2.6	2.6	2.4	2.7	2.0	3.3	4.1	3.2	3.2	3.1	4.6	3.6	3.3	3.0
1987[2]																				
1988	12.4	7.4	10.6	8.8	9.3	6.7	15.0	6.4	6.8	10.9	16.1	9.7	9.5	11.4	11.4	9.9	11.3	13.0	12.8	10.1
1989	31.7	22.7	35.4	55.6	46.7	22.5	57.6	19.4	23.6	45.8	40.4	37.2	28.6	40.5	41.5	36.3	27.2	30.7	47.4	35.2
1990	11.8	6.8	12.4	24.3	19.5	5.7	21.0	7.9	7.9	14.6	14.4	10.9	11.2	17.2	12.0	14.0	10.5	10.3	23.8	12.4
1991	9.2	0.6	8.2	11.7	13.4	5.6	14.2	6.9	8.0	10.7	12.5	8.0	8.9	10.2	9.3	10.4	10.2	7.8	13.8	9.3
1992	18.0	9.2	24.7	28.9	31.7	12.9	27.7	11.5	10.9	21.1	21.7	19.8	19.5	22.1	22.2	20.8	17.0	22.5	31.3	20.4
1993																				10.2
Mean	11.9	6.7	12.8	17.6	16.9	7.9	18.8	7.8	8.4	14.7	14.6	12.5	11.5	14.2	13.6	12.9	12.9	12.6	18.1	12.2

[1] Rates conditional upon item field not being blank, e.g. the portion of the data that is imputed, given there is numeric data in the field.
[2] No survey conducted.

Table 8
PACE Survey Conditional Impute Rates[1], By Year and Item

Data Item	1984	1985	1986	1987[2]	1988	1989	1990	1991	1992	1993
Air, Depreciation Costs	0.0	0.0	0.0		0.0	50.4	19.2	13.9	27.2	17.3
Air, Energy Costs	NA	NA	NA		NA	NA	NA	NA	25.0	18.0
Air, Labor Costs	0.0	0.0	0.0		0.0	49.9	18.1	13.2	23.9	16.8
Air, Materials Costs	0.0	0.0	0.0		0.0	48.6	19.1	13.8	26.4	17.1
Air, Other Costs	0.0	0.0	0.0		0.0	55.5	19.5	13.8	NA	NA
Air, Total Operating Costs	22.8	15.5	11.8		29.9	44.8	16.4	11.0	22.7	13.5
Cost Recovered, Air	21.5	5.3	8.5		21.5	8.4	1.6	2.5	26.3	11.5
Costs Recovered, Solid Waste	54.1	13.8	8.3		0.2	5.4	2.9	3.6	23.0	11.3
Costs Recovered, Water	24.4	9.3	11.0		26.0	7.8	1.9	2.2	23.6	11.0
Hazardous, Depreciation Costs	0.0	0.0	0.0		0.0	51.9	16.6	11.4	NA	NA
Hazardous, Labor Costs	0.0	0.0	0.0		0.0	55.2	20.3	15.5	NA	NA
Hazardous, Materials Costs	0.0	0.0	0.0		0.0	56.7	19.7	15.2	NA	NA
Hazardous, Other Costs	0.0	0.0	0.0		0.0	46.6	19.1	14.3	NA	NA
Haz., Total Operating Costs	16.4	11.5	10.8		27.9	44.2	16.8	12.2	NA	NA
Haz., Air Operating Costs	NA	NA	NA		NA	NA	NA	NA	43.8	1.6
Municipal Solid Waste Costs	39.6	10.2	7.6		32.2	50.2	17.7	12.4	24.7	16.4
Nonhazardous, Depreciation	0.0	0.0	0.0		0.0	42.3	18.1	13.6	NA	NA
Nonhazardous, Labor Costs	0.0	0.0	0.0		0.0	42.8	22.3	16.9	NA	NA

Data Item	1984	1985	1986	1987[2]	1988	1989	1990	1991	1992	1993
Nonhazardous, Materials Costs	0.0	0.0	0.0		0.0	44.5	22.1	15.8	NA	NA
Nonhazardous, Other Costs	0.0	0.0	0.0		0.0	31.9	17.0	13.8	NA	NA
Nonhaz., Total Operating Costs	16.9	22.0	19.6		34.5	31.5	15.2	11.7	NA	NA
Public Sewer Costs	22.2	13.7	13.7		30.8	36.9	15.0	11.5	20.6	14.6
Solid Waste, Hazardous Costs	0.0	0.0	0.0		0.0	1.0	1.1	1.0	31.1	0.2
Solid Waste, Haz. Capital Expend.	NA	NA	NA		NA	NA	NA	NA	40.7	0.0
Solid Waste, Labor Costs	NA	NA	NA		NA	NA	NA	NA	25.0	17.9
Solid Waste, Materials Costs	NA	NA	NA		NA	NA	NA	NA	25.4	19.2
Water, Depreciation Costs	0.0	0.0	0.0		0.0	51.9	17.3	13.5	23.7	16.1
Water, Labor Costs	0.0	0.0	0.0		0.0	49.5	17.4	13.5	24.3	16.5
Water, Haz. Capital Expenditures	NA	NA	NA		NA	NA	NA	NA	43.1	0.0
Water, Hazardous Costs	NA	NA	NA		NA	NA	NA	NA	42.4	0.6
Water, Materials Costs	0.0	0.0	0.0		0.0	49.6	17.2	13.3	25.5	17.1
Water, Other Costs	0.0	0.0	0.0		0.0	51.7	18.2	13.7	NA	NA
Water, Contract Service Costs	NA	NA	NA		NA	NA	NA	NA	26.0	16.1
Water, Total Operat. Costs	24.2	18.4	12.9		31.5	44.9	14.6	10.2	20.8	14.4

NA -- Not Applicable, question not asked.
[1] Rates conditional upon item field not being blank, e.g. the portion of the data that is imputed, given there is numeric data in the field.
[2] No survey conducted.

Table 9
Ratio of New Pollution Abatement Capital Expenditures to Total Capital Expenditures

Year	Blank Data	No Invest	No PA Invest	1-5%	6-10%	11-25%	26-50%	51-75%	76-100%	101-150%	151-200%	> 200%
1979	45.4	0.5	10.7	22.6	6.2	7.0	3.7	1.5	0.8	0.5	0.2	1.0
1980	44.7	0.7	9.6	24.8	5.6	6.9	3.7	1.5	0.7	0.5	0.2	1.0
1981	46.5	0.6	11.8	22.2	5.8	6.1	3.4	1.2	0.8	0.5	0.2	0.8
1982	41.4	3.9	29.6	13.8	3.6	4.0	2.1	0.7	0.4	0.2	0.1	0.4
1983[1]												
1984	74.7	1.1	3.4	10.8	3.2	3.3	1.7	0.6	0.3	0.2	0.2	0.4
1985	72.7	1.6	3.9	11.5	3.1	3.5	1.8	0.7	0.4	0.4	0.1	0.4
1986	70.1	1.3	4.4	11.5	3.5	3.9	2.3	1.0	0.6	0.4	0.1	0.7
1987[2]												
1988	73.6	1.2	40.0	12.0	3.8	4.1	2.5	0.9	0.5	0.4	0.3	0.7
1989	56.1	2.6	14.5	12.3	3.8	4.8	2.6	1.1	0.6	0.5	0.2	0.8
1990	54.2	3.0	15.1	12.1	3.9	5.1	3.0	1.2	0.7	0.5	0.3	0.9
1991	56.1	2.0	14.6	10.9	3.9	5.2	3.0	1.5	0.9	0.7	0.3	0.8
1992	53.9	1.5	12.9	13.8	4.7	5.5	3.5	1.4	0.8	0.7	0.4	0.9
1993	54.6	1.0	11.9	15.0	4.7	5.7	3.2	1.6	0.7	0.6	0.2	0.8
Mean	55.6	1.6	14.0	14.9	4.3	5.0	2.8	1.1	0.6	0.5	0.2	0.7

[1] No data available.
[2] No survey conducted.

Table 10
Ratio of Pollution Abatement Depreciation Costs to Total Depreciation

Year	Blank Data	No Deprec	No PA Deprec	1-5%	6-10%	11-25%	26-50%	51-75%	76-100%	101-150%	151-200%	> 200%
1979	43.5	0.0	6.7	27.2	8.7	8.9	3.1	0.9	0.2	0.2	0.1	0.3
1980	42.4	0.0	6.6	30.5	8.2	8.0	2.6	0.7	0.3	0.1	0.1	0.3
1981	43.4	0.0	6.0	30.3	7.9	8.1	2.7	0.8	0.2	0.1	0.1	0.4
1982	34.7	0.0	28.8	23.3	5.4	5.2	1.6	0.4	0.2	0.1	0.1	0.2
1983[1]												
1984	4.7	3.0	43.9	30.5	6.9	6.9	2.2	0.8	0.3	0.3	0.1	0.4
1985	17.1	2.2	29.9	32.3	7.6	6.9	2.3	0.7	0.3	0.3	0.1	0.4
1986	15.6	1.8	33.4	31.3	7.5	6.8	2.0	0.7	0.3	0.3	0.1	0.4
1987[2]												
1988	45.5	1.2	5.6	31.4	6.9	6.2	1.9	0.6	0.2	0.2	0.1	0.2
1989[2]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1990[2]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1991[3]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1992[3]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1993[3]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mean	30.9	1.0	20.1	29.6	7.4	7.1	2.3	0.7	0.3	0.2	0.1	0.3

[1] No data available.
[2] No survey conducted.
[3] Depreciation not collected in LRD.

Table 11
Ratio of Pollution Abatement Labor Costs to Total Labor Costs

Year	Blank Data	No Labor	No PA Labor	.1-1%	2-5%	6-25%	26-50%	51-75%	76-100%	101-150%	151-200%	> 200%
1979	38.9	0.0	6.8	41.8	10.3	2.1	0.0	0.0	0.0	0.0	0.0	0.0
1980	37.6	0.0	6.1	43.4	10.5	2.3	0.1	0.0	0.0	0.0	0.0	0.0
1981	37.5	0.0	6.1	43.0	10.8	2.4	0.1	0.0	0.0	0.0	0.0	0.0
1982	24.3	0.0	34.6	31.9	7.4	1.7	0.1	0.0	0.0	0.0	0.0	0.0
1983[1]												
1984	0.0	0.9	40.7	45.0	10.2	2.4	0.1	0.0	0.0	0.0	0.0	0.0
1985	0.0	1.2	31.2	51.6	12.8	2.9	0.2	0.1	0.0	0.0	0.0	0.0
1986	0.0	0.5	35.2	47.7	13.1	3.0	0.2	0.0	0.0	0.0	0.0	0.0
1987[2]												
1988	43.3	0.6	0.0	42.1	11.3	1.5	0.1	0.0	0.0	0.0	0.0	0.0
1989	29.5	0.3	18.4	36.0	12.7	2.8	0.2	0.0	0.0	0.0	0.0	0.0
1990	47.5	0.3	2.5	34.2	12.4	2.8	0.2	0.0	0.0	0.0	0.0	0.0
1991	49.9	0.0	2.3	32.6	12.3	2.8	0.2	0.0	0.0	0.0	0.0	0.0
1992	37.5	0.0	0.0	44.6	13.0	2.3	0.1	0.0	0.0	0.0	0.0	0.0
1993	39.7	0.0	2.7	42.0	13.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0
Mean	29.7	0.3	14.4	41.2	11.5	2.4	0.1	0.0	0.0	0.0	0.0	0.0

[1] No data available.
[2] No survey conducted.

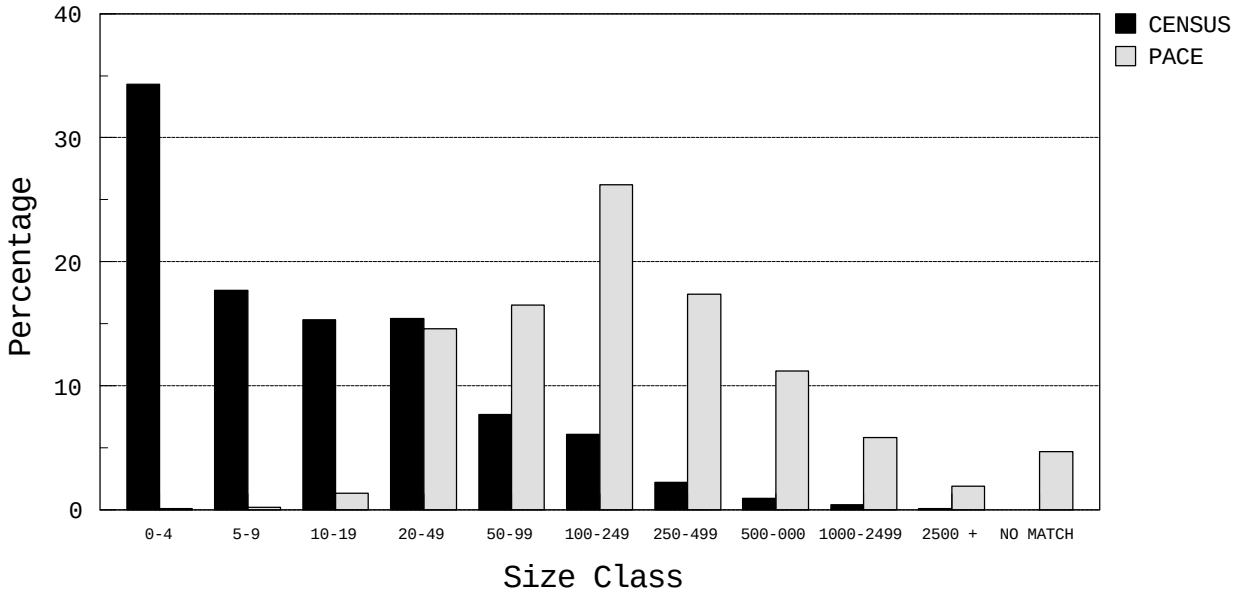
Table 12
Ratio of Pollution Abatement Materials Cost to Total Materials Cost

Year	Blank Data	No Material	No PA Material	.1-1%	2-5%	6-25%	26-50%	51-75%	76-100%	101-150%	151-200%	> 200%	Mean Ratio
1979	42.4	0.0	7.8	44.2	4.8	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.8
1980	41.2	0.0	7.0	46.1	5.0	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.5
1981	41.7	0.0	6.0	46.4	5.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.5
1982	30.5	0.0	30.5	34.4	3.9	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.4
1983[1]													
1984	0.0	1.9	43.1	47.7	6.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
1985	0.0	1.5	33.8	54.6	8.3	1.5	0.1	0.0	0.0	0.0	0.0	0.0	0.6
1986	0.0	1.0	36.1	52.4	8.6	1.6	0.2	0.0	0.0	0.0	0.0	0.0	1.7
1987[2]													
1988	42.9	0.6	0.0	48.0	7.2	1.1	0.1	0.0	0.0	0.0	0.0	0.0	1.3
1989	28.8	0.4	17.5	42.6	8.3	2.1	0.2	0.0	0.0	0.0	0.0	0.0	1.1
1990	45.7	0.1	2.4	40.9	8.2	2.1	0.1	0.0	0.0	0.0	0.0	0.0	1.4
1991	48.2	0.0	2.2	39.0	8.4	1.9	0.1	0.1	0.0	0.1	0.0	0.0	1.3
1992	37.8	0.0	4.0	47.3	8.4	2.1	0.2	0.1	0.0	0.0	0.0	0.0	1.2
1993	43.1	0.0	4.7	42.5	7.3	2.1	0.2	0.1	0.0	0.0	0.0	0.0	1.4
Mean	28.7	0.4	15.0	46.6	7.3	1.4	0.1	0.0	0.0	0.0	0.0	0.0	3.2

[1] No data available.
[2] No survey conducted.

Figure 1

LRD and PACE Size Distribution*, 1992



* Number of Employees

Figure 2

PACE Industry Distribution, 1992

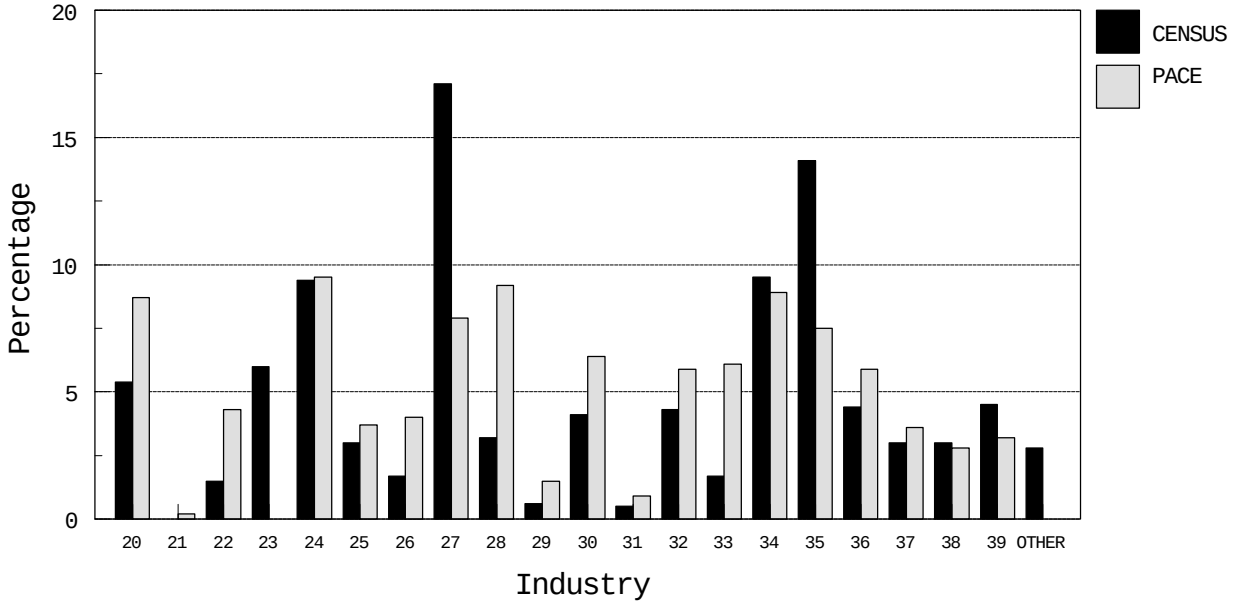
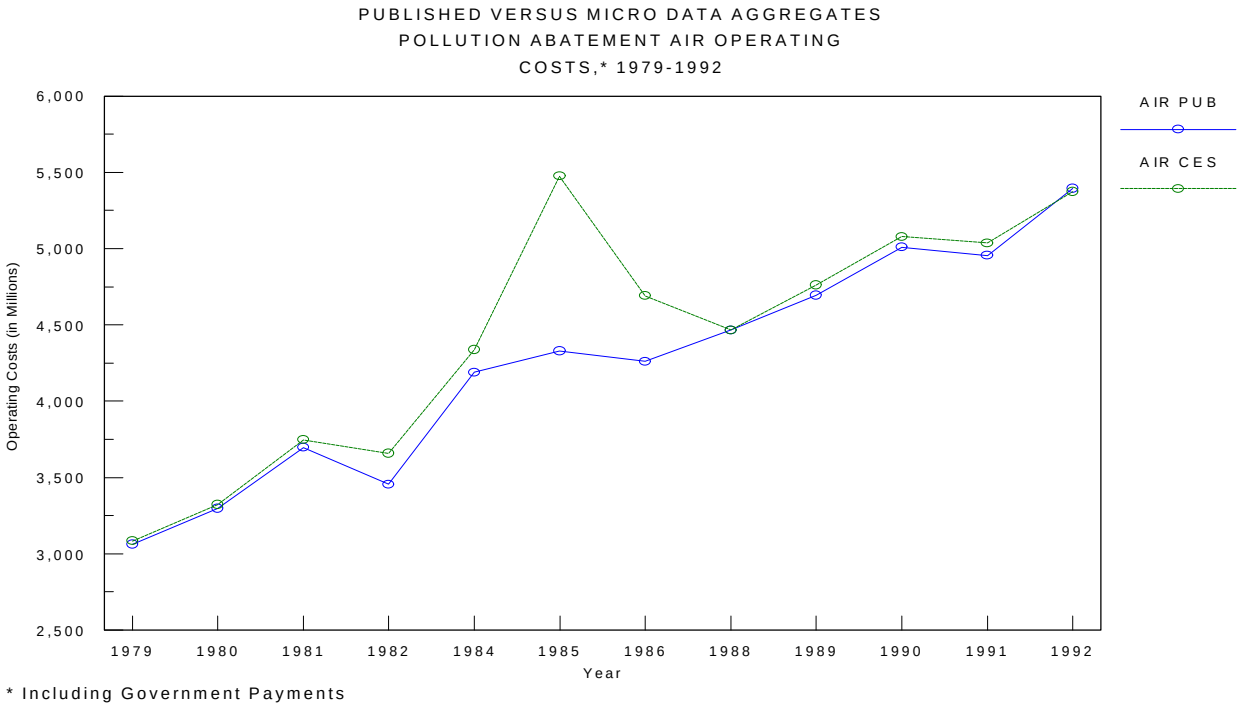


Figure 3A



* Including Government Payments

Figure 3B

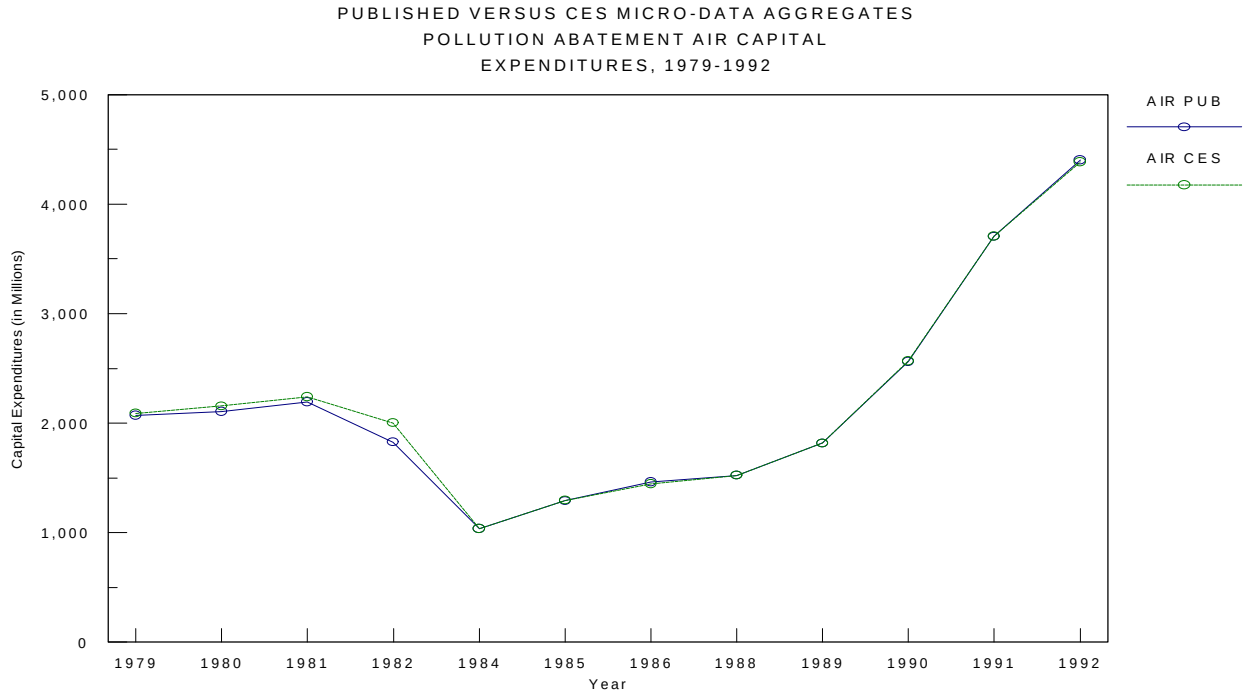
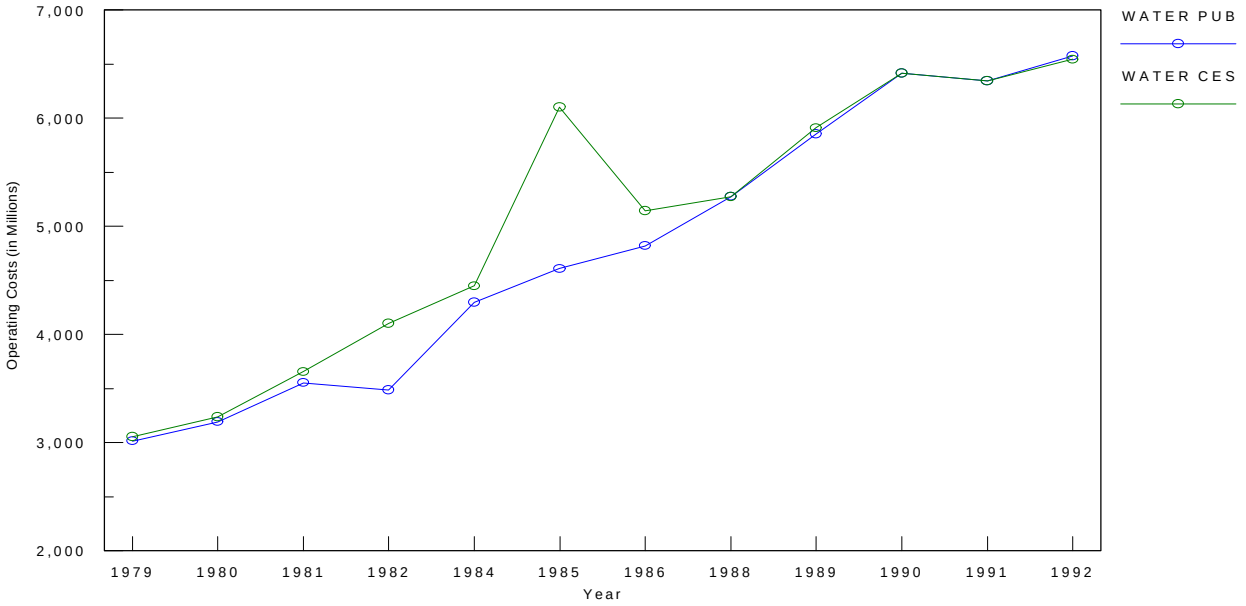


FIGURE 4A

PUBLISHED VERSUS MICRO DATA AGGREGATES
POLLUTION ABATEMENT WATER OPERATING
COSTS,* 1979-1992



* Including Government Payments

Figure 4B

PUBLISHED VERSUS CES MICRO-DATA AGGREGATES
POLLUTION ABATEMENT WATER CAPITAL
EXPENDITURES, 1979-1992

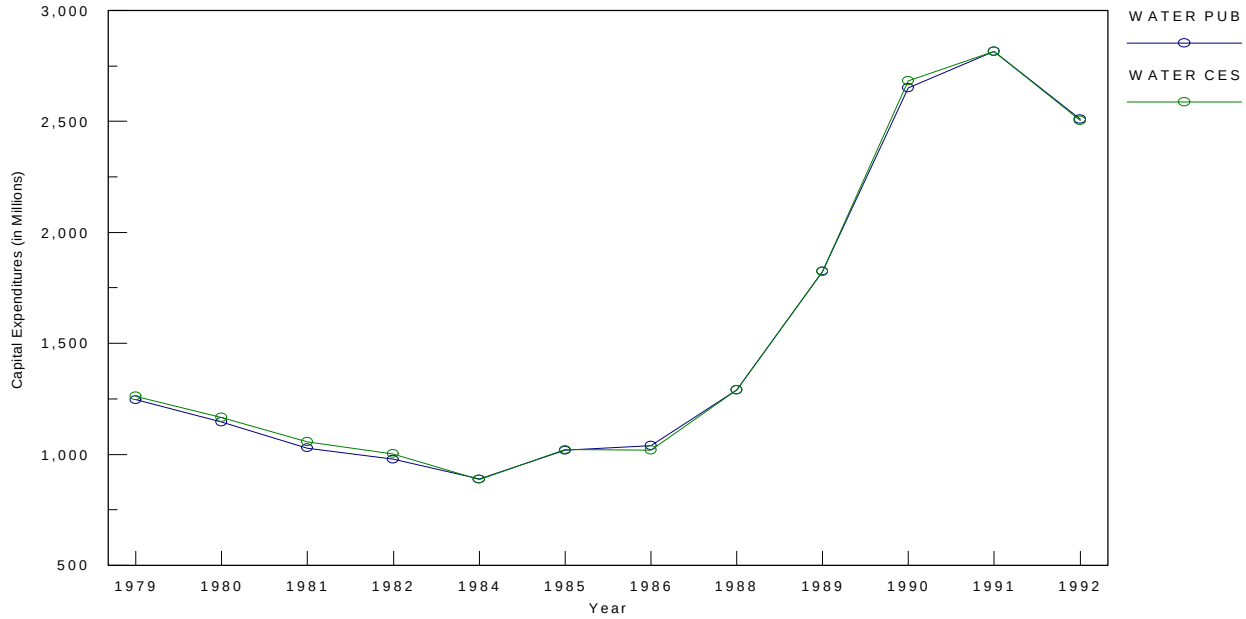
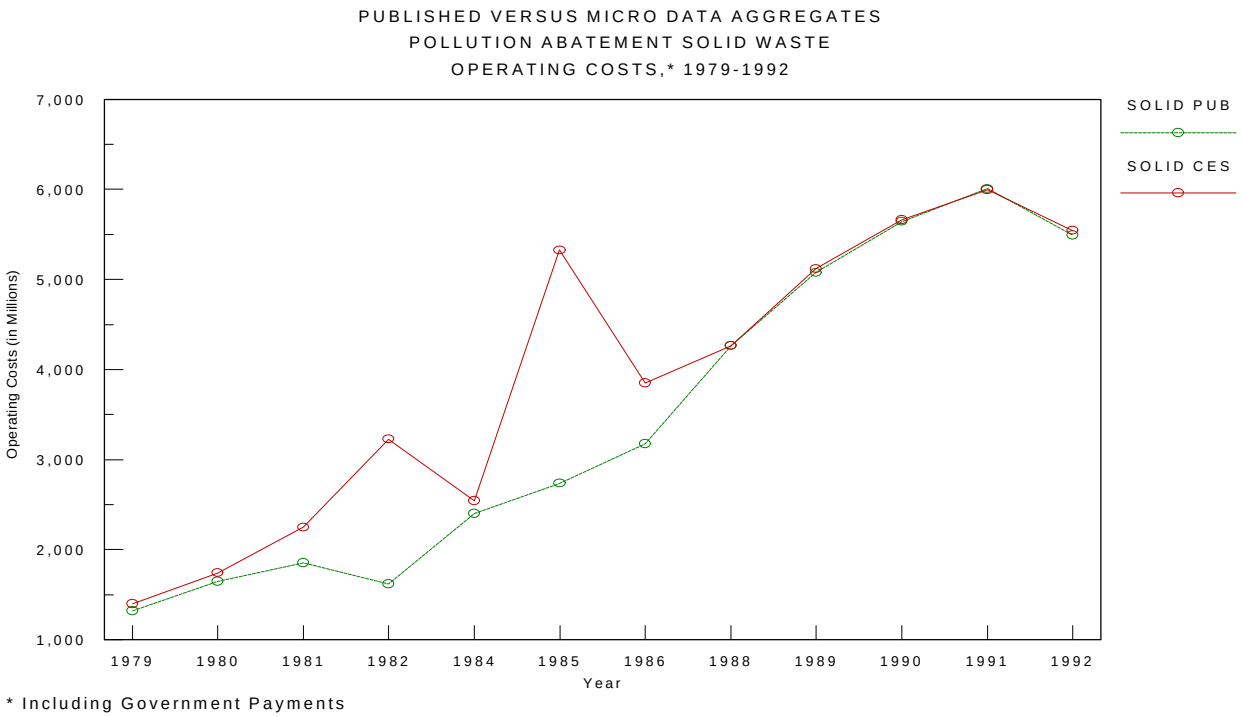


Figure 5A



* Including Government Payments

Figure 5B

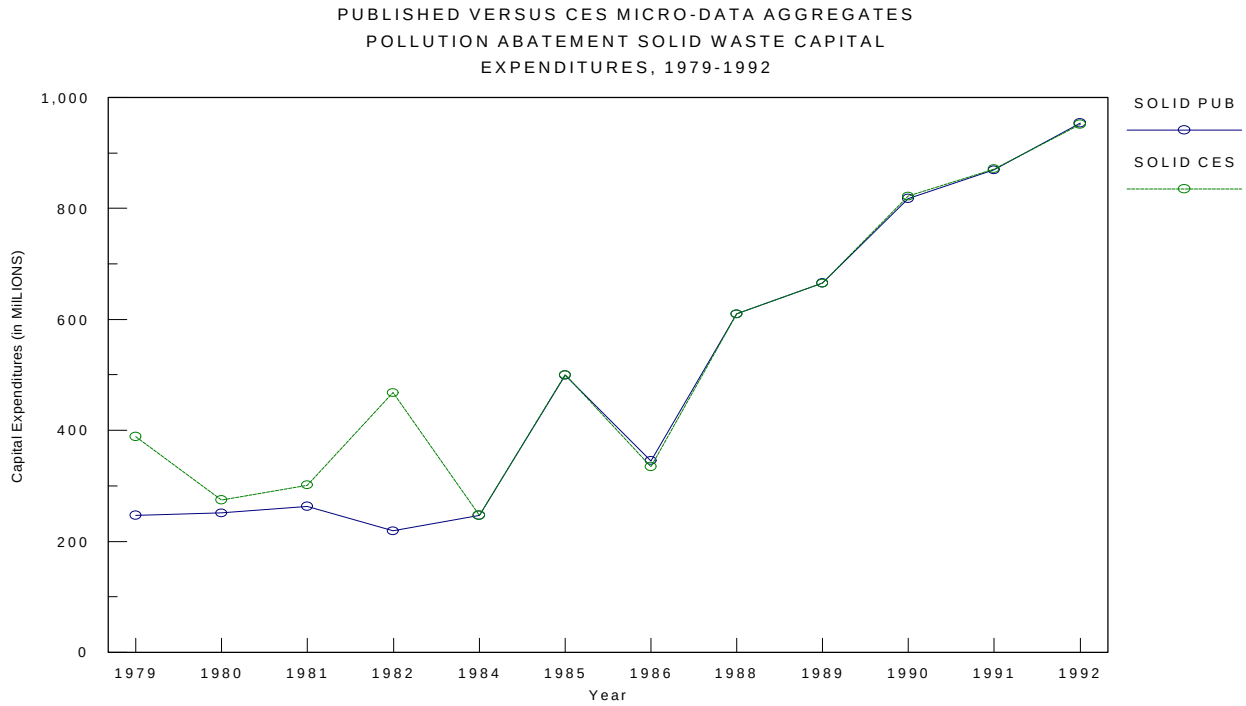
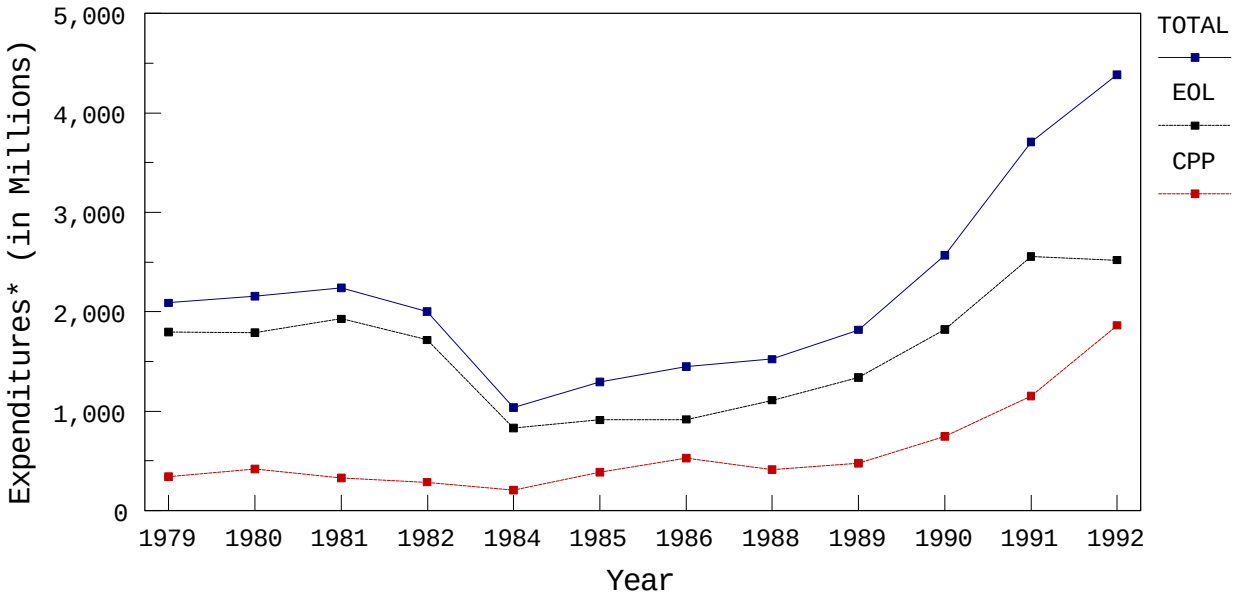


Figure 6

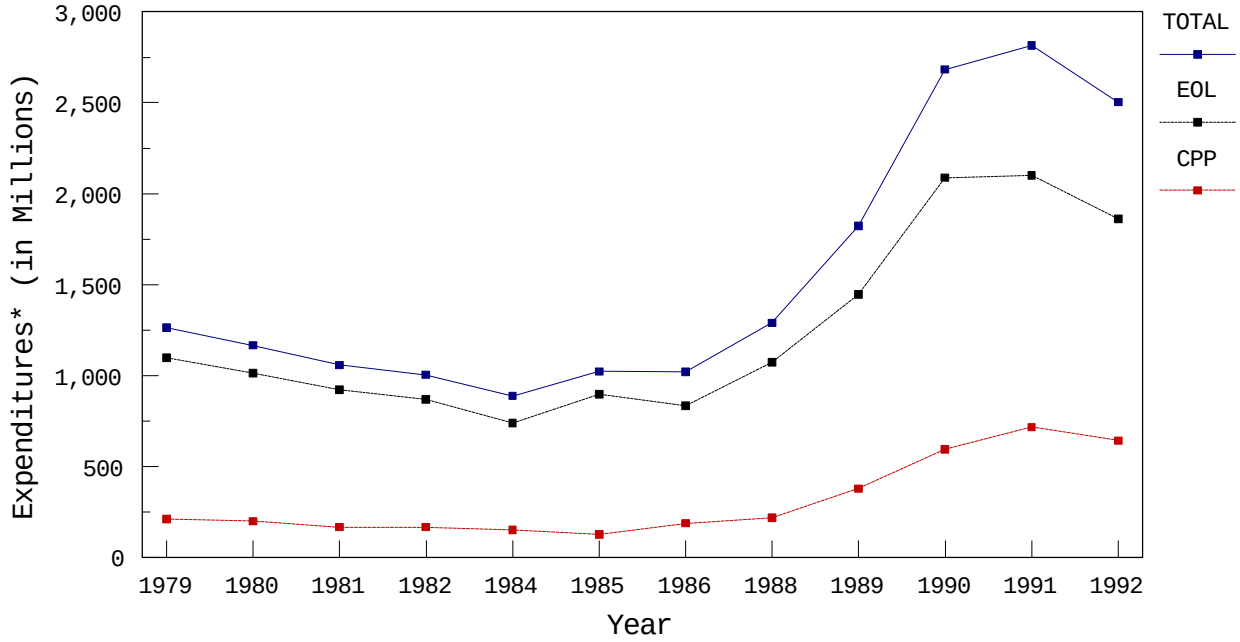
Air Pollution Abatement Capital Expenditures*, By Method, 1979-92



* Weighted

Figure 7

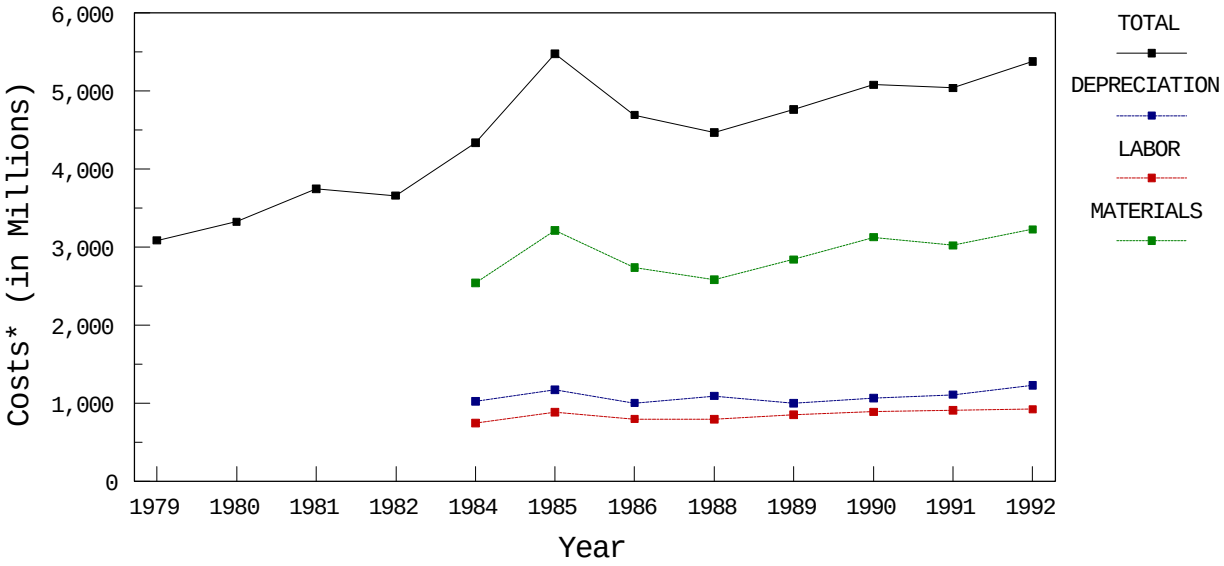
Water Pollution Abatement Capital Expenditures*, By Method, 1979-92



* Weighted

Figure 8

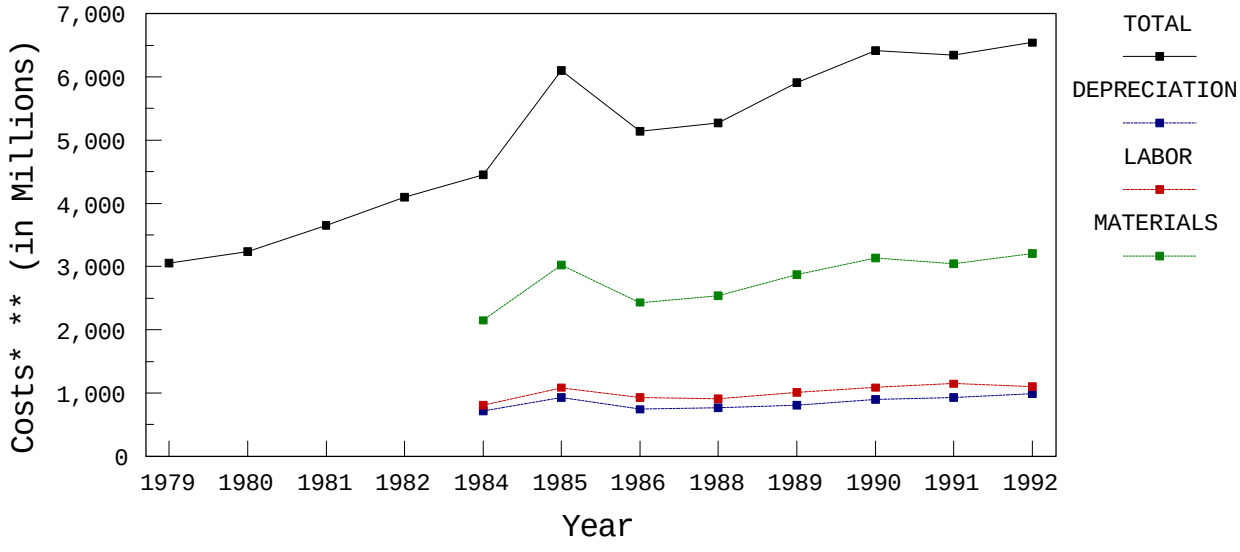
Air Pollution Abatement Operating Costs*, By Category, 1979-92



*Weighted

Figure 9

Water Pollution Abatement Operating Costs* **, By Category, 1979-92



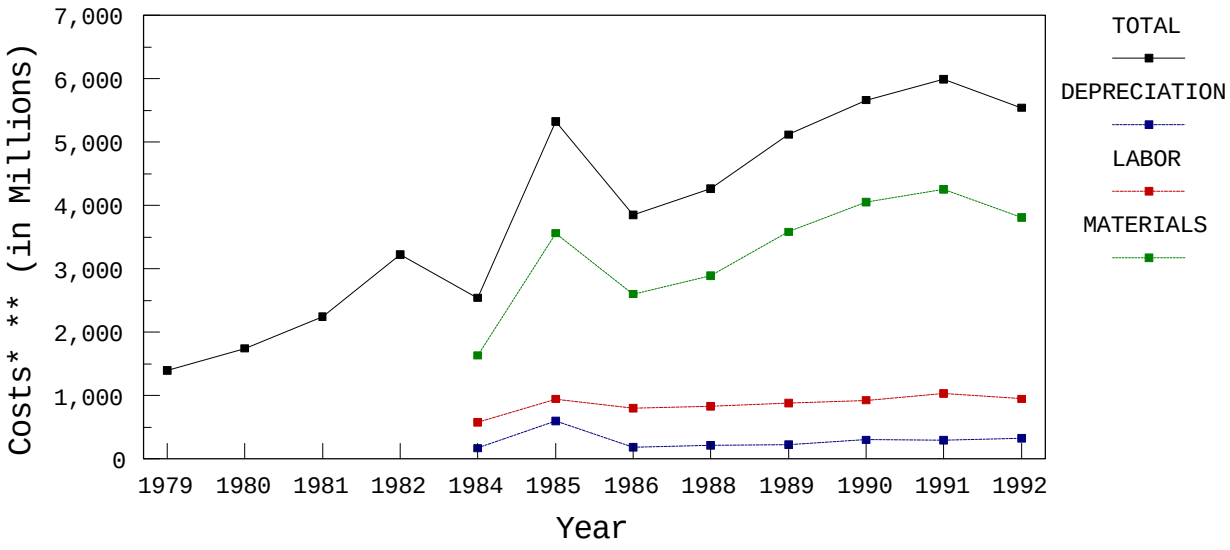
* Weighted

** Including Government Payments

Figure 10

Solid Waste Pollution Abatement Operating Costs*

By Category, 1979-92



* Weighted

** Including Government Payments

APPENDIX

Sample Survey Forms:
1979-93