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Comparing the 1994 and 1999
Pollution Abatement Costs and Expenditures Surveys**

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Abstract

Since 1973, the Pollution Abatement Costs and Expenditures (PACE) survey has been the principle source of information on U.S. industries' capital expenditure and operating costs associated with pollution abatement efforts. The PACE survey was discontinued after 1994 and then revived in 1999 for one year – in a substantially different form than the preceding surveys however, making longitudinal analysis quite difficult. Conceptual differences include matters as fundamental as the scope and meaning of *pollution abatement* as well as the definition of *operating costs*. A number of other critical changes also exist, including ones of industrial coverage and sample selection. This paper is the first comprehensive effort to document the many changes in the PACE survey across these years and to provide a detailed guide for researchers and policymakers who wish to compare the 1994 and 1999 data. Overall, we find a 27% decline in environmental spending by the manufacturing sector between these two years, though there appears to be significant heterogeneity across industries. We discuss potential reasons for this dramatic decline, focusing mainly on issues of survey methodology and design. This paper should help inform current efforts to redevelop the PACE survey and re-establish it as a regular, annual survey.

Subject Area: Costs of Pollution Control

Keywords: pollution abatement, survey data, environmental costs, manufacturing

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I. Introduction

Since 1973, the Pollution Abatement Costs and Expenditures (PACE) survey has been the principle source of information on U.S. industries' capital expenditure and operating costs associated with pollution abatement efforts. The data published from this survey (e.g., U.S. Bureau of the Census, 1994) are widely used by government agencies, academic researchers, and industry to estimate the costs of environmental regulations and analyze their effects. For budgetary reasons the PACE survey was discontinued after 1994 and then revived for just one year – in 1999 – in a substantially different form than the preceding surveys.¹ These 1999 data were released in November 2002.²

Our study is the first comprehensive effort to document the many conceptual changes in the PACE survey between 1994 and 1999. It is extremely important to note that many of these changes make it impossible to *directly* compare even such “core” data items as pollution abatement operating costs. As we will make clear, things similarly named are not necessarily similarly defined – a fact that is not necessarily apparent from the 1999 PACE publication (U.S. Bureau of the Census, 2002). Here, we provide a detailed guide – with appropriate cautions and caveats – for researchers and policymakers who wish to utilize the 1999 data in a longitudinal context. Our paper also discusses a number of critical measurement issues and challenges, including ones of survey methodology and design. This study should help inform current efforts to redevelop the PACE survey and re-establish it as a regular, annual survey.

The paper proceeds as follows. In Section II, we briefly highlight the importance of the PACE survey and discuss just some of the many ways that its data have been used. In

¹ Note that a survey was also not conducted for reference year 1987.

² See Iovanna *et al.* (2003) for a history of the 1999 PACE survey.

Section III of the paper, we detail many of the important changes in the survey between 1994 and 1999. Here we highlight the changes in form design that directly affect data comparability. It is true that many expenditure items were collected in a substantially different manner on the 1999 survey than on previous surveys. For example, some costs were no longer disaggregated by pollution media (i.e., air, water, solid waste, etc.) and/or separated into capital expenditures and operating costs. Some new data items were introduced in 1999; other long-standing ones were eliminated however, such as capital depreciation costs and cost offsets. In Section III, we also discuss the critical conceptual differences between the recent survey and its predecessors. Perhaps most important, *pollution abatement* was fundamentally redefined to exclude pollution prevention, recycling, and disposal – leaving just the *treatment* of pollution. Pollution abatement also excluded related administrative activities as well as monitoring & testing. Additionally, *operating costs* were redefined to exclude capital depreciation and permit-related expenses. Finally, there were notable differences in sample selection and industrial coverage that also affect the comparability of the 1999 PACE estimates with those from prior years. Most significant were the addition of establishments with fewer than 20 employees, the switch in the U.S. industrial classification system, and changes in the way in which data from the non-manufacturing sector were collected and presented.

Nevertheless, with appropriate aggregations of and adjustments to the published PACE statistics from the respective years, a comparison of pollution abatement spending in 1994 and 1999 can be made, albeit cautiously. This is the subject of Section IV. Overall, we find a 27% decline in environmental spending by the manufacturing sector between these two years. However, there appears to be some significant heterogeneity

across industries. For example, we find declines in expenditures of 16% and 60% in the plastics and petroleum industries, respectively, but increased expenditure among steel mills and pulp mills.

Section V discusses some of the potential reasons for the dramatic changes in environmental spending between these two years, focusing mainly on issues of survey methodology and design relating to the 1999 version of the PACE. In particular, we believe that limited data editing, conservative imputation, altered questionnaire design, less-than-explicit instructions, and some other factors may have resulted in 1999 expenditures that were too low. Finally, we conclude in Section VI with some recommendations for any future PACE surveys.

II. Importance of the PACE survey

The importance of the PACE survey to policymakers is perhaps best summarized in a January 15, 2002 letter from the Environmental Economics Advisory Committee (EEAC) of the EPA's Science Advisory Board to Governor Christie Whitman, then Administrator of the U.S. Environmental Protection Agency (EPA):

The PACE Survey data provide a truly unique tool for evaluation of the costs of compliance with environmental regulations. The collection of these data has provided the United States with an important source of information to facilitate the evaluation of environmental programs and, in turn, to improve the design and performance of these programs. EPA has used the PACE data in its Cost of Clean reports, the Section 812 Clean Air Retrospective Cost Analysis, numerous sector-specific studies, Regulatory Impact Analyses, analyses of recycling activities, and national studies of environmental protection activities. The relatively low cost of the PACE Survey, combined with its great benefits to EPA, means that the annual Survey provides the Agency with a tremendous return on its investment.

Furthermore the EEAC noted:

At once, the PACE Survey provides a means to assess the costs of environmental regulations in aggregate and individually, and it provides important data with which to compare the cost-effectiveness of alternative regulatory approaches. The systematic collection of information on these costs of regulation is essential to meet expanding legal requirements for review of the costs of regulation, and it is important for EPA's efforts to develop sound and effective regulations.

Over the years, a number of academic studies have used data from the PACE survey to examine how environmental regulation impacts U.S. manufacturing. Among these studies are those that have used the published aggregate statistics (i.e., data at the state-level or by industry) and those that have used the plant-level microdata.³ Among the former, Gray (1986, 1987) examined the impact of environmental regulation on the productivity of 450 manufacturing industries and found that industries with high pollution abatement costs had larger productivity slowdowns in the 1970s. Barbera and McConnell (1987, 1990) also used industry-level PACE data and found that the costs associated with environmental regulation reduced productivity in three of the four industries in their 1987 study, and in all five industries in their 1990 study. More recently, Levinson (2001) used published PACE data to construct an industry-adjusted index of state environmental compliance costs and found that states with apparently more stringent environmental regulations experienced less foreign direct investment in the chemical manufacturing industry.

In terms of studies that have used the plant-level data from the PACE survey, Gray and Shadbegian (1998) examined the impact of investment in pollution abatement

³ The establishment-level survey data are confidential, collected and protected under Title 13 of the U.S. Code. Restricted access to these data can be arranged through the U.S. Census Bureau's Center for Economic Studies. See <http://www.ces.census.gov/> for details.

capital on the investment in “traditional” capital (used to produce output). They find that, among pulp and paper mills, expenditure on the former in fact “crowds out” investment in the latter almost dollar-for-dollar. In another study, Gray and Shadbegian (2002) found that manufacturing plants in the paper, steel, and oil industries had lower productivity levels when their environment-related costs were higher. In contrast, Berman and Bui (2001) found little effect of regulatory costs on the productivity of oil refineries.⁴

Becker (2001) has also used establishment-level data from the PACE survey, to examine the effects of the Clean Air Act on air pollution abatement (APA) capital expenditure and operating costs. As might be expected, he found that heavy emitters of the “criteria” air pollutants located in stringently-regulated NAAQS non-attainment counties generally had higher APA outlays. This study also revealed potential shortcomings in the PACE survey data. In a more recent study, Becker (2003) found that certain community characteristics had *additional* effects on the APA expenditures of nearby polluters, over and above formal regulatory requirements.

III. Changes in the PACE survey

In this section, we discuss many of the important changes to the PACE survey between the version in the early-1990s and that in 1999.

Scope of the survey

In terms of sample size, the manufacturing component of the survey is somewhat

⁴ This result is at least somewhat consistent with the results of Gray and Shadbegian (2002) in that, of the three industries they studied, the impact of pollution abatement costs on productivity was the smallest for oil.

larger in 1999. The 1994 PACE publication reports that 17,800 manufacturing plants were sampled, while in 1999 well over 19,000 were selected. In both instances, the sampling frame consisted of establishments in the prior Census of Manufactures (i.e., 1992 and 1997, respectively) along with plants opening in the intervening years (i.e., 1993 and 1998). Note that up to and including 1993, the PACE sample had been a strict subset of the contemporaneous Annual Survey of Manufactures (ASM).

One important difference in sampling between the PACE survey of 1999 and those since 1976 is that the 1999 sampled establishments with fewer than 20 employees. These had previously been deemed a relatively insignificant portion of the universe of polluting plants. In particular, according to PACE publications, “early surveys showed that [these] establishments contributed only about 2 percent to the pollution estimates while constituting more than 10 percent of the sample size.” Since the 1980 PACE, “no adjustment is made to account for these establishments.” Below, we will examine whether this group is still a small percentage of total pollution abatement expenditures.

The 1999 sample also differs from the 1994 sample in terms of industrial coverage. Some of the differences are associated with the replacement, in 1997, of the Standard Industrial Classification (SIC) system with the North American Industrial Classification System (NAICS) and therefore are not unique to the PACE survey. In addition to the significant re-categorization of production activity *within* manufacturing, which alone makes cross-year comparisons difficult, some activity previously defined as manufacturing is now classified as non-manufacturing and vice versa. Table A-1 (in Appendix A) shows industrial activity that has been *removed from* manufacturing under NAICS, while Table A-2 shows industrial activity that has been *moved into*

manufacturing under NAICS. Details on within-manufacturing changes can be found at <http://www.census.gov/epcd/ec97brdg/INDXNAI3.HTM#31-33>.

Another difference in industrial coverage between previous versions of the PACE and the 1999 survey is that the 1999 PACE surveyed plants in the apparel industry (formerly SIC 23). According to PACE publications, the reason for their prior exclusion was that “these establishments operate primarily in rented quarters where the abatement of pollution (probably most of which is solid waste) is generally arranged by the landlord. Capital expenditures for pollution abatement in such establishments are probably minimal.” And indeed, in 1999, NAICS 315 – which accounts for about 70% of the output of what had been SIC 23 – had a negligible amount of capital expenditure and no more than \$8 million of operating costs.⁵ Table A-3 shows the NAICS industries that correspond to the former SIC 23.

The 1999 PACE also canvassed certain non-manufacturing establishments, in particular those engaged in mining (NAICS 21) and electric power generation (NAICS 22111). This is somewhat of a break from the past. From 1988 to 1994, the Census Bureau also collected data on pollution abatement expenditures from mining companies and electric utilities, and statistics for these industries were presented in the PACE publications. However, the survey instrument used (Form PA-2) was a supplement to the Census Bureau’s Plant and Equipment Survey and was somewhat different from the PACE survey that manufacturing plants received (Form MA-200). Most importantly, it did not inquire about pollution abatement operating costs — it only asked about capital expenditures. Another important difference is that the PA-2 was sent to *firms* primarily engaged in those activities, not *establishments*. A firm-level survey may yield

substantially different estimates than an establishment-level survey if firms have a large amount of “secondary” activity — that is, for example, mining firms with non-mining ventures.⁶ For these and other reasons, we will not focus on PACE’s non-manufacturing industries in this paper.

One extremely important caution we would like to convey here, for those interested in comparing 1999 PACE expenditures to those in prior years, is that “All industries” in the tables of previous PACE publications denotes *just the manufacturing industries* (less SIC 23), while “All industries” in the 1999 publication implies all manufacturing industries *as well as the mining and electric power generation industries*.⁷ The manufacturing-only data begin farther down the 1999 tables, with NAICS 31-33. Failing to realize this can be critical. Table 1 summarizes this as well as the other major “scope” issues faced by those wishing to compare 1999 PACE data to the older PACE data.

Concepts and definitions

In addition to these changes in industrial coverage and sample selection, there were significant changes in the data that the PACE survey intended to capture. This is true for

⁵ Note that 16% of what is NAICS 315 came from somewhere other than SIC 23.

⁶ This can actually be seen in the 1994 data. The PA-2 was also sent to firms primarily engaged in petroleum and coal products (SIC 29), which is also in scope to the establishment-level PACE survey (MA-200). The estimates based on the firm-level survey suggest that SIC 29 had \$4.7 billion of capital expenditures for the abatement of air, water, solid waste, nonmedia and other pollutants. The PACE survey, on the other hand, suggests that this industry had just \$2.6 billion of such expenditures.

⁷ Of course, neither captures the pollution abatement expenditures of truly all industries since there are polluting industries that have been out-of-scope to the PACE survey, then and now. For example, among the excluded sectors are construction, agriculture (e.g., crop production, hog farms), wholesaling (e.g., petroleum, chemicals), retail (e.g., gasoline stations), transportation (e.g., trucking), services (e.g., dry cleaning, auto repair, hospitals, universities), utilities (e.g., landfills, incinerators), and government-owned enterprises that are out-of-scope to Census Bureau surveys.

Table 1

Summary of main scope issues

- (1) Estimates for “All industries” in the 1994 tables are for manufacturing only, while “All industries” in 1999 also encompasses mining and electric power generation. Estimates for just manufacturing (NAICS 31-33) begin farther down the 1999 tables.
- (2) Since 1973, the apparel industry (SIC 23) had been excluded from the survey. This industry was included again however in the 1999 survey. (See Table A-3.)
- (3) With the replacement of the SIC system with NAICS, some industrial activities are no longer classified as manufacturing (see Table A-1), while others are newly classified as manufacturing (see Table A-2).
- (4) Since 1976, establishments with fewer than 20 employees had been excluded from the PACE survey, and no adjustments were made for their missing expenditures after 1980. In 1999, these established were once again included in the PACE sample.

even the most fundamental data items, such as pollution abatement operating costs and pollution abatement capital expenditures. We now attempt to explain the various changes in these two core concepts.

Operating costs

In its previous incarnations, the PACE survey opened with a stand-alone question on pollution abatement operating costs (see Item 3 in Appendix B), where *abatement* was broadly defined to include techniques in pollution prevention, recycling, treatment, collection, and disposal, as well as related administrative activities and monitoring & testing. Operating costs were to be disaggregated into 3 pollution media – air, water, and solid/contained waste – and further disaggregated into 5 categories of costs (within each media): depreciation, salaries & wages, fuel & electricity, contract work/services, and

materials/leasing/miscellaneous.⁸ Item 4 of the survey then asked respondents to estimate the percent of the air, water, and solid waste totals in Item 3 directed toward the abatement of *hazardous* air, water, and solid waste, respectively. Item 5 inquired about payments to governments (federal, state, county, or local) for pollutant removal, namely for: (a) sewage services⁹ and (b) solid/contained waste collection & disposal.¹⁰ Operating costs associated with the prevention, replacement, removal, and monitoring of (inferior or leaking) underground storage tanks (USTs) were to be reported exclusively in Item 9. Likewise, operating costs specifically associated with site cleanup were to be reported in Item 10. Finally, operating costs for the abatement of “other” pollutants (namely radiation, multimedia pollutants, and noise “that would otherwise disturb the surrounding community”) were captured in Items 11 and 12.

In the 1999 PACE, operating costs were collected in a much different manner (see Item 2B in Appendix C). As in prior PACE surveys, data were collected separately for air, water, and solid waste. However, multi-media also appears here, as its own category, which had not been the case in prior surveys. In addition, the 1999 PACE recognized the *disposal* of solid waste and the *recycling* of solid waste (see Item 2C-1 and Item 2C-2) as distinct from the *abatement* of solid waste (Item 2B-3). It is very important to note that these three had been just a single expense category prior to this survey.¹¹

⁸ The grouping of expenses in these last three categories has changed over the years. Early on, equipment leasing was its own category, with “materials, supplies, services, and other costs” as another. Later, “materials, supplies, fuel, and electricity” was a category along with “services, equipment leasing, and other costs.” Meanwhile, there were always separate categories for depreciation and labor.

⁹ Except “sanitary” sewage. However, if expenditure on such sewage could not be separated from expenditure on “industrial” sewage, respondents were to report the entire amount.

¹⁰ Except the collection & disposal of office and cafeteria trash. Again, if this could not be separated from expenditure on “industrial” solid waste, then the entire amount was to be reported.

¹¹ There appears, however, to be some difference in the definition of recycling. In particular, the 1999 survey explicitly states that the “burning of waste materials for fuel are not included in this category.” Furthermore, the 1999 PACE recognized a distinction between post-process and in-process recycling, the

Another obvious difference is that the 1999 PACE collected operating costs in the same item as capital expenditures, and as the percentages attributable to *hazardous* pollutants, which had not been the case before. More importantly, respondents were no longer asked to disaggregate operating costs by category (i.e., depreciation, salaries & wages, etc.). This is obviously a loss for researchers interested in these types of expenditures. A more fundamental question is whether this change in any way impacts the quality (and comparability) of the *total* operating cost numbers. After all, the same question, asked two different ways, may yield different answers.

There are also some very significant changes in the *definition* of pollution abatement operating costs between 1994 and 1999 that users of these data absolutely need to be aware of. In particular, the 1999 survey employed a much narrower definition of pollution abatement operating costs, along a number of dimensions. For example, costs associated with the testing & monitoring of emissions, conducting environmental audits & studies, developing pollution abatement operating procedures, completing environmental reporting requirements, training, preparing documents related to environmental protection, and other such administrative costs were no longer included in the definition. Instead, in 1999, these were recognized as distinct environmental activities and their expenditures were collected near the end of the survey form, in Items 4C (environmental monitoring & testing) and 4D (administration of environmental programs) in particular. Note that respondents were not asked to disaggregate these expenditures by pollution media (i.e., air, water, and solid waste). Furthermore, these particular operating costs were lumped together with their respective capital

former being an end-of-line technique (captured in Item 2C-2) while the latter is a prevention technique (captured in Item 3B).

expenditures. (This fact alone complicates longitudinal comparisons with prior years, as we shall see in Section IV.) In 1999, the manufacturing sector had \$1.7 billion of expenditure on these two “new” items, which previously would have been reported among “traditional” pollution abatement operating costs or capital expenditures.

In addition, operating costs associated with pollution prevention techniques were also no longer reportable among the “traditional” pollution abatement operating costs, as they once had been.¹² Instead, such outlays were to be reported in Item 3B of the 1999 survey, which (again) lumped together both capital expenditures and operating costs, as well as lumping together the prevention of pollution of all media (see Appendix C). Furthermore, the instructions on how to report this item were perhaps less explicit than they could have been. To take one example, in the 1994 survey, respondents were instructed to include the “incremental costs for consumption of environmentally preferable materials and fuels” — that is, the cost of “cleaner” inputs minus the cost of “dirtier” alternatives. No such guidance was offered in the 1999 survey, which leads one to wonder whether costs such as these were captured or not.

Another very important conceptual change in operating costs is that the 1999 survey no longer deemed the depreciation of pollution abatement capital stock (equipment and structures) an operating cost. And unlike the abovementioned costs, depreciation was not collected elsewhere on the 1999 PACE survey. In 1994, the depreciation of pollution abatement capital in the manufacturing sector totaled almost \$3

¹² It should be noted that these issues with pollution prevention, administration, monitoring & testing, disposal, and recycling have more to do with a revised definition of *pollution abatement* than a changed definition of operating costs. In particular, for the 1999 survey, pollution abatement was redefined to include only the treatment of pollutants after their generation (not including recycling and disposal), while previously, prevention techniques leading to the reduction and elimination of pollution generated had also been deemed abatement, as had the treatment, recycling, and disposal of pollutants, as well as related administrative activities and monitoring & testing.

billion, representing over 15% of total pollution abatement operating costs.¹³ Adjusting for such a major definitional difference (in addition to the others above) is obviously very important when making cross-year comparisons, as we do in Section IV.

Meanwhile, payments to governments for the removal and disposal of industrial wastes, previously collected separately, were to be combined with other disposal operating costs in Item 2C of the 1999 survey.¹⁴ Costs associated with leaking or inferior underground storage tanks (USTs) were again a separate line item in the 1999 survey (Item 4A-2), however it very likely did not include anything beyond their removal and replacement. In contrast, Item 9 on the 1994 PACE survey also included the monitoring of USTs as well as prevention activities (i.e., the “installation of safeguards for existing underground tanks”). In 1999, expenditures on the former were presumably included in the new item specifically concerned with environmental monitoring (Item 4C) and the latter were included in pollution prevention (Item 3B). In any event, in 1999, operating costs related to USTs were combined together with UST capital expenditures, where previously they were reported separately. Likewise, operating costs and capital expenditures associated with site cleanup were also combined together, where previously they had been distinct. However, in 1999, the operation and maintenance of Superfund sites was separated from other types of site cleanup (Item 4A-1 and Item 4A-3, respectively), where previously they were combined. Again, cleanup-related testing & monitoring, compliance auditing, environmental studies, and other administrative costs – which previously were included in these operating costs – were imbedded in other items in the 1999 survey.

¹³ This percentage had been even higher in the past, peaking at over 24% in 1979.

¹⁴ Note that the “payments to governments” item on the 1999 PACE survey (i.e., Item 7A) has absolutely

Finally, in the 1994 survey, operating costs explicitly included “permits and costs incurred obtaining permits.”¹⁵ In the 1999 survey, costs incurred in obtaining permits were likely included among administrative costs (Item 4D) while the permits themselves were captured in Item 7A-1 (i.e., payments to government through permits, fees, and charges) or Item 7B-1 (tradable permits bought). The 1999 survey also included questions on payments to governments through fines and penalties (Item 7A-2) and “other expenditures as a result of penalties, such as payments for supplemental environmental projects” (Item 7A-3). Presumably environmental taxes, including Superfund contributions, were to be included in Item 7A-1, along with environmental permits and fees. The 1994 survey, however, explicitly excluded “taxes, fines, legal fees, and Superfund taxes and contributions” from its definition of operating costs. This is yet another reason why it will not be possible to get fully conformable definitions of costs across these two years.

Capital expenditures

In terms of pollution abatement capital expenditures, the 1994 version of the PACE survey contained a stand-alone question (see Item 7 in Appendix B) asking respondents to report such expenditures by 3 pollution media – air, water, and solid/contained waste – and by 2 types of capital: the *end-of-line* variety and that associated with *production process enhancements*, replacements, additions, and alterations. End-of-line (EOL) capital treats pollutants after their generation,¹⁶ while production process enhancements

nothing in common with the “payments to governments” questions on the older PACE surveys.

¹⁵ Prior to 1993, however, permit costs were excluded from the PACE’s definition of operating costs.

¹⁶ Examples include: dust collectors, scrubbers, and precipitators for air pollution abatement; trickling filters, settling ponds, clarifiers, and spill containment dikes for water pollution abatement; cardboard balers, compactors, bins, improved waste containments, and incinerators for solid/contained waste. (Taken from page 11 of the 1994 PACE instruction booklet.)

(PPE) capital is capital that is embedded in production process changes meant to reduce or avoid the generation of pollutants.¹⁷ As with operating costs, respondents were asked to estimate the percent of expenditures attributable to the abatement of hazardous air, water, and solid waste, respectively. Item 8 further inquired as to the proportion of *non-hazardous* air pollution abatement capital expenditure devoted toward the six “criteria” air pollutants covered under the Clean Air Act versus other non-hazardous air pollutants. Finally, as was the case with operating costs, capital expenditures on USTs, site cleanup, and the abatement of “other” pollutants (i.e., multi-media, noise, and radiation) were reported separately in Items 9 through 11, respectively.

In the 1999 PACE survey, capital expenditures were collected in a substantially different fashion, and much of the preceding discussion on the collection of operating costs applies here as well. (As such, we will recap the prior discussion only briefly.) Again, recalling Item 2B, data were collected separately for air, water, and solid waste, as well as a new independent multi-media category. And, again, the disposal and recycling of solid waste were recognized as distinct from its abatement/treatment – or from prevention for that matter. Spending on USTs – with the exception of monitoring as well as preventative measures – was collected in a separate item, but with no distinction between operating costs and capital expenditures, as had been the case in prior surveys. The same is true for site cleanup expenses.

Meanwhile, pollution monitoring & testing equipment – be it for air, water, solid waste, underground storage tanks, multimedia, etc. – was reported in Item 4C

¹⁷ Examples include equipment and structures necessary for the conversion to substitute fuels that generate fewer air pollutants, conversion to a closed or partially closed loop system for water pollution abatement, or conversion enabling the recycling of scrap materials. Prior to 1992, this type of expenditure was called *change-in-production process* (CIPP) capital.

(environmental monitoring & testing), where previously it had been included in the PPE capital expenditure for the particular media. Furthermore, in 1999, such expenditure was combined with monitoring & testing operating costs, severely complicating any longitudinal data analysis. Similarly, the capital expenditures associated with the administration of environmental programs (e.g., audits, studies, reporting, training, etc.) were also now reported independent of media (Item 4D), though this change is much more likely to have impacted the reporting of operating costs than capital expenditures.

In another obvious break from prior PACE surveys, the reporting of capital expenditures for the *treatment* of pollutants was decoupled from expenditures on the *prevention* of pollution, with Item 2 and Item 3, respectively. It is important to point out here that one of the more nuanced differences between the 1999 PACE survey and what came before is that the recent survey strictly defined *pollution abatement* as the treatment of pollutants after their generation, excluding recycling and disposal, while process changes leading to the reduction or elimination of pollution generation was labeled *pollution prevention*. In contrast, in 1994, all types of capital expenditures – prevention, treatment, recycling, disposal, and monitoring & testing – were defined as pollution abatement. Treatment and disposal were deemed EOL techniques, while prevention, (post- and in-process) recycling, and monitoring & testing were deemed PPE. Therefore, the “pollution abatement capital expenditure” in Item 2B of the 1999 survey, together with “disposal capital expenditures” of Item 2C-1, was meant to be similar (if not identical) to the EOL capital expenditure in the older surveys. Meanwhile, in 1999, PPE capital was captured in Item 2C-2 (post-process recycling capital), the Item 3B question on pollution prevention, and the Item 4C question on monitoring & testing. Of course, in

contrast to past surveys, the last two items lumped together capital expenditures and operating costs and made no distinction between pollution media.

Perhaps more important however than *how* PPE/prevention capital expenditure was reported across these years is *what* was to be reported. Such capital expenditures pose unique reporting challenges, since the relevant costs are often commingled with capital investment for non-environmental purposes.¹⁸ For example, the conversion to a production process that uses more environmentally-friendly fuels or materials may involve the installation of a new piece of production machinery with certain environmental features imbedded in it. Since the earliest days of the PACE survey, respondents were instructed to estimate the pollution abatement portion of this investment as the *extra cost* of pollution abatement features: “i.e., your actual spending less what you would have spent without the pollution abatement features built-in.” Presumably this became increasingly difficult to do as production equipment *without* said pollution abatement features became rarer. Beginning with the 1992 PACE survey, the following guidance was added to the instructions, to aid respondents facing such difficulties:

Special instructions: Estimating the pollution abatement portion (distinct from production efficiency, energy conservation, employee safety, etc.) of a process enhancement may not be feasible in all cases. For these cases, report in this manner: Do ***not*** include any of the project cost ***unless*** the primary purpose is environmental protection. If the primary purpose of the project is environmental protection, report the whole production process enhancement project expenditure. Indicate in the remarks section that this is the case. ***Caution:*** A project with the primary purpose of improving production efficiency may include pollution abatement features added to meet legal requirements. Since the primary purpose of such a project is still not environmental

¹⁸ In contrast, an end-of-line device – such as a scrubber – has only one purpose, and reporting such capital expenditures are generally thought to be rather straightforward.

protection, do not report *any* of the production process enhancement.

Whether or not one agrees with this particular conceptualization, at least it was relatively explicit: If possible, separate out the pollution abatement portion of capital expenditures; otherwise, report all [none] of the costs if the primary purpose for undertaking the investment was [was not] environmental protection.

The 1999 survey, on the other hand, is not explicit on the matter of what to report. Little guidance was actually offered in the Item 3 instructions. Earlier in the instruction booklet, however, the following appears under the definition of pollution prevention:

Pollution prevention can be an inherent part of the production process, in which case production and pollution prevention may be said to occur jointly in an “integrated process.” However, for the purposes of this survey, in order for any expenditure to be attributable to pollution prevention the integrated process must have been selected primarily for environmental protection, i.e., an alternative production process would have been chosen absent this consideration.

While this is not necessarily inconsistent with the notion put forth in previous PACE surveys, it also does not rule out other interpretations. Our point is that such ambiguity may have implications for the comparability of the capital expenditure estimates from the two years.

New items

In addition to reformulating some old concepts, the 1999 PACE survey introduced some new data items as well. For example, expenditures on habitat protection (Item 4B), which includes wetlands mitigation banking and riparian buffer strips, had never been collected before by the PACE survey. Likewise, much of the expenditures in Item 7 (other payments) are new to the PACE, including payments to governments through fees,

charges, fines, penalties, and other means, as well as the revenues from tradable SO₂ and NO_x permits.¹⁹ The 1999 PACE also asked a series of 21 yes/no questions concerning the plant's engagement in various types of pollution abatement (Item 2A) and pollution prevention (Item 3A) activities, participation in voluntary environmental programs (Item 5), and receipt of tax credits or subsidies for their environmental activities (Item 6). The results of these dichotomous questions, however, do not appear in the PACE publication.

Perhaps the most important addition to the 1999 survey – with potentially the greatest impact – was the checkboxes that appear next to the expenditures items indicating “Information not available or not collected to provide an estimate” (see Appendix C). Establishments received the following instructions on how to report their data:

Answer all questions. If you can not answer a question from your plant records, please estimate the answer carefully.... If you are unable to provide estimates because your facility does not keep the necessary records or the records are unavailable (i.e. in storage or archived), please mark the [stated] box.

The implications of this unprecedented choice are not fully understood. Presumably item non-response was higher than it would have been without this sanctioned option.

Furthermore, when these boxes were checked, it is not necessarily clear what respondents had in mind. To some, a reported zero expenditure might be consistent with “information not available or not collected.” To others, checking this box might indicate a lack of confidence in the submitted response. Still others may have checked the box because they had expenditures but did not estimate them. A post-survey “response analysis survey” of respondents suggested that the majority (but certainly not all) of those that checked these boxes had the final motivation. In any event, it is not necessarily clear

¹⁹ The *costs* of permits, however, had been included in the 1993 and 1994 PACE surveys.

whether the checkbox is meant to apply to the capital expenditure item, operating costs, or both.²⁰

Eliminated data items

In addition to abandoning some of the expenditure detail previously collected (e.g., operating costs by category; pollution prevention capital expenditure by media; etc.), there were other items that the 1999 PACE survey simply did not collect. Most notable is capital depreciation costs, which was already discussed above. Cost offsets (i.e., “operating expenses recovered as a result or an off-shoot of pollution abatement techniques”) were also not measured in 1999. In 1994, these had totaled some \$1.7 billion. Also excluded in 1999 were expenditures on the abatement of noise, radiation, and “other” pollutants, which in 1994 amounted to \$39 million in capital expenditure and \$178 million in operating costs. And very notable exclusions from the 1999 publication are the tables on expenditures by state and 2-digit SIC (3-digit NAICS) industry. While these data were collected, at least in principle, estimates were not produced chiefly because of quality concerns.

IV. Comparing PACE expenditures across the years

With the discussion above in mind, we will now attempt to compare 1994 and 1999 PACE expenditures. Comparison of the published data obviously takes some effort. Concept redefinitions necessitate the addition and subtraction of certain items in order to achieve comparable numbers. And because the 1999 survey often did not separate out

²⁰ Complicating matters even more, responses of zero were not entered from the survey form. Therefore, it is impossible to distinguish zero responses (which can be a legitimate value, especially for the type of

expenses by pollution media or into capital expenditures and operating costs, significant aggregation sometimes becomes necessary. We'll note here that, in general, adjusting for differences in sampling and industrial coverage cannot be done with the published statistics alone. Below, we make these adjustments using the underlying plant-level microdata, which we have access to.

End-of-line capital expenditures

In terms of capital expenditures, the simplest comparison to make is that of the end-of-line (EOL) variety. This was collected in the top line of Item 7 on the 1994 survey (see Appendix B), and estimates appear by 2-digit SIC industry in Tables 4a-4c of the 1994 publication and by state in Tables 6a-6c. Note that EOL capital expenditures accounted for 52%, 70%, and 62% of *total* pollution abatement capital expenditures for air, water, and solid waste, respectively.

As noted above, in 1999, EOL capital expenditures were *disposal capital expenditures plus pollution abatement capital expenditures*. (Therefore this is not the same as the identically-named pollution abatement capital expenditures that appear in Tables 1, 2, 3, etc. of the 1994 publication, which also include PPE capital.) These 1999 EOL expenditures were collected in the first column of Item 2B and 2C-1, respectively, and estimates appear in Tables 1, 3, 4a, and 7a of the 1999 publication.

Beyond this, we must adjust for the four differences in scope summarized in Table 1. Table 2 tallies all the necessary adjustments to the data. Note that the industries that were reclassified as non-manufacturing under NAICS did not account for much of 1994 EOL capital expenditure – a mere 0.08%. A much more important adjustment is the

expenditures under consideration here) from non-responses (i.e., true missing values).

subtraction of the (weighted) expenditures of plants with fewer than 20 employees in 1999. Here they account for 2.1% of expenditures. After this, the final two adjustments to the 1999 data account for a relatively small amount of the remaining expenditures: NAICS industries that were once in SIC 23 account for just 0.03% of outlays, and NAICS industries that are new to manufacturing account for only 0.04%.

After the appropriate adjustments are made, we see that there was a 3.9% decline in *nominal* spending on EOL capital by the manufacturing sector between these two years, and an 11.9% decline in *real* terms.²¹ However, a more relevant metric is expenditure normalized by the level of economic activity, since manufacturing may have increased or decreased over this period. We therefore compute and present dollars of EOL capital expenditure per \$1,000 of value added.²² We see that, overall, such expenditure fell 25.9% between these two years, with EOL capital for air, water, and solid waste falling 20.9%, 29.8%, and 32.4%, respectively.

Prevention/PPE capital expenditures

Evaluating capital expenditures related to prevention and recycling activities – formerly known as *production process enhancements* (PPE) – is impossible since much of these expenditures were combined with prevention operating costs in Item 3B of the 1999 survey (and not separated by media in any event). However, even if one were to

²¹ The GDP implicit price deflator implies price increases of about 9.04% between these two years.

²² Nominal value added in the manufacturing sector in 1994 totaled \$1,406,467.9 million, after eliminating SIC 23 and those industries that left manufacturing under NAICS, as well as establishments with fewer than 20 employees. Nominal value added in 1999 totaled \$1,822,171.3 million, after removing activity that once was SIC 23 or that was in non-manufacturing under the SIC system, and after removing establishments with fewer than 20 employees. These numbers imply a 29.6% growth in *nominal* manufacturing activity and an 18.8% growth in *real* terms, using this appropriately modified definition of manufacturing. These numbers were computed from statistics available in the 1994 and 1999 Annual Survey of Manufactures (ASM) publications and the adjustments implied by tables found in Appendix A.

Table 2*End-of-line capital expenditures*
(in millions of dollars)

	1994				
	<i>Source</i>	<i>Air</i>	<i>Water</i>	<i>Solid Waste</i>	<i>Total</i>
EOL capital exp. for "All industries"	Tables 4a, 4b, 4c	2,228.1	1,698.4	521.5	4,448.0
NAICS non-manufacturing industries	<i>microdata</i>	-1.0	-1.2	-1.4	-3.6
Adjusted total		2,227.1	1,697.2	520.1	4,444.4
Expenditures per \$1,000 of value added (in dollars)		\$1.58	\$1.21	\$0.37	\$3.16
	1999				
	<i>Source</i>	<i>Air</i>	<i>Water</i>	<i>Solid Waste</i>	<i>Total</i>
Abatement capital exp. for NAICS 31-33	Table 1	2,313.4	1,588.9	307.9	4,210.2
Disposal capital exp. for NAICS 31-33	Table 7a	-	-	+153.2	+153.2
Establishments with <20 employees	<i>microdata</i>	-36.1	-47.9	-7.1	-91.1
SIC 23 industries	<i>microdata</i>	-0.0	-0.2	-1.1	-1.3
SIC non-manufacturing industries	<i>microdata</i>	-0.6	-0.9	-0.1	-1.6
Adjusted total (1999 dollars)		2,276.7	1,539.9	452.8	4,269.4
Adjusted total (1994 dollars)		2,087.9	1,412.2	415.3	3,915.4
Percentage change		-6.3%	-16.8%	-20.1%	-11.9%
Expenditures per \$1,000 of value added		\$1.25	\$0.85	\$0.25	\$2.34
Percentage change		-20.9%	-29.8%	-32.4%	-25.9%

assume that

- (a) *none* of the \$2.1 billion dollars in combined prevention expenditure was operating costs (i.e., it was all capital expenditure);
- (b) it was only for air, water, and solid waste (and not also for multimedia, USTs, etc.);
- (c) *all* of the \$507.6 million in monitoring & testing costs in 1999 was capital expenditure (this was previously treated as PPE capital) and not operating costs;
- (d) plants with under 20 employees contributed nothing to the 1999 prevention and recycling totals; and
- (e) the adjustments for changed industrial coverage would matter little;

there was still an enormous decline in such prevention/PPE capital expenditures. In particular, even with these ridiculously generous assumptions, prevention/PPE capital expenditures still fell 32.7% relative to manufacturing activity. This is quite contrary to expectations, since prevention and recycling as well as monitoring & testing has surely

Calculations are available from the authors upon request.

become more – not less – prevalent in the United States. Perhaps, however, the prevention expenditure in particular is done more for production efficiency reasons than for environmental protection, in which case these expenditures *should* have been excluded from the 1999 PACE survey.

Operating costs, prevention, and other costs

Ideally, we would be able to examine operating costs independently. However, because operating costs are often combined with capital expenditures in the 1999 survey, the lowest common denominator between the two surveys quickly becomes quite large.

As discussed above in Section III, there are a number of additions we must make to the basic *pollution abatement operating costs* statistics collected in Item 2B of the 1999 survey and found in Tables 1, 3, and 4b of the publication. First, operating costs associated with disposal and recycling (collected in Item 2C and found in Table 7a) must be added to the solid waste total in order to be comparable to the 1994 definition of abatement. Furthermore, operating costs associated with pollution prevention (Item 3B), administration of environmental programs (Item 4D), and environmental monitoring & testing (Item 4C) must be also added to achieve comparability. The first is found in Table 8a of the 1999 publication; the latter two are in Table 9a. However, all of these items also include related capital expenditures!²³

Therefore, to maintain comparability we must add the appropriate capital expenditures to 1994's basic *pollution abatement operating costs* numbers (collected in

²³ One can imagine that there is not much capital associated with administrative activities, beyond some relatively inexpensive office equipment perhaps. Monitoring & testing, however, surely contains some significant capital investment, as does pollution prevention.

Item 3 and found in Tables 1, 2, 7, 8a-8c, 9, 10a-10c, and 11a-11b).²⁴ In 1994, monitoring & testing equipment was to be included in PPE capital expenditure (i.e., the second line of Item 7), as was pollution prevention capital. The appropriate PPE figures (for air, water, and solid waste) can be found in Tables 4a, 4b, and 4c of the 1994 publication. However, since 1994 PPE capital expenditures (for solid waste) also include capital for recycling efforts, we must then add this item in to the 1999 total. Recycling capital expenditures were collected in Item 2C-2 of the 1999 survey and appear in Table 7a of the publication.

This is not all. Note that the scope of the prevention, administration, and monitoring & testing statistics in 1999 is wider than just air, water, and solid waste. Prevention, for example, also presumably encompasses multimedia pollutants and underground storage tanks (USTs), while monitoring & testing and administration cover those two concerns as well as site cleanup. As a result, we must add expenditures on these three categories to the 1994 total. Operating costs associated with USTs (Item 9), site cleanup (Item 10), and multimedia pollutants (Item 11-12) can be found in Table 13a-13b of the 1994 publication. Capital expenditures on those same items can be found in Table 12a-12b. Both operating costs and capital expenditures must obviously be included here since they are inseparable in 1999.

These particular additions, however, include more than just prevention, administration, and monitoring & testing. They obviously also include the abatement/treatment of multimedia pollutants, the replacement of leaking or inferior

²⁴ Note that the PAOC figures in the 1994 publication include the payments to governments for sewage services and the collection and disposal of industrial waste (from Item 5), which is fine since such expenditures are already imbedded in 1999's numbers for water pollution abatement and solid waste disposal.

USTs, the operation and maintenance of Superfund sites (remediation), as well as costs associated with other types of site cleanup (e.g., leaks and spills). Therefore, these expenditures must of course be added to the 1999 total to maintain comparability.

Multimedia capital expenditures and operating costs were asked in Item 2B of the 1999 survey and appear in Tables 1, 3, and 4b of the publication, while the remaining three costs were asked in Item 4A and appear in Table 9a.

Finally, operating costs in the 1994 survey subsume the costs of permits.

Therefore, two additional items must be added to the 1999 total: tradable permits bought (Item 7B-1) and payments to government through permits, fees, and charges (Item 7A-1), estimates of which appear in Table 10a. However, since the 1994 definition of operating costs explicitly excluded taxes, fines, and such, the addition of the latter implies that the 1999 total will be somewhat too high.

Table 3 summarizes and tallies the various additions just described. Certain subtractions must also occur. In particular, as we noted above, the 1999 survey explicitly excluded capital depreciation from its definition of operating costs, and these costs were not collected elsewhere on the survey. We must therefore subtract off depreciation costs from the 1994 total. Depreciation costs for air, water, and solid waste were asked as part of Item 3 of the survey and were published in Tables 11a-11b. The portion of operating costs attributable to depreciation was not collected however for USTs, site cleanup, and multimedia pollutants. We therefore estimate these costs. In particular, we recognize that depreciation costs for air, water, and solid waste (combined) were 38.95% of their combined total capital expenditures. We apply this same ratio to the capital expenditure in these three other areas. The result is \$3.05 billion of depreciation costs that are

subtracted in 1994. The only other subtraction necessary in 1994 is the expenditures by industries (or shares of industries) that are no longer classified as manufacturing under NAICS. Just \$76.2 million – or 0.37% of the total – is lost as a result of this adjustment.

Subtractions also need to occur on the 1999 side. The most important of these is the (weighted) expenditure of plants with fewer than 20 employees. According to the microdata, these facilities contributed \$646.3 million of expenditure, or about 3.2% of the total here. After this, the adjustments for SIC 23 and non-manufacturing SICs are relatively small, at \$22.3 million and \$15.6 million, respectively.

After all the appropriate adjustments have been made, we see a 13.6% decline in real expenditures across these two years, and a 27.3% decline when measured against manufacturing value added. This decline is only slightly larger than the one seen earlier in EOL capital expenditure.

And though we cannot measure the change in total operating costs separately, we can still estimate a lower bound of its change. In particular, if we eliminate all capital expenditures from the 1994 total, we are left with \$17,361.2 million in operating costs, or \$12.34 per \$1,000 of value added. Then if we (unrealistically and generously) assume that all the joint expenditures (on monitoring & testing, prevention, UST replacement, etc.) are strictly operating costs and contain absolutely no capital expenditures, we have \$10.56 of operating costs per \$1,000 of value added in 1999 (after eliminating capital expenditures for recycling and multimedia). This implies a decline in operating costs between these two years of *at least* 14%. Given the improbable assumptions we employ, the actual decline is of course much greater.

Table 3
Operating costs, prevention, and other costs
(in millions of dollars)

		1994			
	<i>Source</i>	<i>Air</i>	<i>Water</i>	<i>Solid Waste</i>	<i>Total</i>
Abatement operating costs for "All industries"	Table 1	6,139.1	7,031.5 ^a	5,601.4 ^b	18,772.0
Capital depreciation costs for "All industries"	Table 11a	-1,471.7 ^c	-1,102.3 ^c	-378.0 ^c	-2,952.0
PPE capital exp. for "All industries"	Tables 4a/4b/4c	+2,082.6	+730.5	+317.0	+3,130.1
UST capital exp. for "All industries"	Table 12a	-	-	-	+74.1
UST operating costs for "All industries"	Table 13a	-	-	-	+181.4
UST depreciation costs	<i>estimated</i> ^d	-	-	-	-28.9
Site cleanup capital exp. for "All industries"	Table 12a	-	-	-	+183.5
Site cleanup operating costs for "All industries"	Table 13a	-	-	-	+1,460.0
Site cleanup depreciation costs	<i>estimated</i> ^d	-	-	-	-71.5
Multimedia capital exp. for "All industries"	Table 12a	-	-	-	+5.3
Multimedia operating costs for "All industries"	Table 13a	-	-	-	+78.5
Multimedia depreciation costs	<i>estimated</i> ^d	-	-	-	-2.1
NAICS non-manufacturing industries	<i>microdata</i>	→	→	→	-76.2
Adjusted total					\$20,754.2 ^e
Expenditures per \$1,000 of value added					\$14.76
		1999			
	<i>Source</i>	<i>Air</i>	<i>Water</i>	<i>Solid Waste</i>	<i>Total</i>
Abatement operating costs for NAICS 31-33	Table 1	3,977.5	4,277.4	1,818.8	10,073.7
Disposal operating costs for NAICS 31-33	Table 7a	-	-	+3,123.4	+3,123.4
Recycling operating costs for NAICS 31-33	Table 7a	-	-	+1,190.9	+1,190.9
Administrative costs for NAICS 31-33	Table 9a	→	→	→	+1,159.4
Monitoring & testing costs for NAICS 31-33	Table 9a	→	→	→	+507.6
Government permits, etc. for NAICS 31-33	Table 10a	→	→	→	+695.0 ^f
Tradable permits bought by NAICS 31-33	Table 10a	→	→	→	+12.0
Pollution prevention costs & exp. for NAICS 31-33	Table 8a	→	→	→	+2,101.9
Recycling capital exp. for NAICS 31-33	Table 7a	-	-	+120.1	+120.1
UST replacement costs & exp. for NAICS 31-33	Table 9a	-	-	-	+57.8
Site cleanup remediation costs & exp. for NAICS 31-33	Table 9a	-	-	-	+761.9
Other site cleanup costs & exp. for NAICS 31-33	Table 9a	-	-	-	+80.0
Multimedia capital exp. for NAICS 31-33	Table 1	-	-	-	+177.1
Multimedia operating costs for NAICS 31-33	Table 1	-	-	-	+166.6
Establishments with <20 employees	<i>microdata</i>	→	→	→	-646.3
SIC 23 industries	<i>microdata</i>	→	→	→	-22.3
SIC non-manufacturing industries	<i>microdata</i>	→	→	→	-15.6
Adjusted total (1999 dollars)					19,543.2
Adjusted total (1994 dollars)					17,923.0
Percentage change					-13.6%
Expenditures per \$1,000 of value added					\$10.73
Percentage change					-27.3%

^a The PAOC for water in Table 1 already includes the \$1,315.5 million of payments to governments for sewage services. See Table 10b.

^b The PAOC for solid waste in Table 1 already includes the \$301.8 million of payments to governments for collection and disposal of industrial waste. See Table 10c.

^c Distribution based on the underlying microdata.

^d We assume that depreciation costs are 38.95% of relevant capital expenditures.

^e According to Tables 12a and 13a, there was another \$179.5 million in expenditures for "other pollutants within the scope of this survey but not reported elsewhere on this form." It is not exactly clear what these other pollutants are and whether they were also in scope to the 1999 survey. We do *not* include these costs here.

^f While the cost of permits was included in the definition of operating costs in 1994, the payment of taxes, fees, and such were not. This number, therefore, includes too much expenditure. No reasonable adjustments can be made however.

Total costs and expenditures

Since the expenditures we examine in Table 3 do not overlap with the EOL capital expenditures we examine in Table 2, we can combine them to form a more comprehensive picture. Table 4 shows that, overall, there was a 27.1% decline in expenditures per \$1,000 of value added. This is closer to the change for operating costs, prevention, and other costs (27.3%) than for EOL capital expenditures (25.9%), reflecting the fact that the former costs account for

Table 4
Total costs & expenditures
(in millions of nominal dollars)

	1994	
1999		
EOL capital expenditures (adjusted)	4,444.4	4,269.4
Operating costs, prevention, and other costs (adjusted)	20,754.2	19,543.2
Total (adjusted)	25,198.6	23,812.6
Expenditures per \$1,000 of value added	\$17.92	\$13.07
Percentage change		-27.1%

about 82% of total costs and expenditures. These declines are all the more dramatic given evidence of double-reporting of expenditures by some 1999 PACE respondents.²⁵

We will also note at this point that, according to Tables 2 and 3, establishments with fewer than 20 employees spent some \$737.4 million in 1999, which accounts for 3.0% of the expenditure by the entire manufacturing sector. This reflects an increase in importance since the last time such plants were surveyed – in the late 1970s – when they

²⁵ In particular, according the post-survey *response analysis survey*, a fair number of establishments apparently reported disposal & recycling costs in both Items 2C and 2B-3 (i.e., abatement of solid waste), reported prevention expenditures in both Items 3B and 2B (i.e., pollution abatement), reported recycling expenses in both Items 2C-2 and 3B (i.e., pollution prevention), and occasionally reported their “other” expenditures and payments (Items 4 and 7) in Items 2 or 3 as well. Some effort was made to eliminate “obvious” cases of double-reporting, but significant double-counting surely remains in the 1999 PACE data.

accounted for 2% of expenditures according to PACE publications. And over this time period, these establishments' share of manufacturing's value added actually decreased slightly, from 5.2% in 1977 to 5.1% in 1997, according to Census of Manufactures statistics. This implied increase in the intensity of environmental expenditures for this segment of the population is entirely consistent with the notion that, for various reasons, environmental regulators tend to target smaller establishments *later* than their larger counterparts (see, for example, Becker and Henderson 2000).

A look at specific industries

Here we repeat the above exercises (in our Tables 2-4) for four specific industries: petroleum refineries, steel mills, plastic material & resin manufacturing, and pulp mills. These industries were chosen because they are quite pollution-intensive and therefore should have had high levels of pollution abatement expenditure. Indeed, in 1994 at least, three of these industries were among the top five 4-digit SIC industries in terms of pollution abatement operating costs. They were also chosen because their SIC-NAICS mappings are fairly simple.²⁶ In the interest of brevity, we present only final, adjusted expenditures per \$1,000 of value added in Table 5.²⁷

We see here that the reported expenditure in the plastics industry declined 15.8%, which seems fairly substantially, but is in fact a smaller decline than the 27% seen in total

²⁶ In particular, SIC 2821 (plastic materials & resins) is now simply NAICS 325211. That is, it did not splinter into any other NAICS categories, and NAICS 325211 is comprised only of plants from the former SIC 2821. Similarly, SIC 2911 (petroleum refining) is now simply NAICS 324110, with no splintering or merging, and SIC 2611 (pulp mills) is now simply NAICS 322110. SIC 3312 (steel) is a bit more complicated, but still rather straightforward. It split into two parts: 99.2% of it is now classified as NAICS 331111 (iron & steel mills), with the rest assigned to NAICS 324199 (all other petroleum & coal products). On the flip side, 99.0% of NAICS 331111 came from the former SIC 3312, and 25.4% of NAICS 324199 came from the former SIC 3312. In contrast, SIC 2869 (industrial organic chemicals n.e.c.), which was the industry with second highest operating costs in 1994, is not considered here because of the complexity of its SIC-NAICS mapping, splintering as it did between five NAICS categories.

manufacturing. Petroleum refineries, on the other hand, reported over 60% less PACE expenditure per value added. Meanwhile, steel mills reported 11% *more* expenditure in 1999 than in 1994, and calculations for pulp mills also suggest an increase in reported expenditure.²⁸

V. Discussion

Overall, the evidence suggests a dramatic fall in reported expenditures between 1994 and 1999. Furthermore, all expenditure categories have seen a decrease: EOL capital expenditure (air, water, and solid waste), PPE/prevention capital expenditure, and total operating costs. Our look at specific industries, however, suggests some significant heterogeneity, with some

Table 5
Total costs & expenditures for select industries

	<i>Plastic materials and resins mfg.</i>	<i>Petroleum refineries</i>	<i>Steel mills</i>
Expenditures per \$1,000 of value added: 1994	\$55.48	\$218.24	\$57.53
Expenditures per \$1,000 of value added: 1999 ^a	\$46.70	\$86.79	\$64.00
Percentage change	-15.8%	-60.2%	+11.2%

^a Figures include expenditures by establishments with fewer than 20 employees and therefore may be slightly higher than they should be for comparability.

industries experiencing a decrease and others an increase.

Why is there such a decline? One possibility is that this reflects a real change in environmental spending, as manufacturing activity (potentially) shifted toward “cleaner”

²⁷ Calculations are available from the authors.

²⁸ Computations for pulp mills are plagued by the suppression of key data items in the 1999 publication (for confidentiality reasons). Therefore, we can only reliably produce a *range* for the estimate: from a decrease of 2.9% in reported expenditures to an increase of 20.3%. Our best estimate is that reported expenditures increased 8.5% (from \$109.17 per \$1,000 of value added to \$118.46).

industries and/or expenditures necessitated by environmental regulations eventually eased. However, on the first point, it is important to note that particularly big and “dirty” industries (e.g., petroleum refineries) also experienced dramatic declines, not just total manufacturing. And the second notion *could* potentially be true for something like capital expenditures, but it is much harder to imagine that operating costs and prevention-related spending would fall – and fall so much so quickly.

Another possibility is that the spending estimates for years leading up to the survey’s hiatus were too high. This of course is hard to prove or disprove. Evidence suggests however that, if anything, the opposite is true (e.g., Becker 2001, Gray and Shadbegian 2002, Shadbegian and Gray 2003). A much more likely scenario however is that issues with the 1999 survey led to reported expenditures that were too low. In particular, we believe some of the following factors may have played important roles in 1999:

- *A long hiatus.* Record-keeping and reporting on environmental costs were presumably much better – especially among large “certainty” establishments – when the PACE was a regular, annual survey.
- *Usual freshman year issues.* Most surveys, unless they are *extensively* pre-tested, take a number of years to accomplish all that they set out to do. In particular, instructions and question-wording may need some fine-tuning, and editing and imputation procedures generally require further development. Given the substantial changes in the PACE survey, and the long hiatus since the last one, the 1999 PACE survey might reasonably be viewed as a first-year survey.
- *A delayed mail out.* For a variety of reasons, the 1999 PACE survey was mailed out fairly late, in September 2000. With eight months having elapsed since the end of the reference year, and 20 months since the beginning of that year, it is not hard to imagine that establishments would have had difficulties recalling and estimating many of their environmental expenditures. This, of course, is in addition to the *normal* difficulties faced by plants reporting under the best of circumstances.
- *The “information not available” checkboxes.* The introduction of the “Information not available or not collected to provide an estimate” checkbox next to each expenditure

item may have (perhaps inadvertently) raised item non-response. That is, on the margin, some establishments may have checked this box in lieu of providing their best estimate.

- *Conservative imputation for item non-response.* Some imputation for item non-response was done on the 1999 survey, however it was probably rather conservative relative to prior PACE surveys. This conservatism was largely due to the fact that there are few good “signals” on which items actually require imputing and a real lack of defensible imputation algorithms. Imputation was also limited to just operating costs for air, water, solid waste, disposal, and recycling — thereby excluding prevention expenditures as well as spending on administration, monitoring & testing, multimedia pollutants, and so forth.²⁹
- *Limited and “asymmetric” data editing.* Some amount of data editing was done on the 1999 survey — to correct suspected cases of double-counting, to fix expenditures reported in *dollars* rather than *thousands of dollars*, and to treat otherwise implausibly high values. There was no examination of and editing for implausibly low values however. Again, defensible mechanisms are very hard to come by, especially with no prior year data to establish norms for each industry.
- *Less-than-explicit instructions.* Relative to the 1994 PACE at least, the instructions in 1999 were much less explicit. The 1994 instruction booklet, for example, contains long, detailed lists of items to be included and excluded from expenditures. Another example is the elaborate directions on how to report PPE/prevention capital expenditures (see Section III above). It is not necessarily clear that this would have lead to *lower* reporting in 1999, but it certainly might have.
- *Overly broad questions.* In contrast to the 1999 survey, which asked for just a single operating cost number (per media), the older PACE surveys asked respondents to attribute their operating costs (by media) to five separate expense categories: depreciation, salaries & wages, fuel & electricity, contract work, etc. Perhaps this additional prompting reduces the potential for omitting expenditures. At the very least, the same question asked two different ways may yield different results.
- *Question placement.* In 1999, some key expenditures items – particularly, administration and monitoring & testing – were found near the end of the survey form, where item non-response may be more prevalent and/or where the implicit suggestion may be that these are less important expenditures. The importance of question placement can perhaps be seen in the case of expenditures on multimedia pollutants, which was asked on the final page of the 1994 survey but on the second page of the 1999 survey. Interestingly, reported multimedia expenditures (per dollar of value added) rose 327.3% between the two years.

²⁹ Capital expenditures of all types were also exempted from imputation, which had been the case in the past as well.

VI. Recommendations

In light of the above discussions, we offer some recommendations for any future PACE surveys:³⁰

- Provide clear, detailed, and explicit instructions, along the lines of the 1994 PACE survey. Plainly define key concepts, offer instructive examples, and explain how particularly difficult items (e.g., incremental material and fuel costs, PPE/prevention capital expenditures) are to be reported. Among other benefits, reducing ambiguity should also lessen the incidence of double-counting.
- Great care should be taken to name and define concepts in a longitudinally-consistent manner. In the 1999 survey, a number of fundamental concepts took on radically new meanings (e.g., *pollution abatement*, *operating costs*, *end-of-line capital*, *PPE/prevention capital*, and *all industries*) making cross-year comparisons extremely difficult, if not impossible, and at the very least extremely confusing to the casual data user.
- Do not provide establishments with the option to not respond to an item, as was the case with the “information not available” checkboxes in the 1999 survey. Surely, plants are better able to estimate their expenditures than the Census Bureau can impute them.
- Design the survey instrument with the eventual imputation algorithm(s) in mind. As it turned out, imputation in the 1999 PACE was rather *ad hoc*, and there were few good signals on which items actually needed imputing. One idea is to structure questions in the following manner:
 - ▶ *Did your facility undertake any of the following air pollution abatement techniques?*
 - ▶ *If yes, report your facility’s operating costs here.*
 - ▶ *Did your facility incur any capital expenditures related to air pollution abatement?*
 - ▶ *If yes, report your facility’s capital expenditures here.*
- Data entry *must* include reported zeros. This is essential for proper imputation (for item non-response) and is also extremely important for microdata research.
- Examine and edit data for implausibly low values, particularly in critical industries. Suspicious cases might be identified using industry-level norms developed from historical expenditure data. A resolution may require following up with a respondent (e.g., by phone).
- Include capital depreciation in the definition of operating costs.

³⁰ See also Burtraw *et al.* (2001).

- If activities such as environmental administration and monitoring & testing are to be recognized as distinct from the treatment, prevention, recycling, and disposal of pollution – and they from each other – they should at least be placed together on the survey form and given equal footing. One can imagine, for example, a grid with these six basic activities as columns and the various types of expenditures (e.g., salaries & wages, materials & supplies, contract work, capital investment, etc.) as the rows. Such an arrangement may also reduce the potential for double-reporting expenditures across activities, which occurred with some frequency on the 1999 PACE survey.
- Do not have respondents pool capital expenditures and operating costs, as was the case on a number of items on the 1999 survey. The economic meaning of these expenditures is quite different and therefore they must be kept distinct.
- Send a sample survey form to intended respondents before the beginning of the reference year and collect data immediately at the end of the reference year. This may lead to better record-keeping during the reference year, reduce recall bias, and result in higher quality estimates.
- Publish state-by-industry (2-digit SIC / 3-digit NAICS) tables on key expenditure items. Note that achieving high quality estimates at this level of detail may require larger sample sizes than is typical, but the result is well worth the cost. Such tables were produced up until 1999 and proved extremely popular.
- The PACE sample should (again) be a strict subsample of the Annual Survey of Manufactures. This had been the case up until 1993. This would yield a much larger, more representative sample for microdata research.
- Over-sample *newer* establishments and ask them for their *historical* cost data. It turns out that new facilities with the potential to pollute are generally required (by their environmental permits) to install pollution abatement technologies *before* they begin operation. To the extent that these capital expenditures occur in the calendar year(s) before the plant begins operation – and therefore before the establishment is in the Census Bureau’s business register and thus capable of being sampled – these costs are not captured by a traditional “current year” survey instrument like the PACE. This omission is potentially enormous and is very likely growing in importance. A survey that includes retrospective questions would help in measuring capital expenditures by facilities under construction.
- Continue collecting data from establishments with fewer than 20 employees. This paper has shown that these facilities now account for a greater fraction of expenditure than they did when they were last surveyed in the late 1970s (i.e., 3% versus 2%) – a trend that, we think, is likely to continue.

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Appendix A³¹

Table A-1: Industrial activity no longer classified as manufacturing under NAICS

100%	of	SIC 2411 (logging)
100%	of	SIC 2711 (newspaper publishers)
100%	of	SIC 2721 (periodical publishers)
100%	of	SIC 2731 (book publishers)
100%	of	SIC 2741 (miscellaneous publishers)
99%	of	SIC 2771 (greeting card publishers)
13%	of	SIC 3732 (boat repair)

Table A-2: Industrial activity now classified as manufacturing (NAICS industries)

2.5%	of	311330 (confectionery manufacturing from purchased chocolate)
1.8%	of	311340 (non-chocolate confectionery manufacturing)
7.2%	of	311612 (meat processed from carcasses)
100%	of	311811 (retail bakeries)
18.8%	of	313311 (broadwoven fabric finishing mills)
0%	of	313312 (textile & fabric finishing mills)
15.1%	of	314121 (curtain & drapery mills)
5.7%	of	315999 (other apparel accessories & manufacturing)
100%	of	326212 (tire retreading)
100%	of	334611 (software reproducing)
42.0%	of	334612 (prerecorded CD, tape, & record producing)
3.7%	of	335312 (motor & generator manufacturing)
7.3%	of	337110 (wood kitchen cabinet & counter top manufacturing)
2.4%	of	337121 (upholstered household furniture manufacturing)
2.9%	of	337122 (non-upholstered wood household furniture manufacturing)
100%	of	339116 (dental laboratories)

Table A-3: NAICS industries that correspond to the former SIC 23

100%	of	313222 (Schiffli machine embroidering)
85%	of	314121 (curtain & drapery mills)
100%	of	314129 (other household textile product mills)
100%	of	314911 (textile bag mills)
100%	of	314912 (canvas & related product mills)
73%	of	314999 (all other miscellaneous textile product mills)
100%	of	315 (apparel manufacturing) except:
		<i>100% of 3151 (apparel knitting mills)</i>
		<i>36% of 315992 (glove & mitten manufacturing)</i>
		<i>6% of 315999 (other apparel accessories & manufacturing)</i>
50%	of	323113 (commercial screen printing)
43%	of	336360 (motor vehicle seating & interior trim manufacturing)
16%	of	339994 (broom, brush, & mop manufacturing)

³¹ Source: "1997 Economic Census: Bridge Between NAICS and SIC"
(<http://www.census.gov/epcd/ec97brdg/>)

Appendix B: Questions from the 1994 PACE survey

ITEM 3 – OPERATING EXPENSES FOR POLLUTION ABATEMENT EXCEPT PAYMENTS TO GOVERNMENT FOR POLLUTANT REMOVAL

Expense Category	Media					
	Air		Water		Solid/Contained Waste	
a. Depreciation	301	\$, ,000	311	\$, ,000	321	\$, ,000
b. Salaries & Wages	302	\$, ,000	312	\$, ,000	322	\$, ,000
c. Fuel & Electricity	303	\$, ,000	313	\$, ,000	323	\$, ,000
d. Contract Work/Services	304	\$, ,000	314	\$, ,000	324	\$, ,000
e. Materials, Leasing, Miscellaneous	305	\$, ,000	315	\$, ,000	325	\$, ,000
f. Total	306	\$, ,000	316	\$, ,000	326	\$, ,000

ITEM 7 – NEW CAPITAL EXPENDITURES FOR POLLUTION ABATEMENT BY MEDIA

Type	Media					
	Air (a)		Water (b)		Solid/Contained Waste (c)	
End-of-Line	701	\$, ,000	711	\$, ,000	721	\$, ,000
Production Process (pollution abatement portion)	702	\$, ,000	712	\$, ,000	722	\$, ,000
Total by Media	703	\$, ,000	713	\$, ,000	723	\$, ,000
Percent Hazardous	See Item 8.		714	.0%	724	.0%

Appendix C: Questions from the 1999 PACE survey

Item 2 POLLUTION ABATEMENT, DISPOSAL AND RECYCLING

B. Pollution Abatement Costs and Expenditures by Medium			
<p>Report total pollution abatement costs and expenditures. Also report the percentage of the total capital expenditures and operating costs that are for hazardous emissions, discharges, or wastes. To avoid double counting, please record expenditures in one media category only. Report the total capital expenditures and NOT the financed or depreciated amount.</p> <p>(REPORT DOLLARS IN THOUSANDS.)</p> <p>What were the TOTAL pollution abatement costs and expenditures for this facility in 1999 for –</p>			
	Pollution abatement capital expenditures	Pollution abatement operating costs	Information not available or not collected to provide an estimate
220		230	240
1. Abatement of air emissions?	\$ 000	\$ 000	<input type="checkbox"/>
What percent of expenditures and costs were for hazardous air emissions?	221 %	231 %	241 <input type="checkbox"/>
222		232	242
2. Abatement of water discharges?	\$ 000	\$ 000	<input type="checkbox"/>
What percent of expenditures and costs were for hazardous water discharges?	223 %	233 %	243 <input type="checkbox"/>
224		234	244
3. Abatement of solid wastes?	\$ 000	\$ 000	<input type="checkbox"/>
What percent of expenditures and costs were for hazardous solid wastes (including mixed wastes)?	225 %	235 %	245 <input type="checkbox"/>
226		236	246
4. Abatement of multi-media pollutants?	\$ 000	\$ 000	<input type="checkbox"/>
What percent of expenditures and costs were for hazardous multi-media pollutants (including mixed wastes)?	227 %	237 %	247 <input type="checkbox"/>

Item 2 POLLUTION ABATEMENT, DISPOSAL AND RECYCLING – Continued			
C. Disposal and Recycling Costs and Expenditures			
<p>Report on-site and off-site disposal and on-site (post process) and off-site recycling costs and expenditures in the appropriate categories below.</p> <p>(REPORT DOLLARS IN THOUSANDS.)</p>			
	Disposal capital expenditures	Disposal operating costs	Information not available or not collected to provide an estimate
250		260	290
1. On-site and off-site disposal?	\$ 000	\$ 000	<input type="checkbox"/>
What percent of expenditures were for disposal of hazardous pollutants (including mixed wastes)?	251 %	261 %	291 <input type="checkbox"/>
	Recycling capital expenditures	Recycling operating costs	Information not available or not collected to provide an estimate
270		280	292
2. On-site (post process) and off-site recycling?	\$ 000	\$ 000	<input type="checkbox"/>

Item 3 POLLUTION PREVENTION				
A. Indicate (<i>Mark (X)</i>) those pollution prevention activities that occurred at this facility in 1999.		Yes	No	Don't know
	1. Process or procedure modifications?	301 <input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	2. Redesign or reformulation of products?	302 <input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	3. Substitution or modification of equipment or technologies?	303 <input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	4. In-process recycling, recovery, recirculation, and reuse of materials?	304 <input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	5. Substitution of raw materials?	305 <input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	6. Improvements or modifications to housekeeping, maintenance, training or inventory control?	306 <input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	7. Improvements or modifications to prevent leaks and spills?	307 <input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	8. Other? <i>Specify in the "Remarks" section, Item 9.</i>	308 <input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
B. If you check YES to any of the activities, report the total (e.g., capital, operating) costs and expenditures for these activities. (REPORT DOLLARS IN THOUSANDS.)	Amount		Information not available or not collected to provide an estimate	
	310	\$	000	311