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Retrospective Evaluation of the Costs of Complying with Light-Duty Vehicle Surface Coating Requirements

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Abstract

This paper compares the U.S. Environmental Protection Agency's (EPA) ex-ante compliance cost estimates for the 2004 Automobile and Light-Duty Truck Surface Coating National Emission Standards for Hazardous Air Pollutants to ex-post evidence on the actual costs of compliance based on ex-post cost data gathered from a subset of the industry via pilot survey and follow-up interviews. Unlike many prior retrospective studies on the cost of regulatory compliance, we use this newly-gathered information to identify the key drivers of any differences between the ex-ante and ex-post estimates. We find that the U.S. EPA overestimated the cost of compliance for the plants in our sample and that overestimation was driven primarily by differences in the method of compliance rather than differences in the perunit cost associated with a given compliance approach. In particular, the U.S. EPA expected facilities to install pollution abatement control technologies in their paint shops to reduce emissions of hazardous air pollutants, but instead these plants complied by reformulating coatings.

Keywords

retrospective cost analysis; air regulation; benefit-cost analysis; transportation; Q52; Q53; Q55; Q58

1. Introduction²

The extent to which ex-ante estimates of the costs of regulation differ from ex-post estimates is an empirical question of considerable interest to policymakers, regulated entities, and the public. Several recent Executive Orders encourage the use of retrospective analysis as a mechanism for reviewing and potentially revisiting the design of existing regulation “in light of changed circumstances, including the rise of new technologies” (White House, 2012). The accuracy of ex-ante cost estimates for proposed regulations also is frequently the subject of public comment. However, despite its potential importance, “rigorous retrospective

¹The views expressed in this paper are those of the authors and do not necessarily represent those of the U.S. Environmental Protection Agency (EPA).

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analysis of federal regulation is not commonly conducted...[as it is] both complicated and expensive to develop” (Morgenstern, 2015).

In this paper, we compare ex-ante estimates of the direct costs of complying with the 2004 National Emission Standard for Hazardous Air Pollutants (NESHAP) for automobile and light-duty truck surface coating to ex-post estimates of costs. Surface coating operations for automobile and light-duty trucks were listed as a major source category for hazardous air pollutants in 1992.³ In 1999, the U.S. EPA requested information from automobile assembly plants on hazardous air pollutant (HAP) emissions from surface coating operations. The NESHAP was proposed at the end of 2002 and finalized in 2004. Surface coating operations at existing plants had up to three years from promulgation to comply; new plants had to comply as soon as operations began.⁴

The 2004 NESHAP was chosen at random for retrospective cost analysis from 42 economically significant regulations promulgated by the U.S. EPA between 1995 and 2005.⁵ At the time of promulgation, the regulated universe consisted of a relatively well understood and already regulated sector for pollutants such as volatile organic compounds (VOCs), and the U.S. EPA had identified several available technologies that could be used to bring HAP emissions into compliance. To our knowledge, this is the first retrospective study of the costs of the 2004 NESHAP. Unlike many prior retrospective studies on the cost of regulatory compliance, we also attempt to identify the key drivers of any differences between the ex-ante and ex-post estimates. We utilize a U.S. EPA (2014) conceptual framework to accomplish this task.

The paper is organized as follows. Section 2 briefly describes the prior literature, including the conceptual framework we use to evaluate costs of compliance ex-post. Section 3 describes the impetus and timeline for regulatory action. Section 4 summarizes the U.S. EPA’s ex-ante cost estimates for the 2004 surface coating NESHAP, including key drivers, sources of uncertainty, and possible exogenous factors. Section 5 discusses the approach and data used to conduct an ex-post assessment of compliance costs. Section 6 presents the results. Section 7 discusses overall implications and key limitations of the analysis.

2. Prior Literature

Several reviews of ex-post studies indicate that the U.S. EPA tends to overestimate aggregate compliance costs ex-ante (e.g., Putnam, et al., 1980; Hodges, 1997; Goodstein and Hodges, 1997; Harrington, et al., 2000; U.S. OMB, 2005). Researchers point to failure to account for technological innovation, errors in baseline specification, optimistic compliance

³The Clean Air Act requires the U.S. EPA to list industrial categories of major sources of one or more HAPs and to establish a NESHAP for those categories. Major sources of HAPs are defined as new or existing facilities that emit 10 tons or more annually of any single HAP or 25 tons or more annually of a combination of HAPs. A NESHAP is typically based on an assessment of the degree to which emission reductions have been achieved at the best performing facilities in a source category using existing abatement control techniques. This standard is referred to as Maximum Achievable Control Technology (MACT).

⁴At the time of the 2004 NESHAP, 14 states and one California air control district regulated VOCs from light-duty vehicle surface coating consistent with 1977 national control technology guidelines. New or substantially modified surface coating operations also were subject to 1979 new source performance standards for VOCs (EPA, 2002).

⁵Economically significant regulations, those that have costs or benefits of \$100 million or more in any single year, are subject to extensive analytic requirements per Executive Order 12866.

assumptions, and reliance on maximum instead of mean cost information as possible explanations for overestimation (Goodstein and Hodges, 1997; Harrington, et al., 2000). Evidence of the U.S. EPA's ability to accurately estimate per-unit costs ex-ante is more mixed (Harrington, et al., 2000). It is difficult to generalize to the larger universe of U.S. EPA regulations due to a paucity of ex-post data, differences in scope of analysis and methodology across studies, the relatively small number of regulations that have been examined ex-post, and a bias towards examining market-based approaches, a relatively rare regulatory approach (e.g., U.S. EPA, 2014; Harrington, et al., 2000).

Two recent projects by the U.S. EPA (2014) and Resources for the Future (Morgenstern, 2015) aimed to conduct ex-post cost evaluations for a wider array of environmental regulations than previous studies and focus on the underlying reasons for inconsistencies between ex-ante and ex-post estimates. The U.S. EPA (2014) also sought to bring greater consistency to retrospective cost assessment through development and use of a common conceptual framework (Table 1).

In line with older studies, the U.S. EPA and Resources for the Future efforts found evidence of ex-ante cost overestimation in several cases. Identified reasons for differences between ex-ante and ex-post estimates included incorrect assumptions regarding the pace of technological innovation, failure to account for flexibilities available in the regulation as well as behavioral responses, and unexpected exogenous changes in factors such as fuel prices. Both studies cautioned against generalizing their findings to the larger regulatory space given numerous data challenges, and the non-representative nature of the case studies (U.S. EPA, 2014; Morgenstern, 2015). Our study adds evidence to the growing literature of ex ante overestimation of compliance costs.

3. The U.S. EPA's Ex-Ante Cost Estimates

This section describes the methods used and main drivers of compliance costs in the ex-ante analysis of the 2004 NESHAP and assesses the sources of uncertainty and exogenous factors (e.g., unrelated changes in market demands, oil prices) that may influence ex-post assessment.

3.1 Ex Ante Cost-Estimation

The U.S. EPA estimated ex-ante that the total annualized costs of the 2004 surface coating NESHAP would be \$154 million (in 1999\$) and expected them to be divided fairly evenly between capital (\$75 million) and operating and maintenance (\$76 million) costs. Administrative costs accounted for about \$2 million of total ex-ante compliance costs, annually. On average, compliance costs translated to about \$25,000 per ton of HAP controlled (U.S. EPA, 2004). The U.S. EPA used an engineering cost approach to estimate facility-level compliance costs for the 2004 NESHAP (i.e., no behavioral market adjustments by producers or consumers).⁶

⁶While work practice standards were required, the U.S. EPA did not quantify their cost. The work practice standards require that plants develop and implement practices and procedures to ensure all coatings, thinners, cleaning materials, and waste materials that contain organic HAPs are stored and conveyed from one location to another in closed containers, and that organic HAP emissions are

In 1999, automobile assembly plants reported to the U.S. EPA estimated HAP emissions and any control technologies or practices already in place for each paint shop, differentiated by coating stage.⁷ The U.S. EPA characterized the data associated with primers and topcoats as particularly reliable. Based on this information, the U.S. EPA determined that 60 paint shops were subject to the rule, and identified the following compliance options (U.S. EPA, 2002; 2004):

- (1) Add an oxidizer for facilities that do not already have electrodeposition oven controls;
- (2) Reformulate primer-surfacer coating to substitute non-HAP for HAP solvents if the HAP/VOC ratio for the primer-surfacer is greater than 0.3;
- (3) Reformulate top coating if the HAP/VOC ratio for the topcoat is greater than 0.3; and
- (4) Add controls to the exhaust from the automated zones of spray booths to control any remaining HAPS above the Maximum Achievable Control Technology (MACT) floor, after applying (1), (2), and (3).⁸

The costs of these strategies varied widely, from an average of \$540 per ton of HAPs controlled for strategy 2 or 3 to \$40,000 per ton for strategy 4 (Table 2). By far, the most common projected compliance strategy was strategy 4. Only two plants were expected to rely solely on process changes, by modifying or reformulating coating materials. About 60 percent of plants were expected to use more than one compliance strategy. In addition, 11 plants (eight of which were used to set the MACT floor) were expected to only face administrative costs.

Ex-ante costs were drawn from the literature or industry sources (U.S. EPA, 2002). For plants expected to implement one or more compliance strategy, total annualized capital and operating costs ranged from \$1,800 to \$13 million per plant, with an average annualized cost of \$2.6 million. In addition to capital and operating costs for controlling HAP emissions, the U.S. EPA assumed existing plants that installed add-on controls would incur performance testing costs once every 15 years (U.S. EPA, 2004). Because plants already had detailed recordkeeping systems in place to comply with pre-existing VOC regulations, the U.S. EPA assumed a one-time cost to modify these systems for HAP emissions of \$20,000 per plant, as well as annual recordkeeping and reporting costs of \$18,000 per plant (U.S. EPA, 2004). Plants not already in compliance were assumed to incur \$15,600 in annual monitoring costs (U.S. EPA, 2002).

minimized during the cleaning, storage, and conveyance of equipment, or the cleaning and purging of coating systems (U.S. EPA, 2004).

⁷Vehicle surface coating at U.S. assembly plants has three main steps: surface preparation, priming operations, and finishing operations. Most of the HAPs from surface coating are reportedly released in the second and third steps. Priming operations apply a primer coating via electrodeposition, a sealant for spot-welded joints, an antichip sealant for vulnerable areas of the body, and a primer-surfacer coating. Finishing operations apply a basecoat to add color and a clearcoat to protect the color coating; collectively, the basecoat and clearcoat are referred to as the topcoat (U.S. EPA, 2004).

⁸A MACT floor specifies the minimum level of HAPs control required. For existing sources, the MACT floor is the average emission rate of the least-emitting 12 percent of facilities.

3.2 Main Drivers of Ex-Ante Cost Estimates

One ex-ante driver of capital and operating costs was the degree to which a plant emitted organic HAPs above the standard for each step in the surface coating process. The plants with the highest estimated annual rate of organic HAP emissions from combined operations were among those with the highest annualized cost of compliance. Those with the lowest annual rate of organic HAP emissions either had no or very low estimated direct compliance costs.

Another key driver of ex-ante compliance costs was the assumption that plants would sequentially adopt control strategies not already in place (i.e., begin with strategy 1 and end with strategy 4). However, applying control strategies in this way assumes that plants will not necessarily implement the lowest cost strategy first, contradicting what we might expect based on economic theory. If in fact firms minimized costs, then fewer thermal oxidizers would be installed in favor of greater reformulation relative to the U.S. EPA's ex-ante expectation. A possible caveat to this is the possibility of hard-to-quantify indirect costs such as loss of market share over time due to lower quality (i.e., less durable) coatings (U.S. EPA, 2002; 2004).

The U.S. EPA assumed that new paint shops would incur few additional compliance costs since they would have to install controls for VOCs and odors from topcoat systems that rely on water or solvent-based materials. However, it acknowledged that, even with these controls, new plants may still need to lower the HAP content of coatings to meet the NESHAP (U.S. EPA, 2004). It also assumed that new plants would not incur additional testing and monitoring costs, though they would have annual recordkeeping and reporting costs (U.S. EPA, 2002).

3.3 Main Sources of Uncertainty

The key sources of uncertainty when estimating compliance costs were how each plant would actually comply and the per unit cost of doing so. MACT standards are performance-based, which means that firms can choose how to comply with emission limits, so one might expect firms to pursue available lower cost and/or more effective techniques than those evaluated by the U.S. EPA. Compliance costs attributable to the rule would also hinge on already planned equipment and material upgrades. The U.S. EPA's ex-ante analysis did not address whether plants were already planning to replace equipment in painting shops prior to the rule, though it acknowledged that plants made regular upgrades.

3.4 Exogenous Factors

A major unknown, potentially exogenous, factor is the role of technological change. The U.S. EPA recognized that it was possible to (1) reformulate liquid coatings to rely on low or non-HAP chemicals (e.g., use water or lower-HAP solvents); (2) switch to powder coatings, which do not release HAPs; (3) raise the solids content of the coating, which reduces the "amount of solvent carrier needed" and therefore reduces HAP emissions; or (4) modify the way coatings are applied to achieve a higher transfer efficiency. Nevertheless, it did not explicitly factor any of these into its analysis (U.S. EPA, 2002).

The options discussed in greatest detail by the U.S. EPA were (1) and (2). Water-based and powder coatings represented almost 20 percent and less than 10 percent of coatings (by weight) applied to motor vehicles in 1998, respectively (U.S. EPA, 2004).⁹ Absent the standard, experts projected only a moderate increase in water-based and powder coatings - to 25 percent and 13 percent, respectively - by 2008 (Freedonia Group, 1999). The U.S. EPA also mentioned an existing joint effort between auto manufacturers and suppliers to develop low-HAP coatings, with an initial focus on powder coatings, though it recognized barriers to their use (e.g., application method and equipment changes to achieve the coating quality needed) (U.S. EPA, 2002).¹⁰

4. Data for Ex-Post Evaluation

While the literature contains some information on technological change in the automobile coating process (e.g., Akafush, et al., 2016; Freedonia Group, 2008) and the manufacturersupplier relationship when developing new processes or technologies to reduce emissions in paint shops (Geffen and Rothenberg, 2000), we found no studies that assessed compliance costs retrospectively or yielded specific data on key drivers of compliance costs for the 2004 NESHAP.¹¹ Given this lack of information, we administered a pilot survey followed by interviews with nine plants subject to the 2004 NESHAP. As a means of verifying the survey results, we also commissioned a cost estimate based on contractor expertise. While the contractor relied on confidential facility-level information from the pilot survey to identify specific compliance actions, estimated costs were generated independently using publicly available sources.

The pilot survey and interview approach is motivated by lessons learned from the 2014 U.S. EPA retrospective cost study. In particular, we are interested in demonstrating its viability as a retrospective cost assessment tool, given that those “case studies suffer from a lack of comprehensive cost information on treatment technologies and mitigation strategies at the plant level, limiting our ability to make definitive statements on the reasons for differences between ex-ante and ex-post cost estimates” (Kopits, et al., 2014).

We originally intended to mimic the information collection strategy of the Pollution Abatement and Cost Expenditures (PACE) survey (Gallaher, et al., 2006): the survey on plant-level compliance strategies was to be followed by site visits to gain a better understanding of the industrial processes at play and, later, independent cost estimates of compliance to verify the results. Responses to the pilot survey, however, revealed that compliance was achieved primarily through reformulation of coatings rather than installation of capital equipment. As such, site visits were deemed unnecessary and replaced with telephone interviews to discuss survey responses in detail and to gain a better understanding of reformulation costs.

⁹Of the plants used to set the MACT floor, half relied on powder coatings, though in several cases they had recently undergone major renovations or installed new paint shops.

¹⁰Switching to powder coating required installing a new primer-surfacer system, at a cost \$26 million – \$30 million, and removing previous coating equipment, at a cost \$8 million – \$10 million (U.S. EPA, 2004). One paint supplier estimated that switching from solvent- to water-based coatings would cost \$10 million – \$20 million.

¹¹We also examined Securities and Exchange Commission (SEC) 10-K filings for two publicly listed companies, GM and Ford, between 1998 and 2005. The 2004 NESHAP and associated costs were not discussed in detail.

4.1 Pilot Survey Participants

We designed and administered a pilot survey to nine automotive assembly plants operating in the United States. We chose nine in line with Paperwork Reduction Act requirements.¹² Criteria used to select a plant for the sample were:

- responded to the U.S. EPA's original data collection request for the rulemaking;
- had an operating paint shop;
- was owned and operated by the same company as at the time of rule promulgation; and
- did not have an open U.S. EPA enforcement investigation at the time of the study.

Approximately 30 (three of which have multiple production lines/facilities) of the 60 assembly plants that the U.S. EPA had identified as subject to the 2004 NESHAP met these criteria, representing 10 different manufacturers. Twenty of the plants were located in the Midwest (i.e., Michigan, Ohio, Illinois, Indiana, and Kansas), seven in the Southeast (i.e., Kentucky, Tennessee, Missouri, and South Carolina) and three in the South (i.e., Louisiana, Alabama, and Texas). Annual production at these plants averaged 211,000 vehicles in 2003, with the smallest plant producing about 20,000 vehicles and the largest producing more than 450,000 vehicles. Eight of these plants were expected ex-ante to already be in compliance with the regulation at the time of promulgation and therefore to only incur monitoring and reporting costs.

Auto Industry Forum, a trade association actively involved in the rule's development, shared project information with members and provided us with contact information for manufacturers willing to participate in the pilot study. While our sample of plants is not necessarily representative of the industry, we aimed for diversity among participants in terms of company ownership, geography, sales volume, and degree to which a plant was expected to be above the MACT standard. Information that could connect specific responses to individual plants or companies is kept confidential.

The nine facilities that participated in the pilot survey are owned by six different manufacturers. No manufacturer responded for more than two facilities. Four respondents are in the Midwest; five are in the Southeast. In one case, a firm provided responses for two production facilities at the same plant. In only one case had a production line/facility permanently ceased production since the promulgation of the NESHAP. One of the selected paint shops was used to set the MACT floor while another was initially considered for setting the rate; thus, neither was expected to need additional HAP reductions to meet NESHAP requirements. Plants ranged in age from 17 to 35 years old with an average age of 28 years. Though six of the plants had undergone major paint shop renovations or expansions since they were established, none were HAP-related. Respondents had slightly larger production volumes (about 250,000 vehicles) in 2003, on average, compared to the

¹²While covered by Information Collection Request approval, U.S. OMB Control No: 2090-0028, the sample is nevertheless in compliance with the Paperwork Reduction Act, which prohibits federal agencies from administering surveys to more than nine individuals or entities without prior approval from OMB.

larger sample of qualifying plants. The plants in our sample represented about 25 percent of total annualized ex-ante compliance costs and 29 percent of domestically produced vehicles in 2007.

A comparison of our sample of nine to the 30 plants that met our criteria for potential inclusion shows that we oversampled plants from the Midwest and under-sampled plants from the Southeast. The percent of the sample expected to already be in compliance (22 percent) is roughly similar to what was expected for all 30 plants (27 percent). A clear limitation of our sample is that we cannot generalize our findings to plants owned by the four manufacturers that did not receive the survey. In addition, it is not clear to what degree our findings can be generalized to other plants owned by the same firm; we discuss this in the conclusion.

4.2 Survey Instrument and Interviews

We modeled the survey instrument after the 2005 PACE survey redesign administered by the U.S. EPA and the U.S. Census Bureau, which emphasized improved identification of production process changes associated with regulatory requirements (Ross, et. al, 2004).¹³ The questionnaire asked about baseline HAP or VOC abatement activities prior to 2004, capital expenditures and operating costs for each major HAP or VOC abatement activity between 2004 and 2007, as well as monitoring, recordkeeping, and reporting costs.¹⁴ The pilot survey was administered in 2013 by Abt Associates.

We conducted follow-up phone interviews with six auto manufacturers to better understand changes to the surface coating process and the costs incurred to meet the 2004 NESHAP (compliance was primarily through reformulation of primer-surfacer and top coatings). Generally, interview participants were either plant managers or corporate engineers. The interviews were approximately 45 minutes in length, also administered by Abt Associates, and included an engineer with expertise in the automobile manufacturing and abatement process.

When conducting these interviews, we encountered a somewhat unanticipated challenge: the passage of time. Actions taken by plants to comply with the 2004 NESHAP occurred more than a decade ago. Staff, recordkeeping, and even ownership structure at some plants changed substantially over this time. While staff could often tell us what actions the plant took to comply, it was more difficult to supply data on the cost of complying. Because of the difficulty in estimating certain elements of the cost of compliance, we also interviewed representatives from two major paint suppliers with the permission of the auto manufacturers they serve.

¹³See Wolverton, et al. (2017) for the survey instrument and follow-up interview questions. For more on PACE, see <https://www.epa.gov/environmental-economics/pollution-abatement-costs-and-expenditures-2005-survey>.

¹⁴In addition, the questionnaire collected information on plant location and age, date of the last major renovation or expansion, other Federal, state, or local regulations that influenced decisions to newly install or implement lower HAP or VOC abatement strategies, energy and waste disposal costs, one-time shutdown costs due to compliance activities, and depreciation expenses from newly installed abatement equipment.

5. Assessing Costs Retrospectively

This section compares ex-ante to ex-post estimates for each cost component from the U.S. EPA (2014) conceptual framework, identifying possible key drivers of substantial differences when possible. Table 9 summarizes the main sources of information and overall findings by cost category. Since the U.S. EPA focused on direct compliance costs associated with the 2004 NESHAP in its ex-ante analysis, they are also the focus of our assessment.

5.1 Regulated Universe

Recall that the U.S. EPA determined that 60 plants would be subject to the NESHAP. Since that time, substantial restructuring and consolidation in U.S. vehicle manufacturing resulted in the closure of 23 facilities. Web searches confirm that seven of these plants closed before or during the period in which controls would have been put in place to comply with the 2004 NESHAP and therefore likely did not incur compliance costs. In its regulatory analysis, the U.S. EPA estimated that the impact of the regulation on market prices would be small (U.S. EPA, 2004).¹⁵ Thus, it concluded ex-ante that no plant would close due to the regulation.¹⁶ Media reports also suggested that facility closure decisions had little to do with U.S. EPA HAP (or VOC) regulations, instead being driven by high workforce costs, increasing pressure from foreign competition, and a mismatch between the composition of types of vehicles produced and consumer demand (Gordon, 2005; Kropko, 2006; Taylor, 2007).^{17, 18} While we do not evaluate the accuracy of the U.S. EPA's benefits estimation for the 2004 surface coating NESHAP in this paper, it is also worth noting that a smaller than expected regulated universe would lower benefits relative to the ex-ante estimate.

5.2 Baseline Information

Characterizing the baseline for a cost analysis typically involves identifying a counterfactual: what emission-reducing technologies or process changes would have been adopted by plants absent the new regulation (holding possible future regulations constant)? To characterize the baseline, the U.S. EPA relied on 1996, 1997, and 1998 calendar year data from a questionnaire on the types of emission controls already in place, including changes to coatings or solvent mixtures. While the U.S. EPA described the types of technologies used to control paint shop HAP and VOC emissions prior to the 2004 NESHAP, it did not identify the specific approaches in use at particular plants (U.S. EPA, 2002). Thermal oxidation, which destroys organic HAP or VOC emissions in the waste stream over a wide range of concentrations, was identified as the most common abatement approach at automotive paint

¹⁵In a separate chapter of its analysis, the U.S. EPA estimated that compliance costs from the 2004 NESHAP would increase the price of a light-duty vehicle by no more than \$3.10 (or no more than 0.01 percent), resulting in a decline in domestic vehicle production of between 17 and 384 vehicles (U.S. EPA, 2004).

¹⁶We also compared the U.S. EPA's ex-ante estimate of compliance costs for plants that subsequently closed to those that remained open. We do not find any evidence that expected compliance costs were substantially higher for plants that closed.

¹⁷Between 2004 and 2011, Ford closed six plants and GM closed nine plants. Domestic auto manufacturers faced increased competition from Japanese manufacturers and high health care and labor costs during the 2000s. These factors reportedly led to huge and unsustainable losses – in the 2005/2006 timeframe GM and Ford reported \$10.6 billion and Ford \$12.7 billion losses, respectively.

¹⁸The U.S. EPA did not account for plant openings in its analysis; since new paint shops must meet existing VOC regulations, the 2004 NESHAP was expected to result in little additional cost. Only three new light-duty vehicle assembly plants have opened in the U.S. over the past decade.

shops prior to the 2004 NESHAP (U.S. EPA, 2002). At times, installation of a carbon-based system was also used to concentrate the waste stream prior to feeding it into the oxidizer.

The U.S. EPA's assumptions of what technologies were in use and adopted prior to the rule fit with our survey data. We asked a question regarding technologies adopted and already in use - HAP controls installed or process changes - implemented before 2004.¹⁹ While the nine plants were given the option of identifying additional control strategies, none did so. The results confirm that thermal oxidizers, often in combination with a carbon-based concentration system, were relatively common in our sample prior to 2004 (Table 3). We identified a single discrepancy: the U.S. EPA assumed one plant did not have a thermal oxidizer, but the pilot survey revealed that it had one in place prior to promulgation. As expected, paint shop design alterations to accommodate low emission coatings was relatively rare before 2004.²⁰

With regard to process changes that may not necessarily require capital expenditures, the U.S. EPA observed in its ex-ante analysis that use of water- and powder-based coatings in primersurfacer operations was increasing prior to 2004 and was expected to grow slowly over time absent regulation. Low-HAP reformulated solvent-based coatings were described ex-ante as a current approach but also an area of active research due to quality concerns (U.S. EPA, 2002).

Based on the questionnaire, we find that four of the nine plants in our sample reported using lower HAP or VOC coatings at every stage in the paint shop process prior to 2004. Four plants also used water-based or powder coatings (Table 4), while all but one plant reported that it had reformulated one or more coatings to lower HAP or VOC emissions. The one plant that did not use this approach relied on powder or water-based coatings prior to 2004. Use of lower HAP or VOC materials was also relatively common in primer, sealer, sound deadener, and bonding adhesive prior to 2004.²¹

While the use of powder or water-based coatings may appear to be relatively widespread in our sample prior to 2004, Freedonia (2008) data suggest non-solvent-based coatings represented about 44 percent of automotive industry demand in 2007, which is somewhat higher but still close to what the U.S. EPA had expected ex-ante for powder and water-based coatings alone (37 percent).²² Since the U.S. EPA did not provide information on baseline process changes on a plant-by-plant basis in the ex-ante analysis, we are not able to specify an alternative counterfactual for adoption of low-HAP solvent-based coatings.²³

¹⁹Since the ICR occurred in 1999 and the rule was proposed in 2002, it is possible that some early actions could be potentially attributable to the regulation. None were explicitly identified as such via survey or interview.

²⁰We also found that solvent recovery systems were installed in all but one of the paint shops in the sample to control HAPs prior to 2004. The U.S. EPA's discussion of solvent recovery systems is quite limited. It states that purge recovery systems were in operation in each plant pre-rule, but that no information was available regarding their relative efficiency (U.S. EPA, 2004). The U.S. EPA also noted that technologies to concentrate low solvent vapor in the waste air stream for purposes of recovery were in use at many surface coating facilities. Systems to recover solvents for purposes of reuse were viewed as economically infeasible (U.S. EPA, 2002).

²¹We do not know if formulations adopted prior to 2004 were at a level sufficient to meet all 2004 NESHAP requirements. We also do not know how extensively they were used prior to 2004, though subsequent discussion suggests that low-HAP or VOC formulations may have been used on a limited basis in some plants (e.g., when introducing new colors, but not for existing colors).

²²Freedonia (2008) reports that performance concerns and longer drying times contributed to relatively slow adoption of water-based coatings. Powder coatings were also characterized as a "minor" segment of the market due to capital investment requirements and the need for further product testing.

In follow-up interviews, several manufacturers opined on the reasons for investing in strategies that lowered HAP emissions prior to the 2004 NESHAP. Water-based coatings were used in some plants prior to 2004 to replace old solvent-based paint lines at the end of their natural life, due to global initiatives at the corporate level to comply with state-level regulations (i.e., New Jersey and California), or by design from the beginning for new plants. Reformulation of solvent-based coatings to lower HAPs was mainly driven by global, corporate-level initiatives prior to 2004. Investments in abatement technologies that lower HAPs prior to 2004 were reportedly to control VOC emissions or replace old devices that had reached the end of life.

5.3 Methods of Compliance

For plants not yet in compliance with the 2004 NESHAP, the U.S. EPA anticipated that they would comply using one or more of four strategies: (1) install a regenerative thermal oxidizer, (2) substitute non-HAP for HAP solvents in primer surface coating, (3) substitute non-HAP for HAP solvents in top coating, or (4) install exhaust controls in the spray booth.²⁴ Ex-post evidence suggests that manufacturers often pursued corporate-level strategies to comply with the 2004 NESHAP, which likely substantially reduced heterogeneity in compliance strategies relative to the plant-by-plant evaluation approach used by the U.S. EPA.

While the U.S. EPA anticipated that only two of the nine plants were already in compliance with the 2004 NESHAP, survey results indicated that three plants did not take further action to comply with the regulation (Table 5). Of the six remaining plants, none installed an abatement control device, anticipated to be a common compliance strategy ex-ante. Instead, they implemented process changes to comply with the NESHAP. In follow-up interviews, two manufacturers stated that they implemented process changes in all their facilities, even when they could demonstrate compliance based on pre-existing controls.

The U.S. EPA predicted that five of the nine plants surveyed would either use lower HAP or VOC solvents in their primer-surfacer coating or topcoat (only one was predicted to rely on both), but that these process changes would almost always be accompanied by installation of a thermal oxidizer, exhaust controls, or both. Ex-post information indicates that all six plants that took action to comply with the 2004 NESHAP relied entirely on process changes in both the primer-surfacer and topcoat stages.²⁵ In addition, these plants used compliance strategies not quantified by the U.S. EPA ex-ante: lower HAP or VOC cleaning agents, lower HAP or VOC primer, or actions to lower solvents in the surface coating process more generally.²⁶

²³Fraas and Egorenkov (2018) examine HAP emission reductions due to regulation compared to two alternative counterfactuals by comparing emissions in the regulated sector to either a similar but unregulated sector or to HAP-producing sectors that were regulated after the timeframe for study. Lack of information on abatement technology choices in unregulated sectors inhibit our ability to use a similar methodological approach.

²⁴Compared to the full sample, ex-ante installation of thermal oxidizers is over-represented (44 percent vs. 24 percent). The proportion installing exhaust controls is the same across the two groups. For process changes, the proportion of plants in the sample is within 4 to 8 percentage points of the full sample.

²⁵Use of water-based and powder coatings did not increase significantly from ex-ante projections. The main barriers to increased adoption of water-based coatings were performance issues; barriers to adoption of powder coatings included testing requirements, and significant capital investments (Freedomia Group, 2008).

Many manufacturers started to work on lowering HAP emissions from coatings before the 2004 NESHAP was promulgated, even though they described significant uncertainty regarding the ultimate standard. More than one manufacturer noted that the data request made by the U.S. EPA in 1999 gave them time to strategize regarding how they might meet the NESHAP. Another manufacturer mentioned that as new colors were introduced, it simultaneously reformulated coatings to reduce HAPs; some of these reformulations occurred as early as 2002. (Existing colors were not reformulated until promulgation of the NESHAP.)²⁷

Because manufacturers also reformulated existing paint colors to lower HAP emissions, implementation typically took several years (e.g., began in 2004/2005 with full conversion by 2007) and proceeded in stages. One manufacturer introduced lower-HAP coatings for highervolume colors first, followed by lower-volume colors. Another manufacturer reformulated darker colors first, which were viewed as more forgiving in their application, before moving onto lighter colors.

Why did reformulation dominate as a compliance strategy among survey respondents? First, several sources point out that major manufacturers (as well as paint suppliers) were already cooperatively exploring low-HAP paint formulations prior to promulgation of the NESHAP in part as a response to increased competition by foreign automobile manufacturers and what were anticipated to be “formidable technical challenges” to develop low-emission technologies to meet as-yet unpromulgated requirements of the 1990 Clean Air Act Amendments (New York Times, 1993; Meschievitz, et al., 1995). Second, the automotive coatings industry was fairly concentrated; there were three major U.S. paint suppliers at the time (U.S. EPA, 2004). Pursuing a corporate-level reformulation approach was therefore attractive because it yielded substantial economies-of scale; as one automobile manufacturer noted, eventually noncompliant paints would be more expensive than reformulated paint. In addition, another manufacturer observed that, while coating specifications are unique to a manufacturer, paint suppliers received similar requests from multiple manufacturers to develop compliant coatings.²⁸

5.4 Compliance Costs

In this section, we examine the ex-post evidence related to the initial cost of installing abatement equipment, ongoing annual operating costs, and on-going administrative costs.²⁹ For process changes, one-time research and development (R&D) costs incurred by paint suppliers are also relevant, although these should eventually manifest as a change in a manufacturer’s operating costs.

²⁶The U.S. EPA proposed delisting methyl ethyl ketone as a HAP in 2003 and delisted it in 2005 (EPA, 2004). None of the plants in our sample mentioned this as a factor affecting compliance with the 2004 surface coating NESHAP.

²⁷Hammitt (2000) also found that research of new substitutes for chlorofluorocarbons during rule development for the phase-out lowered compliance costs relative to what was anticipated just a few years prior.

²⁸We also asked plants whether other Federal, state, or local regulations influenced the strategies they pursued to lower HAP or VOC emissions between 2004 and 2007. They did not identify any additional regulatory factors.

²⁹The costs of work practice standards were not analyzed in the U.S. EPA’s ex-ante cost analysis. While two manufacturers in the sample developed a work practice plan for the 2004 NESHAP, they noted fairly minimal costs.

5.4.1 Capital Costs—Because none of the plants invested in abatement control technology, ex-post capital costs associated with the 2004 NESHAP were essentially zero.³⁰ One manufacturer indicated that its goal was to satisfy the NESHAP requirements while avoiding the costs of installing control equipment. This contrasts with what the U.S. EPA anticipated ex-ante: For the seven plants expected to be out of compliance, it estimated upfront total capital costs ranging from \$6 million to \$60 million per plant and a one-time cost of \$9,000 to \$18,000 per plant for performance testing of add-on control device systems (in 1999 U.S. dollars).

5.4.2 Operating Costs—Generating ex-post estimates of operating costs for the 2004 NESHAP proved challenging. On the survey and in follow-up interviews, most plants included an estimate of zero or offered a qualitative explanation that implied very low annual costs. Adopting a lower-HAP formulation was described by plant managers as having a calibration and testing process similar to what occurs when introducing a new paint color (lower HAP or otherwise).³¹

Information provided by manufacturers indicated that paint suppliers conducted R&D over multiple years to design and refine lower HAP formulations. Ultimately, this should manifest as a change in the cost of coatings. However, only one manufacturer roughly quantified incremental operating costs of reformulating its topcoat (specifically, the basecoat) in a followup interview. Other manufacturers could not quantify these costs for several reasons: (1) since compliance was at the corporate level, costs passed along by the paint suppliers were not obvious; (2) changes in the cost of coatings due to reduced HAP content would have been difficult to separate out from other factors but were minimal if present at all; (3) they did not work directly with paint suppliers to develop new low-HAP coatings, instead piggy-backing on work performed for other manufacturers; and (4) the amount of time that had passed between promulgation and the survey made it difficult to recall actual costs incurred.

Because of the paucity of detailed information on the cost of complying with the 2004 NESHAP, we also interviewed two major U.S. paint suppliers, with manufacturer permission, on the R&D costs associated with developing low-HAP emission coatings. The paint suppliers indicated that development of a new formulation requires two to three years of lead time before it can be introduced into the paint line at a manufacturing facility. For the 2004 NESHAP, new formulations were developed to achieve the necessary reduction in solvent content, and the performance of the paint was validated through testing. In 80 to 90 percent of the cases, HAP reductions were achieved by substituting butyl acetate for xylene (the supplier noted that ethyl glycol acetate was more expensive and therefore rarely used). The two suppliers agreed that the testing process for a reformulated topcoat – in particular, the basecoat, the first step in the finishing process – is identical to what would have occurred

³⁰We asked about one-time shutdown costs to install new abatement equipment, but since no equipment was installed there were no shut down costs. Plants also reported zero energy and waste disposal costs.

³¹Consistent with our findings, Freedonia (2008) reported that the adoption of low-HAP solvent-based coatings to meet the U.S. EPA regulatory requirements involved “minimal investment in equipment (since generally all solvent systems utilize the same application equipment) and personnel training (since most paint shop employees are familiar with solvent-based systems, no new training is required.”

for a new color. One supplier noted that additional quality testing was required to reformulate the primer-surfacer. The electrodeposited primer and clearcoat were reportedly not reformulated.

One paint supplier stated that it took one person-year to develop a new primer-surfacer and 0.5 person-year to develop a new topcoat (basecoat), with each person-year valued at about \$100,000. The supplier confirmed that these costs were passed onto manufacturers indirectly via paint prices. Both paint suppliers offered rough estimates of the change in the per-gallon cost of reformulating a NESHAP compliant basecoat, which is equivalent to the increase in the price of the paint to the manufacturer once all reformulation costs are passed through (Table 6). In general, the estimates provided by the suppliers were significantly lower than those from the manufacturers, who are one step removed from the actual reformulation process.

To verify the results, we commissioned an independent cost estimate from a contractor (Table 6), who used publicly available historical information on the cost of two possible substitute solvents to develop bottom-up estimates of the incremental cost per gallon of basecoat paint.³⁶ The per gallon cost estimates developed through this process are lower than the manufacturer or supplier estimates. This may be because they are based solely on the replacement cost of the solvent and do not account for the cost of validation and testing.

Comparison of Ex Post and Ex Ante Operating Cost Estimates: To compare ex-post and ex-ante estimates, it is necessary to calculate compliance costs at the plant level. If we rely on the manufacturer-provided estimate that a vehicle requires about 1/2 gallon of paint on average, we can calculate the increase in costs on a per-vehicle basis and combine this information with sales data to calculate the average ex-post compliance cost per plant (Table 6).³⁷ The ex-post basecoat reformulation estimates from paint suppliers, which are likely to be the most accurate, range from about \$50,000 to \$250,000 per plant. The U.S. EPA's ex-ante estimate falls at the low end of the range of these ex-post estimates.

One paint supplier indicated that the cost of primer-surfacer increased one to two percent after compliance with the NESHAP (Table 7).³⁸ As with the basecoat estimate, the independent cost estimate is low and likely missed important validation and testing costs.³⁹ The U.S. EPA's ex-ante estimate for reformulating the primer-surfacer coating for the plants we surveyed is well within the estimated ex-post range offered by the paint supplier.

³⁶The cost per gallon for each solvent was derived by multiplying the paint density (8.5 pounds/gallon) by the percent of solvent by weight (18 percent) and then by the unit cost of the solvent (\$0.53/pound for xylene; \$0.69/pound for ethyl acetate; \$0.89/pound for butyl acetate, in 2013 dollars). The incremental cost was then derived by taking the difference between the cost of xylene and its low-HAP substitute. The main source of information for solvent costs was ICIS (2008). Solvent weight and density were taken from the U.S. EPA (1995) and Papasavva, et al. (2001).

³⁷We use 2004 production levels. While the U.S. EPA used 1999 production levels in its ex-ante analysis, they are very similar to 2004 production levels. By 2008, production levels declined slightly.

³⁸Primer-surfacer costs of about \$25 per gallon (in 2014 dollars) imply an increase in the cost of \$0.25 – \$0.50 per gallon in 2014 dollars or \$0.18 – \$0.35 per gallon in 1999 dollars.

³⁹The cost per gallon for each solvent was derived by multiplying the density of the paint (8.5 pounds/gallon) by the percent of solvent by weight (9 percent) and then by the unit cost of the solvent (\$0.53/pound for xylene; \$0.69/pound for ethyl acetate; \$0.89/pound for butyl acetate, in 2013 dollars). The incremental cost was then derived by taking the difference between the cost of xylene and its low-HAP substitute.

In addition to the costs incurred by paint suppliers to reformulate coatings, two manufacturers noted that a small amount of staff time was periodically dedicated to coordinating with paint suppliers, particularly during the testing and paint-line conversion stages.⁴⁰

5.4.3 Administrative Costs—Ex-ante, the U.S. EPA assumed that almost all plants would incur one-time costs of \$20,000 (in 1999 dollars) to modify existing recordkeeping systems as well as annual costs of about \$2,000 per plant, which is somewhat consistent with ex-post estimates. One of the five manufacturers that provided quantitative estimates incurred no additional monitoring or recordkeeping costs because it already tracked the information required by the 2004 NESHAP. The remaining manufacturers described costs associated with modifying an existing or building a new database to track HAP emissions. Estimates ranged from \$26,000 to \$52,000 (in 1999 dollars) at the corporate level.⁴¹ The U.S. EPA estimated that monitoring would cost \$15,600 per plant annually. Most manufacturers made no mention of monitoring costs in the ex-post pilot survey.

5.5 Total Compliance Costs

Since a main difference between the ex-ante and ex-post estimates is the choice to comply by reformulating coatings instead of installing abatement controls, it is not surprising that there is a large discrepancy between total ex-ante and ex-post compliance costs for the nine plants we surveyed (Table 8). Once the cost of installing and operating abatement controls is deducted from the total, the U.S. EPA's ex-ante estimate falls within the estimated ex-post range.

The U.S. EPA's ex-ante estimate of administrative costs is more than eight times larger than ex-post estimates. The magnitude of the U.S. EPA's estimate is driven by the assumption that plants would incur substantial annual costs for monitoring and recordkeeping, for which there is little ex-post evidence. Ex-ante and ex-post estimates of the cost to set up or modify an existing recordkeeping system are roughly similar. However, the U.S. EPA assumed ex-ante that plants would individually set up recordkeeping systems, while ex-post information indicates that most manufacturers updated or built databases at the corporate level.

6. Overall Implications and Study Limitations

We compare ex-ante estimates of the direct costs of compliance with the 2004 NESHAP for surface coating of light-duty vehicles to ex-post estimates based on data collected through a pilot survey and follow-up interviews administered to nine assembly plants. Unlike many prior retrospective studies on the cost of regulatory compliance, we use this information to identify the key drivers of any differences between ex-ante and ex-post estimates.

⁴⁰One manufacturer estimated that it took two staff engineers about 10 percent of their time during the R&D stage (lasting several years), 25 percent of their time during the testing or trial stage (about one year in length), and about 40 percent of their time at the conversion stage (about one year in length). When combined with wage rates from the Bureau of Labor Statistics (BLS), this is about \$150,000 in additional costs per plant (in 1999 dollars).

⁴¹The loaded hourly wage for a computer systems analyst is \$69.48 in 2013 dollars (\$49.69 in 1999 dollars). The range is based on whether we assume the analyst worked full or part time to develop the system over six months.

Analysis of the data indicates that the U.S. EPA likely substantially overestimated the direct cost of complying with the 2004 NESHAP for the plants we surveyed. This is primarily because plants reformulated their coatings to emit fewer HAPs rather than install expensive abatement control technology. Managers often had difficulty estimating compliance costs associated with these process changes. Thus, we supplemented the plant-level information with data from two paint suppliers that had performed R&D to reformulate coatings for several leading manufacturers. While we do not consider the indirect costs of the 2004 NESHAP, given the relatively low direct cost estimates, it seems likely that there were few if any quantifiable indirect costs.

Because we only have ex-post information for a subset of plants, it is not possible to produce an aggregate ex-post compliance cost estimate. However, there are several reasons we might expect that the U.S. EPA also overestimated compliance costs for the sector as a whole. First, fewer plants likely incurred compliance costs than expected since many plants closed prior to 2007 for reasons unrelated to the regulation. Second, many companies pursued a corporatewide compliance strategy of reformulating coatings. If process changes also dominated for other firms, then ex-post compliance costs were likely lower than expected. Third, by design the MACT standards are performance-based, which means that firms can choose how to comply with emission limits. Since lower cost techniques than those evaluated by the U.S. EPA were available, it is likely that other firms also pursued lower cost abatement options.

Many manufacturers were already taking action or actively supporting R&D to reduce HAPs from paint shops prior to the 2004 NESHAP as part of global and/or corporate-level initiatives, in response to state regulations, or when upgrading outdated equipment. While many of these pre-existing efforts were accounted for by the U.S. EPA ex ante, the 2004 NESHAP may have accelerated technological change already under way in the industry, which could also lower compliance costs relative to the ex-ante estimate. Some of the manufacturers also noted that the 1999 U.S. EPA data request on HAPs prompted them to introduce reformulated coatings prior to promulgation, though they described significant uncertainty about the stringency of the eventual MACT standard and thus limited anticipatory actions to new colors.

While this study only represents ex-post evidence on compliance with a single environmental regulation, the findings also suggest that there may be ways to improve analyses of similar types of regulations ex-ante. For instance, analysis that explores how ex-ante estimates may change when lower-cost technologies in development become more widely available could help regulators understand how robust cost estimates are to alternative scenarios. In addition, a clear understanding of whether investment decisions are made at the plant or firm-level could inform whether it is most appropriate to evaluate plant compliance strategies as independent from one another.

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Table 1:**Conceptual Framework for Ex-Post Cost Assessment**

<i>Cost Component</i>	<i>Assessment of Questions Posed</i>
Regulated Universe	What types of entities are required to comply with the rule? How many entities of each types are required to comply?
Baseline	To what extent are abatement technologies already in use prior to the rule?
Methods of Compliance	What types of technologies or methods are used to comply? How often are these compliance strategies used?
Direct Compliance Costs	What are the initial or one-time compliance costs (e.g. capital)? What are the ongoing compliance costs (e.g. operation and maintenance)?
Indirect Compliance Costs	What are the indirect compliance costs (e.g., quality trade-offs)?
Opportunity Costs	Are there other major opportunity costs associated with the rule (e.g., in related markets)?

Source: U.S. EPA, 2014

Table 2:**Ex-Ante Control Costs by Major Compliance Strategy**

Compliance Strategy	Annualized Capital Cost (1999\$)	Additional Annual Operating Cost (1999\$)	Cost per Ton of HAP Controlled	Number of Plants Expected to Adopt
No additional controls		-		11
(1) Add regenerative thermal oxidizer to electrostatic oven	\$118,000	\$127,000/year	\$8,200/ton	14
(2) Substitute non-HAP for HAP solvents in primer surface coating	None	\$0.23/pound of solvent	\$540/ton	21
(3) Substitute non-HAP for HAP solvents in top coating	None	\$0.23/pound of solvent	\$540/ton	15
(4) Install exhaust controls to spray booth	\$20,000/ton	\$20,000/ton	\$40,000/ton	45

Source: U.S. EPA, 2002; 2004.

Table 3:

Survey Results on Baseline Control Devices Operating in a Plant's Paint Shop

Control device	Proportion of paint shops in which it was operating prior to 2004
Thermal oxidizer	6/9
Carbon-based concentration system	4/9
Solvent-recovery system	8/9
Paint shop design alterations to alter coating used	1/9

Table 4:

Survey Results on Baseline Coating Process Changes

Coating Process Change	Proportion of paint shops with coating process changes prior to 2004
Lower HAP or VOC primer	7/9
Lower HAP or VOC primer-surfacer	4/9
Lower HAP or VOC topcoat or clearcoat	5/9
Lower HAP or VOC sealer, sound deadener, or bonding adhesive	8/9
Lower HAP or VOC cleaning agents	5/9
Powder or water-based coatings	4/9

Table 5:

Comparison of Ex-Ante and Ex-Post Compliance Strategies for Surveyed Plants

Compliance Strategy	Proportion of Plants Adopting	
	Ex-Ante	Ex-Post
No additional controls	1/9	3/9
Add regenerative thermal oxidizer to electrostatic oven	4/9	0/9
Substitute non-HAP for HAP solvents in primer-surfacer coating	4/9	6/9
Substitute non-HAP for HAP solvents in top coating	2/9	6/9
Install exhaust controls in spray booth	7/9	0/9
Other	0/9	6/9

Table 6:

Estimated Incremental Operating Costs of a Reformulated Topcoat (1999\$)

Incremental Cost Increase	Ex-Post			Ex-Ante
	Manufacturer Estimate ³²	Paint Supplier Estimate ³³	Paint Supplier Estimate ³⁴	Independent Estimate ³⁵
Per Gallon of Paint	\$1.25 – \$4.13	\$0.26 – \$0.71	\$0.21 – \$0.84	\$0.17 – \$0.39
Average per Plant (\$1,000s)	\$152 – \$501	\$65 – \$172	\$51 – \$204	\$21 – \$47
				U.S. EPA Estimate ³⁵
				--
				\$53

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\$30 – \$100/gallon (2006 dollars) with about 10 percent of the cost due to solvents prior to reformulation. The manufacturer estimated that about 15 percent of the current cost is due to solvents. The manufacturer estimated an additional cost of \$0.30–\$0.80/gallon to comply, depending on whether the coating was solvent- or water-based, respectively. We assume these values are expressed in 2006 dollars. The manufacturer indicated that reformulating the basecoat resulted in a one to two percent increase in the cost of the coating, with a gallon of basecoat costing \$30 – \$60/gallon (in 2014 dollars), depending on the solvent used. The U.S. EPA expected to use this compliance strategy. The U.S. EPA used an incremental cost of \$0.23/pound of solvent to switch from xylene to ethyl acetate but did not provide enough information to estimate the cost of this strategy.

Table 7:

Incremental Operating Costs of Reformulated Primer-Surfacer Coating (1999\$)

Incremental Cost Increase	Ex-Post		Ex-Ante
	Paint Supplier Estimate	Independent Estimate	U.S. EPA Estimate
Per Gallon of Paint	\$0.18 – \$0.35	\$0.09 – \$0.20	--
Average per Plant (\$1,000s)	\$15 – \$29	\$7 – \$16	\$22

Table 8:

Comparison of Total Ex-Ante and Ex-Post Compliance Cost Estimates for Nine Surveyed Plants

	Ex-Ante U.S. EPA Estimate	Ex-Post Estimate (using low paint supplier estimate)	Ex-Post Estimate (using high paint supplier estimate)
Total Annualized Compliance Cost	\$35.9 million	\$148,000 ^A	\$264,000 ^B
Annualized Capital & Operating Cost for Abatement Controls	\$35.7 million	\$0	\$0
Annualized Cost to Reformulate Coatings	\$192,000	\$148,000 ^A	\$264,000 ^B
Total Annualized Administrative Costs	\$321,000	\$38,000	\$38,000
Annualized Cost of One-Time Recordkeeping Costs	\$20,000	\$15,000	\$15,000
Annualized Ongoing Administrative Costs	\$301,000	\$23,000	\$23,000

^A: Uses the low paint supplier estimate;

^B: Uses the high paint supplier estimate. All other ex-post estimates in columns 3 and 4 are from manufacturer responses.

Table 9:

Summary of Findings by Cost Component

Components of Cost Estimate			Source of Ex-Post Information	Assessment (Compared to Ex Ante)
Regulated Universe	Number of automobile manufacturers with paint shops		Annual production by assembly plant, 2003–2008	Smaller than expected – nearly one third of plants closed for reasons unrelated to environmental regulation
Baseline use of abatement controls and process changes to lower HAPs			Survey	Abatement controls – reasonable Process change – used more than expected
Methods of Compliance	Abatement controls		Survey	Smaller use than expected – U.S. EPA predicted this as main method of compliance but no one used
	Process Changes		Survey	Large use than expected – main compliance strategy compared to moderate uptake predicted
Compliance Costs	Direct, One-Time	Capital	--	Smaller than expected – no one used, so no costs
	Direct, On-Going Cost	Process Changes	Survey and interviews; indep. cost assessment	Possibly somewhat larger than expected for basecoats; reasonable for primer-surfacer
		Monitoring, recordkeeping, reporting	Survey results and interviews	Lower than expected
	Indirect		--	--
Opportunity Costs			--	--
PER PLANT NET COSTS	Likely lower than expected – driven mainly by different methods of compliance rather than substantial misestimation of abatement costs associated with a given method of compliance			
TOTAL COSTS	Difficult to assess since we only have information for a subset, but if process change dominated for other facilities as well, then likely lower than expected			