Sam Houston State University
Department of Economics and International Business
Working Paper Series

High Priority Violation Policy and Targeting Enforcement: An Empirical Analysis of its Effectiveness and Efficiency

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SHSU Economics & Intl. Business Working Paper No. 14-11
December 2014

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High Priority Violation Policy and Targeting Enforcement:

An Empirical Analysis of its Effectiveness and Efficiency

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Abstract

The High Priority Violation (HPV) Policy represents a way to target enforcement in environmental regulations; serious air pollution violators are targeted with timely and appropriate enforcement, and such enforcement usually means high degree of regulatory scrutiny. Despite the importance of enforcement, the empirical literature on the effectiveness and efficiency of targeting enforcement is very limited. This paper provides the first empirical evidence on the effects of HPV policy and the externalities associated with this policy. To examine HPV targeting, dynamic panel models are employed using a rich plant-level dataset consisting of 8,736 major manufacturing facilities nationwide during the period 2001-2010. Our results suggest positive specific deterrence effects of HPV status—a four-month increase on the HPV listing time in the previous year leads to about one extra month of compliance. We also find general deterrence effects of HPV targeting—a typical facility, regardless of its HPV status, increases its compliance rate when there is an increase in the amount of fines imposed on other HPV facilities within the same state. Both the specific and general deterrence effects of enforcement differ by HPV status—HPV facilities on average are less responsive to additional specific or general enforcement actions. Thus the efficiency of HPV targeting is undermined. Potential reasons for the inefficiency include high abatement costs for HPV facilities and the inadequate addressing of the High Priority Violators by the regulators. This paper explores the effectiveness as well as efficiency of HPV policy and has important policy implications.

Keywords: Air pollution regulation; High Priority Violation Policy; firm compliance; Clean Air Act

JEL Classification: D62; Q53; Q58

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1. Introduction

With limited monitoring and enforcement resources, it is impossible for environmental regulators to inspect all regulated firms frequently. One natural response is to prioritize the resources and target a group of firms such as serious violators or repeat violators. In environmental enforcement literature, this is usually referred to as targeting enforcement or leverage enforcement. Under such enforcement regime, targeting certain firms create leverage effects on both targeted firms and those not targeted, resulting in increased compliance. The High Priority Violation (HPV) policy represents such targeting enforcement in practice. The HPV Policy was implemented by the Environmental Protection Agency (EPA) in 1999. Under the HPV Policy, facilities regulated under the Clean Air Act (CAA) are targeted if their violations are found to be serious and meet the classification criteria specified in the policy. Once a facility is classified as a High Priority Violator, it will face stringent regulatory scrutiny from the EPA and State-Local agencies, including but not limited to monthly conference calls between EPA and State-Local agencies regarding the violation, continuous monitoring by the regulator until the violation is resolved, and specific enforcement actions with detailed timeframes. As an important regulatory policy on air pollution control, the HPV policy helps federal, state and local agencies better prioritize the use of limited enforcement sources on serious air pollution violators.

To our best knowledge, there is no empirical evaluation of this policy after its implementation over a decade ago. In addition, while targeting enforcement has been widely discussed and verified to be in use in practice through various empirical analyses of environmental policies, few studies actually examine the effectiveness and efficiency of such enforcement strategy. Given the broad adoptions of the targeting enforcement and the significant amount of resources allocated to targeting, it is critical to empirically evaluate its effectiveness and efficiency in deterring violations. This paper is the first to address these issues by focusing on the HPV targeting enforcement. The effectiveness of targeting is verified by examining whether HPV status has any positive and significant impact on facility compliance. Next, we examine whether and how the marginal effect of enforcement varies by HPV status. If the targeting enforcement results in reduced violations coming mostly from HPV facilities, then regulators may focus extensively on such serious violators. However if non-HPV facilities are more responsive to morning and enforcement under targeting regulations, then targeting enforcement may not be as efficient as it is intend to be. Thus determining the existence and nature of the heterogeneity of enforcement responses allows us to make inferences about the efficiency of the HPV targeting.

There is rich literature available on targeting enforcement modeling in environmental regulation based on the pioneering work of Harrington (1988). In his model, firms are placed into two groups according to their compliance status, with those violators being placed in the targeted group and facing higher sanctions and more inspections. Harrington demonstrates that the leverage in the enforcement between the two groups creates greater incentives for firms in both groups to comply compared to regulations under a static enforcement regime in which all firms face the same inspection frequency and sanctions. Others have extended Harrington's model to various regulatory settings and structures, including Russell (1990), Harford (1991), Harford and Harrington (1991), Raymond (1999), Stafford (2008), and Friesen (2003). More recently, Liu and Neilson (2013) consider targeting enforcement in a setting in which firms compete to be moved out of the targeting group through rank-order tournaments; this creates additional incentives for firms to comply. Gilpatric, Vossler, and McKee (2011) consider a similar type of targeting enforcement in the self-auditing regime and conduct lab experiments to test the model.

Based on the theoretical models of targeting enforcement, empirical studies of monitoring and enforcement have begun to incorporate targeting enforcement in their analyses. Such studies often empirically test whether violating facilities face higher inspection frequencies and sanctions and then take the targeting enforcement into consideration in their model specifications. For example, in a study of the air pollution regulations on American steel industry, Gray and Deily (1996) report that steel plants with better expected compliance status face less enforcement pressure. Stafford (2002) notes that facilities regulated under the Hazardous Waste Program face higher inspection probabilities if violations are found in the previous period. Rousseau (2007) examines whether an environmental inspection agency in Belgium uses a targeting approach in the textile industry and concludes that firms are selected for inspection based on their compliance behavior and capacity.

In contrast, there is scant empirical analysis of the effectiveness or efficiency of targeting. Helland (1998) examines the role of targeting in water pollution regulations in the pulp and paper industry. He demonstrates that while targeting induces plants to increase self-reported violations, it has no significant effects on deterring violations. He further points out that since inspections are also determined by the characteristics of the surrounding community, it opens the door to interest group influence. Eckert (2004) investigates the roles of warnings and inspections in the regulations of petroleum storage sites in Manitoba, Canada. His findings suggest that warnings are used to group sites for targeting and by increasing the probability of future inspections, warnings have a deterrent effect on violations. In a review of empirical evidence on the effectiveness of environmental monitoring and enforcement, Gray and Shimshack (2011) point out that the efficiency of targeting repeat offenders might be compromised due to the higher compliance costs and less responsiveness to enforcement actions by frequent violators.

The main challenge in the evaluation of targeting enforcement is the difficulties in verifying the targeting status of each individual firm or facility. In previous empirical works such as Helland (1998) and Eckert (2004), targeting is revealed through empirical testing. Thus, their analysis of the effectiveness of targeting is indirect. Even though significant relationship can be established between compliance status and the probability of inspections, it only implies that, on average, firms with bad compliance history may face higher inspection probabilities. However, it may not be appropriate to assume that every violating firm is targeted. The significant relationship between compliance and inspection may also be driven by targeting serious or frequent violators, and therefore, the line between being targeted and not targeted is rather ambiguous. Consequently, the effects of the targeting that is investigated in previous literature may be biased due to misclassification of targeting status. In comparison, the HPV Policy provides a great opportunity for researchers to investigate the effectiveness and efficiency of targeting enforcement. Under the HPV Policy, detailed classification criteria are available to guide the authorities to determine whether a violation is an HPV or not. Facilities being classified as HPVs will receive Notice of Violation or Finding of Violation within 90-150 days after the discovery of the violation and their HPV status will be tracked in the AIRS Facility Subsystem (AFS) until full compliance is restored. Therefore, the HPV facilities are fully aware of their targeting status and future actions taken upon them. This feature enables us to clearly differentiate between facilities that are targeted under the HPV Policy and those not targeted.

Thus we are able to directly measure the effects of targeting on compliance and also examine the differential effects of enforcement by HPV status.

The investigation of the efficiency of targeting enforcement is also related to the literature on differential deterrence effects of monitoring and enforcement across facility characteristics, such as facility size, financial status, industry, and community characteristics. While examining the effects of strict liability policy on the level of uncontrolled releases of pollutants, Alberini and Austin (2002) find that the effects differ across firm size with smaller firms releasing more pollution. Gray and Shadbegina (2005) discuss the differential deterrence effects across firm size and ownership structure for the pulp and paper mills in the 1980s. Deily and Gray (2007) also confirm the differential effects on compliance across firm size. Earnhart (2009) finds that the effects of enforcement on compliance differ depending on capacity utilization and permit conditions in U.S. chemical manufacturing facilities. More recently, in an investigation of the plant-level air emissions, Hanna and Oliva (2010) demonstrate that abatement costs can play an important role in facility responses to enforcement actions.

In this paper, we examine the differential deterrence effect of enforcement by facility HPV status. Since a substantial amount of resources are allocated to the monitoring and enforcement on HPV facilities, it is expected for such facilities to be more responsive to monitoring and enforcement actions. However, if the deterrence effects on non-HPV facilities are greater than those on the HPV facilities, then HPV targeting may not be as efficient as it is intended to be. To explore the efficiency of HPV targeting, we consider both the specific deterrence effects of enforcement on the facility itself and the general deterrence impacts of enforcement on other facilities. We examine whether the specific and general deterrence of monitoring and enforcement actions differ between HPV and non-HPV facilities.

Using panel data on 8,736 manufacturing facilities over a ten-year period, we estimate dynamic panel data models to investigate the effects of HPV listing on facility compliance with the CAA and the differential deterrence effects. Our results suggest that a facility’s HPV status has significantly positive impacts on its compliance behavior. On average, four additional months on the HPV list in the previous year lead to one more month of compliance in the current year. We also find general deterrence effects of HPV targeting; a representative facility, regardless of its HPV status, increases its compliance rate when fines imposed on other HPV facilities within the same state rise. However, both the specific and general deterrence effects of enforcement differ by HPV status–HPV facilities are less responsive to additional enforcement actions. When inspections of a facility itself or fines on other HPV facilities increase, non-HPV facilities reduce more violations on average than HPV facilities. Thus the efficiency of HPV targeting is undermined. Potential reasons for the inefficiency include high abatement costs for HPV facilities and the inadequate addressing of the High Priority Violators by the regulators.

The rest of the paper is organized as follows. Section 2 of this paper offers a brief description of the HPV Policy, followed by the discussions of data and empirical specifications in Section 3. Results are presented in Section 4 and Section 5 concludes.

2. Targeting with the HPV Policy

The HPV Policy was implemented by the Environmental Protection Agency (EPA) in the third quarter of fiscal year 1999 and is administrated by the EPA and state/local agencies. According to the HPV document issued by the EPA in 1999, the HPV Policy "provides a new method of prioritizing violations for enforcement purposes" (EPA, 1999). The purpose of this policy is to direct the highest scrutiny and oversight from the regulator to the most important and environmentally significant violations.

The HPV Policy replaces the Significant Violator Policy that was used in air pollution regulation previously. In comparison to the Significant Violators Policy, the HPV Policy specifies more restrictive criteria for a violation to be classified as an HPV; this allows regulators to better target firms with serious violations. The policy applies to violations at a major source, violations related to a pollutant for which the source is considered major, or those affecting minor source status at a synthetic minor source.[3] There are three ways for a violation to be classified as an HPV. First of all, a violation may fit one or more of the ten General HPV Criteria that deal with specific types of violations such as failing to obtain permits or violations of the Air Toxics Requirement. Second, a violation is compared with five Matrix Criteria that cover

[3] In air pollution regulation, a source is considered to be major if its potential to emit is above certain thresholds established by various regulatory programs. In general, a minor source refers to any stationary source that is not major. Permits are required for all major sources but not for minor sources. The synthetic minor source is sometimes referred to as a conditional major source. For such sources, federally enforceable limitations or conditions are required to ensure that its potential to emit is below the major source thresholds.

violations of emission limits. The details about the ten General HPV Criteria and five Matrix Criteria are provided in Appendix A. Last, with mutual agreement of the state/local agency and EPA, a violation may also be categorized as an HPV on a discretionary basis.

Continued emissions from the HPVs can create critical threats to the environment and thus should be addressed in a timely manner. Therefore, the HPV policy specifies detailed timeframes for enforcement actions to be taken against those violations. Once a facility is identified as a High Priority Violator, it faces a series of enforcement actions and continuous monitoring until the violation is corrected. Figure A.1 in Appendix B provides an outline of the HPV enforcement timeline. The enforcement clock, Day Zero in the enforcement timeframe, usually starts within 45 days after the violation is revealed through inspections or 30 days for self-reported violations. If additional information is needed, then Day Zero should start within no more than 90 days after the violation is discovered. During the time between when a violation is discovered and Day Zero, the authority will review the case to determine whether the violation is an HPV. If an HPV is confirmed, the enforcement clock starts, indicating the beginning of enforcement actions to be taken against the HPV.[4] First, within 60 days from Day Zero, the state/local agency must issue a Notice of Violation/Finding of Violation to the corresponding facility. Such notices may also be issued by the EPA. Meanwhile, the state/local agency and the EPA should discuss the compliance status of every HPV case through conference calls on a monthly basis. The agencies also discuss the optimal method to correct the violation and the appropriate lead of enforcement for each ongoing HPV case. If the violation remains unresolved by the150th day, there should be a focused, case-specific communication between the state/local agency and the EPA to determine specific actions in order to address the case. During this communication, the EPA may also take over the lead if necessary. By the 270th day since Day zero, an ongoing HPV should be either resolved, i.e., the source is returned to compliance, or addressed, i.e., an administrative or judicial order should be put in place for compliance purposes. If there is a lead change from the state/local agency to EPA, then the EPA needs to address or resolve the violation by the 300th day. For complex violations, additional time may be requested and granted on a case-by-case basis. During the whole process of addressing the violations until the case is fully resolved, the State/Local agency or EPA may take follow-up

[4] Multiple violations may be discovered during the same investigation or at the same source. Such violations will be grouped and assigned the same Day Zero if they occur within 30 days of each other.

actions to ensure appropriate progress, especially when a schedule is established for the HPV to return to compliance. The intensive interaction between the violator and the agencies effectively put the HPVs in the targeted group for enforcement.

Although the HPV Policy does not establish new standards or alter the way a fine is calculated, the EPA intends to collect fines on all HPVs. It is expected that the amount of the fines will reflect the seriousness of the violations and the economic benefit of the noncompliance to the violator. Overall, fines assessed should be sufficient to maintain effective deterrence for the penalized facility as well as other regulated facilities.

The average number of inspections and average amount of fines imposed on HPV and non-HPV facilities in our sample data are shown in Columns (2) and (3) in Table 1. Among the 8,736 CAA-regulated manufacturing facilities, 1,497 of them appeared on the HPV list at least once during 2001-2010. Comparisons of the enforcement measures between the HPV and non-HPV facilities reveal that the HPV facilities were targeted with much high inspection rates and sanctions. The average number of inspections on HPV facilities in the same year and the year after was more than 4 times higher than that of the non-HPV facilities, while the fines on HPV were about 100 times higher than that of the non-HPV facilities. In fact, a total of $161 billion of fines were assessed on violations during 2001-2010, over 87% of which were imposed on HPV facilities.

[Insert Table 1]

Table 1 also provides the average number of inspections and average amount of fines on non-HPV facilities with violations and without violations. The difference in the enforcement measures between the two types of non-HPV facilities was much smaller. While on average the violating non-HPV facilities might have still been targeted, such targeting was much less significant than the targeting on HPV facilities. The leverage effects of such targeting were also inadequate to induce high level of compliance. In addition, it may also be inappropriate to assume all violating facilities were targeted for enforcement purpose. Without the identification of HPV facilities, it would be difficult to accurately determine the targeted group of facilities.

Another channel to keep the HPVs being closed monitored of the regulators is tracking the HPV status, facility compliance status, and any associated enforcement actions. When an

HPV is identified, it should be promptly and accurately recorded in the EPA's AIRS Facility Subsystem (AFS). In the AIRS system, an HPV flag is used to reflect the HPV status and the lead of the investigation. Accordingly the compliance status of the corresponding facility should also be changed to reflect the violation. During the process of addressing the violation, any Timely & Appropriate (T&A) actions taken shall be recorded in the system. After an HPV is resolved, the compliance and HPV status will be switched back. Such tracking is required for all HPVs, even if an HPV is immediately corrected, without any enforcement action or without any penalty. The AIRS system is updated by the EPA and/or State on a monthly basis to reflect any status change.

3. Data and Empirical Specifications

3.1 Data

Our main source of data is the EPA's Enforcement and Compliance History Online database. This database tracks the compliance, inspections, enforcement, and HPV status of all EPA-regulated facilities. Because the HPV Policy applies to air pollution regulation only, we focus our analysis on manufacturing facilities that are regulated under the CAA.[5] We consider facilities that are federally reportable since enforcement and compliance data on such facilities are more reliable.[6] In addition, government facilities are excluded from the sample because their compliance behavior and enforcement history can be systematically different from non-government facilities.

Overall, a total of 8,736 facilities are included in the analysis; the time frame for the sample is 2001-2010. The distribution of facilities across the nation is shown in Figure 1.

[Insert Figure 1]

Pennsylvania, Virginia, and North Carolina have the highest number of regulated facilities in our sample, with each state holding over 600 facilities. Nevada, Wyoming, and Illinois are among the states with the lowest number of facilities, with each state having less than 20 facilities.

[5] Manufacturing facilities are identified using NAICS code 31-33.
[6] According to the EPA, "A facility is federally reportable if its emission classification is 'major' or 'synthetic minor,' or it is subject to NSPS or NESHAP requirements and its source-level compliance status is not equal to 'no applicable state regulation' " (EPA, AFS document, August 2012).

Under the CAA program, facilities are required to self-report their emissions. Self-reported data are widely used in empirical studies of monitoring and enforcement (see Laplante and Rilstone, 1996; Earnhart, 2004; Shimshack and Ward, 2005).The use of self-reported data may raise the question of strategic misreporting. However, sanctions on intentional misreporting range from criminal fines to jail time, which can be strong incentives for facilities to truthfully self-report (Shimshack and Ward, 2005).[7] Thus, researchers generally consider facility self-reports to be truthful (Shimshack and Ward, 2005). Nevertheless, the self-reported data are used in this study with cautions.

We obtain community characteristics variables from the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, and the U. S. Census Bureau. These variables include real annual income per capita; unemployment rate; population density; total employment in manufacturing industry; total manufacturing firm establishments; percentage of the population with high school diploma and above; and percentage of white population. All community variables are collected at the county level and matched to the facilities.

Variable descriptions and summary statistics are provided in Table 2. The first variable, *compliance rate*, is the percentage of time that a facility is in compliance in a given year. Overall, facilities are in compliance for 91.66% of the time on average in a given year. A further look at the data reveals that about 67% of the facilities are in compliance through the entire sample period while about 2% of the facilities are never in compliance. Our main variable of interest, *HPV*, measures the percentage of time a facility is listed as an HPV in a given year. The average percentage of time facilities are listed as HPVs is about 3.48% with a standard deviation of 16.74%. Of the 8,736 facilities included in our sample, about 83% of them are never listed as HPVs and about 0.5% of them are never taken off the HPV list. Figure 2 shows the detailed distribution of the HPV facilities in 2001 and 2010, the first and last years in our sample period. In 2001, a total of 326 facilities were classified as HPVs in at least one month of the year; Pennsylvania and South Carolina had the highest number of HPV facilities, with 24 in each state.

[7] When the accuracy of the data is tested explicitly, results are mixed. Telle (2013) recently raises concerns about the reliability of self-reported data. Other studies that test on the validity of self-reported data do not reject the accuracy of the data (Laplante and Rilstone, 1996; Shimshack and Ward, 2005).

In 2010, the total HPVs reduced to 254; California ranked the first with 25 HPVs while Tennessee and Texas tied for the second place with 24 HPVs.

[Insert Figure 2]

[Insert Table 2]

The next two variables, *Inspection* and *Fines*, are enforcement measures on a facility itself. On average, each facility is inspected once every year and pays about $1.85 million in penalties in a given year. The variables *Inspection on others* and *Fines on others* measure the average number of inspections and the average amount of fines (in millions of dollars) imposed on all other facilities within the same state. These two variables effectively measure the general deterrence effects of enforcement. We further separate other facilities in the same state into two groups based on their HPV status: a targeted group of HPVs and a non-targeted group of non-HPVs. *Inspection on other HPVs; fines on other HPVs; Inspection on other non-HPVs;* and *fines on other non-HPVs* are used to capture the monitoring and enforcement actions imposed on these two groups of facilities. A direct comparison of the summary statistics of inspections and fines on the two groups reveals that HPV facilities are more frequently inspected and heavily sanctioned. The average number of inspections on a typical HPV facility is as high as 3.81 while the average for a representative non-HPV facility is only 0.87. The average amount of fines on other HPVs is as high as $41 million, while the corresponding average for other non-HPVs is less than half of a million dollars. Such significant differences in enforcement between the two groups are expected as a result of enforcement targeting under the HPV policy.

The rest of the variables capture the economic and demographic variations that are associated with a facility. We employ four annual county economic variables: real income per capita, ; unemployment rate; total manufacturing firm establishments; and total employment in manufacturing industry. Three county demographic variables are included: percentage of population with high school diploma and above; population per square mile; and percentage of white population.

3.2 Endogeneity

Endogeniety can arise in the empirical analysis of the relationship between compliance and enforcement, especially with the presence of targeting. Results reported in this paper are no exception. For targeting enforcement based on compliance status, it is expected that how a facility is inspected will be correlated with its compliance decisions. This give rises to reverse causality and endogeneity.[8] In the case of the HPV Policy, facilities with High Priority Violations face higher inspection frequency and higher sanctions. If no actions are taken to control for reverse causality and endogeneity, a negative relationship may be obtained between compliance and enforcement, implying that more inspections or higher sanctions actually lead to lower compliance rate. Earlier studies of compliance and enforcement address the issue of endogeineity by including lagged enforcement variables. However, conditions that influence a facility's compliance decision usually persist over time and certain violations, especially those classified as HPV, and may take months or years to correct. Thus lagged enforcement variables can only partially mitigate the issues. Another approach to address the issue of endogeneity in the literature is to use instrument variables and include the predicted inspection probabilities instead of the actual inspection in the second stage of the regressions. A third approach is the use of proxy variables. For example, several studies (Shimshack and Ward 2005, 2008) include the enforcement actions imposed on other similar plants to examine the deterrence effects on a specific plant. This is usually referred to as general deterrence effects, while the specific deterrence effects refer to those effects resulting from enforcement actions imposed on a plant itself.

Given the presence of endogeneity and the persistence of compliance status, the empirical model should ideally include the lagged compliance status as a control variable when investigating facility compliance. However, in linear dynamic panel-data models that include lags of the dependent variable and fixed individual effects as covariates, the unobserved fixed effects are correlated with the lagged dependent variables, making standard estimators inconsistent. Arellano and Bond (1991) derived a consistent Generalized Method of Moments (GMM) estimator for the parameters of this model. For our research, we adopt the Arellano-Bond estimator in our empirical analysis. Dynamic panel models allow for gradual adjustments to enforcement policy and mitigate the potential endogeneity due to unobservable time-varying

[8] Gray and Shimshack (2011) provide a more detailed discussion of reserve causality and endogeneity in measuring the deterrence effects of enforcement.

heterogeneity that may be correlated with the error term. In addition, we also use the lagged enforcement variables approach and consider the specific and general deterrence effects in our model specification to further address the endogeneity and reverse causality issues.

3.3 Econometrics Models

The dynamic model to be estimated takes the following specifications:

$$C_{ijt} = \alpha_0 + \sum_{l=1}^{k} \rho_n C_{ijt-l} + \theta H_{it-1} + \gamma' P_{ijt-1} + \delta' E_{jt} + \varphi' Y_t + u_i + \varepsilon_{ijt},$$

where C_{ijt} indicates the percentage of time that facility i in county j complies with regulatory requirements in year t. C_{ijt-l} is the lagged dependent varible, where $l = 1,2, \dots k$. H_{it-1} denotes lagged HPV status. P_{ijt-1} is a vector of lagged monitoring and enforcement variables measuring specific and general deterrence. E_{jt} includes county economic and demographic characteristics. The individual facility fixed effects and the year dummies are u_i and Y_t. The random error term is denoted by ε_{ijt}.

The dependent variable (C_{ijt}) measures a firm's compliance rate in a given year. [9] We calculate the percentage of time in a given year that a facility complies with the CAA regulation. The lags of the dependent variable are also included as control variables in the equation. One of the fundamental requirements for the Arellano-Bond estimator is that the error term does not exhibit higher-order serial correlations such as autoregressive process of order 2 [AR (2)]. Our autoregressive test suggests that such condition is satisfied.

HPV status, H_{it-1}, is included in the model as the percentage of time in a previous year a facility is listed as a High Priority Violator.[10] This is our main variable of interest for the investigation of the effectiveness of targeting enforcement. Since HPVs are serious violations

[9]Compliance data are available on a monthly basis. We use yearly aggregate data instead for the following reasons. First, the compliance data for almost 88% of the facilities in our sample are missing in April 2002. In addition, compliance data are missing for all facilities in Texas between June 2006 and September 2009. Using aggregated compliance rate annually eliminate the need to arbitrarily fill in missing data. Second, the Arellano-Bond model cannot be readily applied to panel data with a monthly bivariate dependent variable. As discussed in Section 3.2, when targeting enforcement is involved, serious endogeneity issue arises. Without full control for the endogeneity, the relationship between compliance and enforcement obtained may be misleading.
[10] We also consider including HPV status as a dummy variable and the results are similar.

and it may take time for a facility to fully correct such violations, the one-year lag of this variable is included. The corresponding coefficient θ is expected to be positive and significant, indicating that being listed as a High Priority Violator in the previous year is associated with improvement on compliance in the current year.

The lagged enforcement variables in vector P_{ijt-1} include annual average number of inspections and amount of penalty specific to the facility itself, and the aggregate annual number of inspections and amount of penalty imposed on all other HPV and non-HPV facilities within the same state. To examine the efficiency of targeting enforcement, i.e., differential enforcement responses, we include in the models, the interactions between all lagged enforcement variables and a dummy variable indicating whether facility i is a High Priority Violator. Significant coefficients on the interaction terms may imply differential enforcement effects between the HPV facilities and non-HPV facilities. In a separate estimation, we include enforcement measures on other HPV facilities and other non-HPV facilities as well as the corresponding interaction terms with the HPV dummy variable. Such specification allows us to explore the general deterrence of targeting and the differential enforcement responses in more details.

In addition to monitoring and enforcement, community influence may also play a role in regulating facility emissions and compliance decisions (Earnhart, 2004). To account for the impacts of economic and social changes in the county, annual economic and demographic variables at the county level are included. These variables are included to partially address the omitted variable problem discussed in Gray and Shimshack (2011).

This empirical model is estimated using the Arellano-Bond dynamic panel-data estimation procedure. The level equation is first transformed into first-difference equation and the first-difference lagged dependent variables are instrumented with the higher-order lags of the level term.

4 Empirical Results

4.1 Baseline Results

Table 3 reports the results from the baseline estimation. We consider four model specifications: The first two models focus on specific and general deterrence effect of HPV targeting on compliance, and the last two models address differential enforcement responses by HPV status.

[Insert Table 3]

4.1.1 Specific and general deterrence effect—effectiveness of HPV targeting

We first examine Models (1) and (2) to inspect the effectiveness of HPV targeting. In Model (1), the general deterrence measures are included as the average number of inspections and average amount of fines on all other facilities in the same state. In Model (2), we separate the general deterrence measures into four variables: the average inspections and fines on other HPV facilities and non-HPV facilities, respectively.

The main variable of interest, *HPV*, has significant and positive effects on compliance in both models. The more frequently a facility appears on the HPV list in the previous year, the higher the compliance rate subsequently. Specifically, a four-month increase on the HPV listing time in the previous year leads to about one extra month of compliance in current year. This confirms the specific deterrence effects of HPV listing as targeting enforcement. Interestingly, the positive effect of HPV targeting diminishes as inspections further rise. The direct effect of inspections on a facility itself is significant and positive. In particular, an extra of ten inspections over the course of a year results in about 2.3% increase in the compliance rate. Nevertheless, this effect is smaller on HPV facilities as the coefficient of the interaction between *Inspection* and a dummy variable indicating the facility's HPV status (*HPV Dummy*) is negative and significant. Fines imposed on a facility itself do not show any significant effects. One possible explanation for this insignificant effect is that perhaps a violating facility has already adjusted its compliance behavior when it is inspected and violation is discovered. Thus when fines are assessed at a later time, the facility makes no further adjustment in its compliance behavior.

Model (1) show that general enforcement on other facilities in the same state has a positive but insignificant impact whereas Model (2) confirms the general deterrence effects of enforcement on other HPV facilities in the same state. In particular, the positive and significant coefficient on *Fines on other HPV facilities* in Model (2) suggests that a higher amount of penalties on other facilities in the same state induces higher compliance rate for a given facility. However, increased enforcement on other non-HPVs (either raising penalty or inspections) does not have a significant impact. Note that the general deterrence effects only appear in Model (2) where fines are further disaggregated based on facility HPV status. More importantly, only the enforcement on other HPVs has a significant influence on a firm's compliance behavior, implying that the general deterrence effects primarily come from fines imposed on other HPVs. The general deterrence effects of inspections, though, are not significant in either model. The findings regarding the general deterrence effects suggest that enforcement actions taken against HPV facilities may be more visible to others in the same states. Also, while there are various forms of inspections, sanctions on an HPV facility can send the strongest signal to other facilities about the intension and determination of the regulator to deter and sanction serious violations.

Overall, we find that HPV targeting helps increase the overall compliance no matter whether the target is the facility itself or other HPV facilities in the same state. This suggests that there are significant specific as well as general deterrence effects of HPV targeting. It is worth noting that the specific deterrence effect of HPV targeting diminishes for a given HPV facility as the number of inspections on the facility itself further rises,

4.1.2 Differential specific and general deterrence effect—efficiency of HPV targeting

Models (3) and (4) in Table 3 assess the efficiency of HPV targeting. In addition to the variables included in Models (1) and (2), Models (3) and (4) also includes the interaction terms between the average general enforcement measures and a dummy indicating the facility's HPV status.

The differential specific effects are represented by the interactions between the specific enforcement variables (enforcement on the facility itself) and *HPV dummy*. Consistent with results shown in Models (1) and (2), the interaction between *Inspection* and *HPV dummy* is negative and significant in Models (3) and (4).On the margin, an extra inspection imposed on an HPV facility results in less improvement in compliance rate than an extra inspection on a non-HPV facility. Taking into account the significant and positive coefficient of *Inspection*, we can infer that although inspections on a facility help improve compliance, such effects weaken when the additional inspection is allocated to an HPV facility. Thus, there are differential responses to enforcement between HPV and non-HPV facilities, with the non-HPVs being more responsive to inspections on themselves. Since there are already intensive inspections on the HPVs, it is probable that the effects of an additional inspection can only provide very limited incentive for the HPV to further improve its compliance, especially when the facility faces certain constraints such as high abatement costs. However, a non-HPV facility is less frequently inspected; thus, an additional inspection in a given year can give the facility substantial incentive to correct violations, if any.

The general deterrence effects become stronger and more significant in the last two models that include interactions between *HPV dummy* and general deterrence variables compared to Models (1) and (2). Further, the results show a similar pattern in terms of the differential enforcement responses. Compared to Model (1), both average general enforcement measures on other facilities in Model (3) become significant with a greater magnitude. The coefficients on the interactions between *HPV Dummy* and average inspections and penalties on all other facilities are negative and significant, indicating that the general deterrence effects of enforcement differ between HPV and non-HPV facilities, with HPV facilities being less responsive. When the general deterrence effects are further disaggregated based on the HPV status of other facilities in Model (4), significant general deterrence effects are found for fines on other HPV facilities and on other non-HPVs. However, the coefficients on the interactions between *HPV dummy* and *Fines on other HPV Facilities* as well as the interactions between *HPV Dummy* and *Fines on other non-HPVs* are both negative and significant. In summary, even though enforcement on other HPVs results in positive effects on both HPV and non-HPV facilities, such effects differ between the two groups of facilities. The increase in compliance resulting from the general enforcement on other HPVs is much higher for non-HPV facilities than the targeted HPV facilities.

The findings of the differential specific and general enforcement responses suggest that while inspections and fines can deter violations in general; more deterrence effects come from the non-targeted/non-HPV facilities than the targeted/HPV facilities. Although enforcement on targeted HPVs plays an important role in deterring violations in general, the efficiency of such targeting is undermined by the less responsiveness of the targeted group. While it may be costly for the regulator to maintain high level of enforcement on HPV facilities, such facilities are not as responsive to enforcement as non-HPV facilities.

The inefficiency of the HPV targeting may be due to two potential reasons. First, the abatement costs for certain targeted group, HPV facilities, may be prohibitively high so that the facilities cannot further reduce their emissions even facing high inspection probability and sanctions. Second, in 2009, EPA issued an evaluation report of the operations of the HPV Policy (EPA, 2009). The report is based on evaluations of HPV cases in selected EPA regions between October 1, 2005 and December 31, 2007. It is reported that the State and EPA regional offices did not fully follow the HPV policy, and about 30%-46% of the HPV cases are not addressed 270 days after the confirmation of the HPV. This can also contribute to the inefficiency of the HPV policy.

4.1.3 Other control variables

County characteristics also play a role in determining the facility's compliance behavior, although very limited. Facilities located in counties with more manufacturing firm establishments in the previous year tend to have a higher compliance rate. However, other variables do not have any significant effects.

All lagged dependent variables are statistically significant, as shown in Table 3. This indicates that a facility's compliance rate depends on its own compliance history, implying dynamic adjustments in firms' compliance behavior. Thus, it is important to include the lagged dependent variables to control for pre-existing conditions as well as to mitigate the endogeneity problem due to possible unobservable factors influencing the compliance behavior.

4.2 Alternative Specifications and Robustness Checks

To verify the consistency of the findings from our baseline models, we conduct robustness checks using two variations of Model 4 since it provides more details.

In our baseline model, we include the general deterrence enforcement as the average number of inspections and average amount of fines. An alternative way to examine the general deterrence effects is to consider the aggregate measures. This allows us to explore the collective enforcement effects of all other HPV or non-HPV facilities in the same state. Thus, we include the general enforcement measures as the total number of inspections and total amount of fines on other HPV and non-HPV facilities in the same state. As a second robustness check, we take into consideration the persistency of facility compliance behavior and include one-year and two-year lags of all enforcement variables.

The results are reported in Table 4. Column 2 shows the results from the model using aggregate general enforcement variables whereas Column 3 reports the ones from the specification including two lags of all enforcement variables. In general, the results in Column 2 are similar to our baseline model estimations. HPV targeting is effective but not fully efficient. When using total enforcement measures, we find that HPV listing and inspections on a facility have positive and significant impacts on facility compliance although the effect of HPV listing diminishes as inspections further rise, consistent with the specific deterrence effects examined earlier. In addition, inspections and fines imposed on all other HPV facilities in the same state have general deterrence effects on all facilities, regardless of their HPV status. As previously noted, HPV facilities are less responsive to inspections on itself and enforcement on other HPV facilities in the same states. Non-HPV facilities consistently show greater responses to penalties on all other non-HPV facilities in the same state, supporting the relative efficiency argument discussed before.

The specification with two lags of enforcement variables in Column 3 also illustrates a similar picture. Both one- and two- year lags of HPV status and inspections have positive and significant impacts on compliance. Thus HPV targeting is effective in reducing noncompliance. General deterrence effects on compliance are significant for fines on HPV facilities lagged one year; such effects fade two years later. In addition, both the specific and general enforcement result in greater improvement in compliance for non-HPV facilities than for HPV facilities.

In the two model specifications in Table 4, certain interactions terms between the HPV dummy variable and the general deterrence variables are significant but the general deterrence variables themselves are insignificant. For example, the interaction between HPV dummy and fines on other non-HPVs lagged one period is significant and negative in Column 3 but the coefficient on fines on other non-HPVs is insignificant. This suggests that the direct effect of general enforcement on other non-HPVs is insignificant for all facilities on average, but differential effects still exist between HPVs and non-HPV facilities.

5 Conclusions

This paper explores the effectiveness and efficiency of targeting enforcement with a focus on HPV targeting. Under the HPV Policy, facilities regulated under CAA are targeted with intensive inspections and enforcement actions if their violations are found to be important and serious. Nevertheless, little is known about the effectiveness and efficiency of this policy. In addition, no studies explore the externalities associated with this policy and how the externalities differ across types of facilities. This paper helps fill the void in the literature.

Using panel data on major manufacturing facilities nationwide during the period 2001-2010, we estimate dynamic panel data models that control for both the potential endogeniety of enforcement and the persistence of compliance status. Our results suggest that a facility's HPV status has a positive and significant impact on its compliance behavior (referred to as specific deterrence effect). On average, a four-month increase in the HPV listing time in the previous year results in about one more month of compliance in the current year although the effect diminishes as the number of inspections further rises. We also find general deterrence effects of HPV targeting such that a typical facility, regardless of its HPV status, increases its compliance rate when fines imposed on other HPV facilities within the same state increase. However, both the specific and general deterrence effects of enforcement differ by HPV status: the HPV facilities are less responsive to additional specific or general enforcement actions. Thus the efficiency of HPV targeting is undermined. Potential reasons for the inefficiency include high abatement costs for HPV facilities and the inadequate addressing of the High Priority Violators by the regulators. The findings have important policy implications regarding environmental enforcement. Our results are robust across various alternative specifications.

REFERENCES

Alberini, A., and D. Austin. 1999. "Strict Liability as a Deterrent in Toxic Waste Management." *Journal of Environmental Economics and Management* 38, 20-48.

Deily, M., and W. Gray. 2007. "Agency Structure and Firm Culture: OSHA, EPA, and the Steel Industry." *Journal of Law, Economics, and Organization* 23, 685-709.

Earnhart, D. 2004. "The Effects of Community Characteristics on Polluter Compliance Levels." *Land Economics* 80, 208-432.

Earnhart, D. 2009. "The Influence of Facility Characteristics and Permit Conditions on the Effectiveness of Environmental Regulatory Deterrence." *Journal of Regulatory Economics* 36, 247–73.

Eckert, H. 2004. "Inspections, Warnings, and Compliance: The Case of Petroleum Storage Regulation." *Journal of Environmental Economics and Management* 47, 232-259.

Environmental Protection Agency (EPA). 1999. The Timely and Appropriate (T&A) Enforcement Response to High Priority Violations (HPVs), June 23, 1999.

Friesen, L. 2003. "Targeting Enforcement to Improve Compliance with Environmental Regulations." *Journal of Environmental Economics and Management* 46, 72-85.

Gray, W., and M. Deily. 1996. "Compliance and Enforcement: Air Pollution Regulation in the American Steel Industry." *Journal of Environmental Economics and Management* 31, 96-111.

Gray, W., and J. Shimshack. 2011. "The Effectiveness of Environmental Monitoring and Enforcement: A review of the Empirical Evidence." *Review Environmental Economics and Policy* 5(1), 2-24.

Gray, W., and R. Shadbegian. 2005. "When and Why do Plants Comply? Paper Mills in the 1980s." *Law and Policy* 27, 238–61.

Gilpatric, S.M., C.A. Vossler, and M. McKee. 2011. "Regulatory Enforcement with Competitive Endogenous Audit Mechanisms" *The RAND Journal of Economics* 42, 292-312.

Hanna, R. and P. Oliva. 2010. "The Impact of Inspections on Plant-Level Air Emissions." *The B.E. Journal of Economic Analysis & Policy* 10 (1), Article 19.

Harford, J. 1991. "Measurement Error and State-dependent pollution control enforcement" *Journal of Environmental Economics and Management*, 21, 67-81.

Harford, J.D., and W. Harrington. 1991. "A Reconsideration of Enforcement Leverage when Penalties are Restricted." *Journal of Public Economics* 45, 391-395.

Harrington, W. 1988. "Enforcement Leverage when Penalties are Restricted." *Journal of Public Economics* 37, 29-53.

Helland, E. 1998. “The Enforcement of Pollution Control Laws: Inspections, Violations, and Self-reporting.” *The Review of Economics and Statistics* 80(1), 141-153.

Laplante, B. and P. Rilstone. 1996. “Environmental Inspections and Emissions of the Pulp and Paper Industry in Quebec.” *Journal of Environmental Economics and Management* 31, 16-36.

Liu, L, Neilson, S.W. 2013. “Enforcement leverage with Fixed Inspection Capacity.” *Strategic Behavior and the Environment* 3(4), 305-328.

Raymond, M. 1999. “Enforcement Leverage when Penalties are Restricted: a Reconsideration under Asymmetric Information.” *Journal of Public Economics* 73, 289-295.

Russell, C. 1990. “Game Models for Structuring Monitoring and Enforcement Systems.” *Natural Resource Modeling*, 4, 143-173.

Rousseau, S. 2007. “Timing of Environmental Inspections: Survival of the Compliant.” *Journal of Regulatory Economics* 32, 17-36.

Shimshack, J. P. and M. B. Ward. 2005. “Regulator Reputation, Enforcement, and Environmental Compliance.” *Journal of Environmental Economics and Management* 50, 519–540.

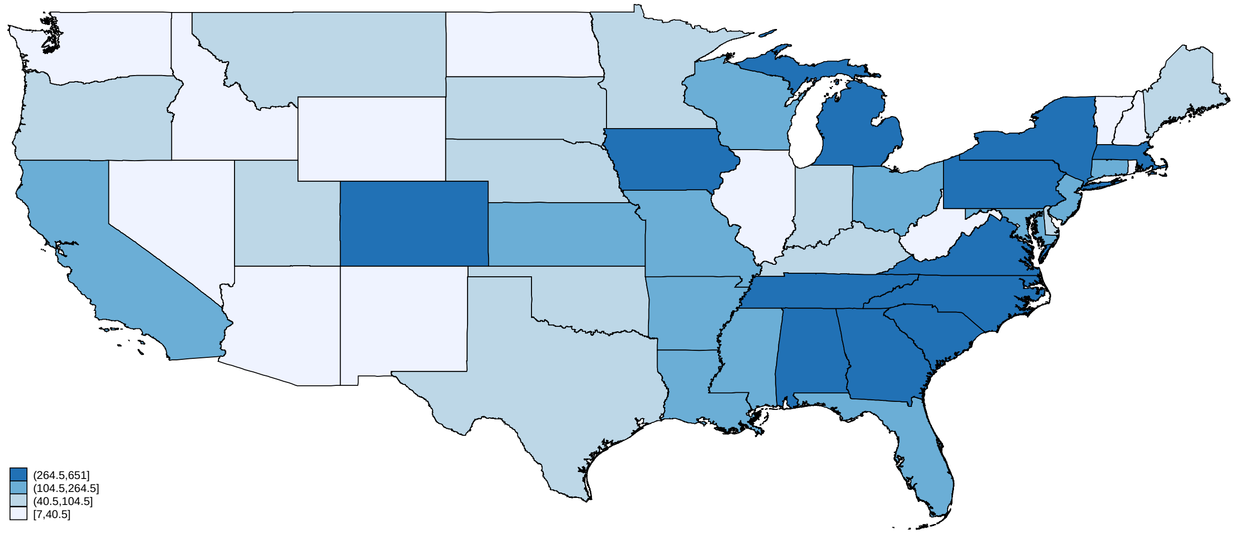
Shimshack, J. P. and M. B. Ward. 2008. “Enforcement and Over-Compliance.” *Journal of Environmental Economics and Management* 55 (1), 90–105.

Stafford, S.L. 2002. “The Effect of Punishment on Firm Compliance with Hazardous Waste Regulations.” *Journal of Environmental Economics and Management* 44, 290-308.

Stafford, S.L. 2008. “Self-policing in a Targeted Enforcement Regime.” *Southern Economics Journal* 74, 934-951.

Telle, K. 2013 “Monitoring and Enforcement of Environmental Regulations. Lessons from a Natural Field Experiment in Norway” *Journal of Public Economics*. Doi:

Figure 1.

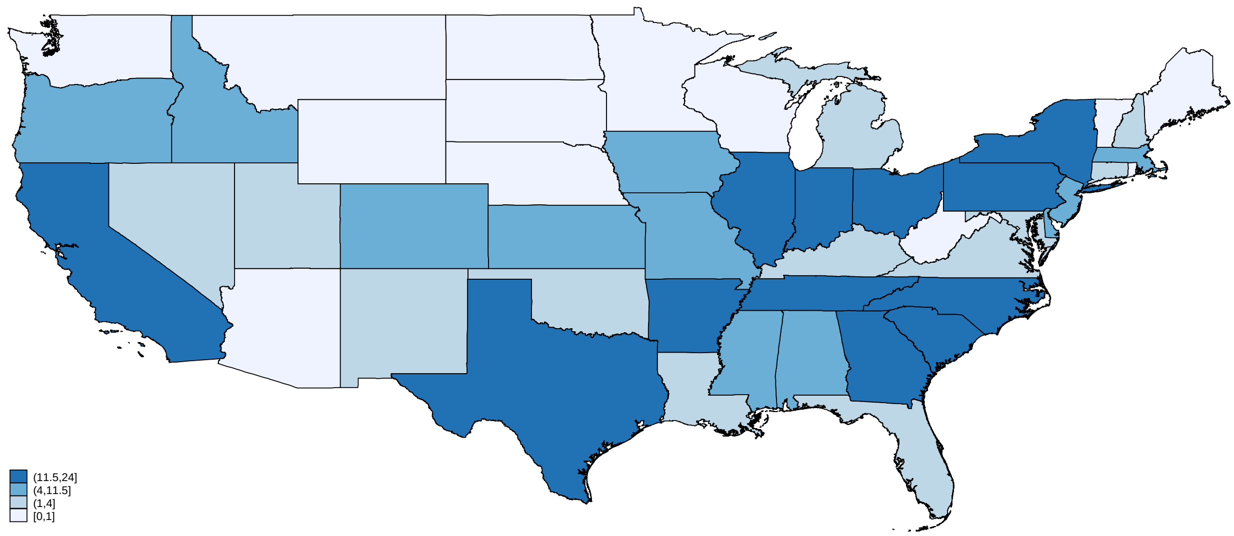


Distribution of facilities across states

Note: D.C., Puerto Rico, Alaska, and Virginal Island are not included.

Figure 2.

HPV facilities in 2001



HPV facilities in 2010

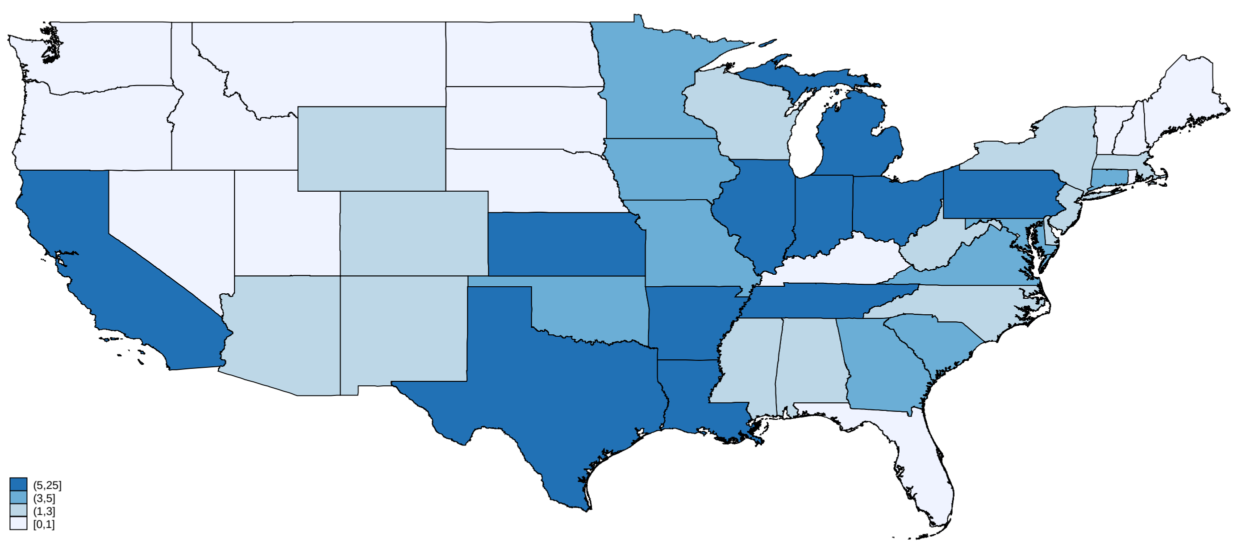


Table 1.

Enforcement Actions on HPV Facilities and Non-HPV Facilities

Enforcement Actions	All Facilities in Sample		Non-HPV Facilities	
	HPV Facilities	Non-HPV Facilities	With Violations	Without Violations
Inspection in same year	3.81	0.87	1.59	0.79
Fines in same year, in millions of dollars	41.31	0.43	1.98	0.25
Inspection in the following year	3.87	0.9	1.52	0.83
Fines in the following year, in millions of dollars	32.60	0.43	2.09	0.24

Note: fines and its corresponding violations may not occur in the same year because it usually takes time for the regulator to assess the fines, issue administration orders or judicial orders. Thus the average fined for facilities with violations are greater than zero.

Table 2.

Variable descriptions and summary of statistics

Variables	Description	Mean	Standard Deviation
Compliance	Percentage of time a facility is in compliance in a given year	91.66	25.73
HPV	Percentage of time a facility is listed as an High Priority Violator in a given year	3.48	16.74
Inspection	Total number of inspections in a given year	0.97	2.7
Fines	Total amount of fines in a given year, in millions of dollars	1.85	79.06
Inspection on others	Average number of inspections on other facilities within the same state	0.97	0.89
Fines on others	Average fines on other facilities within the same state, in millions of dollars	1.85	7.69
Inspection on other HPVs	Average number of inspections on other HPV facilities within the same state	3.13	3.36
Inspection on other non-HPVs	Average number of inspections on other non-HPV facilities within the same state	0.87	0.63
Fines on other HPVs	Average amount of fines on other HPV facilities within the same state, in millions of dollars	47.51	241.11
Fines on other non-HPVs	Average amount of fines on other non-HPV facilities within the same state, in millions of dollars	0.46	3.29
Race	Percentage of white population at the county level	82.3	15.48
Income	Annual income per capita at the county level, adjusted by CPI, log of thousands of dollars	10.37	0.24
Education	Percentage of population with high school diploma and above at the county level	85.61	4.21
Rate	Unemployment rate at the county level	6.07	2.42
Population Density	Number of persons per square mile at the county level	1,061.11	4,726.28
Establishment	Total number of firm establishment in manufacturing industry at the county level	199.68	578.17
Employment	Total employment in manufacturing facilities at the county level	7,347.94	20,758.42

Table 3.

Baseline results

Variables	(1)	(2)	(3)	(4)
L. Compliance rate	0.868***	0.868***	0.871***	0.872***
	(0.0209)	(0.0208)	(0.0210)	(0.0210)
L2.Compliance rate	-0.110***	-0.110***	-0.110***	-0.109***
	(0.0121)	(0.0121)	(0.0121)	(0.0121)
L3. Compliance rate	0.0410***	0.0410***	0.0414***	0.0417***
	(0.00922)	(0.00923)	(0.00925)	(0.00926)
L. HPV	0.241***	0.241***	0.257***	0.255***
	(0.0201)	(0.0201)	(0.0221)	(0.0235)
L. Inspection	0.229***	0.229***	0.192***	0.200***
	(0.0732)	(0.0731)	(0.0727)	(0.0724)
L. Fines	0.00757	0.00760	0.00670	0.00689
	(0.0115)	(0.0115)	(0.0115)	(0.0114)
L. HPV dummy*	-0.246***	-0.246***	-0.167**	-0.177**
L. Inspection	(0.0849)	(0.0849)	(0.0826)	(0.0828)
L. HPV dummy*	-0.00727	-0.00729	-0.00631	-0.00656
L. Fines	(0.0115)	(0.0115)	(0.0115)	(0.0114)
L. Inspection on others	0.0247		0.318*	
	(0.150)		(0.184)	
L. Fines on others	0.00237		0.0301***	
	(0.00683)		(0.00882)	
L. Inspection on other HPVs		0.00864		0.0277
		(0.0507)		(0.0507)
L. Fines on other HPVs		0.000241**		0.000303***
		(0.000115)		(0.000113)
L. Inspection on other non-HPVs		0.00202		0.0914
		(0.277)		(0.306)
L. Fines on other non-HPVs		-0.00844		0.0248*
		(0.00816)		(0.0133)
L. HPV dummy*			-1.066**	
L. Inspection on others			(0.416)	
L. HPV dummy*			-0.0806***	
L. Fines on others			(0.0167)	
L. HPV dummy*				-0.253
L. Inspection on other HPVs				(0.213)
L. HPV dummy*				-0.00448**
L. Fines on other HPVs				(0.00209)
L. HPV dummy*				-0.371
L. Inspection on other non-HPVs				(1.375)
L. HPV dummy*				-0.0507***
L. Fines on other non-HPVs				(0.0190)

Table 3. Cont.

Baseline results

Variables	(1)	(2)	(3)	(4)
Race	-0.0605	-0.0581	-0.0521	-0.0564
	(0.1000)	(0.1000)	(0.1000)	(0.1000)
Income per capita	1.298	1.305	1.255	1.327
	(0.896)	(0.895)	(0.897)	(0.897)
Education	-0.0149	-0.0110	-0.00919	-0.00921
	(0.0444)	(0.0448)	(0.0445)	(0.0449)
Unemployment rate	-0.159	-0.160	-0.163	-0.162
	(0.103)	(0.104)	(0.103)	(0.104)
Population density	-0.00172	-0.00171	-0.00166	-0.00170
	(0.00112)	(0.00112)	(0.00113)	(0.00112)
Manufacturing firm establishments	0.00352	0.00354	0.00360*	0.00351
	(0.00218)	(0.00218)	(0.00217)	(0.00218)
Manufacturing employment	6.48e-06	6.48e-06	6.78e-06	7.34e-06
	(4.66e-05)	(4.67e-05)	(4.64e-05)	(4.67e-05)
Observations	52,416	52,416	52,416	52,416
Facility fixed effects	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Sargan test (p-value)	0.99	0.99	0.99	0.99
Arellano-Bond autocorrelation test AR(2) (p-value)	0.5519	0.5538	0.5161	0.5165

Notes: Robust standard errors are reported in parentheses; ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 4.
Results from robustness checks

Variables	Aggregate Measures	Lagged One and Two Periods
L. Compliance rate	0.880***	0.883***
	(0.0213)	(0.0217)
L2.Compliance rate	-0.111***	-0.0943***
	(0.0122)	(0.0126)
L3. Compliance rate	0.0432***	0.0383***
	(0.00931)	(0.00938)
L. HPV	0.256***	0.259***
	(0.0230)	(0.0232)
L. Inspection	0.199***	0.290***
	(0.0713)	(0.0700)
L. Fines	0.00702	0.00532
	(0.0115)	(0.0111)
L. HPV dummy* L. Inspection	-0.188**	-0.271***
	(0.0818)	(0.0832)
L. HPV dummy* L. Fines	-0.00653	-0.00500
	(0.0115)	(0.0111)
L. Inspections on other HPVs	0.00824**	0.0371
	(0.00392)	(0.0509)
L. Fines on other HPVs	4.83e-05**	2.19e-07*
	(2.42e-05)	(1.13e-07)
L. Inspection on other non-HPVs	3.96e-05	0.0628
	(0.000957)	(0.315)
L. Fines on other non-HPVs	0.00149***	2.01e-05
	-0.00046	(1.98e-05)
L. HPV dummy* L. Inspection on other HPVs	-0.0305*** (0.00634)	-0.305 (0.214)
L. HPV dummy* L. Fines on other HPVs	-0.00108** (0.000423)	-1.54e-06 (2.83e-06)
L. HPV dummy* L. Inspection on other non-HPVs	0.00867*** (0.00319)	0.488 (1.383)
L. HPV dummy* L. Fines on other non-HPVs	-0.0143*** (0.00303)	-7.68e-05** (3.01e-05)

Table 4. Cont. Results from robustness checks

Variables	Aggregate Measures	Lagged One and Two Periods
L2. HPV		0.0551***
		(0.0168)
L2. Inspection		0.186**
		(0.0756)
L2. Fines		-0.00169
		(0.00231)
L2. HPV dummy* L2. Inspection		-0.210**
		(0.0855)
L2. HPV dummy* L2. Fines		0.00186
		(0.00235)
L2. Inspections on other HPVs		0.000576
		(0.0538)
L2. Fines on other HPVs		-1.62e-07
		(1.77e-07)
L2. Inspection on other non-HPVs		-0.377
		(0.368)
L2. Fines on other non-HPVs		-1.26e-05
		(3.16e-05)
L2. HPV dummy*		-0.0225
L2. Inspection on other HPVs		(0.224)
L2. HPV dummy*		6.21e-06
L2. Fines on other HPVs		(3.89e-06)
L2. HPV dummy*		1.575
L2. Inspection on other non-HPVs		(1.202)
L2. HPV dummy*		-5.02e-05
L2. Fines on other non-HPVs		(3.92e-05)
Race	-0.0528	-0.0568
	(0.101)	(0.101)
Income per capita	1.264	1,375
	(0.897)	(911.2)
Education	-0.0127	-0.0120
	(0.0449)	(0.0451)
Unemployment rate	-0.140	-0.164
	(0.104)	(0.105)
Population density	-0.00166	-0.00174
	(0.00114)	(0.00115)

Table 4. Cont. Results from robustness checks

Variables	Aggregate Measures	Lagged One and Two Periods
Manufacturing firm establishments	0.00352 (0.00216)	0.00342 (0.00223)
Manufacturing employment	8.42e-06 0.00352	1.21e-05 0.00342
Observations	52,416	52,416
Facility fixed effects	YES	YES
Year fixed effects	YES	YES
Sargan test (p-value)	0.99	0.99
Arellano-Bond autocorrelation test AR(2) (p-value)	0.5458	0.3154

Notes: Robust standard errors are reported in parentheses; ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Appendix A. HPV Identification Criteria

Meeting one or more of these criteria means a violation is an HPV. [Source: The Timely and Appropriate (T&A) Enforcement Response to High Priority Violations (HPVs), EPA, 1999]

A.1 General HPV Criteria

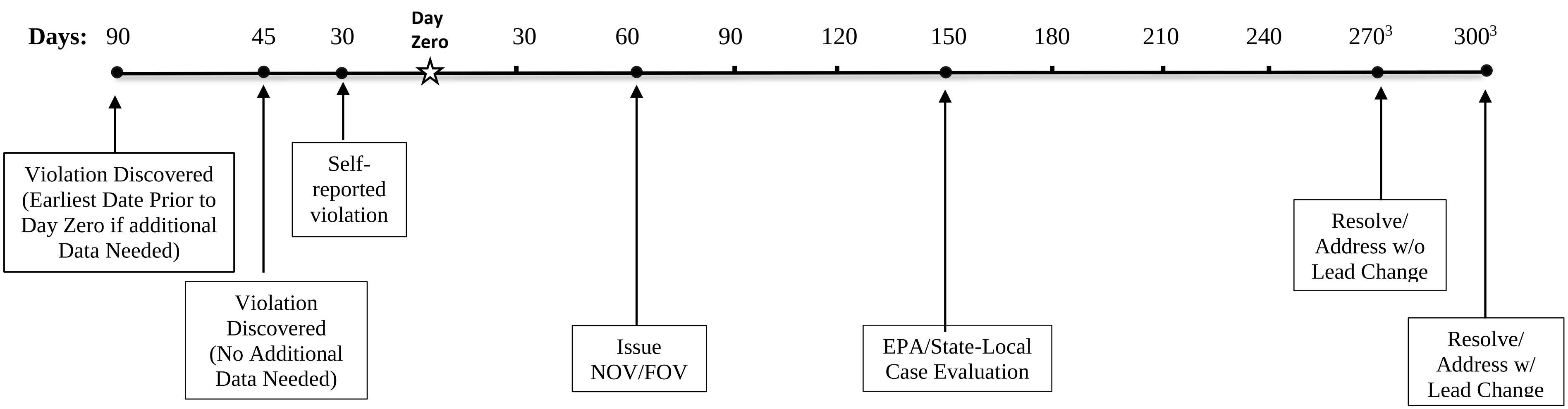
1. Failure to obtain a PSD permit, an NSR permit and/or a permit for a major modification of either
2. Violation of an air toxics requirement that either results in excess emissions or violates operating parameter restrictions
3. Violation by a synthetic minor of an emission limit or permit condition that affects the source's PSD, NSR or Title V status
4. Violation of any substantive term of any local, state or federal order, consent decree or administrative order
5. Failure to submit a certification
6. Failure to submit a permit application within sixty (60) days of the applicable deadline
7. Violations that involve testing, monitoring, record keeping or reporting that substantially interfere with enforcement or determining the source's compliance with applicable emission limits
8. A violation of an allowable emission limit detected during a reference method stack test
9. Clean Air Act (CAA) violations by chronic or recalcitrant violators
10. Substantial violation of Clean Air Act Section 112(r) requirements

A.2 Five Matrix Criteria

1. Violation of allowable emissions limitation, detected by stack testing
2. Violation of applicable emissions limitation, detected by coatings analysis, fuel samples, other process materials sampling, or raw/process materials usage reports
3. Violation of parameter limits where parameter is a direct surrogate for an emissions limitation, detected by continuous/periodic parameter monitoring
4. Exceedance of applicable non-opacity standard, detected by CEMS
5. Exceedance of applicable opacity standard (detected by COMS or by VE)

Appendix

Timely and Appropriate Enforcement Timeline [1, 2]



[1] A regularly scheduled State-Local/EPA conference call should be held at least monthly.

[2] The timeline applies to the agency (EPA or the State-Local) initiating the action. Parallel actions and lead changes may occur at any time.

[3] Timeline may be extended in a complex case. Also, followup may be necessary to complete the case or to monitor compliance schedule.

Figure. 1. HPV enforcement timeline.

Source: The Timely and Appropriate (T&A) Enforcement Response to High Priority Violations (HPVs), EPA, 1999.