Economics Bulletin

Volume 33, Issue 3

Analysis of Firm Compliance with Multiple Environmental regulations

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Abstract

When a firm is regulated by multiple environmental programs, the firm may manage its compliance with these programs systematically so that the regulation of one program can affect firm decisions regarding compliance with other programs. Faced with budget constraints on compliance expenditure, a firm is likely to reduce its compliance with one program when certain incentives to comply better with another program arises. Such incentives can include more frequent inspection or higher penalties under another program. This paper examines the existence of such negative spillover effects across programs. A fixed effects model is estimated using data on facilities regulated under CAA (Clean Air Act) and RCRA (Reservation and Conservation Recovery Act). Results confirm negative spillover effects. Increases in RCRA penalties as well increases in RCRA inspections on other facilities result in facilities complying less with CAA regulations.

The author would like to thank the College of Business Administration in Sam Houston State University for the financial support through the Summer Faculty Research Grant.
Citation: Lirong Liu, (2013) "Analysis of Firm Compliance with Multiple Environmental regulations", *Economics Bulletin*, Vol. 33 No. 3 pp. 1695-1705.
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Submitted: January 16, 2013. **Published:** July 11, 2013.

1. Introduction

When a firm is regulated by multiple environmental programs, the firm may manage its compliance with these programs systematically so that regulation of one program can affect firm decisions regarding compliance with other programs. Faced with budget constraints on compliance expenditure, a firm is likely have to reduce its compliance with one program when certain incentives to comply better with another program arises. The incentives include more frequent inspection or higher penalties under another program. Such relationships reflect the spillover effects across environmental programs. This paper examines the existence of such spillover effects by asking whether monitoring and enforcement actions taken under one program negatively affect firm compliance with other programs.

The study of spillover effects across environmental programs can reveal important policy implications. When regulations are not independent, optimal monitoring and enforcement strategies require coordination between the multiple programs. Consider the situation where an increase in a firm's abatement level under program A increases its marginal abatement cost under program B. As a result of the increase, the firm's optimal abatement level (and hence its compliance under program B) decreases, although the monitoring and enforcement parameters under that program remain unchanged. This substitution within regulations means certain emissions are crowded out from one program to the other. That is, a firm reduces its emissions under program A, but emits more under program B due to the increased marginal abatement costs under program B. From a society's perspective, substituting programs result in increased total abatement costs and higher social optimal level of emissions. Therefore coordination among regulators is required to achieve the social optimum.

To date, the majority of the empirical literature on the effectiveness of environmental monitoring and enforcement has focused on single medium program. Grey and Shimshack (2011) provide the most recent literature review on this topic. In their review, the spillover effects are defined as the impact of regulatory actions aimed at one facility on the environmental performance of other facilities. Such spillover effects are found in Shimshack and Ward (2005), Gray and Shadbegian (2007), and Decker and Pope (2005). The spillover effects discussed in this paper refer to the effects of regulatory actions under one program on facility compliance with other programs. The only paper that discusses such spillover effects is Liu (2012), which investigates the effects of Clean Air Act (CAA) enforcement on compliance with Reservation and Conservation Recovery Act (RCRA) for facilities in Michigan and finds positive spillover effects.[1]

Literature on monitoring and enforcement focusing on single environmental program can also be suggestive. For example, Botre et al. (2007) show that technological innovation in automotive catalytic converters results in lower nitrogen oxides but increased ozone. Sigman (1996) and Gamper-Rabindran (2006) find that changes in regulations can lead firms to transfer pollutants from a regulated medium such as air to a different medium such as landfill or water. Alberini (2001) also addresses substitution, but from a different perspective. She examines the relationship between underground and aboveground storage tanks for petroleum

[1] This paper differs from Liu (2012) in the several aspects. First, instead of focusing on one state, facilities in all states across the nation are considered. The results from the study of facilities in one state cannot be readily extended to facilities in other states and analysis of a national sample can provide a more comprehensive view. Second, Liu (2012) focuses on the effects of CAA regulations on RCRA compliance. In comparison, this study examines the effects of RCRA regulations on CAA compliance. Third, the panel data model selected for this study explicitly controls for potential heteroscedasticity and auto-correlation, which are not considered in Liu (2012).

products and hazardous substances due to extensive regulations on underground storage. She finds substitution between underground and aboveground storage tanks following the regulatory changes. These studies suggest substitution-inducing regulations (or negative spillover effects), but do not explicitly consider regulatory programs simultaneously. Theoretically when a firm faces additional compliance requirement either induced by tougher enforcement or changes in the regulation itself, the firm is more likely to reduce its compliance with other programs due to constraints on compliance budget.

Complementary regulations are also possible. Intensive monitoring and enforcement under one program may also induce firms to adopt cleaner inputs for production or upgrade manufacturing processes in ways that reduce emissions in general. Thus, actions taken to reduce emissions under one program may have positive spillover effects.

Given that the spillover effects, if exist, can be either positive or negative, this paper employs empirical analysis to determine the nature of such effects. This empirical work focuses estimating the impacts of monitoring and enforcement under both RCRA and CAA on facility compliance with CAA. Negative spillover effects are found across programs. Increasing RCRA penalty or RCRA inspections on other facilities leads to less compliance with CAA. Thus there is a substituting relationship between the two programs.

The rest of the paper is organized as follows. Section II discusses the data and the empirical model. Results and interpretations are presented in Section III and Section IV concludes.

2. Data and Econometric model

2.1 Data

Facility compliance data are obtained from the Environmental Protection Agency's (EPA) Enforcement and Compliance History Online (ECHO) database. The ECHO database tracks the compliance, inspection and enforcement histories of all EPA-regulated facilities.

Under CAA program, facilities are required to self-report their emissions. CAA compliance data are available on a monthly basis at the source level. Self-reported data are widely used in empirical studies of monitoring and enforcement (see Laplante and Rilstone, 1996; Earnhart, 2004a; Shimshack and Ward, 2005).The use of self-reported data may raise the question of strategic misreporting. Some of the literature uses self-reported data directly without addressing potential issues. 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 (Shimshack and Ward, 2005). In addition, as stated in Shimshack and Ward (2005), sanctions on intentional misreporting range from criminal fines to jail time. Thus, the self-reported data are used in this study with cautions.

According to Earnhart (2004a), community characteristics may also play important roles in facility emissions and compliance decisions. Therefore, community characteristics are obtained to control for potential influence of community pressures on facility compliance. The major data sources for these characteristics include the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, and the U. S. Census Bureau. The control variables include real annual income per capita, unemployment rate, college graduate rate, minority rate, and population density at the county level. For counties without detailed statistics, the corresponding state level statistics are used instead.

In selecting facilities to be included in the analysis the following criteria are used. First, the facilities must be regulated under both CAA and RCRA since the purpose of this study is to investigate the effects of RCRA regulation on CAA compliance. Second, the facilities should be federally reportable since enforcement and compliance data on such facilities are more reliable. [2] Third, government facilities are excluded from the sample since their compliance behavior and enforcement history can be systematically different from non-government facilities. Overall, a total of 5,849 facilities are included in the analysis; the time frame for the sample is 2001-2010.[3, 4] The distribution of facilities across the nation is summarized in Table 1. Among all the states considered in the sample, Pennsylvania has the highest number of facilities (about 11% of the 5,849 facilities) while Vermont has the lowest number with about 9 facilities.

Table 1
Distribution of facilities across states

State	Count	Percentage	State	Count	Percentage
Alabama	276	4.71	Montana	22	0.38
Arizona	21	0.36	Nebraska	57	0.97
Arkansas	36	0.61	Nevada	20	0.34
California	302	5.15	New Hampshire	28	0.48
Colorado	43	0.73	New Jersey	65	1.11
Connecticut	41	0.70	New Mexico	19	0.32
Delaware	49	0.84	New York	242	4.13
District of Columbia	19	0.32	North Carolina	362	6.18
Florida	179	3.05	North Dakota	17	0.29
Georgia	230	3.92	Ohio	127	2.17
Idaho	16	0.27	Oklahoma	113	1.93
Illinois	152	2.59	Oregon	85	1.45
Indiana	256	4.37	Pennsylvania	645	11.00
Iowa	142	2.42	Rhode Island	16	0.27
Kansas	125	2.13	South Carolina	209	3.57
Kentucky	74	1.26	South Dakota	23	0.39
Louisiana	162	2.76	Tennessee	288	4.91
Maine	31	0.53	Utah	38	0.65
Maryland	78	1.33	Vermont	9	0.15
Massachusetts	209	3.57	Virginia	435	7.42
Michigan	112	1.91	Washington	101	1.72

[2] According to 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)”
[3] Due to the lack of complete CAA compliance records, 19,900 facilities in the ECHO downloadable dataset are excluded from the analysis, although they satisfied the selection criteria stated above.
[4] Compliance records in April 2002 are missing for about 90% of the facilities that satisfy the selection criteria. Instead of excluding those facilities, it is assumed that their compliance status in April remained the same as in March 2002. Changing this assumption did not significantly affect the results.

Minnesota	64	1.09	West Virginia	74	1.26
Mississippi	44	0.75	Wisconsin	63	1.07
Missouri	116	1.98	Wyoming	26	0.44

*Hawaii, Puerto Rico, Alaska, and Virginal Island are not included.

Variable descriptions and summary statistics are provided in Table 2. The first variable, *CAA compliance*, is the number of months that facilities are in compliance in a given year. Overall, the facilities are in compliance for 10.61 months on average. About 54.3% of the facilities are in compliance throughout the ten years while 24.6% of them are never in compliance over the same period. The set of variables from *CAA inspection to RCRA penalty* are inspections and penalties under the two programs in the previous year. The average annual CAA penalty lagged one year is $6400, while the average annual RCRA penalty lagged one year is $540. The penalties variables are included with natural log transformation. The average number of annual CAA inspections lagged one year is 0.79; one particular facility was inspected 28 times in a certain year. The number of annual RCRA inspections lagged one year is just 0.33, but the maximum number of inspections is as high as 71 in a certain year for one particular facility. The average number of annual CAA inspections of facilities other than the given facility in the same state is .78, which is similar to the average number of inspections on the given facility.

Table 2

Variable Description and Summary of Statistics

Variables	Description	Mean (Standard deviation)	Min, Max
CAA compliance	Number of months in a given year that facilities are in compliance	10.67 (3.42)	0, 12
CAA inspection	Annual number of CAA inspections, lagged one year	.79 (.75)	0, 28
CAA penalty	Annual amount of CAA penalty in $1000, lagged one year	6.4 (152)	0, 1.65e+04
Other CAA inspection	Average annual number of CAA inspections on other facilities in the same state	.78 (.20)	0, 1
Other CAA penalty	Average annual amount of CAA penalty on other facilities in the same state, in $1000	1.86 (0.005)	.0005, 240
RCRA inspection	Annual number of RCRA inspections, lagged one year	.33 (1.43)	0, 71
RCRA penalty	Annual amount of RCRA penalty in $1000, lagged one year	.54 (35.8)	0, 7700
Other RCRA inspection	Average annual number of RCRA inspections on other facilities in the same state	.33 (.26)	0, 2.35
Other RCRA penalty	Average annual amount of RCRA penalty on other facilities in the same state, in $1000	0.18 (0.004)	0.0003, 51

Race	Percentage of white in population	81.27 (15.68)	13.54, 100
Income	Annual income per capita at the county level, adjusted by CPI, in $1000	33.10 (8.84)	14, 112
College	Percentage of population with college education or above	85.28 (4.42)	62.1, 97
Rate	Unemployment rate	6.36 (2.61)	1.9, 29.7
Population Density	Number of persons per square miles	1043 (4180)	.64, 69,121

The remaining variables, *Race*, *Income*, *College*, *Unemployment Rate*, and *Population Density*, are selected to control for community characteristics. Those variables are included in the estimation after natural log transformation.

2.2 Econometric model

Instead of presenting a full theoretical model, this paper briefly outlines the model developed in Liu (2012). Consider a firm that is regulated under two environmental programs, A and B. The optimal abatement strategy for the firm is to set the expected marginal benefit of abatement (the avoided potential inspection costs and penalty) equal to the marginal abatement cost for each program. Here I define two effects:

1. Within program effects: the effects of regulatory actions on firm compliance within the same program.
2. Cross program effects: the effects of regulatory actions under one program on firm compliance with the other program. This is the spillover effects investigated in this paper.

First, the within program effects are expected to be positive. When a firm faces higher inspection frequency or penalty, the marginal benefit of abatement for the firm increases. Thus with a convex abatement cost function, the optimal abatement level will increase. Second, the cross program effects depend on the interaction between the two programs within the same firm. For example, under certain circumstances, the regulator may allow for certain violation under program A in exchange for better compliance with program B, as suggested in Heyes and Richman (1999). Then enforcement actions under program B, which induces better compliance, will result in non-compliance under program A. To verify the within program effects and the cross programs, empirical approach is used to indirectly test the effects of enforcement under both programs on firm compliance with one program.

The dependent variable is the number of month a facility is in compliance in a given year. Even though the dependent variable is the number of months a facility is in compliance, the typical panel data count model is inappropriate. The count model requires the events of the counts to be independent. However a facility's compliance status can be dependent from one month to the next. In particular, a facility's violation status can last for months if a major violation is found and difficult to correct. Thus the dependent variable will be treated as a continuous variable in the estimation.

Following previous literature on compliance, the monitoring and enforcement measures considered here are sorted into specific and general deterrence (Grey and Shimshack, 2011). To capture the specific effects, inspections and penalties under CAA and RCRA are included. Those variables are included as lagged effects instead of contemporaneous effects for the following reasons. First, the current inspection or penalty may be correlated with the facility's current compliance status and this can cause endogeneity. Including lagged variables can alleviate the issue to certain extent. Second, it may take time for the monitoring and enforcement actions to have an impact on the facilities, and it takes time for facilities to correct violations revealed during inspections. The general deterrence refers to the spillover effects defined in Grey and Shimshack (2011)—the impact of enforcement at a specific facility on other facilities in general. The general deterrence is represented by the average number of inspections on other facilities within the same state.

In summary, the econometric model can be expressed as follows:

$$C_{it} = \alpha_i + \beta E_{it} + \gamma G_{it} + \varepsilon_{it},$$

where C_{it} denotes the number of compliance months in a given year, *i* denotes the facility, *t* denotes time, *E* includes all monitoring and enforcement measures, *G* is a vector of all other control variables including community characteristics, and ε_{it} is the error term.

The model is estimated using a fixed effects model that controls for heteroscadasticity and autocorrelation.

3. Results and Discussion

Table 3 provides the estimation results. Important parameters of interest are those related to monitoring and enforcement measures.

First, positive within-program effects are confirmed by the significant and positive coefficient of *CAA inspection*. An additional *CAA inspection* can increase facility compliance by about 0.03 months on average in a given year, *ceteris paribus*. In comparison, *CAA penalty* shows significant but negative effects on CAA compliance with a coefficient of 0.033. The negative effects of *CAA penalty* is unexpected and deserve further examination. When a violation is found during inspection or self-reported, the facility will receive notices from the authority regarding the violation. If the violation persists, a fine is usually the last enforcement action. Thus penalties may reflect some inherent conditions that are hard for the violating facility to overcome or correct. For facilities that are persistent violators, one may observe decreased compliance with increased penalties. In terms of the general deterrence, both *other CAA inspections* and *other CAA penalty* show insignificant effects on CAA compliance. Thus no general effects are found within the same program in this study.

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Table 3
Estimation results

VARIABLES	Estimation	Standard Errors
CAA inspection	0.028*	0016
CAA penalty	-0.033***	0.007
Other CAA inspection	0.0002	0.0006
Other CAA penalty	-0.003	0.005

RCRA inspection	0.0016	0.018
RCRA penalty	-0.034**	0.014
Other RCRA inspection	-0.002*	0.0006
Other RCRA penalty	0.0097***	0.003
Minority rate	1.130	1.518
Per capita income	-0.189	0.142
College	-0.024	0.116
Unemployment Rate	-0.084*	0.047
Population Density	0.479	0.370
Observations	52,641	

Notes: ***, **, and * significant at the 1%, 5%, and 10% levels, respectively;

Now turn to the spillover effects across programs. The RCRA penalty and other RCRA inspections both show significant and negative effects on CAA compliance. Thus, negative cross program effects are confirmed and the relationship between CAA and RCRA is substituting. In terms of the specific effects, *RCRA penalty* is negative and significant while *RCRA inspection* is insignificant. One unit increase in the log of *RCRA penalty* increases facility CAA compliance by 0.03 month on average in a given year. The general deterrence of RCRA shows mixed results though. First, *other RCRA inspection* turns to be negative and significant. One more inspection under RCRA on other facilities increases CAA compliance by 0.002 month a year. This is in accordance with negative spillover effects. The other general deterrence, *other RCRA penalty*, shows negative and significant effects on CAA compliance. A unit increase in the log of *other RCRA penalty* will result in an increase of 0.01 month in CAA compliance. While this may seem to contradict to the conclusion above, the result should be interpreted with cautions. RCRA penalty on other facilities is likely to work through its impact on the specific facility's decision on RCRA compliance, which in turn, will impact the specific facility's compliance with CAA. Thus the negative effects could be the results of the negative impact of this general deterrence on the facility's RCRA compliance.

The finding of a substitution relationship between the two programs bears important policy implications. When evaluating monitoring and enforcement actions, regulators usually consider the benefits and cost of such actions and make decisions within the same program. However, substituting regulations imply that for a regulator, the effects of monitoring and enforcement actions are not limited to the benefit of improved compliance within the same program. Given the negative spillover effects across the two programs, CAA and RCRA, regulators should also take into account the decreased compliance with CAA caused by monitoring and enforcement actions in RCRA. To achieve the social optimal levels of abatement and emissions, regulators of the two programs should coordinate their monitoring and enforcement actions.

The negative spillover effects confirmed in this study does not necessarily contradict the findings of positive spillover effects in Liu (2012). First, this study examines compliance with CAA and Liu (2012) investigates compliance with RCRA. Different environmental programs have different compliance requirements and enforcement strategies. Some programs uses emissions standards while others issue permits; certain programs require self-reporting while the rest rely on inspections or voluntary disclosure to reveal violations. These differences may result in different compliance behaviour under various programs. Second the polluting mediums involved in the two studies are different and thus the abatement technology is different. Such differences determine that certain technological update may help reduce emissions through other mediums simultaneously while some technological changes may crowd out emissions from one medium to others. Finally, the conclusion of positive spillover effects found in Liu (2012) is based on the analysis of facilities in Michigan only, which may not hold for facilities across the nation. In comparison the negative spillover effects found in this study applies to facilities across the nation in general.

The rest of the control variables have limited impacts on compliance. Among the four variables of community characteristics, only unemployment rate turns out to be significant. The unemployment rate is an indicator of the local labor market. The negative coefficient indicates that communities with higher unemployment rate put less pressure on the polluting facilities and allow for relatively bad environmental performance.

4. Conclusion

This paper investigates firm compliance with multiple environmental regulations. Using data on facilities that are regulated under both CAA and RCRA across the nation, a fixed effects model is estimated to examine the within-program effects and cross program effects. The within-program effects refer to the impact of regulatory measures on compliance within the same program, while the cross-program effects refer to the impact of regulatory measures under one program on compliance under other programs.

As expected, the within program effects are positive. The inspections under CAA improve facility compliance with CAA significantly. The cross-program effects are found to be negative. Penalties under RCRA and inspections under RCRA imposed on other facilities within the same state induce facilities to comply less with CAA. Therefore, the RCRA program has negative spillovers on the CAA program and the two programs are substituting. Given the findings, coordination among regulators is called for to achieve social optimum. When regulators take monitoring and enforcement actions under RCRA, further consideration should be given to the effects of those actions on facility compliance with other programs such as CAA.

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