What Affects the Environmental Performance of Pipelines in the US?
An Empirical Analysis

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Sarah L. Stafford, College of William and Mary

Introduction

The recent controversy over the Keystone XL pipeline project and the Exxon Mobil pipeline spill in Montana in July of 2011 have highlighted concerns about the environmental impacts of the U.S. pipeline network. In late 2011, Congress approved and President Obama signed the Pipeline Safety, Regulatory Certainty, and Job Creation Act in an effort to improve the safety of pipelines in the U.S. The Act significantly increases funding for federal inspections of pipelines and the fines associated with violations of pipeline regulations and, in accordance with the act, the administration's 2013 fiscal year budget increases PHMSA funding by 60 percent and adds 120 new federal inspectors. However, while numerous studies have assessed the effectiveness of federal enforcement in improving compliance with other environmental regulations, to my knowledge no one has yet analyzed the effect of federal enforcement efforts on pipeline compliance. The goal of this paper is to provide the first empirical analysis of the environmental performance of pipelines and to determine the factors that have the largest effect on pipeline compliance. The paper will focus primarily on the effect that federal inspections, enforcement actions, and fines have had on compliance and environmental performance. The results of this analysis should provide insight into whether the changes mandated under the Pipeline Safety, Regulatory Certainty, and Job Creation Act are likely to achieve their goal of improving pipeline safety.

Background on the Pipeline Industry

Many liquid products are most cost-effectively transported via pipelines. However, many of the products transported by pipeline can pose significant threats to human health and the environment if leaked or released from the pipeline. Although pipelines are designed and constructed to maintain structural integrity since the transported materials have intrinsic value (unlike many effluent substances, such as hazardous wastes or by-products), many factors make it difficult to avoid leaks and other releases during a pipeline's lifetime. Natural disasters, such as flooding, earthquakes, and storms, can result in pipeline failures, as can accidental human, machine, and animal intrusions. Additionally, pipelines may develop leaks or ruptures due to corrosion from the materials being transported or material fatigue from fluctuating temperature and pressure conditions.

In the U.S. over 2.5 million miles of pipelines transport gas and other hazardous liquids. Overall, pipelines are a relatively safe mode of transportation compared to alternatives such as tankers and rail cars, and the pipeline transmission safety record has improved significantly over time. However, more than 100 significant pipeline releases occur each year, and deaths from pipeline accidents are, unfortunately, not rare occurrences.

Established in 2005 as a division of the Department of Transportation, the Pipeline and Hazardous Safety Materials Administration (PHMSA) regulates pipelines that transmit natural gas and other gas or hazardous liquids. Within PHMSA, the Office of Pipeline Safety (OPS) implements the regulatory program. PHMSA sets minimum federal standards with which all pipeline operators must comply. As is true with many other environmental regulations, states can pass supplementary regulations. Additionally, pipelines in "high consequence" areas are subject to a stricter set of controls due to the increased risk for public and environmental safety damage.

Both federal and state regulators enforce PHMSA regulations. In theory, standard inspections are conducted every couple of years on all pipelines and more often on pipelines with higher potential risks. If a pipeline crosses state borders, enforcement generally falls to OPS, while states inspect most intrastate lines. However, not all states have been certified or approved to conduct intrastate inspections; in those states all pipeline inspections are conducted by federal regulators. Conversely, OPS has authorized some states to act as its agent and inspect interstate pipelines in addition to interstate pipelines. To complement formal enforcement, PHMSA-regulated pipelines must also self-inspect and report to PHMSA any violations discovered during the course of required inspections.

OPS is a relatively small agency. In 2011 (prior to the passage of the Pipeline Safety, Regulatory Certainty, and Job Creation Act) there were under 120 inspectors working for OPS out of five regional offices (Trenton, NJ; Atlanta, GA; Kansas City, MO; Houston, TX; and Denver, CO).[1] An additional 300 inspectors who work for state agencies carry out the majority of pipeline inspections. Standard inspections are designed to ensure that operation and maintenance procedures, abnormal and emergency operating procedures, damage prevention and public education procedures, and pipeline installation, connection, repair, and operations are in compliance with the relevant regulations. Construction inspections include a review of material and component design specifications, welding

[1] "Pipeline Spills Put Safeguards Under Scrutiny," Dan Frosch and Janet Roberts, The New York Times, September 9, 2011.

procedures and welder qualifications, corrosion protection, and installation, as well as post-construction testing. Integrity management inspections are designed to determine whether an operator uses all available information about its pipeline system to assess risks and takes appropriate action to mitigate those risks.

PHMSA can initiate an enforcement case when an inspection identifies a violation of the pipeline safety regulations or in response to an accident. The type of enforcement action taken depends on the safety and regulatory significance of the violation. Minor problems occurring for the first time may only receive a Warning Letter, while more significant violations may require a compliance order that specifies actions the operator must take to come into compliance (e.g., requiring operators to replace pipeline sections or implement corrosion control and remediation strategies) or a civil penalty. Civil penalties are generally reserved for serious violations leading to deaths, injuries, or significant environmental damage. Regulators may impose civil penalties as severe as $100,000 for each day a violation existed, up to a maximum of $1,000,000. Since 2008, PHMSA has proposed over $21 million in civil penalties.[2]

Related Literature

The objective of this paper is to better understand the role that federal inspections and enforcement actions have in increasing pipeline compliance and environmental performance. To my knowledge, there are no existing papers that explicitly model

[2] Testimony of Cynthia L. Quarterman (Administrator, Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation) before the House Energy and Commerce Committee, June 16, 2011.

compliance with pipeline regulations, either theoretically or empirically.[3] However, there is a large literature examining compliance with environmental regulations more broadly, and I use this as a starting point for the analysis.

The traditional economic view of environmental compliance assumes that a regulated entity's decision to comply or not is a rational one based on the objective of profit maximization. The basic framework for these models is Becker's (1968) paper on the economics of crime, which was adapted by Russell, Harrington, and Vaughan (1986) to provide a comprehensive application to environmental regulation. While a number of interesting variations on these models have been developed over the past two decades to allow for various complexities such as imperfect information, self-reporting, principal-agent relationships, and dynamic settings, in all of these deterrence-based models compliance is ultimately improved by increasing the expected cost of noncompliance – either by increasing the likelihood that a violator gets caught or by increasing the level of sanctions associated with violations.

While deterrence-based models dominate the economics literature on environmental compliance, a number of papers in other fields have recognized alternative motivations for compliance or reasons for noncompliance. For example, a regulated entity may comply with regulations out of an inherent sense of duty to obey rules or because of social pressure, even if the probability of detection is very low or the punishment for a violation is negligible. Alternatively, even with severe sanctions or a high probability of detection, if a regulated entity's managers do not understand the regulatory requirements,

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[3] There are a number of papers that analyze pipeline incidents from an engineering perspective to better understand the distribution of pipeline failures (see, for example Sosa and Alvarez-Ramirez, 2009). These papers do not examine regulatory structures or policies.

or have poor internal controls, even well-intentioned regulated entities may still violate regulations. Finally, some violations, such as those triggered by extreme weather, may occur despite a regulated entity's impeccable operations. In such cases, deterrence-based measures would prove generally ineffective at increasing compliance. Of course, while some theoretical models focus on a particular motive underlying the compliance decision, in practice the compliance decision is likely to depend on a number of different objectives and factors which differ across facilities.

According to Gray and Shimshack (2011), most policy-makers and scholars believe that an enforcement regime of inspections and sanctions is generally effective at increasing compliance with environmental regulations, and most regulated entities cite rigorous monitoring and enforcement as a primary motivator of their environmental compliance decisions. A number of empirical analyses confirm these beliefs. For example, Gray and Deily (1996) and Gray and Shadbegian (2005) examine air pollution compliance for steel mills and pulp and paper mills in the U.S., respectively, and find that both inspections and enforcement actions have a statistically significant positive impact on compliance. Looking at compliance with U.S. water regulations, Earnhart (2004) and Glicksman and Earnhart (2007) similarly find that inspections and sanctions deter violations at water treatment plants and chemical facilities, respectively. Stafford (2002) shows that compliance inspections and penalties for violations have a significant deterrent effect on violations at facilities subject to hazardous waste regulations.[4]

These results from the environmental compliance literature echo findings in other regulatory areas. In particular, a number of papers examine the deterrent effect of

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[4] See Gray and Shimshack (2011) for a comprehensive survey of the empirical literature on environmental monitoring and enforcement.

Occupational Safety and Health Administration (OSHA) inspections and sanctions on workplace injuries. Many of these papers (see, for example, Gray and Scholz, 1993; Gray and Mendeloff, 2005; and Haviland et al. 2010) find that inspections and sanctions do deter injuries, although the effects of deterrence depend significantly on the characteristics of the regulated entity being inspected or sanctioned and whether the inspection results in a sanction. The goal of this paper is to add evidence from another closely related regulatory program, PHMSA, on the deterrent effect of federal inspections and enforcement in increasing compliance and performance with regulations.

Framework for the Analysis and Description of the Data

While pipelines are fixed structures, they are not constrained within a particular geographic area like most entities subject to environmental regulation. For example, Figure 1 shows the natural gas pipeline network in the U.S. This network includes over 300,000 miles of transmission pipelines, more than 1,400 compressor stations that maintain pressure on the natural gas pipeline network and assure movement of the gas, and more than 16,000 delivery and receipt points. Federal and state regulators divide pipelines into 'inspection units'. For operators with small amounts of pipeline mileage, the entire company may constitute one inspection unit. Regulators may divide larger operators based on operating areas (e.g., cities or metropolitan areas), company organization (e.g., all elements reporting to a single vice president), or other factors. Unfortunately, data on pipeline compliance and enforcement is not available at the inspection unit level. Thus this analysis focuses on the aggregate compliance behavior and environmental performance of individual pipeline operators, rather than the compliance status of a particular section of a pipeline. This analysis is most analogous to firm-level studies of compliance and environmental performance, such as Khanna and Anton (2002) and Thornton, Gunningham, and Kagan (2005), although it is based on data reported to the federal government rather than data collected through a voluntary survey.

As of the beginning of 2012 there were 2,705 PHMSA-regulated pipeline operators in the U.S. Of these, 1,921 operate less than 10 miles of pipeline, 440 operate between 10 and 100 miles of pipeline, and 344 operate 100 miles or more of pipeline. For the purposes of this analysis, I focus only on those operators that operate 100 miles or more of pipeline. These operators represent over 90% of all pipeline incidents that occurred between 2006 and 2011 and 80% of all federal inspections during that same time frame.[5]

PHMSA provides data on operators' compliance status and environmental performance starting in 2006. The compliance and performance measures include the total number of incidents, fatalities, and injuries each year; the total dollar amount of property damage each year; and the total barrels of product spilled and the net barrels of product lost each year. Table 1 presents a summary of these measures for 2010 for the operators in this study. First, note that for all of these measures, the majority of operators have nothing to report.[6] The most widely reported measure is property damage, followed closely by incidents. Property damage is reported more often than incidents because events that

[5] An "incident" is defined as any event that results in a death or personal injury necessitating in-patient hospitalization; an explosion or unintentional fire; any event that results in property damage of $50,000 or more (excluding cost of material lost); any event that results in unintentional loss of five gallons or more of hazardous liquid or carbon dioxide or three million cubic feet of gas; any emergency that results in an emergency shutdown of a facility; or any other event that is significant in the judgment of the operator.
[6] Most of this data is self-reported. For the purposes of this analysis I assume the self-reported data is accurate, as evaluation of the accuracy of the self-reported data is beyond the scope of this study.

cause less than $50,000 in property damage are not considered incidents if they do not also result in fatalities, significant injuries, or sufficient loss of material. Given the relatively small number of operators that report in a given year, I aggregate performance data for 2009 and 2010 to increase the number of operators reporting. The mean and standard deviations for the aggregated data are presented in Table 2 which presents summary statistics for all variables used in the analysis. Note that the summary statistics are for all operators in the study, not just those reporting.

One of the principal challenges that can arise when trying to estimate the effectiveness of inspections and enforcement on environmental compliance or performance is that of endogeneity, or reverse causality, which can occur if there are omitted explanatory variables or the compliance and enforcement decisions are made simultaneously. With respect to the omitted variables concern, due to data limitations the analysis may not include some factors that affect not only the operator's environmental performance but also the regulator's decision to conduct inspections. For example, significant flooding in an area may cause pipelines to rupture, but might also bring increased inspections to that area as well. With respect to the simultaneity concern, contemporaneous inspections may be endogenous to the number of incidents reported if inspections serve as a significant mechanism through which incidents are discovered or reported. Similarly, the number of enforcement cases and amount of proposed penalties in a particular period are likely to depend on the number of incidents and fatalities that occur in that same time period. To address this concern I lag the inspections and enforcement variables, which may be endogenous, and I also include the lagged dependent variable as an explanatory variable. Ideally I would also use an instrumental variables approach to control for endogeneity, but due to the limited information available about pipeline inspections and enforcement, I have not been able to find any valid instruments to use for such an approach.

The first set of explanatory variables presented in Table 2 depicts the level of federal and state enforcement for each operator in the analysis. The three federal measures – $\textit{Federal Inspections}_{06\text{-}08}$, $\textit{Federal Cases Initiated}_{06\text{-}08}$, and $\textit{Federal Proposed Penalties}_{06\text{-}08}$ – each capture a different aspect of the specific deterrence a particular operator faces from federal sources, as they capture the level of inspections and enforcement for that specific operator during the 2006-2008 period. In contrast, the three state measures are all general deterrence measures that capture the general level of enforcement for the states through which the operator's pipelines run. The state measures are general measures rather than specific measures because the state data is only available at the aggregate level. For each state I first normalize the relevant variable X – $\textit{State Inspections}_{06\text{-}08}$, $\textit{State Actions Taken}_{06\text{-}08}$, and $\textit{State Assessed Penalties}_{06\text{-}08}$ – by the total number of pipeline miles in the state. For each operator i, I then use data on the total number of pipeline miles the operator has in each state j to construct each measure x for that operator as follows:

$$\sum_j Miles_{ij} * \frac{X_j}{Miles_j}$$

The state inspection data was obtained through a Freedom of Information Act request, while the data on state compliance actions taken and penalties assessed was collected from the PHMSA website.

The next set of explanatory variables measures past performance (i.e., performance during the 2006-2008 period) and, due to limited data capturing operator characteristics, is used in conjunction with the analogous 2009-2010 variables to control for differences in underlying propensities to comply with pipeline regulations. Additionally, Sosa and Alvarez-Ramirez (2009) show that the number of previous incidents positively correlates with future incidents. One of the operator characteristics that I can control for is the *Miles* of pipeline the operator owns. Both *Miles* and *Miles Squared* are included in the analysis to account for the fact that longer pipelines have more opportunities for failure. I also include the dummy variable *Intrastate* which indicates whether the pipeline operator only operates in a single state. While PHMSA concentrates enforcement efforts on interstate pipelines, federal inspectors do inspect intrastate pipelines on occasion. *Number of States* measures the number of states through which the pipeline passes, while the four regional dummies capture the Census region(s) in which the operator operates. Finally there are four dummy variables that capture the type of pipelines and the materials transported in the pipelines that each operator owns:

- *Gas Gathering* lines collect and move natural gas from wells or offshore vessels to storage or processing facilities.
- *Gas Transmission* lines transport natural gas from gathering lines or storage facilities to distribution centers, storage facilities, power plants, and industrial customers and municipalities. These are generally the longest type of gas lines and are usually underground.
- *Gas Distribution* lines move natural gas to industrial customers and residences and are usually located in underground utility easements along streets.

- *Hazardous Liquid* lines transport hazardous liquids, usually over long distances and underground.

Results

Table 3 presents the results of the ordinary least squares regression for each of the six 2009 to 2010 performance variables. In the first column, the dependent variable is the number of incidents reported in 2009 and 2010. Looking first at the federal enforcement variables, notice that none of the coefficients are negative. Moreover, the positive coefficients for *Federal Cases Initiated*$_{06\text{-}08}$ and *Federal Proposed Penalties*$_{06\text{-}08}$ are both significant – the opposite of what one would expect if past enforcement actions served to increase overall environmental performance. One possible explanation could be that it takes a long period of time for operators to change their performance; thus, operators with past incidents that warranted significant enforcement may be more likely to continue to report a high number of incidents. To control for this, I did include past incidents (*Dependent Variable*$_{06\text{-}08}$) in the regression which also has a positive and significant sign, but it may not be a perfect control. The results for the state enforcement variables are more consistent with expectations. Both *State Inspections*$_{06\text{-}08}$ and *State Penalties Assessed*$_{06\text{-}08}$ have negative coefficients, and the former is significant.

Looking across the other performance variables, it is interesting to note that the results for the enforcement measures are quite mixed. *Federal Inspections*$_{06\text{-}08}$ and *Federal Proposed Penalties*$_{06\text{-}08}$, always have positive coefficients, and those coefficient are significant in a number of the regressions. On the other hand, *Federal Cases Initiated*$_{06\text{-}08}$ has a negative coefficient for all but the *Incidents* regression, and the coefficient is significant for all but the *Fatalities* regression. The state enforcement results are also mixed. In contrast to the negative relationship between federal cases and performance – or, more correctly, non-performance – all of the significant coefficients on *State Actions Taken*$_{06\text{-}08}$ are positive. Similarly, while federal proposed penalties are positively related to non-performance in most of the regressions, all of the coefficients on *State Penalties Assessed*$_{06\text{-}08}$ are negative. *State Inspections*$_{06\text{-}08}$ has a negative and significant coefficient only in the *Incidents* regression, but has a positive and significant coefficient in the *Net Barrels Lost* regression. While one might expect that some of this inconsistency could be caused by multicollinearity among the federal and state enforcement variables, the variables are not as highly correlated as one might expect. Only three pairs of variables have a correlation coefficient above 0.6: *Federal Inspections* and *Federal Cases Initiated* have a correlation coefficient of 0.67; *Federal Inspections* and *State Inspections* have a correlation coefficient of 0.70, and *State Inspections* and *State Actions Taken* have a correlation coefficient of 0.76.

Clearly these results paint a very mixed picture of the effectiveness of federal and state enforcement efforts at deterring poor environmental performance at pipelines. In particular, in terms of predicting the success of the Pipeline Safety, Regulatory Certainty, and Job Creation Act in increasing pipeline safety, there is no evidence at all that indicates federal inspections or fines increase environmental performance, although there is some evidence that state inspections and penalties can have such an effect. While *Federal Cases Initiated*$_{06\text{-}08}$ does have a relatively consistent negative and significant effect on non-performance, the Pipeline Safety, Regulatory Certainty, and Job Creation Act explicitly focuses on increased federal inspections rather than more rigorous enforcement; thus, it is not clear how the number of cases initiated will change with increased enforcement resources.

The remaining results in Table 3 provide some insight into why federal enforcement may not be particularly effective at decreasing poor environmental performance. First, observe that the coefficient on the lagged dependent variable in each regression (listed as *Dependent Variable*$_{06\text{-}08}$) is positive and significant for four of the regressions. Thus, for overall incidents, injuries, gross barrels spilled, and net barrels lost, there is considerable persistence across time – particularly when one recalls the difference in time frames across the two variables (three years to two years). The less predictable nature of fatalities and property damage makes intuitive sense and is consistent with the Sosa and Alvarez-Ramirez (2009) finding that more severe incidents are unpredictable.

I had expected that the nonperformance measures would all be positively related to the length of the pipeline, but interestingly *Miles* has the expected positive and significant coefficient only in the *Incidents* regression. For *Fatalities*, *Injuries*, and *Property Damage*, longer pipelines have fewer negative outcomes, *ceteris paribus*. Also, across all of the regressions the coefficient on *Miles Squared* is negative (although significant in only two of the six regressions). Of course, there are a number of other variables that indirectly capture the length of the pipeline, including the state enforcement variables. However, these results suggests for at least some of the performance variables, there may be important non-linearities.

While very few of the remaining explanatory variables have a consistent effect on the performance variables, note that *Gas Gathering* has a significant and positive coefficient in the *Fatalities*, *Injuries*, and *Property Damage* regression. Comparing the size of the three significant *Gas Gathering* coefficients to the mean and standard deviation for the three performance measures, note that operating a gas gathering pipeline is quantitatively a very important determinant for fatalities, injuries and property damage and may help explain why federal and state level enforcement actions are not more important deterrents for at least these types of non-performance.

To try and better understand the mixed results presented in Table 3, I next analyzed federal inspections and enforcement as a function of past performance. Table 4 presents the results of ordinary least square regressions of $\textit{Federal Inspections}_{09\text{-}10}$, $\textit{Federal Cases Initiated}_{09\text{-}10}$, and $\textit{Federal Proposed Penalties}_{09\text{-}10}$ as a function of the lagged performance measures, the lagged dependent variable, and the explanatory variables used in the performance regressions. Looking first at the results for the *Federal Inspections* regression, note that only $\textit{Fatalities}_{06\text{-}08}$ has a positive and significant coefficient among the performance measures, indicating that federal inspectors do target operators for inspections if there have been fatalities at the operator's pipelines in the recent past. Interestingly, the coefficient on $\textit{Injuries}_{06\text{-}08}$ is negative and significant which is not consistent with the idea of targeting based on past performance. This pattern shows up in both of the other regressions; that is, the coefficient on $\textit{Fatalities}_{06\text{-}08}$ is positive and significant for both *Federal Cases* and *Federal Penalties*, while the coefficient on $\textit{Injuries}_{06\text{-}08}$ is negative for both and significant for *Federal Cases*. $\textit{Barrels Lost}_{06\text{-}08}$ is also a significant determinant of $\textit{Federal Cases Initiated}_{09\text{-}10}$, while both $\textit{Incidents}_{06\text{-}08}$ and $\textit{Property Damage}_{06\text{-}08}$ are significant determinants of $\textit{Federal Proposed Penalties}_{09\text{-}10}$.

For both *Federal Inspections* and *Federal Cases* there is some persistence across the two periods given the positive and significant coefficients on the lagged dependent variable. There are a number of possible explanations for this result. Recall that pipelines which pass through "high consequence" areas are subject to more stringent regulation and may also face more inspections. Similarly, pipelines carrying particularly hazardous materials may be inspected more often. Interestingly, there is a negative relationship between current and lagged *Federal Penalties*, so that facilities which faced higher penalties in the past face lower penalties currently, *ceteris paribus*.

Next, consider the lagged state enforcement variables. *State Inspections*$_{06\text{-}08}$ has a positive coefficient in all three regressions, and it is significant for *Federal Cases* and *Federal Penalties*. If state inspections uncover behavior that helps federal regulators initiate enforcement proceedings, one would expect to see a positive relationship between these variables. Interestingly, the negative and significant coefficient on *State Actions Taken*$_{06\text{-}08}$ suggests that federal regulators may take into account state actions and hold off on their own enforcement actions against operators that have been subject to state actions in the recent past. However, the positive and significant coefficient on *State Penalties Assessed*$_{06\text{-}08}$ in the *Federal Cases* regression is inconsistent with such an interpretation.

Looking next at the operator characteristics variables, as expected longer pipelines face more inspections than shorter pipelines, although they are not subject to more federal cases or higher federal penalties, *ceteris paribus*. This finding makes sense, as inspections should depend on the potential for harm, while enforcement actions should depend on actual harm. The insignificant coefficients on all of the regional dummies indicate there are not significant differences in the number of inspections based on the regions through which a pipeline runs. However, there are significant differences in the number of federal cases and penalties proposed by region, even after controlling for performance. While there are many possible explanations for these findings, they are consistent with regulators in different regions having different opinions about when cases should be initiated and how penalties should be set. Interestingly, even though the regressions in Table 3 suggest that pipeline performance depends on the type of pipeline – *Gas Gathering*, *Gas Distribution*, etc. – there is no variation in federal enforcement across the different types of pipelines.

Discussion

The goal of this paper is to provide insight into the role that federal inspections, enforcement actions, and fines have had on pipeline compliance and environmental performance and, in particular. to examine whether the increased inspections funding and civil penalties mandated under the Pipeline Safety, Regulatory Certainty, and Job Creation Act are likely to increase pipeline safety. The results of the analysis do not provide compelling evidence that either federal inspections or civil penalties serve as particularly effective deterrents. In fact, I find that lagged federal inspections and penalties are positively associated with environmental non-performance, although the results have to be interpreted with some care as lagging the enforcement variables may not fully correct for omitted variables or endogeneity between enforcement and performance.

Interestingly, my analysis does find that the number of federal cases initiated against an operator does have a significant deterrent effect on many forms of environmental non-performance, although not for incidents in general. Thus, in theory increasing the number of federal cases would result in better environmental performance. However, the Pipeline Safety, Regulatory Certainty, and Job Creation Act focuses on increasing inspections and fines, not increasing the number of cases, although additional cases could indirectly result from the Act.

The analysis of federal inspections, enforcement cases, and proposed penalties suggests that some targeting of federal enforcement resources is based on past performance, but the results suggest that there may be room for improvement. If federal enforcement resources were better targeted, the deterrent effect of such resources might increase. The analysis also points out some variation across regions in enforcement that could indicate inefficient resource deployment. Finally, the analysis reveals interesting patterns between state and federal enforcement efforts. Additional research to better understand the relationship between such efforts could help increase our understanding of how such resources are currently coordinated and whether better coordination might increase deterrence.

Table 1: 2010 Performance Measures for

Operators with 100 or More Miles of Pipeline (N=344)

Performance Measure	Facilities with Nothing to Report	For Facilities that Report			
		Mean	Std. Dev.	Minimum	Maximum
Number of Incidents	236 (69%)	3.96	4.75	1	26
Number of Fatalities	340 (99%)	2.75	3.50	1	8
Number of Injuries	337 (98%)	9.14	18.57	1	51
Property Damage (in Million $s)	235 (68%)	10.40	67.50	0.003	601
Gross Barrels Spilled (thousands)	285 (83%)	2.91	10.21	0.002	70.19
Net Barrels Lost (thousands)	298 (87%)	2.66	10.68	0.001	70.19

Table 2: Summary Statistics for the Variables Used in the Analysis

Variable	Description	Mean	Std. Dev.
Performance Measures (Dependent Variables)			
$Incidents_{09-10}$	Number of incident reported during 2009-2010.	2.51	6.32
$Fatalities_{09-10}$	Number of fatalities reported during 2009-2010.	0.04	0.47
$Injuries_{09-10}$	Number of injuries reported during 2009-2010.	0.23	2.79
Property $Damage_{09-10}$	Property damage reported during 2009-2010 in million $s.	3.63	38.29
Barrels $Spilled_{09-10}$	Barrels spilled during 2009-2010 in thousands of barrels.	0.65	4.44
Barrels $Lost_{09-10}$	Net barrels lost during 2009-2010 in thousands of barrels.	0.45	4.04
Enforcement Measures			
Federal $Inspections_{06-08}$	Number of federal inspections at the operator's facilities during 2006-2008 (100's).	0.33	0.73
Federal Cases $Initiated_{06-08}$	Number of federal enforcement cases initiated against operator during 2006-2008.	1.24	2.40
Federal Proposed $Penalties_{06-08}$	Proposed Penalties on the operator during 2006-2008 (million $'s).	0.39	0.25
State $Inspections_{06-08}$	Weighted sum of total state inspections during 2006-2008 (100's).	0.79	1.58
State Actions $Taken_{06-08}$	Weighted sum of total state actions taken during 2006-2008.	8.87	18.90
State Penalties $Assessed_{06-08}$	Weighted sum of total state penalties assessed during 2006-2008 ($100,000's).	0.07	0.28
Past Performance Measures			
$Incidents_{06-08}$	Number of incidents reported during 2006-2008.	3.93	9.75
$Fatalities_{06-08}$	Number of fatalities reported during 2006-2008.	0.03	0.20
$Injuries_{06-08}$	Number of injuries reported during 2009-2010.	0.07	0.46
Property $Damage_{06-08}$	Property damage reported during 2006-2008 in million $s.	2.06	8.63
Barrels $Spilled_{06-08}$	Barrels spilled during 2006-2008 in thousands of barrels.	0.92	5.04
Barrels $Lost_{06-08}$	Net barrels lost during 2006-2008 in thousands of barrels.	0.52	3.62

Variable	Description	Mean	Std. Dev.
Other Operator Characteristics			
Miles	Miles of pipeline, in thousands	1.42	2.60
Intrastate	= 1 if all operations in the same state	0.39	0.49
Number of States	Number of states through which the operator's pipeline passes.	3.17	3.28
Region 1	= 1 if any pipeline is located in the Northeast.	0.11	0.32
Region 2	= 1 if any pipeline is located in the Midwest.	0.38	0.49
Region 3	= 1 if any pipeline is located in the South.	0.63	0.48
Region 4	= 1 if any pipeline is located in the West.	0.29	0.45
Gas Gathering	= 1 if operations include natural gas gathering.	0.24	0.43
Gas Transmission	= 1 if operations include natural gas transmission.	0.75	0.44
Gas Distribution	= 1 if operations include natural gas distribution.	0.26	0.44
Hazardous Liquid	= 1 if operations include hazardous liquid transmission.	0.44	0.50

Table 3: OLS Results for Various Measures of Environmental Performance

	Incidents	**Fatalities**	**Injuries**
Federal Inspections$_{06-08}$	0.33 (0.34)	0.04 (0.06)	0.42 (0.32)
Federal Cases Initiated$_{06-08}$	0.17* (0.09)	-0.02 (0.01)	-0.18** (0.08)
Federal Proposed Penalties$_{06-08}$	1.32** (0.64)	0.02 (0.11)	0.70 (0.58)
State Inspections$_{06-08}$	-0.68** (0.34)	-0.05 (0.05)	0.003 (0.31)
State Actions Taken$_{06-08}$	0.01 (0.02)	0.02** (0.002)	0.15** (0.01)
State Penalties Assessed$_{06-08}$	-0.73 (0.59)	-0.12 (0.10)	-0.65 (0.54)
Dependent Variable†$_{06-08}$	0.47** (0.02)	0.13 (0.13)	0.58** (0.30)
Miles	0.75** (0.30)	-0.08* (0.05)	-0.63** (0.27)
Miles Squared	-0.02** (0.01)	-0.002 (0.002)	-0.01 (0.01)
Intrastate	0.37 (0.36)	-0.01 (0.06)	-0.15 (0.32)
Number of States	0.31** (0.10)	0.02 (0.02)	0.04 (0.09)
Region 1	0.20 (0.58)	0.04 (0.09)	-0.23 (0.53)
Region 2	-0.51 (0.41)	0.03 (0.06)	0.22 (0.37)
Region 3	-0.52 (0.42)	-0.10 (0.07)	-0.58 (0.38)
Region 4	-1.12** (0.42)	-0.002 (0.07)	0.21 (0.39)
Gas Gathering	0.04 (0.36)	0.13** (0.06)	0.82** (0.33)
Gas Transmission	-0.71* (0.40)	-0.08 (0.07)	-0.31 (0.37)
Gas Distribution	0.56 (0.40)	0.07 (0.06)	0.43 (0.36)
Hazardous Liquid	0.51 (0.39)	-0.07 (0.06)	-0.39 (0.36)
Constant	-0.18 (0.61)	0.04 (0.10)	0.26 (0.55)
R-squared	0.84	0.27	0.33

Sig. at the 5% level; *Sig. at the 10% level.; † Equal to the dep. var. for the period 2006-2008.

Table 3, Continued

	Property Damage	Gross Barrels Spilled	Net Barrels Lost
Federal Inspections$_{06-08}$	0.08* (0.04)	0.55 (0.45)	0.42* (0.25)
Federal Cases Initiated$_{06-08}$	-2.04* (1.06)	-0.39** (0.12)	-0.51** (0.65)
Federal Proposed Penalties$_{06-08}$	77.80** (7.76)	3.93** (0.82)	1.07** (0.46)
State Inspections$_{06-08}$	2.55 (4.22)	0.41 (0.45)	0.66** (0.25)
State Actions Taken$_{06-08}$	1.37** (0.20)	0.004 (0.02)	-0.01 (0.01)
State Penalties Assessed$_{06-08}$	-14.17* (7.25)	-0.33 (0.76)	0.38 (0.42)
Dependent Variable†$_{06-08}$	0.22 (0.25)	0.62** (0.04)	1.11** (0.03)
Miles	-7.73* (3.69)	-0.19 (0.39)	-0.08 (0.21)
Miles Squared	-0.19 (0.13)	-0.01 (0.01)	-0.02** (0.01)
Intrastate	-3.88 (4.40)	-0.60 (0.46)	-0.31 (0.26)
Number of States	0.75 (1.22)	-0.05 (0.12)	-0.12* (0.07)
Region 1	6.71 (7.14)	-0.35 (0.76)	-0.56 (0.42)
Region 2	0.02 (4.94)	-0.59 (0.52)	0.12 (0.29)
Region 3	-13.02** (5.11)	-0.65 (0.54)	-0.08 (0.30)
Region 4	-8.49* (5.14)	-0.60 (0.55)	0.11 (0.30)
Gas Gathering	8.58* (4.45)	-0.13 (0.47)	-0.04 (0.26)
Gas Transmission	-12.00** (4.98)	0.52 (0.53)	0.31 (0.29)
Gas Distribution	3.05 (4.85)	-0.56 (0.51)	-0.76** (0.28)
Hazardous Liquid	-5.46 (4.78)	0.51 (0.51)	0.16 (0.28)
Constant	17.31** (7.31)	0.97 (0.77)	0.58 (0.42)
R-squared	0.36	0.46	0.80

** Sig. at the 5% level; *Sig. at the 10% level.; † Equal to the dep. var. for the period 2006-2008.

Table 4: OLS Results for Various Measures of Federal Enforcement, 2009-2010

	Federal Inspections	Federal Cases Initiated	Federal Proposed Penalties
$Incidents_{06-08}$	0.25 (0.22)	0.003 (0.008)	0.002** (0.001)
$Fatalities_{06-08}$	43.14** (8.20)	1.02* (0.31)	0.08* (0.05)
$Injuries_{06-08}$	-13.31** (3.50)	-0.32** (0.13)	-0.02 (0.02)
Property $Damage_{06-08}$	0.10 (0.21)	-0.01 (0.01)	0.008** (0.001)
Barrels $Spilled_{06-08}$	0.05 (0.47)	-0.01 (0.02)	0.001 (0.002)
Barrels $Lost_{06-08}$	-0.07 (0.65)	0.06** (0.02)	-0.001 (0.003)
Dependent Variable†$_{06-08}$	0.18** (0.03)	0.21** (0.03)	-0.06* (0.03)
State $Inspections_{06-08}$	0.02 (0.03)	0.006** (0.001)	0.00002** (0.0001)
State Actions $Taken_{06-08}$	-0.26* (0.16)	-0.12** (0.01)	-0.0013* (0.0007)
State Penalties $Assessed_{06-08}$	3.78 (5.52)	0.37* (0.21)	0.02 (0.02)
Miles	6.03** (2.84)	-0.15 (0.11)	0.016 (0.013)
Miles Squared	-0.18* (0.11)	-0.0003 (0.004)	-0.0011** (0.0005)
Intrastate	-3.28 (3.37)	0.27** (0.13)	0.01 (0.01)
Number of States	0.62 (0.94)	0.08** (0.03)	0.004 (0.005)
Region 1	1.56 (5.42)	0.44** (0.21)	0.10** (0.03)
Region 2	-2.42 (3.79)	0.28* (0.14)	0.01 (0.02)
Region 3	-1.90 (3.91)	0.08 (0.15)	0.02 (0.02)
Region 4	-0.04 (3.92)	0.34** (0.15)	0.03* (0.02)

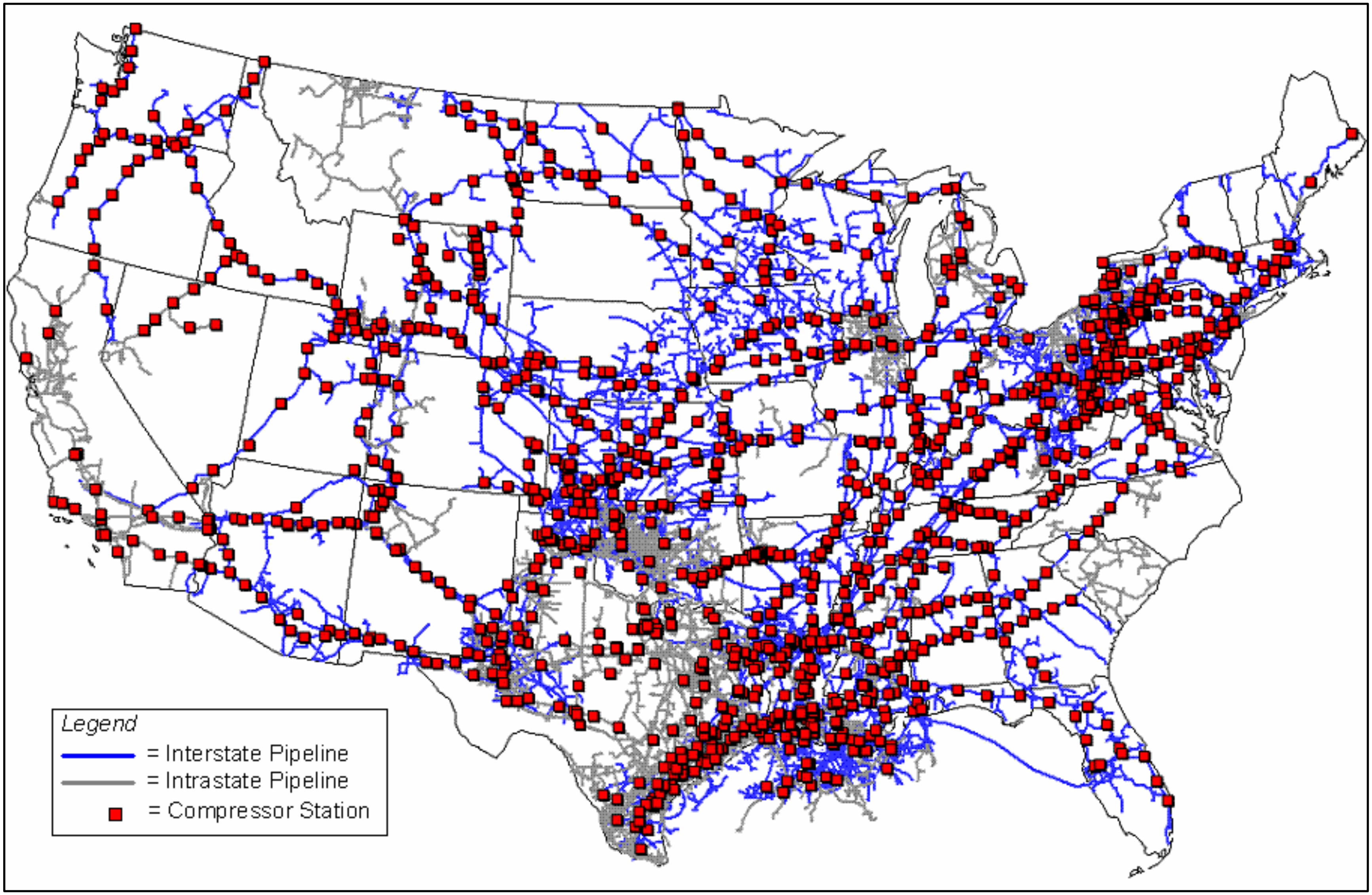
**Signif. at the 5% level; *Signif. at the 10% level; † Equal to variable at the top of the column for 2006-08

Table 4, Con't

	Federal Inspections	Federal Cases Initiated	Federal Proposed Penalties
Gas Gathering	-2.18 (3.36)	0.03 (0.13)	0.003 (0.016)
Gas Transmission	-0.43 (3.85)	0.05 (0.15)	0.026 (0.018)
Gas Distribution	-2.73 (3.70)	-0.09 (0.14)	0.005 (0.018)
Hazardous Liquid	0.66 (3.66)	0.17 (0.14)	0.026 (0.018)
Constant	3.43 (5.67)	-0.52** (0.21)	-0.84** (0.27)
R-squared	0.59	0.63	0.43

**Signif. at the 5% level; *Signif. at the 10% level; † Equal to variable at the top of the column for 2006-08.

Figure 1: U.S. Natural Gas Pipeline Network



Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Natural Gas Transportation Information System.

References

Becker, Gary S. 1968. "Crime and Punishment: An Economic Approach." Journal of Political Economy, 76:169-172.

Earnhart, Dietrich. 2004. "Regulatory Factors Shaping Environmental Performance at Publicly Owned Treatment Plants," *Journal of Environmental Economics and Management* 48: 655–81.

Glicksman, R., and Dietrich Earnhart. 2007. "The Comparative Effectiveness of Government Interventions on Environmental Performance in the Chemical Industry," *Stanford Environmental Law Journal* 26: 317–71.

Gray, Wayne B. and Mary Deily. 1996. "Compliance and Enforcement: Air Pollution Regulation in the U.S. Steel Industry," *Journal of Environmental Economics and Management* 31: 96–111.

Gray, Wayne B. and John Mendeloff. 2005. "The Declining Effects of OSHA Inspections on Manufacturing Injuries, 1979-1998," *Industrial and Labor Relations Review* 58:571-587.

Gray, Wayne and Ron Shadbegian. 2005. "When and Why Do Plants Comply? Paper Mills in the 1980s," *Law and Policy* 27: 238–61.

Gray, Wayne B. and Jay P. Shimshack. 2011. "The Effectiveness of Environmental Monitoring and Enforcement: A Review of the Empirical Evidence," *Review of Environmental Economics and Policy* 5:3–24.

Gray, Wayne B., and John T. Scholz. 1993. "Does Regulatory Enforcement Work? A Longitudinal Study of OSHA Enforcement," *Law and Society Review* 27:177–213.

Haviland, Amelai et al. 2010. "What kinds of injuries do OSHA inspections prevent?" *Journal of Safety Research* 41:339-345.

Khanna, Madhu and William Rose Q. Anton. 2002. "Corporate Environmental Management: Regulatory and Market-Based Incentives," *Land Economics* 78:539-558.

Russell, Clifford S., Winston Harrington and William J. Vaughan. 1986. Economic Models of Monitoring and Enforcement: Enforcing Pollution Control Laws, Washington, D.C: Resources for the Future.

E. Sosa and J. Alvarez-Ramirez. 2009. "Time-Correlations in the Dynamics of Hazardous Materials Pipeline Incidents," *Journal of Hazardous Materials* 165:1204-1209.

Stafford, Sarah. 2002. "The Effect of Punishment on Firm Compliance with Hazardous Waste Regulations," *Journal of Environmental Economics and Management* 44: 290–308.

Thornton, Dorothy, Neil Gunningham, Robert Kagan. 2005. "General Deterrence and Corporate Environmental Behavior," *Law & Policy* 27:262-288.