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An Empirical Analysis

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Introduction

The recent controversy over 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 which significantly increases funding for federal inspections of pipelines and the fines associated with violations of pipeline regulations in an effort to improve the safety of pipelines in the U.S. However, while there have been numerous studies of 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.[1] 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 be able achieve their goal.

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[1] I plan to incorporate differences in state enforcement in the next version of the paper.

Background on the Pipeline Industry

Many liquids are most cost-effectively transported via pipelines and many of those liquids can poses significant threats to human health and the environment if leaked or released from the pipeline. Pipeline are designed and constructed to maintain structural integrity because the materials being transported have intrinsic value (unlike many substances that can cause damage to human health and the environment such as hazardous wastes or by-products), but 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 intrusion. Additionally, pipelines may develop leaks or ruptures due to corrosion from the materials being transported or material fatigue from fluctuating temperature and pressure conditions.

The U.S. has over 2.5 million miles of pipelines that 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, there are still more than 100 significant pipeline releases a year and deaths from pipeline accidents are unfortunately not rare occurrences.

Pipelines that transmit natural and other gas or hazardous liquids are regulated by the Pipeline and Hazardous Safety Materials Administration (PHMSA), a division of the Department of Transportation established in 2005. 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. PHMSA regulations are enforced by both federal and state regulators. If a pipeline crosses state borders, enforcement generally falls to OPS, while states inspect most intrastate lines. In theory, standard inspections are conducted every couple of years on all pipelines and more often on pipelines with higher potential risks. To complement formal enforcement, PHMSA-regulated pipelines must also self-inspect and report any violations discovered during the course of required inspections to PHMSA.

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.[2] The majority of inspections are carried out by an additional 300 inspectors who work for state agencies. Standard inspections include a review of the operator's documented processes, procedures and records, a review of operating records, and observation of employees work performance. 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 be treated with a Warning Letter while more significant violations may require a compliance order, specifying actions the operator must take to come into compliance (e.g., requiring operators to replace pipeline sections or

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

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 and can be as much 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.[3]

Related Literature

To my knowledge this is the first empirical analysis of the relationship between enforcement and pipeline compliance and environmental performance although there are a number of econometric analyses of pipeline incidents which focus on understanding the distribution of pipeline incidents as a failure process (see, for example Sosa and Alvarez-Ramirez, 2009). However, there have been numerous empirical studies that have examined the role of inspections and enforcement at increasing compliance and environmental performance in other regulatory programs.

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. These beliefs are confirmed by a number of empirical analyses. 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

[3] 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.

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]

This paper will add to the empirical literature on enforcement and compliance by providing evidence on the effectiveness of inspections and enforcement in increasing environmental compliance and performance with pipeline regulations.

Framework for the Analysis and Description of the Data

While pipeline 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 be considered an inspection unit. Larger operators may be divided 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. Thus this analysis

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

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.

There are 2,705 PHMSA-regulated pipeline operators in the U.S.[5] 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 of more of pipeline.[6] PHMSA provides data on operators' compliance status and environmental performance from 2006 to 2010. 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.[7] Table 1 presents a summary of these measures. First note that for all of these measures, the majority of operators have nothing to report.[8] The most widely reported measure is property damage, followed closely by incidents. Property damage is reported more often than incidents

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[5] Data on pipeline operators is available at http://primis.phmsa.dot.gov/comm/reports/operator/Operatorlist.html?nocache=1242#.

[6] I intend to expand the dataset to include additional operators in the next version of this paper.

[7] An incident is defined as any event that results 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.

[8] Or choose not to report. Most of this data is self-reported. For the purposes of this analysis I assume the self-reported data is accurate.

because events that cause less than $50,000 in property damage are not be 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, for this analysis I decided to 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 of the variables used in the analysis. Note that the summary statistics are for all operators in the analysis, not just those reporting.

The first set of explanatory variables presented in Table 2 measure federal enforcement for the operators in the analysis. These variables measure the specific deterrence for each operator as they capture the level of inspection and enforcement that the operator faced during the 2006 to 2008 period. Note that only federal inspections, cases, and penalties are captured by these variables as data on state inspections by operator is not available. I lag the enforcement measures used in the analysis to control for potential endogeneity. In particular I am concerned that contemporaneous inspections may be endogenous to the number of incidents reported if inspections serve as a significant mechanism through which incidents are discovered and/or reported. Similarly, I would expect the number of enforcement cases and proposed penalties to depend on the number of contemporaneous incidents and fatalities. However, I do not believe that current performance will affect the number of inspections or enforcement cases initiated in the past.

The next set of explanatory variables measure past performance (i.e., performance during the 2006 to 2008 period) and are used in conjunction with the analogous 2009-

2010 variables to control for differences in underlying propensities to comply with pipeline regulations because I have limited data that capture operator characteristics. 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. Both *Miles* and *Miles Squared* are included in the analysis to account for the fact that longer pipeline 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, particularly if the pipeline passes through a "high consequence" area. *Number of States* measure 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 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

As a first step I conducted an ordinary least squares regression for each of the 2009 to 2010 performance variables as a function of the explanatory variables. The results are presented in Table 3. In the first column, the dependent variable is the number of incidents reported in 2009 and 2010. Looking first at the enforcement variables, notice that the coefficient on *Inspections per 100 Miles*$_{06\text{-}08}$ is negative and significant suggesting the federal inspections are effective at reducing incidents that endanger human health and the environment. However, the coefficients on *Cases Initiated*$_{06\text{-}08}$ and *Proposed Penalties*$_{06\text{-}08}$ are both positive and 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, and 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.

Looking across the other performance variables, there are similar mixed results for the enforcement measures overall: for all but the *Fatalities* regression there are both positive and negative significant coefficients on the enforcement variables. Perhaps most importantly for predicting the success of the Pipeline Safety, Regulatory Certainty, and Job Creation Act in terms of increasing pipeline safety, there is very limited evidence that federal inspections or fines increases performance. Only the *Incidents* regression has a negative and significant coefficient on *Inspections per 100 Miles*$_{06\text{-}08}$ which would imply that inspections serve as an effective deterrent. In fact, there is a positive and significant coefficient on *Inspections per 100 Miles*$_{06\text{-}08}$ in the *Injuries*, *Gross Barrels Spilled*, and *Net Barrels Lost* regressions. Similarly only the *Fatalities* regression has a negative and significant coefficient on *Proposed Penalties*$_{06\text{-}08}$ while the *Incidents*, *Property Damage*, *Injuries*, *Gross Barrels Spilled*, and *Net Barrels Lost* regressions all have positive and significant coefficients. Interestingly, for all of the performance measures other than *Incidents*, *Cases Initiated*$_{06\text{-}08}$ does have a negative and significant coefficient providing reasonably solid evidence that enforcement cases do have a deterrent effect. However, the Pipeline Safety, Regulatory Certainty, and Job Creation Act explicitly focuses on increased inspections rather than more rigorous enforcement and thus it is not clear how the number of cases initiated will change with increased enforcement resources.

Looking at the remaining results in Table 3, note that the coefficient on the lagged dependent variable in each regression (listed as *Dependent Variable*$_{06\text{-}08}$) is positive and significant sign in all of the regressions except the *Fatalities* regression. Thus for all of the performance measures except fatalities, there is persistence across time. The less predictable nature of fatalities makes intuitive sense and is consistent with the low R^2 for the fatalities regression as well as Sosa and Alvarez-Ramirez (2009) finding that more severe incidents are unpredictable. Also notice that *Miles* does have the expected positive and significant coefficient across all of the performance measures, and in all but one of the regressions the coefficient on *Miles Squared* is negative. However none of the other operator characteristics have consistent effects across the various performance measures.

This is not necessarily problematic as the performance measures are quite different from one another and there may be technical reasons why operators of *Gas Distribution* lines have more fatalities and injuries, but fewer net losses.

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 *Total Inspections*$_{09\text{-}10}$, *Cases Initiated*$_{09\text{-}10}$, and *Proposed Penalties*$_{09\text{-}10}$ as a function of explanatory variables. Looking first at the results for the *Inspections* regression, note that three of the lagged performance variables, *Incidents*$_{06\text{-}08}$, *Property Damage*$_{06\text{-}08}$, and *Barrels Spilled*$_{06\text{-}08}$, have positive and significant coefficients, which suggested that regulators do target operators for inspections based on past performance. Interestingly, the coefficient on *Injuries*$_{06\text{-}08}$ is negative and significant which is not consistent with the idea of targeting. Also note that there is significant persistence in who is inspected that is not related to performance as past inspections are an important predictor of current inspections (i.e., the coefficient on *Dependent Variable*$_{06\text{-}08}$ is positive and significant). There are a number of possible explanations for this result. Recall that pipeline that pass through "high consequence" areas are subject to more stringent regulation and may also be inspected more often. Similarly pipelines carrying particularly hazardous materials may be inspected more often.

Looking next at the Operator Characteristics, as expected longer pipelines face more inspections that shorter pipelines, as do pipeline that cross many state borders. There are also significant differences in the number of inspections based on the Regions through which a pipeline runs, as evidenced by the significant coefficients on all of the regional dummies. Recall that a pipeline operator may have pipelines in multiple regions. Thus that the location of the pipeline affects the level of enforcement directed at the pipeline in ways that are not associated with differences in performance. While there are many possible explanations for these findings, they could be evidence that the inspection targeting process is not currently maximizing deterrence.

The results for *Cases Initiated* and *Proposed Penalties* are not as conclusive. The only performance measure that has a significant effect on the number of enforcement cases initiated is $\textit{Fatalities}_{06\text{-}08}$ and the only performance measure that has a significant effect on the proposed penalties is $\textit{Property Damages}_{06\text{-}08}$.[9] While the effects are positive as expected, it is surprising that neither injuries or property damage has a significant effect on the number of cases initiated and that neither injuries or fatalities has a significant effect on the proposed penalties. Also, note that there are regional differences in both cases and penalties: in particular, operators with pipelines in Region 1 are more likely to have enforcement cases initiated and to face higher proposed penalties.

Discussion and Next Steps

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 increase inspections funding and

[9]While one might be concerned that the insignificance of the coefficients on the lagged performance variables is due to multicollinearity, I do not believe that this is a problem. First, only $\textit{Barrels Spilled}_{06\text{-}08}$ and $\textit{Barrels Lost}_{06\text{-}08}$ are highly correlated with a correlation coefficient of 0.82. No other pair for performance variables has a correlation coefficient that exceeds 0.55. Also, there is no change in significance when I exclude various lagged performance variables from the specification.

civil penalties mandated under the Pipeline Safety, Regulatory Certainty, and Job Creation Act are likely to be effective at increasing pipeline safety. The results of the preliminary analysis do not provide compelling evidence that either federal inspections or civil penalties serve as particularly effective deterrents. While increased inspections result in a significant decrease of pipeline incidents, the results suggest that increased inspections are positively related to injuries and the amount of material spilled, even after controlling for past performance. Similarly, proposed penalties do appear to reduce the number of fatalities, but are positively associated with incidents, injuries, and material spilled. However, the number of cases initiated does appear to have a consistent deterrent effect on all types of performance except for incidents in general. What is unknown if whether the increased inspections and fines that result from the Pipeline Safety, Regulatory Certainty, and Job Creation Act will also result in increased cases.

From the analysis of inspections, enforcement cases, and proposed penalties, it also appears that the PHMSA might be able to better target its inspection and enforcement resources to provide more deterrence. While inspections do appear to be driven in part by past performance, the number of cases initiated and the level of proposed penalties are not as clearly tied to performance. Moreover, geography appears to play are relatively significant role in the deployment of resources. If enforcement resources were deployed to maximize deterrence, we might see an increase in environmental performance even without the increased resources mandated by the the Pipeline Safety, Regulatory Certainty, and Job Creation Act.

The analysis presented in this paper is a preliminary analysis. In subsequent versions of this paper I plan to increase the database to include smaller operators.

Additionally, I plan to expand the database to include some measure of state inspection efforts to get a better sense of the relative roles of federal and state enforcement. Finally, I would like to collect additional data on pipeline operators to more fully describe the differences between the operators in the analysis.

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)			
$\text{Incidents}_{09\text{-}10}$	Number of incident reported during 2009-2010.	2.51	6.32
$\text{Fatalities}_{09\text{-}10}$	Number of fatalities reported during 2009-2010.	0.04	0.47
$\text{Injuries}_{09\text{-}10}$	Number of injuries reported during 2009-2010.	0.23	2.79
$\text{Property Damage}_{09\text{-}10}$	Property damage reported during 2009-2010 in million $s.	3.63	38.29
$\text{Barrels Spilled}_{09\text{-}10}$	Barrels spilled during 2009-2010 in thousands of barrels.	0.65	4.44
$\text{Barrels Lost}_{09\text{-}10}$	Net barrels lost during 2009-2010 in thousands of barrels.	0.45	4.04
Enforcement Measures			
Inspections per 100 $\text{Miles}_{06\text{-}08}$	Number of federal inspections at the operator's facilities during 2006-2008 per 100 miles of pipeline.	0.66	1.52
$\text{Cases Initiated}_{06\text{-}08}$	Number of federal enforcement cases initiated against operator during 2006-2008.	1.24	2.40
$\text{Proposed Penalties}_{06\text{-}08}$	Proposed Penalties on the operator during 2006-2008 in million $s.	0.39	0.25
Past Performance Measures			
$\text{Incidents}_{06\text{-}08}$	Number of incidents reported during 2006-2008.	3.93	9.75
$\text{Fatalities}_{06\text{-}08}$	Number of fatalities reported during 2006-2008.	0.03	0.20
$\text{Injuries}_{06\text{-}08}$	Number of injuries reported during 2009-2010.	0.07	0.46
$\text{Property Damage}_{06\text{-}08}$	Property damage reported during 2006-2008 in million $s.	2.06	8.63
$\text{Barrels Spilled}_{06\text{-}08}$	Barrels spilled during 2006-2008 in thousands of barrels.	0.92	5.04
$\text{Barrels Lost}_{06\text{-}08}$	Net barrels lost during 2006-2008 in thousands of barrels.	0.52	3.62
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

Variable	Description	Mean	Std. Dev.
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, 2009-2010

	Incidents	Fatalities	Injuries	Property Damage	Gross Barrels Spilled	Net Barrels Lost
Inspections per 100 Miles$_{06\text{-}08}$	-0.26** (0.06)	0.01 (0.01)	0.11* (0.06)	-0.03 (0.76)	0.19** (0.08)	0.28** (0.04)
Cases Initiated$_{06\text{-}08}$	0.29** (0.05)	-0.02* (0.01)	-0.18** (0.05)	-1.28** (0.60)	-0.37** (0.07)	-0.53** (0.04)
Proposed Penalties$_{06\text{-}08}$	1.65** (0.33)	-0.13** (0.07)	-0.36 (0.34)	67.90** (4.35)	3.92** (0.43)	1.06** (0.24)
Dependent Variable†$_{06\text{-}08}$	0.48** (0.01)	0.11 (0.08)	1.03** (0.18)	0.24* (0.15)	0.61** (0.02)	1.09** (0.02)
Miles	0.24** (0.09)	0.09** (0.02)	0.66** (0.09)	5.11** (1.19)	0.20* (0.12)	0.35** (0.07)
Miles Squared	-0.02** (0.01)	-0.003** (0.001)	-0.02** (0.01)	-0.28** (0.08)	-0.01 (0.01)	-0.02** (0.00)
Intrastate	0.27* (0.16)	-0.03 (0.03)	-0.21 (0.17)	-1.27 (2.10)	-0.09 (0.21)	-0.11 (0.12)
Number of States	0.31** (0.05)	-0.01 (0.01)	-0.19** (0.05)	-1.09 (0.68)	-0.02 (0.07)	-0.06* (0.04)
Region 1	-0.09 (0.29)	0.06 (0.05)	0.13 (0.30)	11.67** (3.80)	0.004 (0.37)	-0.28 (0.21)
Region 2	-0.61** (0.18)	-0.01 (0.03)	0.05 (0.19)	1.09 (2.41)	-0.14 (0.24)	0.27** (0.13)
Region 3	-0.61** (0.17)	-0.03 (0.03)	-0.07 (0.17)	-3.52 (2.21)	0.08 (0.22)	0.17 (0.12)
Region 4	-0.91** (0.19)	0.08** (0.04)	0.75** (0.20)	0.79 (2.56)	-0.12 (0.25)	0.07 (0.14)
Gas Gathering	0.04 (0.10)	0.03* (0.02)	0.20* (0.10)	0.88 (1.33)	-0.03 (0.13)	-0.04 (0.07)
Gas Transmission	-0.16 (0.10)	-0.01 (0.02)	0.01 (0.11)	-1.98 (1.37)	0.12 (0.14)	0.08 (0.08)
Gas Distribution	0.15 (0.12)	0.05** (0.02)	0.30** (0.13)	2.26 (1.63)	-0.15 (0.16)	-0.26** (0.09)
Hazardous Liquid	0.24** (0.11)	0.02 (0.02)	0.13 (0.12)	1.11 (1.48)	0.12 (0.15)	-0.01 (0.08)
Constant	-0.01 (0.12)	-0.02 (0.02)	-0.17 (0.12)	0.55 (1.54)	-0.02 (0.15)	0.02 (0.09)
R-squared	0.85	0.06	0.11	0.24	0.46	0.79

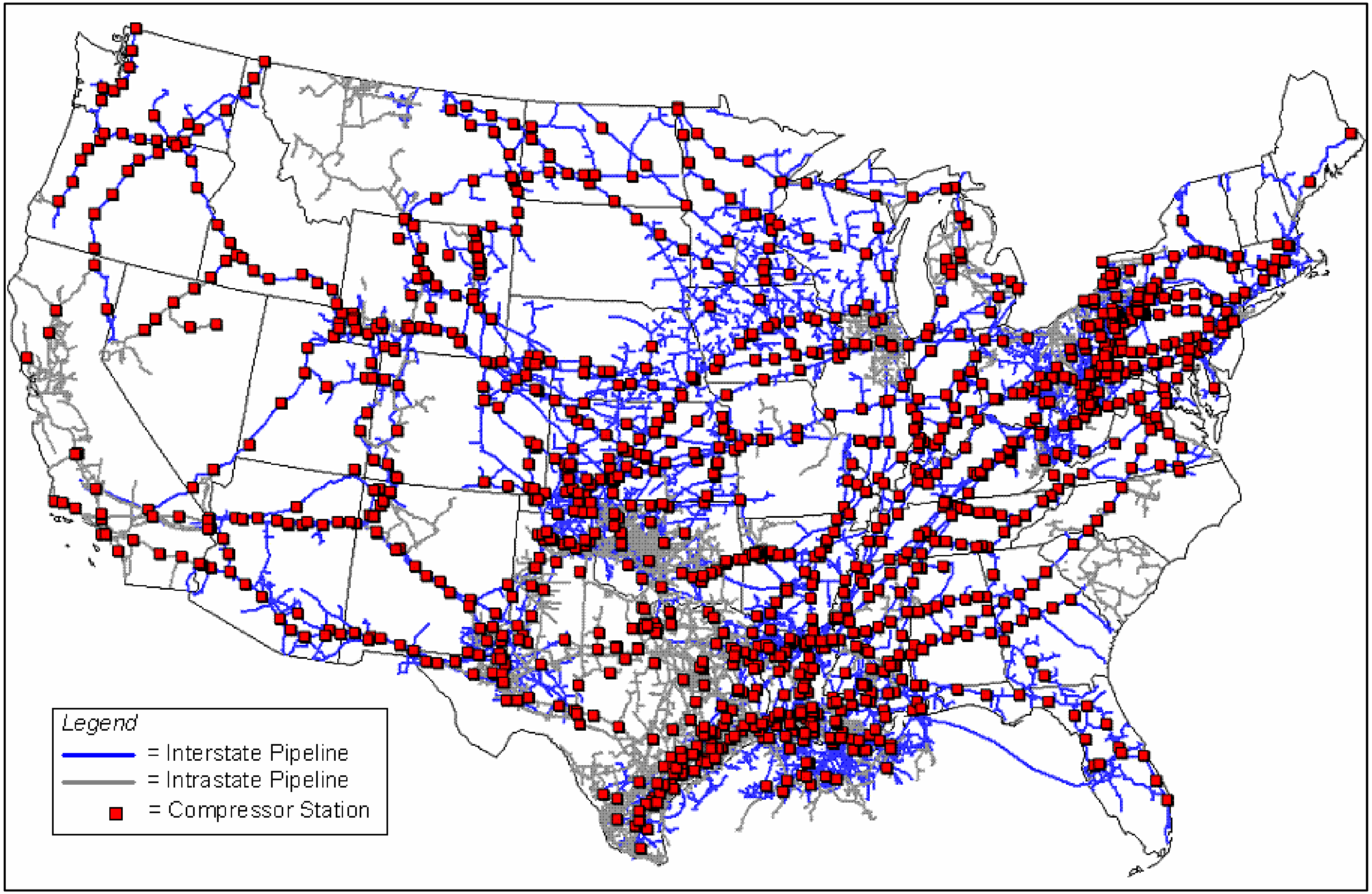
** Significant at the 5% level; *Significant at the 10% level.; † Equal to the variable listed at the top of the column for the period 2006-2008.

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

	Total Inspections	Cases Initiated	Proposed Penalties
$Incidents_{06-08}$	0.046** (0.020)	-0.003 (0.013)	0.001 (0.002)
$Fatalities_{06-08}$	-0.419 (0.770)	0.876* (0.482)	0.086 (0.070)
$Injuries_{06-08}$	-0.947** (0.333)	-0.316 (0.213)	-0.024 (0.027)
Property $Damage_{06-08}$	0.033* (0.020)	-0.012 (0.013)	0.009** (0.002)
Barrels $Spilled_{06-08}$	0.083* (0.046)	-0.005 (0.028)	0.001 (0.003)
Barrels $Lost_{06-08}$	0.004 (0.064)	0.051 (0.039)	-0.002 (0.005)
Dependent Variable†$_{06-08}$	1.026** (0.009)	0.152** (0.055)	-0.068 (0.049)
Miles	0.002** (0.000)	0.194 (0.131)	0.015 (0.015)
Miles Squared	-0.006** (0.001)	-0.001 (0.008)	-0.002 (0.001)
Intrastate	0.047 (0.026)	0.619* (0.363)	0.004 (0.044)
Number of States	0.750** (0.087)	0.050 (0.064)	0.001 (0.008)
Region 1	1.962** (0.478)	1.291** (0.403)	0.172** (0.049)
Region 2	-1.521** (0.304)	0.316 (0.279)	0.017 (0.034)
Region 3	-2.227** (0.028)	-0.065 (0.314)	-0.002 (0.038)
Region 4	-1.270** (0.321)	0.266 (0.288)	0.042 (0.035)
Gas Gathering	0.020 (0.167)	-0.062 (0.339)	0.005 (0.041)
Gas Transmission	0.109 (0.174)	0.090 (0.338)	0.059 (0.041)
Gas Distribution	-0.388* (0.205)	-0.555 (0.511)	-0.371 (0.618)
Hazardous Liquid	-0.259 (0.188)	0.124 (0.347)	0.685 (0.422)
Constant	-0.006 (0.193)	-0.234 (0.432)	-0.126** (0.053)
R-squared	0.71	0.50	0.45

**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

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 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 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.

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

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.