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The Energy Policy Act of 2005: Increased Inspection Frequency and Compliance at Underground Storage Tank Facilities

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Abstract

The Energy Policy Act (EPAct) of 2005 enacted a requirement that all regulated underground storage tanks (UST) containing petroleum or certain other hazardous substances must be inspected for compliance with UST release prevention and detection requirements at least once every three years. Prior to EPAct, a survey by the U.S. Government Accountability Office showed that 62% of states did not inspect USTs regularly or did so at an interval of four years or longer. This research examines the impact of the increase in inspection frequency occurring under EPAct on compliance. A censored bivariate probit model is estimated using detailed data from Arkansas and Louisiana on inspection, compliance, releases, and other socioeconomic and biophysical characteristics of UST facility locations. We find that increased inspection frequency improved compliance with UST requirements in both states. Furthermore, results in Louisiana suggest that compliance at the last inspection reduced the probability of a release. These findings may inform federal and state budget and policy decisions related to UST inspections as well as other environmental or safety policy that rely on inspections to monitor and enhance compliance.

KEYWORDS: compliance; inspection; environmental regulation; Energy Policy Act of 2005; underground storage tank; release prevention

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JEL CODES: K32 Energy, Environmental, Health, and Safety Law, Q5 Environmental Economics; Q53 Air Pollution –Water Pollution – Noise – Hazardous Waste – Solid Waste – Recycling; Q58 Government Policy

1. Introduction

Today there are approximately 561,000 underground storage tanks (UST) that store petroleum or certain other hazardous substances at approximately 202,000 sites that are regulated by the U.S. Environmental Protection Agency's (EPA) UST Program and are subject to compliance inspections (US EPA 2016). These USTs are primarily located at gas stations but also at facilities in other industries such as manufacturing, transportation, wired telecommunications, electric utilities, and hospitals (US EPA 2011). The greatest potential hazard from a leaking UST is that petroleum or other hazardous substances can seep into the soil and contaminate groundwater, the source of drinking water for nearly half of all Americans (USGS 2003). A release from an UST can also present other health and environmental risks, including potential for fire and explosion. The Energy Policy Act of 2005 (EPAct) included amendments that enacted a 3-year inspection requirement for all regulated UST facilities. This requirement increased inspection frequency and regularity at underground storage tanks across the United States. More frequent UST inspections are intended to improve facilities' compliance with UST release detection and prevention requirements, and in doing so prevent accidental releases of harmful substances into the environment. This study examines the impact of EPAct's 3-year UST inspection frequency requirement on UST facilities' compliance with release detection and prevention requirements.

In 1984, the Congress enacted legislation that required EPA to create a comprehensive regulatory program for USTs storing petroleum or certain other hazardous substances. From the inception of the UST program to March 2017, more than 1.8 million USTs have been properly closed, and today there are approximately 2.1 million tanks across the United States. The EPA UST program is designed to prevent releases of petroleum and hazardous substances into the environment, detect releases when they occur, and clean up any contamination from releases. To monitor the large number of tanks, EPA enlisted states' assistance in implementing and enforcing the program. As of 2016, 38 states and the District of Columbia and the Commonwealth of Puerto Rico have approved state UST programs. To obtain EPA approval, state programs must be at least as stringent as the federal requirements (US GPO e-CFR 2013). Despite early efforts, releases were common. From the beginning of the program until 2000, there were over 400,000 releases reported.

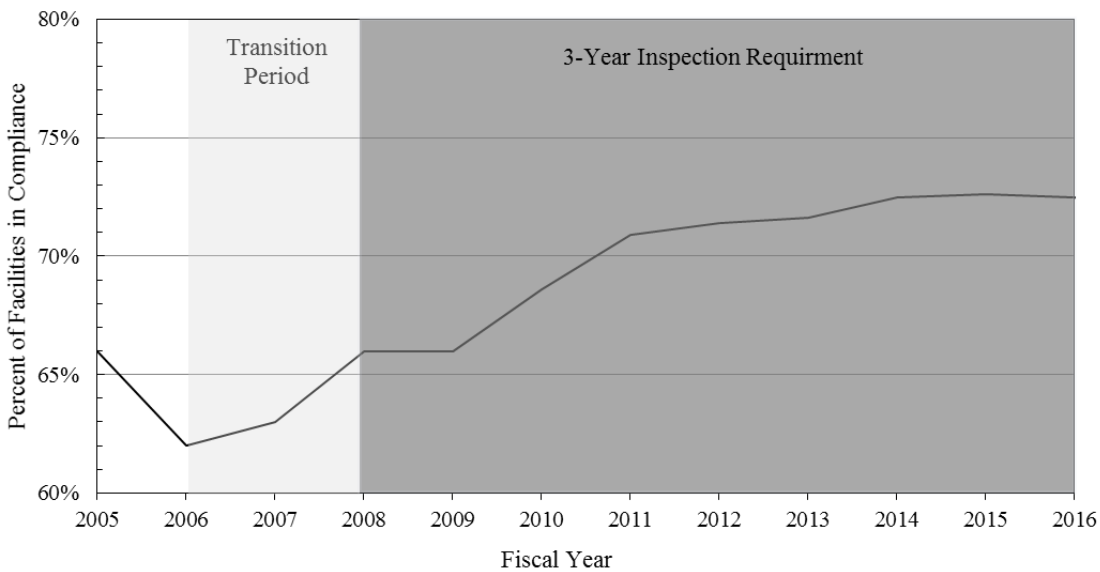
In 2001, the United States Government Accountability Office (GAO) investigated concerns raised by the United States Senate Committee on Environment and Public Works that the UST program was not effectively preventing leaks (US GAO 2001). One aim of the investigation was to determine the breadth of EPA's and the states' tank inspections. Physical inspections confirm whether tanks have been updated and are being properly operated and maintained to prevent and detect releases. Although EPA managers had recommended that inspections take place annually or, where resources are limited, at a minimum of every three years, the GAO survey of state UST programs showed that 62% of states did not inspect USTs regularly or did so at an interval of four years or longer. Based on their findings, the GAO recommended that Congress authorize EPA to establish a federal requirement for the physical inspection of all tanks on a periodic basis.

The EPAct included amendments to Subtitle I of the Solid Waste Disposal Act (SWDA), which is the original 1984 legislation that required EPA to create a comprehensive regulatory program for USTs storing petroleum or certain other hazardous substances. Among other provisions, the UST provisions of EPAct added the requirement that all regulated UST facilities must be inspected to evaluate compliance with UST requirements at least once every three years.[1] Today national compliance rates are higher than before the 3-year inspection requirement. At the end of fiscal year 2005, 66 percent of facilities were in operational compliance but by the end of fiscal year 2016 compliance rates reached 72.5 percent (US EPA

[1] Other provisions include operator training, delivery prohibition, secondary containment, financial responsibility, and cleanup of releases that contain oxygenated fuel additives.

2005; US EPA 2016). This trend, as depicted in Figure 1, represents a significant achievement but the extent to which this improvement in compliance is due to the increase in inspection frequency is unclear. Without controlling for other factors that may impact compliance rates such as facility characteristics or compliance history, the role that increased inspection frequency has taken in these improvements cannot be clearly identified.

Figure 1. National underground storage tank compliance rate



Note: The Energy Policy Act of 2005 provisions for underground storage tanks include a transition phase from August 8, 2005 to August 8, 2007 during which all states receiving Subtitle I funding for their UST programs are required to inspect all active UST facilities that had not been inspected since 1998. After August 8, 2007, the time between concurrent compliance inspections at an UST facility cannot exceed three years.

A national analysis of the impact of the EPAct's 3-year inspection requirement on compliance would be ideal but the data needed is not available. States report aggregated state-level UST information periodically throughout the year to EPA for measuring UST performance. This data is not suited for use in a national analysis of the impact of increasing inspection frequency due to limited data on inspection frequency (i.e., the total annual number of inspections in each state was not reported to EPA until 2008). Furthermore, most state UST programs have insufficient inspection and compliance data from prior to EPAct to be able to examine the impact of changes in inspection frequency on compliance. As an alternative, this analysis uses two UST facility-level datasets; one from the Arkansas Department of Environmental Quality (ADEQ) (2000 to 2012) and one from the Louisiana Department of Environmental Quality (LADEQ) (2001 to 2012). Both datasets include facility characteristics and information on inspection, compliance, and releases from before and after EPAct combined with data on the socioeconomic and biophysical characteristics of the facilities' locations. Prior to the EPAct of 2005, Arkansas and Louisiana inspected tanks at an interval of 4 years or longer, which makes them ideal candidates for evaluating the impact of the EPAct's 3-year inspection requirement on compliance.

While there is a significant body of literature on environmental monitoring and enforcement and the effect of inspections on compliance (see Shimshack (2014) for a comprehensive review), previous studies that explicitly examine the impact of inspection frequency on compliance are limited. Alberini et al. (2008) examine U.S. Food and Drug Administration (FDA) inspections of seafood processors' compliance with sanitation requirements and a new Hazard Analysis and Critical Control Points (HACCP) requirement and find that the anticipated inspection frequency increases the likelihood of compliance with the sanitation program but not with the newer HACCP program. Ko, Mendeloff, and Gray (2010) examine the effect of repeated Occupational Safety and Health Administration (OSHA) inspections and the time between inspections on noncompliance and find that the number of violations cited increased with each additional year since the prior inspection. At regulated facilities in Michigan, Liu (2012) show that inspections at Resource Conservation and Recovery Act (RCRA) facilities have a significantly positive effect on compliance, as well as evidence of positive cross-program effects (i.e., inspections under the Clean Air Act have a positive and significant effect on facility compliance with RCRA). Liu (2012) includes the total number of inspections in the last year as a measure of inspection frequency in her analysis, however, interpretation of the effect of inspection frequency on compliance is limited because RCRA facilities are typically not inspected more than once in a given year. Abualfaraj et al. (2016) also examine inspections frequency within a single year but in the context natural gas wells in Pennsylvania. Specifically, they define an inspection ratio as number of inspections relative to the number of active wells each year and find that a higher inspection ratio (i.e., an individual well is inspected more frequently) lowers the odds of a violation at any given inspection. Our analysis extends the literature by capitalizing on the exogenous implementation of a change in inspection frequency from the EPAct of 2005 and focuses on an environmental hazard that is less observable and less publicized than, for example, Superfund sites but that may pose significant risk to human health and the environment due to the sheer number of USTs storing petroleum and certain other hazardous substances across the nation.

Results from censored bivariate probit models show that the increase in inspection frequency occurring after the EPAct improved compliance of owners and operators at regulated UST facilities in Arkansas and Louisiana and this effect is heterogeneous based on the facility's compliance status at the last inspection—a larger impact for those facilities that were compliant than those that were noncompliant at the last inspection. Furthermore, results in Louisiana suggest that compliance at the last inspection reduces the probability of a release. This analysis provides important insight on the impact of more frequent inspections on UST compliance that can be utilized in making policy and budget decisions. Furthermore, these findings may be useful to other environmental or safety programs that rely on inspections to monitor and enhance compliance.

2. Background: Underground storage tank inspection and compliance

Louisiana

Louisiana's UST state program was approved in 1992. During the late 1980s and 1990s, Louisiana focused on closure of substandard tanks and remediation activities. In 2000, the Louisiana State Legislature established a requirement that 15% of active USTs be inspected each year. UST inspections in Louisiana are announced usually one week in advance. This notice is given to provide the tank owner with the time needed to gather the required paperwork for examination. An inspection typically takes one to three hours, and the inspector goes through each step of the inspection with the facility owner or operator if they are available. All USTs at the facility are inspected. The inspector checks to see if the facility is compliant with a comprehensive list of requirements aimed at preventing and detecting releases such as standards for tanks and piping, spill and overfill prevention equipment, operation and maintenance of corrosion protection systems, release detection, record keeping, and so on. If a violation is identified during an inspection, the inspector will document the violations and confer with the LADEQ Enforcement Division to determine the appropriate type of enforcement action to issue. Usually, a Notice of Deficiency (NOD) or Notice of Potential Delivery Prohibition (NOPDP) is issued.[2]

Facilities that do not return to a compliant status or that do not respond to NODs or NOPDPs receive Compliance Orders from the LADEQ Enforcement Division. Those issued a NOPDP are prohibited from receiving product deliveries, which is referred to as red tagged. When facilities refuse to return into compliance or certain egregious violations occur, the Enforcement Division has the discretion to issue either a formal penalty notice or an Expedited Penalty Agreement.[3]

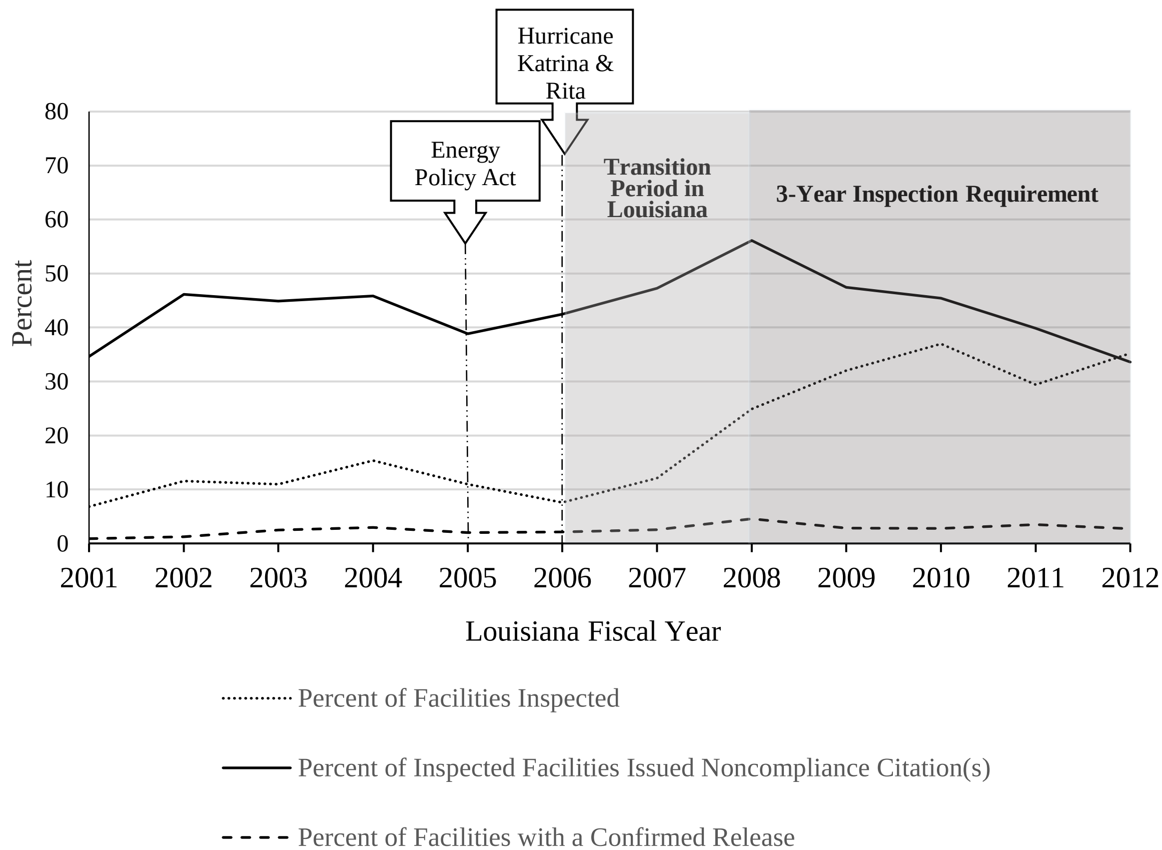
Figure 2 shows the percent of facilities inspected (dotted line), the percent of inspected facilities that received at least one noncompliance citation (solid line), and the percent of facilities at which a release was confirmed (dashed line) in each year from 2001 to 2012. Prior to the EPAct of 2005, roughly 7-15% of Louisiana's UST facilities were inspected each year. This

[2] If the facility has a temporarily closed tank or is an abandoned facility, the Enforcement Division may opt to issue a Compliance Order immediately rather than a Notice of Deficiency.

[3] A facility has the option to sign an Expedited Penalty Agreement, which allows them to settle the violations for a reduced penalty by certifying that violation(s) was corrected within the 30-day timeframe allowed for in the agreement. Signing the agreement is strictly voluntary on the part of the regulated facility. Louisiana has a Delivery Prohibition (Red Tag) program that allows inspectors to red tag tanks at facilities that have certain egregious violations. The delivery prohibition can happen simultaneously with the enforcement actions listed above.

coincides with the time frame during which the Louisiana State Legislature had a requirement that 15% of active USTs be inspected each year.[4] UST inspection frequency requirements were

Figure 2. Louisiana inspection, compliance and confirmed releases (fiscal year 2001-2012)



Note: The Energy Policy Act of 2005 provisions for underground storage tank inspections included a transition phase from August 8, 2005 to August 8, 2007 during which states were required to inspect all active UST facilities that had not been inspected since 1998. This transition period was delayed in Louisiana due to Hurricane Katrina and Rita (August and September 2005, respectively).

[4] From approximately 2000 to the passing of EPAct in 2005, the Louisiana Regional Department of Environmental Quality staff identified 15% of the active UST in their region to inspect. Each region had their own systems of selecting the 15 percent. For example, some just went alphabetically down the site list while others went numerical by facility number. Also, if one region was overloaded with work and could not inspect 15% of their USTs facilities, then Louisiana would do more inspections in another region instead.

signed on August 8, 2005. The provisions included a transition phase from August 8, 2005 to August 8, 2007 during which states were required to inspect all active UST facilities that had not been inspected since 1998. The LADEQ began to focus inspections on these facilities just before Hurricanes Katrina and Rita hit Louisiana (August and September 2005, respectively) but then had to divert resources to deal with the hurricanes' aftermath. As a result, only 7.6% of facilities were inspected in 2006, and the start of the transition period was delayed by one year. Once resources could be directed back to inspections, the LADEQ worked on inspecting those facilities that had not been inspected since 1998, and then towards meeting the requirement of inspecting each UST facility at least once every three years.

More frequent UST inspections are intended to improve facilities' compliance with UST release detection and prevention requirements, and in doing so prevent accidental releases of harmful substances into the environment. From 2001 to 2012, on average each year 2.55 percent of facilities in the sample had a release confirmed. No clear trend in the percent of facilities with a release each year is visible, however, interestingly confirmed releases spike in 2008 when the LADEQ was focused on inspecting those facilities that had not been inspected since 1998. Trends in noncompliance are more apparent. In the years immediately following EPAct, the percent of inspected facilities that had at least one noncompliance citation issued increased, reaching a high of 56% in fiscal year 2008. This increase is likely because many of the facilities inspected during those years were ones that had not been inspected since 1998. From 2009 to 2012, there is a downward trend in the percent of inspected facilities identified as noncompliant, reaching a low of 33.6% in 2012. Overall this improvement in compliance coincides with the establishment of the ongoing 3-year inspection requirement in Louisiana. Our analysis will account for other factors that may also have impacted compliance in order to identify the extent that this observed improvement is due to increased inspection frequency.

Arkansas

Arkansas's UST state program began in 1989. With limited inspection resources, the program categorized facilities in terms of size (i.e., large, medium and small chain stores and single-owned facilities) and aimed to inspect all single-owned facilities but only a representative number of facilities within a single chain. The hope was that if one facility under a chain store's purview was cited for a compliance violation, then corporate would check for similar issues at their other stores. ADEQ continued with this inspection strategy and overtime was able to increase the number of inspectors, so that facilities were generally inspected at intervals of four years or longer prior to the EPAct of 2005 inspection requirement. From 2005 to 2007, ADEQ was able to inspect all facilities that had not been inspected since December 22, 1998 and began the first 3-year inspection cycle in late 2007. ADEQ first went to UST facilities located within source water protection areas, then facilities owned by chains and then single-owned facilities. ADEQ completed the first cycle of inspection by August 2010, and then set out to inspect facilities again before their 3-year anniversary from the previous inspection.

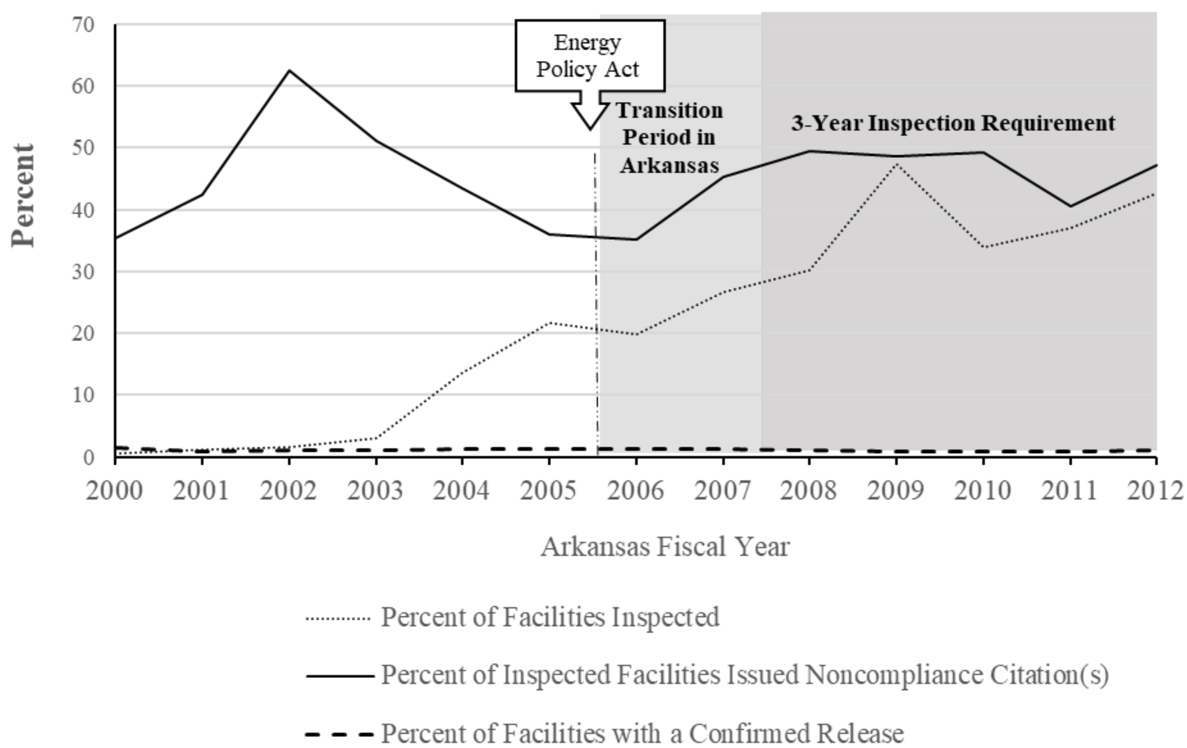
In Arkansas, as in Louisiana, UST inspections are announced usually one week in advance. If a violation is identified during an inspection and it is categorized as related to Significant Operational Compliance, the facility is either given the opportunity to fix the violation within a period of a few days to 30 days or, if the facility is not equipped to fix the violation, it is red-tagged. When a facility is red-tagged it is not allowed to receive fuel.[5] Once the facility is back in a compliant status and notifies ADEQ, the inspector will make a follow-up visit to confirm and remove the red-tag status. Additional enforcement actions such as a notice of violation or consent administrative order are used when facilities fail to return to compliant status and for certain egregious violations.

Figure 3 shows the percent of facilities inspected (dotted line), the percent of inspected facilities that received at least one noncompliance citation (solid line), and the percent of

[5] Facilities in AR have been red-tagged since 1998. Between 1998 and 2007, facilities were mostly red-tagged for failure to upgrade tanks. An amendment in 2007 allowed for red-tagging for Significant Operational Compliance violations.

facilities at which a release was confirmed (dashed line) in each year from 2000 to 2012. Prior to the EPAct of 2005, a very small percentage of facilities were inspected each year, ranging from roughly 1% in 2001 up to 14% in 2005.[6] In the transition period (August 2005-August 2007), there was an initial drop followed by an increase in both the percentage of facilities inspected as well as the percent of inspected facilities that received at least one noncompliance citation at the inspection increased. As Arkansas moves further into the 3-year inspection cycle, there is no clear trend in noncompliance. There is also no clear trend in the percentage of facilities with a confirmed release, which stays around 1% of facilities.

Figure 3. Arkansas inspection, compliance and confirmed releases (fiscal year 2000-2012)



[6] The earliest year of inspection and compliance data in ADEQ's databases is 2002. We were able to obtain digital images of inspection forms for 2000 and 2001 from ADEQ to add additional years of pre-EPAct inspection and compliance results to our analysis.

3. Methods

3.1 Data

This analysis uses Arkansas Department of Environmental Quality (ADEQ) and Louisiana Department of Environmental Quality's (LADEQ) data on inspection, compliance, and releases at UST facilities. The data includes information on facility specific characteristics, results of compliance inspections, and releases. The facilities' addresses were geocoded and matched with location specific socioeconomic data obtained from the 2009-2013 U.S. Census American Community Survey 5-year estimates and biophysical data obtained from the Soil Survey Geographic Database (SSURGO) (US American Communities Survey 2010; U.S. Department of Agriculture 2015). The final LA sample is an unbalanced panel that consists of 108,281 quarterly observations on 4,424 facilities that had at least one active petroleum UST subject to federal UST regulations between 2001 and 2012, and the AR sample includes 105,938 quarterly observations on 3,243 facilities between 2000 and 2012. On average, facilities in both AR and LA have two tanks with an average capacity of approximately 8000 gallons. Tanks on average are older in LA, with the oldest tank at a facility being almost 22 years old versus 17 years in AR (Table 1).

Table 1. Summary statistics of explanatory variables

	Arkansas			Louisiana		
Variable	**Mean**	**Std. Dev.**	**Median**	**Mean**	**Std. Dev.**	**Median**
Years_LastInspection	2.46	1.14	2.37	3.65	1.57	3.02
Total_Inspection[†]	2.12	1.14	2	1.48	0.64	1
Last_Noncompliance	0.47	0.50	0	0.46	0.50	0
Past_Noncompliance[†]	0.29	0.56	0	0.19	0.43	0
Last_Release[†]	0.03	0.17	0	0.05	0.23	0
Number_Tanks[†]	2.56	1.21	2	2.82	1.17	3
Age_OldestTank (years)	17.64	8.54	16.86	21.69	9.77	21.68
Mean_TankCapacity (1000’s of gallons)	8.04	4.55	8	8.36	3.97	8
Depth_WaterTable (meters)	0.37	0.37	0.31	0.47	0.37	0.31
Soil_MostPermeable[†]	0.18	0.38	0	0.43	0.50	0
Distance_FieldOffice (miles)	25.80	17.60	24.43	20.94	16.16	17.08
Density_Population (100’s people/sq mile)	6.87	10.95	2.02	13.82	19.53	6.10
Income_Median (100’s of USDs)	30.89	9.40	30.00	43.83	19.63	40.83
FiscalYear_Q2[†]	0.21	0.41	0	0.20	0.40	0
FiscalYear_Q3[†]	0.27	0.45	0	0.26	0.44	0
FiscalYear_Q4[†]	0.28	0.45	0	0.30	0.46	0
State_OperatorTraining[a†]	0.24	0.43	0	0.46	0.50	0
AR_Last_Enforcement[†]	0.08	0.27	0			
AR_AnnualBudget[b]	5.91	2.44	6.62			
LA_Contract_Inspector [a†]				0.49	0.50	0
LA_TotalHurricaneVisits[b]				20.14	117.09	0

Notes: The variables marked by [a] were included only in the noncompliance equation whereas the variables marked by [b] was included only in the inspection equation. The variables marked by [†] are the discrete variables for which the median value was used in calculating the predicted probabilities in table 4.

3.2 Empirical Model

For the empirical models, we use facility-level panel data in a censored bivariate probit models as detailed in Greene (1992) and Stafford (2002; 2012) for each state. The models include temporal lags (i.e., examine the relationship between current compliance and an UST facility’s compliance status at the last inspection) and control for a variety of facility and location characteristics that may also affect compliance. The censored bivariate probit addresses potential selection bias that could occur if there was any targeting of inspections based on unobserved characteristics of the facilities that would make them, for example, both more likely to be inspected and more likely to violate, particularly, in the pre-EPAct years when each regional office in Louisiana had their own systems of selecting facilities for inspections and Arkansas had a prioritizing strategy based on ownership.

The censored bivariate probit consists of two equations—the selection equation and outcome equation. Here the selection equation is the probability of an inspection, and the outcome equation is the probability of noncompliance. The dependent variable in the inspection equation is a dummy variable that is equal to one if facility *j* is inspected in quarter *t*. In the noncompliance equation, the dependent variable is a dummy variable that equals one if facility *j* inspected in quarter *t* received at least one noncompliance citation. For brevity, from here forward, we will refer to a facility as noncompliant if it had at least one noncompliance citation issued at its inspection.

Both the probability of inspection and noncompliance are expected to depend on a facility's characteristics and history (i.e., inspection, compliance, and release history) as well as socioeconomic and biophysical attributes of the facility's location. Table 1 presents descriptive statistics for the variables used in the inspection and noncompliance equations for each state. We include a common set of variables (rows 1 to 17 in Table 1) and regional dummy variables in both equations to account for these factors as well as variables that are unique to each equation and state (rows 18 to 21 in Table 1). In the remainder of this section, we define the main variables of interest and describe their expected relationships with noncompliance, which is the equation of primary interest in this analysis (Table 2).

For our main variable of interest, we used a continuous measure of inspection frequency, the number of years since the last inspection, rather than a dummy variable that would indicate if the inspection was before or after the EPAct of 2005 3-year inspection requirement. This is because the transition took several years and there is no clear date that establishes a before period (when inspections were less frequent than three years) and an after period (when inspections were at least once every three years). As more time passes since a facility's last inspection, owners and operators may become lax about keeping up with required standards and procedures, and therefore, are more likely to have a violation identified when inspected. The estimated coefficient on *Years_LastInspection* is expected to be positive, *ceteris paribus*.

A noncompliance citation at the last inspection is expected to have a deterrent effect and hence is expected to reduce the likelihood that an UST facility will violate at the current inspection. However, if the facility believes that the cost of complying is greater than the benefits of complying, then the facility may return to a noncompliant state. Therefore, the expected sign of the coefficient on *Last_Noncompliance* is ambiguous. To allow for the heterogeneous effect of increasing inspection frequency for those that were identified as noncompliant at last inspection and those that were compliant, the interaction of inspection frequency and whether the facility was noncompliant at the last inspection is included (*Years_LastInspection*Last_Noncompliance*). Our empirical model also accounts for the effect of a facility's past experience with inspections, occurrence of accidental releases at the last inspection, characteristics such as number, age and capacity of tanks, biophysical characteristics of the UST localities, such as soil. Our model includes indicator variables for the type of inspectors and time period during which the state operator trainings were conducted to control for any effect these variables may have on the compliance. Table 2 identifies the definition of each included variable and its expected relationship with the likelihood of non-compliance.

Table 2. Explanatory variables and their hypothesized signs on likelihood of noncompliance

Variable	Definition	Expected sign of coefficient on likelihood of non-compliance
Years_LastInspection	Time since the last inspection (years)	Positive
Total_Inspection	Number of total previous inspections (count)	Negative
Last_Noncompliance	A dummy variable; **=1** if at least one violation was detected at the last inspection, **=0** otherwise	Ambiguous
Past_Noncompliance	A dummy variable; **=1** if at least one violation was detected at any past inspection *excluding the last inspection*, **=0** otherwise	Ambiguous
Last_Release	A dummy variable; **=1** if at least one release is confirmed since the last inspection; **=0** otherwise	Negative
Number_Tanks	Number of tanks at a facility (count)	Positive

Age_OldestTank	Age of the oldest tank at a facility (years)	Positive
Mean_TankCapacity	Mean capacity of all active tanks (1000's of gallons)	Negative
Depth_WaterTable	Depth of the water table[1] at the UST location (meters)	Positive
Soil_MostPermeable	A dummy variable; **=1** if the soil at UST location has the most permeable soil based on the Soil Survey Geographic Database (SSURGO), **=0** otherwise	Negative
Distance_FieldOffice	Distance from UST facility to the regional LADEQ field office (meters)	Positive
Density_Population	Population density in the census block of the UST location (100's people/sq. mile)	Ambiguous
Income_Median	Median income in the census block of the UST location (1000's of USDs)	Ambiguous
FiscalYear_*Q*	A dummy variable; **=1** for the state's fiscal year quarter *Q* (FiscalYear_Q1, FiscalYear_Q2, FiscalYear_Q3, and FiscalYear_Q4). FiscalYear_Q1 is the excluded base quarter in the model estimation.	Unknown
State_OperatorTraining	A dummy variable; **=1** for the time period when the operator training has begun in the state, **=0** otherwise	Negative
LA_Contract_Inspector	A dummy variable; **=1** if the Louisiana UST inspector is a contractor, **=0** otherwise	Ambiguous
AR_Last_Enforcement	A dummy variable; **=1** if at least one enforcement action since the last inspection, **=0** otherwise	Ambiguous

Lastly, for the censored bivariate probit model to be identified, at least one variable that affects the probability that a facility will be inspected but that does not affect the probability that a facility will be noncompliant should be included in the inspection equation (Wooldridge 2002). For identification purposes, we include the total annual number of hurricane related visits made by LADEQ UST inspectors to facilities, *State_TotalHurricaneVisits*, in the Louisiana inspection equation but exclude it from the noncompliance equation. *State_TotalHurricaneVisits* reflects changes in the resource constraint of the LADEQ. We expect that when the total number of hurricane related visits is higher the resources available to conduct compliance inspections is reduced but that the total number of hurricane related visits would not affect the probability of a violation at an inspected facility. For the Arkansas equation, we include *AR_AnnualBudget*, the annual budget allocated for compliance inspections. We expect that during the study period when the annual budget allocated for compliance inspections is higher the likelihood that a facility will be inspected is higher but that the higher budget would not directly impact the likelihood that the facility would be noncompliant.[7]

4. Results and Discussion

Results of the censored bivariate probit regression are presented in Table 3.[8] In this section, we briefly discuss estimates from the inspection equation before turning the focus to the main results from the noncompliance equation. Inspection strategy over the study period, particularly post-EPAct, should be largely determined by the time since last inspection (*Years_LastInspection*). This is evident in the inspection equation estimates, where the coefficients on *Years_LastInspection* for both Arkansas and Louisiana are positive and significant at the 1% level. Interestingly, results suggest that other factors affect the probability of an inspection. In both states, the probability of an inspection is higher when a facility had a release since the last inspection or has a higher mean tank capacity, and the probability of an inspection is lower, when inspection resources are constrained (*State_TotalHurricanVisits* in Louisiana and *AR_AnnualBudget* for Arkansas). In Louisiana, the probability of an inspection is higher when a facility has older tanks; fewer tanks; is in an area where the water table is further from the surface; or cumulatively has had more inspections. In Arkansas, the probability of an inspection is higher when a facility has newer tanks; more tanks; was compliant at the last inspection; cumulatively has had fewer inspections; is closer to the district field office or in an area with higher median income.

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[7] When *State_TotalHurricaneVisits* was included in Lousiana's noncompliance equation, it was not significant (Coef.= -0.0002; p=0.254). When Annual_USTBudget was included in Arkansas's noncompliance equation, it was marginally significant (Coef. = 0.0145; p=0.164). Note that in the years prior to the 3-year inspection requirement, there was more variation in the annual budget and the number of inspections conducted.

[8] We used Stata 13's *heckprobit* command, which estimates the censored bivariate probit model. We also use clustering to account for non-independence of inspections and compliance outcomes from a single UST facility in our unbalanced panel dataset to allow for potential within-groups (facilities) correlation while modeling econometric error (Rogers 1993; Williams 2000; Wooldridge 2002).

Table 3. Estimation results of the censored bivariate probit model

	Louisiana		Arkansas	
Equation:	**Inspection**	**Noncompliance**	**Inspection**	**Noncompliance**
Years_LastInspection	0.3322***	0.0814*	0.4160***	0.1845***
	(0.007)	(0.049)	(0.022)	(0.064)
Years_LastInspection* Last_Noncompliance	0.0306**	-0.0407*	0.0491*	-0.0316
	(0.012)	(0.022)	(0.049)	(0.028)
Total_Inspection	0.2077***	-0.1109**	-0.0919***	-0.0494***
	(0.012)	(0.047)	(0.011)	(0.019)
Last_Noncompliance	-0.0272	0.5484***	-0.1815***	0.5241***
	(0.030)	(0.090)	(0.046)	(0.081)
Past_Noncompliance	-0.0004	0.1444***	0.0203*	0.1699***
	(0.014)	(0.051)	(0.012)	(0.032)
Last_Release	0.3975***	-0.1126	0.1657***	0.1420
	(0.038)	(0.093)	(0.057)	(0.090)
Number_Tanks	-0.0212***	-0.0205	0.0147**	0.0284**
	(0.006)	(0.015)	(0.007)	(0.013)
Age_OldestTank	0.0050***	0.0120***	-0.0036***	0.0060***
	(0.001)	(0.002)	(0.001)	(0.002)
Mean_TankCapacity	0.0135***	-0.0240***	0.0061***	0.0017
	(0.002)	(0.005)	(0.002)	(0.003)
Depth_WaterTable	0.0397**	0.1560***	-0.0359	0.0155
	(0.018)	(0.052)	(0.026)	(0.044)
Soil_MostPermeable	-0.0221	-0.0318	-0.0350	0.0710*
	(0.015)	(0.039)	(0.025)	(0.040)
Distance_FieldOffice	-0.0002	0.0013	0.0014**	-0.0012
	(0.000)	(0.001)	(0.001)	(0.001)
Density_Population	-0.0003	0.0007	0.0015*	-0.0045***
	(0.000)	(0.001)	(0.001)	(0.002)
Income_Median	-0.0002	-0.0002	-0.0007	-0.0019
	(0.000)	(0.001)	(0.001)	(0.002)
Contract_Inspector		0.1003***		
		(0.037)		
State_OperatorTraining		-0.1835***		-0.0086
		(0.045)		(0.049)
AR_Last_Enforcement			-0.4890***	0.0540
			(0.103)	(0.171)
State_TotalHurricaneVisits	-0.0009***			
	(0.000)			
AR_AnnualBudget			0.0853***	
			(0.005)	
ρ	-0.1125		-0.0236	
	(0.164)		(0.172)	
Log-likelihood	-22,169		-27,749	
Number of Facilities	4,424		3,273	
Censored Observations	102,512		86,159	
Uncensored Observations	5,769		8,008	

Notes: Cluster-robust standard errors. Statistical significance at the 1%, 5% and 10% are represented by ***, **, and *, respectively.

4.1 Effect of inspection frequency on compliance

We now turn to the main hypothesis of the paper: Did the increase in inspection frequency resulting from the EPAct's 3-year UST inspection requirement improve compliance? For both Arkansas and Louisiana, the coefficient on *Years_LastInspection* is positive and statistically significant for those facilities that were compliant at the last inspection (Table 3; *Years_LastInspection* Last_Noncompliance=0*). The coefficient is also positive and statistically significant but lower in magnitude for those facilities that were noncompliant at the last inspection in both states (Table 3; linear combination of coefficients on *Years_LastInspection* and *Years_LastInspection* Last_Noncompliance)*. This suggests that in both Arkansas and Louisiana, regardless of the compliance status at the last inspection, the more time that has passed between inspections, the higher the probability that an UST facility will be noncompliant at the current inspection. However, as more time passes between inspections it may be more difficult for those that had a violation at the last inspection to maintain newly implemented actions required to achieve compliance compared to the facility that was compliant last whose owners and operators just need to maintain previously established actions.

To better illustrate the impact of the 3-year inspection requirement of EPAct on UST owners' and operators' compliance with UST regulations based on our results, we estimate how changes in inspection frequency at a hypothetical representative facility in each state affect the probability of noncompliance. The hypothetical representative facility has the mean values for all continuous explanatory variables and median values for all other discrete explanatory variables (see Table 1 for details). We use the estimates of the censored bivariate probit model presented in Table 3 and the representative facility's characteristics to estimate the predicted probability that a facility will be noncompliant at the time of inspection for three and six years since last inspection. Predicted probabilities from the censored bivariate probit model coefficients show that moving from a 6-year to a 3-year inspection cycle reduces the likelihood that a representative facility will receive a noncompliance citation at the time of inspection by about 11% in Louisiana and 16% in Arkansas (Table 4).

To illustrate the differing effect that increasing inspection frequency has on compliance depending on the results of a facility's last compliance inspection, we also estimate predicted probabilities of noncompliance for a hypothetical representative facility that was noncompliant at the last inspection and for one that was compliant at the last inspection. The reduction in the likelihood of noncompliance moving from a 6-year to a 3-year inspection cycle is slightly larger for facilities that were compliant at their last inspection (about 13% in Louisiana and 17% in Arkansas) relative to the facilities that were noncompliant at their last inspection (about 9% in Louisiana and 16% in Arkansas).

Table 4. Predicted probability of noncompliance at a hypothetical representative facility

	Predicted Pr(*Noncompliance*)		
	Years Since Last Inspection		Change in Predicted
Louisiana	6 Years	3 Years	*Pr (Noncompliance)*
Last_Noncompliance=Mean	0.49***	0.38***	-0.11
	(0.026)	(0.023)	
Last_Noncompliance=0	0.44***	0.31***	-0.13
	(0.027)	(0.023)	
Last_Noncompliance=1	0.56***	0.47***	-0.09
	(0.029)	(0.026)	
Arkansas			
Last_Noncompliance=Mean	0.64***	0.48***	-0.16
	(0.025)	(0.022)	
Last_Noncompliance=0	0.54***	0.37***	-0.17
	(0.040)	(0.031)	

Last_Noncompliance=1	0.70***	0.55***	-0.15
	(0.033)	(0.033)	

Notes: The hypothetical representative facility has the mean values for all continuous explanatory variables, the mean value for noncompliance at the last inspection, and the median values for all other discrete explanatory variables. See Table 1 for means and medians. Standard errors in parentheses. Statistical significance at the 1%, 5% and 10% are represented by ***, **, and *, respectively.

4.2 Effect of Other Explanatory Variables on Compliance

We find other factors also have a statistically significant impact on the likelihood of noncompliance. In both states, *Total_Inspection* had a negative and statistically significant coefficient, suggesting that the more compliance inspections a facility has experienced in the past, the lower the probability that the facility is noncompliant at the current inspection. This suggests that with each additional inspection, the facility owner's knowledge and understanding of the UST requirements and how to meet them may improve.

To account for a facility's compliance history, we included the total number of past inspections at which a facility had at least one violation detected excluding the result of the last compliance inspection (*Past_Noncompliance*). While we would expect that over time as violations are identified at consecutive inspections, a facility's compliance behavior would eventually improve by learning from past mistakes, it may also be that those facilities with a high number of past inspections at which violations were identified are chronic offenders that will habitually violate so the sign of the effect depends on which effect dominates. The coefficient on *Past_Noncompliance* was positive and statistically significant at the 1% level for both states, suggesting a dominating effect of chronic offenders (i.e., those that habitually violate) over a potential learning behavior; that is if a facility cumulatively had a greater number of past inspections where it was noncompliant, the probability of noncompliance at the current inspection is higher. It may also be that these variables are capturing the effect of an unobserved or omitted variable that makes a facility consistently less likely to comply with requirements.

Furthermore, in Arkansas if a facility had an enforcement action since the last inspection, it was more likely to be noncompliant, which further substantiates the dominating effect is that of the chronic offender *(AR_Last_Enforcement).*

To account for the effect that UST facility characteristics may have on the likelihood of noncompliance, we included the age of the oldest tank and the average capacity of the tanks at the facility. We found that in both states UST facilities with an older tank were more likely to violate UST regulations. This is as expected because older tanks may not have modern preventive technologies installed and thus the facilities with older tanks will have higher likelihood of noncompliance (*Age_OldestTank*). No statistically significant effect of average tank capacity on noncompliance was found in Arkansas, however; in Louisiana the higher the average capacity, the less likely the facility was noncompliant. Higher capacity tanks are more likely to have preventive technologies installed in them and thus will likely result in lower likelihood of noncompliance (*Mean_TankCapacity*). Also, single facility owners are more likely to have older and smaller tanks that may have less advanced technologies (e.g., use a dip stick to reconcile petroleum tank inventory) and it may be challenging for these owners to meet UST requirements given all the other requirements simultaneously placed on them as a small business (e.g., Occupational Safety and Health Administration laws and regulations, fire prevention codes, food codes, tobacco and liquor sale laws, etc.).

In Louisiana, inspectors can be state employees or contractors. To capture the effect that the type of inspector may have on the probability of a violation we included a dummy variable that indicates whether the inspection was conducted by a contract inspector (*Contract_Inspector)*. Results suggest that a facility inspected by a contract inspector was more likely to be noncompliant than one inspected by a state-employed inspector. This result may seem counterintuitive; however, it is possible that state-employed inspectors may have a sense of authority and allow a facility some leeway for some minor issues whereas the contract inspector may not have such sense of authority.

Lastly, we account for potential effects of operator training which was also implemented under EPAct.[9] Unfortunately, facility specific data on operator training status was not available. Therefore, we included the dummy variable *State_OperatorTraining* in the compliance equation to account for the time period when some operators and owners may have learned additional information on UST maintenance, testing, and recordkeeping. For Louisiana, the coefficient on *State_OperatorTraining* was negative and statistically significant indicating that even though all owners and operators were not yet trained the presence of operator trainings reduced the likelihood that an inspected facility would have a violation detected. This effect is attributable to operator training to the extent that the dummy for the time period is not capturing other unobservable factors that are unique to that timeframe and influence UST compliance decisions. A statistically significant effect of *State_OperatorTraining* in Arkansas was not identified.

4.3 Sensitivity Analysis

To assess the robustness of our findings with respect to inspection frequency and compliance, we explored several alternative models.[10] First, for both states we estimated a probit model for the noncompliance equation given the insignificance of the correlation coefficient between the residuals from the compliance and inspection equations for both states. Second, for Louisiana we estimated a Poisson regression using the number of citations as a dependent variable for the noncompliance equation rather than a binary measure of noncompliance. The number of citations per inspection was not available in the Arkansas inspection data. The results for these estimations are qualitatively similar and are consistent with our main results that the

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[9] Louisiana established an earlier deadline to develop state-specific operator training requirements for the designated UST system operators as required by the EPAct. The first operator training was held in Louisiana on March 9, 2010. Louisiana had a phase-in period for operator training based on compliance inspection dates. Facilities inspected between February 20, 2010 and November 8, 2011 had to have their operators trained within 9 months of their inspection date. Everyone else had to be trained by August 8, 2012, which was the federal deadline to have designated UST system owners and operators trained. After the state deadline, operator training requirements became part of compliance inspections. Since this added a new major component to the compliance inspection, we do not include compliance inspections conducted after the federal deadline (August 8, 2012).

[10] Results of these analyses are available upon request from the authors.

coefficient on years since the last inspection remains positive and statistically significant. Lastly, one potential limitation of the Louisiana analysis is our inability to account for enforcement actions beyond the initial compliance citations (NODs and NOPDPs) due to lack of data in pre-EPAct years.[11] We estimated a censored bivariate probit model for the reduced sample (primarily consisting of post-EPAct inspections) with and without these enforcement action variables. The results using the reduced sample suggest that excluding these enforcement action variables does not change the effect that other explanatory variables have on noncompliance. Therefore, it is a reasonable assumption that our main results are robust to the exclusion of the additional enforcement action data.

4.4 Inspection frequency, compliance and release prevention

The aim of increasing inspection frequency at UST facilities is to improve compliance with requirements intended to prevent or detect accidental releases of petroleum and other hazardous substances into the environment. This analysis thus far focuses on the impact of increased inspection frequency on compliance and does not address the impact on the environmental outcome of interest—prevention of UST releases of petroleum or certain other hazardous substance. Our ability to examine the impact on the occurrence of releases is limited due to the nature of the release data and potential identification issues. First, the date associated with a release that the LADEQ retains in its records system is the date when an accidental release was confirmed (or discovered).[12] This means that in some cases the confirmed release date is inaccurate—it may be a few to several years after the release occurred before the release is

[11] If we were to include enforcement action data in the analysis, the sample would be reduced by approximately 25% from 5,769 to 4,324 observed inspections, and the observations lost would largely be inspections from prior to the change in inspection frequency that occurred as a result of EPAct. The loss of these pre-EPAct observations would significantly reduce the variation in inspection frequency in the sample and our ability to identify the impact of changes in inspection frequency on compliance.

[12] Facilities are required to report any discovered releases to the LADEQ. In some cases, nearby citizens may notice a leak or fumes and report it to the LADEQ. The LADEQ will in turn visit the facility and confirm whether or not there is a release. Releases are also sometimes discovered during compliance inspections.

confirmed. The Arkansas data has similar issues, which makes it so that we cannot be sure that the confirmed date is the date when the release occurred. This makes the timeline of releases and compliance inspections unreliable in some instances. Second, potential under-reporting of releases in pre-EPAct years may bias results. When inspections are less often—as they were pre-EPAct—facilities may be less likely to report releases in a timely manner or to report them at all. Lastly, increased inspection effort is expected to both reduce the occurrence of releases and to increase the likelihood of detecting or discovering releases. These two opposing effects make it difficult to identify the effect of increasing inspection frequency on releases. To minimize these issues, we examine the relationship between compliance status and accidental releases in post-EPAct years (2008 to 2012) when inspection frequency is relatively consistent due to the 3-year inspection requirement.

Our main analysis showed that increased inspection frequency improved compliance in Louisiana and Arkansas. Here we aim to understand whether compliance at the last inspection affects the likelihood of a release in the time period that follows. We estimate a probit model of the likelihood of a release as a function of the compliance status of the facility at the last inspection; an indicator of whether or not a facility had any enforcement actions since the last inspection; UST facility characteristics; biophysical and socioeconomic characteristics of the UST location; dummy variables for the regions; fiscal year quarters; and for the time period when states began training UST operators on maintenance, testing, and recordkeeping. Results for Louisiana suggest that a facility is less likely to have a release when it was compliant at the last inspection, whereas no statistically significant relationship was identified in Arkansas (Table 5). Returning to the example of a hypothetical representative facility in Louisiana, we estimate predicted probabilities of a release occurring in a given year using the probit model results. For the facility that was compliant at the last inspection in Louisiana, the predicted probability of a release is 1.46% and for the facility that was noncompliant last it is 2.23%. This suggests that when a facility in Louisiana is compliant at the last inspection it is 1.5 times less likely to have a release than a facility that was noncompliant, *ceteris paribus*. In both states a facility was more likely to have a release when they had a higher number of tanks at the facility.

Table 5. Probit model of UST releases post-EPAct (FY 2008-2012)

Variable	**Louisiana**	**Arkansas**
Constant	-3.0400***	-3.2052***
	(0.1129)	(0.1897)
Last_Noncompliance	0.1452***	-0.0063
	(0.0362)	(0.0468)
Number_Tanks	0.0946***	0.1193***
	(0.0141)	(0.0162)
Age_OldestTank	0.0045**	0.0031
	(0.0020)	(0.0032)
Mean_TankCapacity	0.0031	0.0175***
	(0.0046)	(0.0046)
Depth_WaterTable	0.0772	0.0653
	(0.0529)	(0.0731)
Soil_MostPermeable	0.1758***	0.0369
	(0.0385)	(0.0606)
Distance_FieldOffice	0.0007	-0.0034**
	(0.0011)	(0.0017)
Density_Population	0.0003	0.0012
	(0.0008)	(0.0022)
Income_Median	-0.0024***	-0.0028
	(0.0009)	(0.0030)
Enforce_Last	-0.0060	-0.3218
	(0.0475)	(0.2998)
State_OperatorTraini	-0.0696**	-0.0852
ng	(0.0343)	(0.0603)
Log-likelihood:	-2,854	-1,376
Number of facilities:	4,056	3,171
Observations:	62,915	78,784

Notes: Cluster-robust standard errors. Statistical significance at the 1%, 5% and 10% are represented by ***, **, and *, respectively. The dependent variable in the probit model is a dummy variable that is equal to 1 if a facility had at least one accidental UST release in the fiscal year quarter and is 0 otherwise. *Enforce_Last* is a dummy variable that is equal to 1 if the facility had any Enforcement action since the last inspection and is 0 otherwise.

8. Conclusions and Policy Implications

This paper examines the impact of policy changes occurring under EPAct that increased inspection frequency requirements for regulated underground storage tank (UST) facilities to at least once every three years. Specifically, facility-level data from Arkansas and Louisiana on inspection, compliance, releases and other socio-economic and biophysical characteristics of UST localities was utilized to examine the impact of increased inspection frequency on compliance with UST release detection and prevention requirements. A censored bivariate probit model was used to account for the censored nature of the inspection and compliance data and to account for potential bias in estimates due to inspection targeting that may have occurred, particularly in pre-EPAct years. Results suggest that increasing inspection frequency improved UST facilities' compliance in both Louisiana and Arkansas. This finding in the UST context is consistent with previous studies in other contexts that have found evidence that more frequent inspections improve compliance (Alberini et al. 2008 - FDA; Ko, Mendeloff and Gray 2010 - OSHA; Liu 2012 - RCRA; Abualfaraj et al. 2016 - natural gas wells) and adds to the literature because it is the first to utilize an exogenous change in inspection frequency due to the EPAct to identify the effect of more frequent inspections on compliance. We also find that the impact of inspection frequency on compliance is heterogeneous based on a facility's compliance status at the last inspection—larger impact for those facilities that were compliant than those that were noncompliant at their last inspection. This is consistent with previous empirical literature that has consistently shown that inspections improve compliance across a variety of environmental regulation contexts (Shimshack 2014).

The aim of increasing inspection frequency at UST facilities is to improve compliance with release detection and prevention requirements in order to prevent and reduce the size of accidental releases of petroleum and other hazardous substances into the environment. While we were unable to directly examine the impact of increasing inspection frequency on releases due to data limitations and identification issues, results from a probit estimation using a subset of data on releases from the post-EPAct years in Louisiana suggest that a facility is less likely to have a release if no violations were found with UST release prevention and detection requirements at the last compliance inspection. This result is consistent with previous research in the context of workplace safety that find that inspections prevent workplace injuries (Haviland et al. 2012; Hogg-Johnson et al. 2015; Levine et al. 2012; Mendeloff and Gray 2005) as well as with findings in an oil spill prevention context (Epple and Visscher 1984, Cohen 1987, Grau and Groves 1997; Talley, Jin and Kite-Powell 2005).

For policy and budget decision-making, the natural next question relates to comparing the costs of inspection to the avoided costs of prevented releases. A cost-benefit analysis is beyond the scope of this analysis; however, we provide some information on costs in Louisiana for illustrative purposes. The cost of conducting inspections annually is estimated at $96,348 per inspector with each completing 200 compliance inspections (US EPA 2000).[13] In Louisiana, there are roughly 4,400 UST facilities to be inspected. To inspect approximately one-third of the facilities each year, the inspector cost is estimated to be $706,552 dollars. In Louisiana, the average cost of an UST cleanup is $297,448.[14] This only represents a lower bound estimate of the costs from these releases as it does not include negative impacts on nearby property values, human health or ecosystem services (Jenkins et al. 2014; Guignet et al. 2016; Marcus 2016). If the improved compliance from increased inspection frequency prevented just 3 UST releases in a year then the potential cost-savings from avoided cleanups would exceed the direct cost of compliance inspection. Note that this comparison is for illustrative purposes only as it does not capture the full costs and benefits of UST compliance inspections. Specifically, it neither includes costs associated with training inspectors, enforcement, state administrative oversight nor UST owners' compliance costs.[15] Furthermore, it does not include additional potential benefits accruing from avoided product loss and negative impacts on nearby property values, human

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[13] In 2000, annual inspector cost was estimated at $70,000 includes salary, travel costs, benefits, managerial and secretarial support, and inspector equipment. To compare to the cleanup costs, which are the average from 2014-2016, this inspector cost of $70,000 was adjusted using the Consumer Price Index and is equivalent to $96,348 in 2015 dollars.

[14] The average cost of an UST Cleanup is based on 487 UST cleanups completed in Louisiana from fiscal year 2014 to 2016 (Louisiana Department of Environmental Quality, personal communication, December 7, 2016).

[15] Estimated direct compliance costs for individual facilities with UST release detection and prevention requirements in the final revisions to EPA's Underground Storage Tank Regulations are small at approximately $715 per year for the average facility (US EPA 2015).

health and ecosystem services that may be substantial.[16] Future research may further quantify these costs and benefits.

When releases are prevented, many environmental and health risks from UST releases of hazardous substances into the environment as well as remediation costs are avoided which represents cost savings that accrue to owners, operators and public entities charged with remediating contaminated media at regulated facilities. This analysis provides evidence on the important role that more frequent inspections have on facilities' compliance with UST release detection and prevention requirements, and that in turn compliance has on preventing releases. Should the necessary data be available, it would be informative for future research to examine the direct relationship between increased inspection frequency and the prevention of UST releases as well as to expand the geographic scope of this analysis.

[16] For more information on estimated benefits of compliance with UST release detection and prevention requirements based on expert elicitations, refer to the "Assessment of the Potential Costs, Benefits, and Other Impacts of the Final Revisions to EPA's Underground Storage Tank Regulations" (US EPA 2015).

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