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Can Environmental Insurance Succeed Where Other Strategies Fail? The Case of Underground Storage Tanks

Haitao Yin,[1,*] Alex Pfaff,[2] and Howard Kunreuther[3]

Private risk reduction will be socially efficient only when firms are liable for all the damage that they cause. We find that environmental insurance can achieve social efficiency even when two traditional policy instruments—*ex post* fines and risk management mandates with *ex ante* fines—do not. Inefficiency occurs with *ex post* fines, when small firms declare bankruptcy and escape their liabilities, limiting the incentives from this policy tool. Firms ignore mandates to implement efficient risk management because regulatory agencies do not have sufficient resources to monitor every firm. The evolution of the U.S. Environmental Protection Agency's and states' underground storage tank programs suggests that mandating environmental insurance can address inefficiency due to small firms declaring bankruptcy. Comparing insurance mandates to risk management mandates, the burden on a regulator is lower if all it has to do is to confirm that the firm has insurance rather than that the firm has actually, and effectively, implemented required management practices. For underground storage tanks, we show that insurance lowered toxic releases.

KEY WORDS: Environment; fines; insurance; risk management; underground storage tanks

1. INTRODUCTION

For environmental, health, and safety risks, investments by firms in protective measures may fall short of social efficiency if firms are not liable for all the losses caused by their actions. Their actions may have significant negative externalities, such as the loss of well-being of people exposed to pollution or unable or unwilling to use contaminated resources. Thus regulators may levy *ex post* fines, proportional to external damages from discovered violations, so that firms have an incentive to efficiently reduce risks.[4] Yet *ex post* fines may not be a credible threat for small firms, who can declare bankruptcy if such fines exceed their limited assets.[8]

Regulatory agencies could instead mandate *ex ante* risk management processes. Firms would face more frequent smaller fines for not implementing required practices. Examples of process mandates with *ex ante* fines include the U.S. Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) program and the U.S. Environmental Protection Agency (EPA) Risk Management Program (RMP). Both were created under Section 112(r) of the Clean Air Act Amendments of 1990 to help prevent releases of hazardous chemicals. The OSHA PSM program requires facilities containing large quantities of highly hazardous chemicals to implement accident prevention and emergency response measures. The EPA's RMP regulation requires facilities to assess both the likelihood of

[1]Antai College of Economics and Management, Shanghai Jiao Tong University.
[2]Public Policy, Economics and Environment, Duke University.
[3]Wharton School, University of Pennsylvania.
[*]Address correspondence to Haitao Yin, Bldg. 10, Rm. 207, 535 Fahua Zhen Rd., Shanghai, China 200052; tel: 86-21-52301242; fax: 82-21-52302519; htyin@sjtu.edu.cn.

[4]This core point in public economics and environmental economics is also featured in the law and economics literature (see, for example, Coase,[1] Shavell,[2] Polinsky,[3] Segerson and Tietenberg,[4] and Hermalin[5]). Pfaff and Sanchirico[6,7] apply it to environmental auditing, that is, firms' incentives to learn about risk.

accidents and their consequences and to submit a risk management plan. Firms can be fined for failure to comply.

Such *ex ante* fines could help the agency to address the issue of small-firm bankruptcy. However, implementation is constrained by regulatory agencies' limited monitoring capabilities. For example, EPA Region 3 has only five auditors responsible for facility inspection who try to verify whether all firms have effectively implemented required risk management practices. Currently, the chance of being found in violation is extremely low. An effective implementation of frequent small process-violation fines would require considerable additional administrative cost.

We ask how a regulator could create incentives for risk reduction when bankruptcy limits the incentives from *ex post* fines while monitoring constraints limit *ex ante* process mandates. An alternative is that regulatory agencies could mandate that all firms buy environmental insurance. Insurance mandates as substitutes for other environmental policies have not been considered in general.[5] This article aims to fill this gap through an in-depth case study of mandatory insurance for underground storage tanks (USTs). The evolution of UST insurance offers an excellent case that demonstrates that a mandatory insurance can yield more prevention when the "small-firm problem and monitoring constraints" make other methods dysfunctional.

UST releases are the most common source of groundwater contamination. The greatest potential hazard they pose is that contents (petroleum products or other hazardous substances) seep into the soil and contaminate groundwater, the source of drinking water for nearly half of all Americans. Although releases can be managed through equipment upgrades and careful operation, after over 20 years of regulation, about 10,000 UST releases are still confirmed every year.[6]

Releases occur despite the presence of both *ex post* fines/liability and relevant process mandates. Most tank owners are small businesses that are easily bankrupted when a UST release is discovered, so damage-based liability has not produced the desired release deterrence or investment in reducing risks. Process mandates with *ex ante* fines are present in the 1986 UST regulations. Cohen and Kamieniecki[10] and GAO[11] have argued that limited monitoring resources impaired the enforcement of these mandates. GAO[11] documented that the states and EPA simply do not physically inspect USTs frequently enough to ensure compliance with the requirements that certain practices are carried out.

Under an insurance mandate, monitoring constraints do not seem to be an issue because the possession of insurance can be easily verified. Bankruptcy is not an issue either, since regular premiums over time smooth firm costs relative to less frequent and larger fines/liability based on damage. Most importantly, if private insurers price the coverage based upon UST release risks, differentiated insurance premiums provide incentives for firms to improve their risk management. Insurance also guarantees that funds are available to compensate victims when accidents occur.

Yet the norm for dealing with environmental risks has not been to focus on insurance. Freeman and Kunreuther[12] note that insurance requires quantified risks for setting premiums. Although a lack of adequate information is a hurdle for novel insurance, as risk information increases, effective insurance can arise. USTs illustrate this. In the 1980s, private UST insurance was generally unavailable and, when available, was prohibitively expensive. However, once such insurance was more widely marketed beginning in the mid 1990s, premiums fell more than 50% within 10 years as the risks became better understood and managed. Now UST insurance is a well-established product and it reduces risks.

Section 2 highlights the limitations of two traditional policies, *ex post* damage-based fines and risk management mandates using *ex ante* compliance-based fines. It also considers how mandatory insurance might overcome these limitations. Section 3 provides evidence of the evolution over time of UST insurance from a novel to a well-established product. Section 4 then shows that UST insurance has created strong incentives for risk reduction. Section 5 concludes.

2. RISK REDUCTION BY FIRMS FACING REGULATIONS

2.1. External Risks and *Ex Post* (Damage-Based) Fines

A firm i is uncertain about the harm h_i that its operation will cause to all parties. The firm itself

[5] Precedents for mandatory insurance exist in other areas such as workers' compensation, motor vehicle damage, medical malpractice, and boiler explosions.[9] However, its application in dealing with environmental risk has not been examined carefully.

[6] See UST and LUST program performance measures at http://www.epa.gov/oust/cat/camarchv.htm.

suffers losses l_i including damage to employees, higher wages that compensate for risks, and lower profits if consumers favor green firms. We define $d_i = h_i - l_i$ as the external damages.

The firm knows the probability density functions for l_i and d_i (and thus h_i). It is also able to estimate the cumulative distribution functions and their means $\bar{L}_i$, $\bar{D}_i$, and $\bar{H}_i$. The firm decides whether to act at a cost C_i to lower expected future harms from $\bar{L}_i$ to $\bar{L}'_i$ and $\bar{D}_i$ to $\bar{D}'_i$. A firm sees risk reduction as desirable if C_i is smaller than expected private benefit of care $(\bar{L}_i - \bar{L}'_i)$. This diverges from the view of a regulatory agency, which cares about all of the citizens and thus compares the C_i to the expected social benefit of care $(\bar{H}_i - \bar{H}'_i)$, which is greater than $(\bar{L}_i - \bar{L}'_i)$.

For the firm to choose socially efficient risk reduction, a regulatory agency needs to impose costs on the firm for external damage. One option is fines based on observed damages. Such *ex post* fines raise the firm's expected costs of generating external damages. We now focus on setting the right fine. We label as β (<1) the probability the regulatory agency learns of harm and as $f_i(d_i)$ the fine levied upon detection of external damage of magnitude d caused by firm i. A firm that causes d_i damage faces an expected fine $\beta f_i(d_i)$. The regulatory agency wants firms to compare the cost of risk reduction C_i to $(\bar{H}_i - \bar{H}'_i)$ but firms consider only the private reductions $(\bar{L}_i - \bar{L}'_i)$. Expected fines should close the gap.[7] A fine $f_i = d_i/\beta$ achieves that goal. The expected fine given damage d_i is $\beta \times f_i = d_i$, with expectation $\bar{D}_i$.[8,9] Then risk reduction saves the firm private damages $(\bar{L}_i - \bar{L}'_i)$ and expected fines equal to external damages $(\bar{D}_i - \bar{D}'_i)$ totaling $(\bar{H}_i - \bar{H}'_i)$.

However, such an *ex post* fine may work for large firms but not for small firms with limited assets because they may declare bankruptcy if they cannot afford the fine for damages.(8) Fines may be high due to large external damages d_i or low chance that a harm is detected β. In either case, if the costs to firm i when it is caught (private costs plus fines) are greater than its assets A_i, the threat posed by *ex post* fines is limited because the most that the firm can lose is A.[10] In this case, the firm's incentive to take preventive action falls short of the socially optimal level of preventive action that is motivated by $(\bar{H}_i - \bar{H}'_i)$.(16) Thus, small firms' risk reduction will be less than socially efficient.[11] We refer to this as the small-firm problem.[12]

2.2. Process Mandates and *Ex Ante* (Predamage) Fines

To address the small-firm problem, regulatory agencies have formulated technical and management requirements for firms to reduce safety and environmental risks. With process-based regulations of this type, an agency can levy *ex ante* (predamage) fines for not undertaking risk reduction measures. *Ex ante* fines would be much lower than *ex post* fines; this should reduce bankruptcies and thus improve small firms' risk reduction incentives. Assuming there was a sufficiently high probability that firms' processes are audited, this would provide economic incentives for firms to adopt desired risk reduction measures.[13]

[7] Note that because firms are not always discovered, when a firm is caught and fined, its costs will be greater than the harm caused. Socially efficient fines must reflect both external damages and the likelihood of detection (see applications of this in Shavell,(13) Kaplow and Shavell,(14) Innes,(15) Pfaff and Sanchirico(6)).

[8] The fine requires only d_i, observed external damages, not information that only firms may know, for example, l_i, or C_i.

[9] In practice, *ex post* fines are sometimes manifest as liability cost, which may be equal to d_i instead of d_i/β especially if there are no violations of existing regulations.

[10] Even if A is all the firm can lose at the moment, the firm might also perceive a cost of bankruptcy. For instance, it may perceive an expected future stream of profits that it does not want to lose and would not want to lose even if it had to pay the current liabilities above A out of that stream. If it could borrow against those to pay the costs it faces from a violation, it would then effectively not be constrained in its current losses by A. Thus we might consider an alternative interpretation of A to include borrowing against future profits. That would make the group of firms with inefficient risk-reduction incentives smaller, although we believe that the bankruptcy model still has great relevance.

[11] Ringlieb and Wiggins(17) showed that firms tend to spin off their hazardous operations to small entities that can "cheaply" declare bankruptcy in order to escape the threat of *ex post* fines.

[12] In the case of USTs, UST owners and operators are liable for clean-up costs and third-party compensation when a release occurs. A fine is imposed only when there is a violation of UST regulations, including technical standards and reporting requirements. However, this does not have an impact on the small firm problem. UST owners and operators are not able to pay for the clean-up cost and third-party compensation (d_i), let alone the fine (d_i/β). Hence they will not have a financial incentive to take optimal care.

[13] For a simple demonstration, we use R to denote an *ex ante* fine and δ the chance the fine is imposed each year. We further assume that firms can lower the chance of future harm from p to p' after implementing the mandated process requirement and that for simplicity the accident losses are constant values for a given firm. In order to induce firms to adopt mandated process requirements, the *ex ante* fine should be set so that the firm's expected benefits from risk reduction is equal to expected social benefits $(\bar{H}_i - \bar{H}'_i)$, that

Yet monitoring firms' implementation of technical and management requirements such as PSM and RMP requires considerable effort. With limited regulatory resources, OSHA focuses on firms known to have serious workplace problems. Those not in this category have less than a 1 in 80 chance per year of being inspected. This low probability has led some firms not to implement PSM rules. Given limited monitoring capabilities and relatively low fines, these firms have limited economic incentives to respond to OSHA's PSM or other workplace regulations.[18]

EPA's RMP regulations also are not well enforced. The chances of being inspected are low and potential fines are not high. Under the General Duty Clause of the Clean Air Act, fines can be $27,500 per day but EPA staff claim that this is rare, in part due to limited monitoring. EPA's Region 3 has five auditors to inspect all facilities.[18][14] Also, as Boyd[8] pointed out for landfills, risk management requirements do not guarantee risk reduction. Despite requirements since 1979, a 1988 EPA report found that only 36% of landfills monitored groundwater, 7% monitored methane, and 15% had surface water controls. This suggests a monitoring problem.

2.3. Mandated Environmental Insurance

As an alternative to the above programs, a requirement that firms purchase environmental insurance could in principle solve both the small-firm problem and the monitoring problem. Such insurance must be mandatory if the small-firm problem is a key concern. If not, it is likely that many small firms, whether they are risk neutral or risk averse, will not buy coverage voluntarily.

The competitive premium I_i that makes an insurer and a risk-neutral firm i willing to do business equals the firm's expected private loss plus expected external damages. If a small firm's assets are the most it could lose and are less than private losses plus *ex post* fines, then it will not purchase insurance at this premium because its expected losses without the insurance are lower as it can declare bankruptcy. For example, a firm with assets of $100 ($A_i$), chance of accident p, expected private losses of $70 ($l_i$) if an accident occurs, and an *ex post* fine of $80 if discovered would face an actuarially fair insurance premium of $Ii = p * 70 + \beta * p * 80$. This is greater than the expected losses without insurance, $p * l_i + \beta * p * (A_i - l_i) = p * 70 + \beta * p * 30$. Thus small firms will not purchase insurance on their own and insurance must be mandatory.

To enforce purchase of insurance, an agency may use *ex ante* fines or revoke the privilege to operate or may otherwise impose costs. *Ex ante* fines can be smaller in magnitude than *ex post* fines because it is easy to monitor the possession of environmental insurance. A regulatory agency only has to confirm that a firm has obtained an approved insurance policy or, more generally, that the firm has provided legal documentation that sufficient financial resources have been set aside.

Insurance not only addresses bankruptcy and monitoring concerns but also provides other benefits. Without it, large *ex post* fines are incurred infrequently after accidents. With insurance, the costs are predictable and involve relatively small premiums. In addition, insurance provides funds to compensate injured parties for damage. Without insurance, when small firms go bankrupt, some of the fines are unpaid, leaving insufficient funds for compensation. Most importantly, insurance can motivate efficient risk reduction because competitive premiums should effectively reflect the expected total social cost.[20] We will come back to this point in the next sections.

3. UST INSURANCE DEMAND AND SUPPLY

We present the first evidence from the field that mandatory environmental insurance can overcome the small-firm problem and monitoring constraints, and function as an effective tool for risk management, using the case of USTs. We highlight how insurance can in fact overcome hurdles that are associated with other policy instruments for encouraging risk reduction. Unlike *ex post* fines/liability, insurance can motivate both large and small firms to efficiently reduce risk. Insurance is also easy to monitor, unlike mandates to carry out specific risk management actions.

is, $(\bar{L}_i - \bar{L}'_i) + (p - p')[\beta(A_i - \bar{l}_i)] + \delta R = (\bar{H}_i - \bar{H}'_i)$. We then have $R = (p - p')[\mathrm{di} - \beta(A_i - \bar{l}_i)]/\delta$. Levying *ex ante* fines on firms that lack incentives due to infeasibility of *ex post* fines sounds counterintuitive. Yet *ex ante* (previolation) fines for violating mandated processes can be levied anytime, without waiting for a discovered violation, thus, more often than *ex post* fines. Furthermore, if large firms respond to *ex post* fines, process inspections can be focused on small firms. Thus, *ex ante* fines can be more frequent, that is, δ can be significantly higher than β. It is not hard to find that *ex ante* fine R should be much smaller than *ex post* fines $f_i = d_i/\beta$, so small firms are more likely to be able to afford them.

[14] Kunreuther, Metzenbaum, and Schmeidler[19] also emphasized the lack of inspection but do not focus on small firms and bankruptcy.

3.1. Demand: Small-Firm and Monitoring Problems

3.1.1. USTs and Limits on Damage-Based Ex Post *Fines/Liability*

In 1984, Congress directed the EPA to publish regulations that would require owners and operators of USTs (often in gas stations) to prevent, detect, and clean up releases. The regulation imposed strict liability on UST owners and operators (Section 9003 of RCRA Subtitle I). On paper, such *ex post* damage-based liability alone appeared to be sufficient.

In practice, this standard liability policy solution was not effective, as it did not pose a credible threat to most UST owners and operators. Ninety percent of UST owners owned only one station and had net worth less than $90,000.[21] EPA estimated that the cost of cleaning up the groundwater contamination from a leaking tank generally ranged between $75,000 and $225,000 and could even be higher. Most of the firms would go bankrupt should a release occur. This dampened the incentive to prevent accidents and imperiled the supply of funds for compensation. When releases occur and small firms go bankrupt, the financial burden for clean up and compensation of victims often falls on the general taxpayer, not on the firm. In addition to federal expenditures, states have spent over $1 billion annually for cleaning up the damage from these releases.[15]

3.1.2. USTs and Limits on Management Mandates with Ex Ante *Fines*

EPA's UST programs not only include liability but also require specific risk management measures. Technical mandates existed for prevention, detection, and correction of releases from tanks. Tanks installed after December 22, 1988 faced requirements with respect to installation, leak detection, spill, overfill, and corrosion protection. Those installed before December 22, 1988 had to meet requirements by December 1998. For example, all metal UST system components in contact with the ground must be protected from corrosion. In principle, facilities that violate these technical requirements are subject to fines of up to $11,000 per day per tank per violation. If inspections are frequent, such *ex ante* fines create adequate economic incentives to lower risk.

However, commentators agree that the states' environmental agencies do not have adequate resources to monitor compliance with the technical mandates. Cohen and Kamieniecki[10] contend that limited resources versus the size of the regulated community make it impossible to effectively enforce UST technical standards. For example, in 2000, Michigan's UST regulatory agency had 21 inspectors responsible for about 10,000 facilities with 30,000 USTs. According to GAO's 2000 survey, only 19 states physically inspect all of their tanks at least once every three years—the minimum EPA considers effective for monitoring.[16] About 29% of the tank protection devices on regulated tanks were not operated or maintained properly in 2000.[17,18]

The states and EPA regions attribute insufficient enforcement to the lack of personnel and financial resources. In a survey of USTs, 46 states responded that they needed additional resources to enforce UST technical standards.[11] The respondents from North Carolina wrote: "It is critical to have enough inspectors to visit each owner or operator at least once every three years to provide one-to-one assistance. There is no other substitute! Owners and operators need to know that the state will be back to see how they are doing. Field presence is essential!!"[22] Verifying that management is adhering to existing regulations has substantial costs.

In summary, between the inability to impose existing *ex post* liability/fines (due to small owners and operators being dominant) and the inability even to monitor existing management standards or to enforce them using *ex ante* fines (due to a lack of field presence), USTs have small-firm and monitoring problems. Below we consider how insurance fares in addressing these issues.

[15] Federal expenditure for UST cleanups is about $79 million per year. State expenditure comes from UST state funds, which we are going to discuss in detail later in the text. See UST Program Facts at http://www.epa.gov/oust/pubs/ustfacts.pdf.

[16] Ten additional states inspect all of their tanks but less frequently than every three years. The remaining 22 do not inspect all tanks but instead target potentially problematic tanks such as those close to drinking water.

[17] The GAO 2000 survey[22] acquired information from each state on the number of tanks and the percentage of these tanks that had federally required equipment operated properly. Our estimates are based on these data.

[18] Improper operation and maintenance is the leading cause of UST leaks. Half of the respondents to the GAO 2000 survey[22] reported that "operators did not operate and maintain the required equipment properly" as the major cause of UST leaks. None of them said it was not a cause at all.

3.2. Supply: Maturation Over Time to Become an Established Product

3.2.1. Challenges for Novel UST Environmental Insurance

The private insurance market for USTs was not successful initially. In the late 1980s, according to the GAO's 1987 survey, firms claimed that it was very difficult to obtain adequate pollution liability insurance for tanks. One firm said that it contacted 44 insurance companies and was unable to find coverage. Others said that their insurance brokers had to contact as many as 20 insurance companies. Firms also said that the available insurance became more expensive over time. One small firm testified that between 1986 and 1987, its premium tripled from $3,000 to $10,000 for coverage reduced from $4 million to $2 million by the same insurer.[23] The primary reason for the lack of insurance is that private insurers felt tank leaks and the magnitude of potential losses were unpredictable due to limited knowledge. Insurers also felt judicial decisions were becoming less predictable, making it difficult to relate actual risks to risks of court settlements (Cohen and Kamieniecki, p. 111).[10] Such uncertainty about the risks naturally limits insurance markets. Empirical evidence has revealed that actuaries and underwriters tend to charge a much higher price when either the probability is ambiguous, losses are correlated, and/or the claim size was uncertain.[24,25]

Over time, however, owners, regulatory agencies, and insurers have learned about releases and losses. Relevant regulatory requirements and their legal interpretation have also been clarified. Cohen and Kamieniecki (p. 111)[10] note that joint and several liability made it hard to estimate risks of court settlements using the risk in one's operations. This situation improved when Congress passed the Asset Conservation, Lender Liability, and Deposit Insurance Protection Act in 1996.[19] Section 2503 amends Section 9003(h) of the RCRA 6991b(h) so that "participate in management" means "actually participating" in the operations of the insured's facility (not "merely having the capacity to influence, or the unexercised right to control"). This matters in determining a person's liability as an owner or operator of an UST (new RCRA Section 9003(h)(9)(A)) and such a clarification clearly was useful for insurers in the quantification of their associated risk.

3.2.2. Two Complementary Evolutions

3.2.2.1. Policy response. In 1986, Congress amended RCRA (the Resource Conservation and Recovery Act) and directed the EPA to publish regulations requiring UST owners and operators to demonstrate financial capability for cleaning up releases and compensating for damages. These were known as financial responsibility requirements (FRRs). EPA specified two primary ways for UST owners and operators to comply with FRRs: purchasing private insurance and participating in a state fund. This served as a form of mandated demand for insurance that also helped to push its maturation forward.

State funds were created in the late 1980s and early 1990s by many states as a mechanism for FRR compliance. State funds are primarily financed by gasoline taxes. The cost to obtain state fund coverage is low (see more in Section 4); therefore, few UST owners would purchase private insurance when a state fund program is available. However, when a state does not establish a state fund program, UST owners and operators in the state generally purchased insurance in order to demonstrate compliance with FRR. In particular, many small firms that would not voluntarily purchase UST insurance had to buy such coverage to comply with regulatory mandates. Only a few firms used other methods.[20] In 2009, more than 98% of UST owners in Florida, which does not have a state fund program, had the financial backing required by FRRs. Of these, 78% had purchased insurance, 14% self-insured, and the remaining firms utilize other approaches such as letters of credit.

3.2.2.2. Firm population. Shifts in the population of UST owners also facilitated both insurance and regulation. Alberini[26] documented that the number of USTs significantly shrinks after UST regulations were put into place in late 1980s, with USTs being partially replaced with aboveground tanks. Yin,

[19] In April 1992, the EPA promulgated the CERCLA Lender Liability Rule, which had very similar language. However, in Kelley v. EPA, the U.S. Court of Appeals for the District of Columbia Circuit vacated the Rule on the ground that EPA lacked authority to issue the Rule as a binding regulation (15 F.3d 1100 (D.C. Cir. 1994), reh'g denied, 25 F.3d 1088 (D.C. Cir. 1994), cert. denied, American Bankers Association v. Kelley, 115 S. Ct. 900 (1995)).

[20] Mechanisms include self-insurance and obtaining a guarantee, surety bond, or letter of credit. However, they are not widely utilized because financial institutions that need to be involved with most of these mechanisms are reluctant to participate for fear of potential liability.[21]

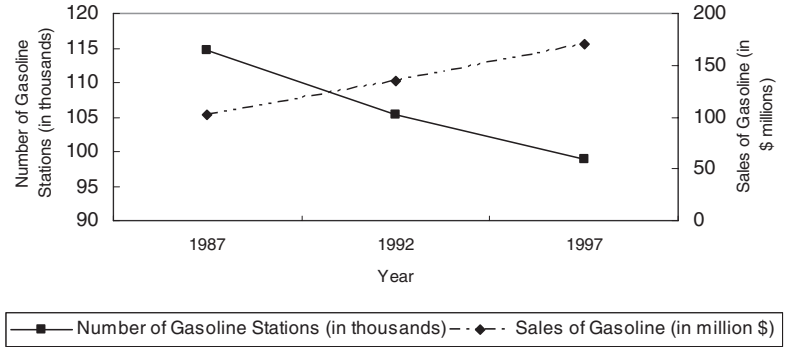

Fig. 1. Number of gasoline stations and sales of gasoline (1987, 1992, and 1997).

Note: Economic census data for gasoline stations after 1997 are not comparable with those before 1997 because of the change from SIC to NAICS. See http://www.census.gov/epcd/ec97brdg/
Data Source: http://www.census.gov/epcd/www/92result.html; 1987 Economic Census CD-ROM;

Employment Size of the Enterprise	Number of Establishments			Change of the Number of Establishments	
	1987	1992	1997	1987–1992	1992–1997
0–4 Employees	34,644	33,149	26,733	−0.04	−0.19
5–9 Employees	18,646	15,916	14,662	−0.15	−0.08
10–19 Employees	11,601	10,314	10,197	−0.11	−0.01
20–99 Employees	12,225	11,193	11,320	−0.08	0.01
100–499 Employees	8,061	8,779	10,277	0.09	0.17
500 + Employees	19,197	21,673	23,660	0.13	0.09

Table I. Number of Gasoline Stations by Enterprise Employment Sizes: 1987, 1982 and 1997

Note: Economic census data for gasoline stations after 1997 are not comparable with those before 1997 because of the change from SIC to NAICS. See http://www.census.gov/epcd/ec97brdg/.
Data Source: http://www.census.gov/csd/susb/index.html & 1987 Economic Census CD-ROM.

Kunreuther, and White[27] observe in addition that it was small-firm UST owners who were more likely to close their USTs in response to increases in compliance costs due to UST regulations. These changes are reflected in the gasoline retailing industry, as most USTs are owned by gasoline stations.

Fig. 1 shows that the number of gasoline stations decreased by 14% from 1987 to 1997, while sales by gasoline stations rose by 67% during the same period. Most of the gasoline stations that exited the market are owned by small firms as demonstrated in Table I. The number of stations owned by firms with 19 or fewer employees decreased by 8.5% from 1987 to 1992, and by 13% from 1992 to 1997. Meanwhile, the number of stations owned by firms with 100 or more employees increased. This shift toward larger firms facilitates the use of insurance. It is well acknowledged that small UST owners have the most difficulties in obtaining insurance for two reasons. One reason is that they lack capital to upgrade or replace their tanks and therefore need to pay a higher premium. Another reason is that insurance premiums are more of an economic shock to small firms compared larger ones. Providing assistance to small UST owners is the most important reason for creating state funds.[20] The shift of firm population toward larger ones reduces political opposition to and improves the economic feasibility (more firms can afford insurance) of a private insurance regime.

3.2.3. Maturation of UST Insurance

As insurance became standard, it became clear that verifying whether a firm has insurance is easy. In Michigan, for instance, the Department of Environmental Quality requires UST owners and operators to submit a certificate with the insurer's signature. This does not involve a large cost to the Department or to the tank owners and operators. Tank owners and operators are subject to a fine of up to $11,000 per tank per day per violation (RCRA Subtitle I, Section 9006(d)(2)) if they do not possess

Table II. Tank Quality and Insurance Premium (per Tank)

Type of Tank		Annual Insurance Premium in 1995	Annual Insurance Premium in 2004
Single-walled			
Tank age	6–10 years	$700 – $1,450	$350 – $470
	11–15 years	$1,500	$500 – $700
	16–30 years	$2,500 – $4,000	$760 – $1,690
Double-walled			
Tank age	6–10 years	$350 – $725	$228 – $302
	11–15 years	$400 – $725	$320 – $356

Note: Data reflect rates charged by Michigan insurers. The premium in 1995 is for $1 million coverage with deductibles of $5,000–10,000. The premium in 2004 is for $1 million coverage with a standard deductible of $5,000.
Source: Public Sector Consultants, Inc.;[28] Michigan Office of Financial and Insurance Services (OFIS).

valid UST insurance. The Michigan Department of Environmental Quality is confident that more than 90% of UST owners and operators have valid insurance in force.[21] Therefore, monitoring is not an issue with mandatory environmental insurance.

One piece of evidence that UST insurance matured is the fall in insurance prices. As the UST insurance market has evolved positively over time, the premiums have decreased significantly. In Michigan, for a 11–15-year-old single-walled tank, the insurance premium was $1,500 in 1995 but only $500–$700 in 2004, as shown in Table II.

Critically, this maturation and accumulation of data also involved shifting premiums to reflect UST risks more accurately. As an example, Table III shows a rate structure that Zurich North America used to set UST insurance premiums. It indicates a belief on the part of the insurer (and most likely also its customer, the UST owner) that releases can be predicted using observable characteristics, such as tank age and structure. This allows for different premiums to be charged for different USTs, for example, $200 for a 5-year-old double-walled tank as opposed to $1,750 for a 31-year-old single-walled tank, quite a significant difference. Corrosion protection, leak detection, and overfill detection efforts are also used to determine risk-based premiums, as seen in Table III.

[21] E-mail with Kevin Wieber at the Michigan Department of Environmental Quality, June 15, 2006.

In summary, UST pollution liability insurance has matured to become a well-functioning and competitive market with a large number of insurance providers.[29] In Florida, for instance, about 100 insurance companies offer insurance policies against UST releases. The 10 top companies provided coverage to about 71% of the 19,000 UST owners in 2009.

That the UST insurance market has evolved to the point of differentiated premiums is evidence supporting the claim that when insurers face the full costs of external damages they pass along these socially efficient incentives in ways that should lead to risk reductions. It is clear that insurers do have an economic incentive to provide premium discounts to the insured party to reflect the lower expected claims payments due to reduced leakage of UST tanks.[22] Below we compare the two mechanisms for FRR compliance—state funds and insurance—and present evidence that of the two, insurance leads to more risk reduction in practice.

4. RISK MITIGATION INCENTIVES WITH UST INSURANCE VERSUS STATE FUNDS

4.1. State Funds

State funds could also at least in principle address the small-firm problem by acting like private insurance: collect fees from firms (and maybe even attempt to do so in proportion to the risk level in firms' operations); then disburse monies as needed when leaks occur. Yet they have not functioned in this way and instead spend tax dollars without creating incentives for risk reduction. Further, since the cost to participate in state funds is subsidized and therefore substantially lower than actuarially fair premiums, the existence of state funds can drive out insurance. Below, we consider funds' impacts on spills and insurance.

4.1.1. Incentive Problems Remain

State funds, as an option for FRR compliance, were a response to the initial lack of private insurance. As shown below, they did not provide incentives for firms to reduce the risks associated with USTs. Most states in the United States established

[22] A detailed discussion of the role that insurance can play in encouraging cost-effective mitigation measures appears in Kunreuther and Michel-Kerjan[30] and Kunreuther, Meyer, and Michel-Kerjan.[31]

Table III. Rate Factors for USTs Used by Zurich North America in 2004

	Base Rates:							
Age	0–5	6–10	11–15	16–20	21–25	26–30	31–35	>35
Single-walled	$284–$339	$350–$470	$500–$700	$760–$1,030	$1,100–$1,380	$1,450–$1,690	$1,750	$1,850
Double-walled	$185–$221	$228–$302	$320–$356	$365–$426	$441–$509	$441–$509	$526–$582	$620

	Yes	No	Unknown
Corrosion protection	0%	+10%	+10%
Leak detection	0%	+10%	+10%
Overfill detection	0%	+10%	+10%
	Yes, claim closed	Yes, claim open	No
Location prior release	10%	20%	0%

Annual premiums are based on $1 million coverage with a standard deductible of $5,000.
Sources: Michigan Office of Financial and Insurance Services (OFIS).

Table IV. Availability of State Fund Program as an FRR Compliance Mechanism

Category	States
No state funds that could be used as an FRR compliance mechanism	AK, MD, NY, DE, HI, OR
Have state funds that could be used as an FRR compliance mechanism	AL, AR, CA, CO, CT, GA, ID, IL, IN, KS, KY, LA, MA, ME, MN, MO, MS, MT, NC, ND, NE, NH, NM, NV, OH, OK, PA, RI, SC, SD, TN, UT, VA, VT, WA, WY
Transition from state funds to private mechanism	AZ: (6/30/2006), FL:(1/1/1999), IA:(11/8/2000), MI:(6/30/1995), TX:(12/23/1998), WI:(1/1/1996), WV:(9/30/2000)
Transition from private mechanism to state funds	NJ (8/31/1997)

Source: U.S. Environmental Protection Agency (EPA); State UST Financial Assurance Funds Survey 1999–2007 (http://www.astswmo.org/publications_tanks.htm).

state fund programs in the early 1990s. Table IV shows the availability of state fund programs by state.

UST state funds are often financed through a gasoline tax. In Illinois, taxes on motor fuel include 1.1 cents per gallon earmarked for UST state funds.[23] The state fund provides UST owners and operators with protection against tank leaks at essentially zero cost to the firms. Although tank owners and operators have to pay a fee to qualify for state fund programs, not only is the fee relatively low ($100 in most states) but also it is paid as part of tank registration whether or not one intends to participate in the state fund program and has nothing to do at all with the underlying riskiness of one's operations or any efforts to reduce those risks.

Another critical feature of state funds, in terms of their lack of incentives to reduce risks, is that they redistribute their funds (from fuel taxes or tank fees) based solely upon need. Thus, not only do costs of participation in state funds not rise with a firm's risk of UST releases but also net benefits of participation may even rise since riskier firms are more likely to draw-money from the fund. In addition, when state fund collections are below disbursements, funds can be lacking to compensate harms.

In contrast, once a firm is commercially insured, it is the responsibility of private insurers to pay for both clean-up costs and third-party compensation should a release occur. Regulations have made it a high priority to clean up damages. Insurers are often forced to pay for damages, so that some party provides funds, even in cases where there was clear fault on the part of the insured.[24]

[23] See all states' gasoline tax rates for UST funds at survey site http://www.astswmo.org/publications_tanks.htm.

[24] In the famous case "Zurich American versus Whittier Properties, Inc.," Zurich American sought to rescind the insurance policy after a release was discovered, on the grounds that Whittier properties, Inc. made a clear misrepresentation in its application. However, the United States Court of Appeals, Ninth Circuit reversed the district court's determination that Zurich could rescind the policy because of EPA's interpretation that "cancellation provision is the exclusive remedy

4.1.2. Driving Out Private Insurance and Private Incentives

Although it has matured to an established product, UST insurance exists in only 13 states in the United States that either have never established a state fund or have ceased their state fund program (see Table IV). The absence of a private UST insurance market in the rest of the states today is due to competition from state funds. As discussed earlier, the cost to obtain state fund coverage is subsidized with a gasoline tax and essentially zero. The subsidies to state fund programs effectively eliminate the demand for private insurance.[25]

This might not matter if the two options for complying with FRRs had similar impacts. However, compared to a state fund program, private insurance has an advantage in inducing more risk reduction efforts. Private insurers, who are responsible for cleanups and third-party claims from tank releases, have an economic incentive to encourage UST owners to invest in risk reduction. Table III demonstrates that private insurers use risk-based pricing and therefore provide premium discounts for risk reduction efforts (discussed in Section 3.2.3). It also shows that premiums will rise by 10% for having no corrosion protection or for having had a prior release. Such a rate structure is designed to reward risk reduction.

In fact, insurers sometimes require potential policyholders to undertake risk-reducing actions before they are willing to provide coverage. For example, UST insurers in Maryland, a state that does not have a state fund program that qualifies for FRR compliance, refused coverage to many petroleum marketers who did not meet underwriting standards. They were uninsurable due to tank age or a failure to provide a record of compliance with tank requirements.[32] Coverage denial provides significant incentives for UST owners and operators to undertake risk mitigation.

Another example of private insurance employing risk-based pricing to encourage UST owners to make their tanks safer involves an agreement between AIG Environmental Group, Inc. (AIG) and Tanknology—NDE International Inc., whereby AIG provided substantial premium discounts for UST owners and operators who are utilizing Tanknology's compliance management or monitoring services. Tanknology's services are believed to reduce the risks of leaks from USTs.[33]

4.2. Insurance has Lowered UST Releases

In this section, we use state-level UST releases data[26] to assess whether the use of private insurance has effectively promoted risk reduction, resulting in fewer tank releases. A negative binomial regression analysis is performed, which is specified as below:

$$\log E(New\_Releases_{it}) = \beta_0 + \beta_1 PostTransition_{it} + \gamma Year_t + \varphi State_i + \varepsilon_{it}.$$

Negative binomial regression is employed because the dependent variable is the number of new tank releases in state i in year t from 1992–2009, which we denoted here as $New\_Releases_{it}$. This is a highly skewed count number. Negative binomial regression has the advantage of being precisely tailored to this type of dependent variable. It also avoids the overdispersion issue that plagued another type of regression that is suitable for highly skewed count data—Possion regression.[27]

The variable of central interest is $PostTransition_{it}$. It varies by state and year. For a given state-year observation, it is equal to 1 only when two conditions are satisfied; first, the state has made a transition from a state fund program to private insurance between 1992 and 2009; second, it is after the switch happened. This is a difference-in-difference specification. The coefficient for $PostTransition_{it}$ assesses whether the transition to private insurance helps lower tank releases compared to what would have happened if such a transition had not occurred.

for misrepresentation, thus foreclosing a rescission remedy." See http://altlaw.org/v1/cases/163048.

[25] It is worth asking whether, in fact, state funds emerge because there is no private insurance market rather than being the driving force in crowding out insurance. As noted above, the absence of a private insurance market was initially what caused state funds to be created. However, this article shows that at this point in time state fund failure was improved upon by insurance. Although it is not simple to prove the argument in either direction, we can say that with state funds run as they are, a private insurance market is hard to sustain.

[26] The data on the number of active tanks and new tank releases are from the by EPA Office of Underground Storage Tank (OUST). They keep track of the number of active and closed tanks, releases reported, cleanups initiated and completed, and emergency responses semi-annually. Available at http://www.epa.gov/oust/cat/camarchv.htm.

[27] Overdispersion occurs because a Poisson regression assumes that given a set of values on explanatory variables, the variance of the dependent variable is equal to its mean. Usually, this assumption is not true. A negative binomial regression relaxes this assumption.[34,35]

For a negative binomial regression, we need to specify an exposure variable reflecting the amount of exposure over which UST releases were observed. A natural candidate is the number of active tanks (by state and year). State fixed effects ($State_i$) are included in the regressions to control for omitted variables that are state-specific and do not change over time. Similarly, year fixed effects ($Year_t$) are included to control for any national trends in the likelihood of tank releases that are common to all of the states.

Table V reports the estimation results (the key findings do not change when we exclude states that had never used a state fund program from analysis). The coefficient for $PostTransition_{it}$ is negative and statistically significant at the 1% level. This suggests that the switch to private insurance helped transition states lower tank releases compared to what would have happened if such a transition had not occurred. The regression suggests that after transition, the expected number of releases in transition states is only about 65% of the expected number of releases if the transition had never occurred (see the Incidence-Rate Ratios column). This provides strong evidence for the strength of private insurance in motivating risk-reduction efforts.

Table V. Impact of Transition to Private Insurance on Number of Tank Releases

	Coefficient Estimates	Incidence-Rate Ratios
PostTransition	−0.43	0.65
	(3.40)**	
Year 1993	0.23	1.25
	(1.90)	
Year 1994	−0.03	0.97
	(0.29)	
Year 1995	−0.09	0.92
	(0.75)	
Year 1996	−0.20	0.82
	(1.64)	
Year 1997	−0.16	0.85
	(1.38)	
Year 1998	0.10	1.10
	(0.83)	
Year 1999	0.29	1.34
	(2.47)*	
Year 2000	−0.34	0.71
	(2.89)**	
Year 2001	−0.73	0.48
	(6.16)**	
Year 2002	−0.77	0.46
	(6.42)**	
Year 2003	−0.69	0.50
	(5.65)**	
Year 2004	−0.73	0.48
	(6.14)**	
Year 2005	−0.75	0.47
	(6.16)**	
Year 2006	−0.96	0.38
	(8.06)**	
Year 2007	−0.97	0.38
	(8.13)**	
Year 2008	−0.97	0.38
	(8.07)**	
Year 2009	−0.97	0.38
	(8.11)**	
State fixed effects	Included	
Observations	908	

Absolute value of z statistics in parentheses.
*significant at 5%; **significant at 1%.

5. DISCUSSION

Traditional policy instruments, such as *ex post* fines and process-based risk management requirements, can be ineffective in motivating efficient risk reduction given the small-firm problem and limited monitoring capabilities of regulatory agencies. Mandatory environmental insurance with premiums reflecting risk can, in contrast, provide appropriate incentives for all UST owners and operators to improve their operations. Our evidence showed that private insurance appears to have an advantage over state funds in encouraging risk reduction activities by firms.

The formation of state funds had some value by providing data so that insurers could price risks. Today, the market for UST commercial insurance seems to have become relatively mature. We might expect a greater reliance on such private insurance over the next few years since the sunset dates for three state fund programs will occur between now and 2011.[28]

Mandatory environmental insurance may not be applicable for every environmental risk. Freeman and Kunreuther[12] note that insurers not only need to identify and quantify risks before offering coverage, but they also need to be able to set premiums for each customer or class of customers as reflected in the firms' risk. Furthermore, demand must be large enough at the proposed premiums for insurers to

[28] The states with sunset dates in 2010 and 2011 are ME (12/31/2010), MO (12/31/2010), and ND (7/31/2011). See State UST Financial Assurance Funds Survey 2007, available at http://www.astswmo.org/publications_tanks_1997-2006-statefinancialassurancefunds.htm.

cover their fixed costs of developing and marketing policies and make a reasonable profit. In this sense, mandates should increase demand and make private insurance feasible.

Future research should explore the potential to extend mandated insurance to other environmental risks. These could include asbestos liability, liability for environmental contaminated property, and lead-based paint.[29] There is also a need to understand how mandatory environmental insurance can best work in combination with other instruments to encourage all firms to adopt socially efficient risk reduction. *Ex post* damage-based fines have a role to play in many situations (especially for large firms), as do third-party audits. Third-party audits, such as those required by ISO certification, are seldom used by insurance companies to adjust premiums or by governments for regulatory monitoring but they could be considered for both these purposes.

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[29] See Chapter 7 in Freeman and Kunreuther[12] for more details on the insurability issues associated with these three risks.

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