RISK-BASED PRICING AND RISK-REDUCING EFFORT: DOES THE PRIVATE INSURANCE MARKET REDUCE ENVIRONMENTAL ACCIDENTS?*

Haitao Yin
Erb Institute
University of Michigan

Howard Kunreuther
The Wharton School
University of Pennsylvania

Matthew W. White
The Wharton School
University of Pennsylvania

October 2007

(Being prepared for submission to the *Journal of Law and Economics***)**

Abstract. This paper examines whether risk-based pricing promotes risk-reducing effort. Such mechanisms are common in private insurance markets, but are rarely incorporated in government assurance programs. We analyze accidental underground fuel tank leaks—a source of environmental damage to water supplies—over a fourteen-year period, using disaggregate (facility-level) data and policy variation in financing the cleanup of leaking tanks over time. We find that eliminating existing state-level government assurance programs and switching to private insurance markets to finance cleanups reduces the frequency of costly underground fuel storage tanks leaks by more than 20 percent. This corresponds to approximately 2,500 accidental fuel-tank leaks avoided in Michigan from 1996 to 2003, a benefit of saved cleanup costs of $30 million per year (in 2003 dollars) and reduction of environmental impact to which it is difficult to attribute a money value. These benefits arise because private insurers mitigate moral hazard by tank owners by providing financial incentives to replace or upgrade leak-prone tanks prior to an adverse event that requires costly cleanup.

Corresponding author: Haitao Yin, Erb Institute, University of Michigan, 3544 Dana Building, 440 Church Street, Ann Arbor, MI 48109 / Tel: (734) 647-5958 / Email: haitaoy@bus.umich.edu

Acknowledgements. We thank Carol Amend (US Environmental Protection Agency), Mark Barolo, William Foskett, Paul Miller, Sammy Ng, and Jerry Parker (US EPA, Office of Underground Storage Tanks), Jan Spoor (Illinois Office of the State Fire Marshall), Jeff Tanner and Kevin Wieber (Michigan Department of Environmental Quality), and Michele Schroeder (Zurich Company N.A.) for extensive assistance with this project and many insightful comments. We also thank seminar participants at The Wharton School and the Erb Institute Colloquium for useful suggestions. This project received financial support from the Wharton Risk Management and Decision Processes Center and the Russell Ackoff Award at the University of Pennsylvania.

I. INTRODUCTION

Many risks facing firms and individuals are spread across the economy through government assurance programs. In the U.S., prominent examples include bank deposit insurance, pension benefit guarantee funds, and hazardous material cleanup funds. A salient feature of many government assurance programs is that they lack any form of risk-based pricing.[1] Instead, they protect beneficiaries from adverse events for a price that does not vary with the individual's likelihood of loss. A common concern is that this practice may exacerbate moral hazard, raising the frequency of adverse events by lessening incentives for risk-reducing effort (Kareken and Wallace, 1978; Akerlof and Romer, 1993; Cooper and Ross, 1998).

In contrast, risk-based pricing is widely employed in private insurance contracts. This can attenuate moral hazard problems by rewarding firms with premium discounts for risk-reducing activities (Freeman and Kunreuther, 1997). In this paper, we investigate whether the absence of risk-based pricing in one class of government assurance programs results in less risk-reducing activity—and more frequent adverse outcomes—than occurs when comparable insurance is arranged in private markets. The policy variation between states in financing the cleanup of leaking underground fuel tanks provides a valuable setting in which to examine this question.

In the late 1980s, new federal regulations required gas stations and other owners of underground fuel tanks to demonstrate they are financially capable of (*i*) cleaning up underground leaks and (*ii*) compensating third parties for consequential damages. Michigan, Illinois, and Indiana soon created state assurance programs to subsidize firms' costs of complying with the new federal regulations. Although the risk of an underground fuel tank leak varies greatly with a tank owner's operating and investment decisions, the price to participate in these state cleanup assurance funds did not vary with the tank's risk. Consequently, tank owners can have costly tank leaks and their consequential damages covered at state expense, while facing little (if any) program-related incentive to "take care" to prevent such leaks.

By the mid-1990s, Michigan's and Illinois' assurance funds became insolvent. However, these states took radically different approaches to their insolvency crises. While Illinois raised its gasoline excise tax to restore its program's solvency, the Michigan legislature terminated its

[1] By *risk-based prices,* we mean insurance premia that (1) are based on an assessment of the insured party's risk of future losses, and (2) vary with the insured party's loss history (or *experience rating*).

state assurance program. Tank owners in Michigan subsequently turned to the emerging market for commercial cleanup and liability coverage in order to comply with the federal financial responsibility requirements. In contrast to state assurance funds, the price structure for market-based insurance gives tank owners incentives to invest in equipment that reduces the chance of accidental fuel tank leaks. This setting provides an opportunity to evaluate whether switching from a government assurance program to the private insurance market promotes risk-reducing activity, and lowers the frequency of these adverse events.

Despite its importance, there are few studies that directly compare the performance of private versus public-sector insurance programs in addressing moral hazard. The empirical difficulty is that moral hazard is typically confounded with selection effects. For example, Wheelock and Wilson (1995) found that banks that were members of the Kansas state deposit insurance system had a higher probability of failure than non-members. As they point out, however, it is unclear whether the Kansas deposit insurance system attracted the most risk-prone banks (adverse selection), or banks tended to become more risk-taking once insured (moral hazard).[2]

Several attributes make our research setting more conducive to the study of moral hazard in government assurance programs. First, federal financial-responsibility regulations require firms either to purchase private insurance or to participate in a state assurance fund.[3] Because the two systems provide comparable insurance benefits but a state fund's cost is (largely) paid by taxpayers, it is a dominant strategy for any tank owner—whether low or high risk—to use the state assurance fund. Only when a state fund is not available do tank owners acquire private insurance. Consequently, there is no sorting between private and public-sector insurance on the basis of a firm's private information about its risk propensity or its cost of risk-reducing effort.

Second, there is little reason to take a "reverse causality" interpretation of the data, in which accident rates in Michigan would have declined (relative to surrounding states) even if that state had not switched to private market insurance. In fact, the evidence available indicates

---

[2] Empirical studies of private versus public-sector insurance programs have proved more successful at evaluating adverse selection, particularly in health care contexts. For example, Hopkins and Kidd (1996) and Sapelli and Torche (2001) argue that adverse selection is most severe for health insurers that are restricted by rules that limit price discrimination, thereby preventing premiums from varying according to the insured party's risk.

[3] Aside from private insurance and state fund programs, other methods such as obtaining a guarantee, obtaining a surety bond, and obtaining a letter of credit can also be used to comply with Financial Responsibility Requirements (40 CFR §280.90-115). However, for most tank owners, these methods are not appealing or applicable because some of them are more expensive than insurance; others do not transfer the risk in the same way as insurance does, or may require assets to be pledged as collateral that are beyond the resources of the average tank owner (GAO, 1988).

that Michigan should—and did—expect to have a larger future tank cleanup problem than other states at time it decided to terminate its public assurance fund program. Consequently, this study provides informative findings regarding the effects of switching to the risk-based pricing system used in private insurance markets.

The findings are quite striking. Michigan's policy transition reduced the fraction of underground fuel tanks with accidental releases[4] by more than 20 percent, relative to surrounding states that maintained state assurance fund programs. This finding is robust to adjustments that account for the (slight) differences among these states in the initial age and number of tanks at stations and other facilities with underground fuel tanks, and to changes in technical (physical) tank regulations over time by federal regulators.

These findings have an important and useful policy implication. The US Environmental Protection Agency estimates that 12,000 new underground fuel tank releases occur each year in the United States.[5] Petroleum products (such as gasoline and diesel fuel) that leak underground tend to enter groundwater flows; if undetected, this can pose a public health hazard by contaminating public drinking water supplies, and require costly remediation. The reduction in fuel tank release rates we document corresponds to more than 2,500 avoided fuel tank accidents in Michigan from 1996-2003. It costs about $90,000 on average to clean up a contaminated site.[6] Therefore, the policy transition has rewarded Michigan with saved cleanup costs of about $30 million per year (in 2003 dollars) and reduction of environmental impact to which it is difficult to attribute a money value. We conclude that the risk-based pricing mechanisms used in private insurance markets are effective instruments to mitigate moral hazard and promote risk-reducing effort. For the more than thirty states that presently operate similar state assurance fund programs, it would appear that adopting the market practice of risk-based pricing may alleviate ongoing solvency crises and reduce the costly burden of future fuel tank accidents.[7]

The paper proceeds as follows. Section II provides background information on the technology and risks of fuel tank accidents, and what owners can do to reduce the likelihood of these accidents. Section III summarizes federal and state regulations, and the incentives these regulations create. Section IV addresses the policy variation in three states for which we have detailed

[4] Our data cover all the *accidental releases* which include both underground tank fuel leaks and spills. Because accidental releases are predominately tank leaks, we use release and leak interchangeably in this paper.
[5] US EPA Office of Underground Storage Tanks, *2006 Corrective Action Performance Measures Data.*
[6] *State Financial Assurance Funds Survey* (1999-2004)
[7] *State Financial Assurance Funds Survey* (2004).

data: Michigan, Illinois and Indiana. Here we also describe the key differences between private insurance and these states' assurance fund programs, emphasizing how the former generate risk-reduction incentives. Section VI summarizes the data and methodological issues. Section VII presents the main empirical results, and Section VIII examines alternative explanations. Section IX concludes with a brief discussion of policy implications.

II. TECHNOLOGY AND RISK-REDUCING ACTIVITY

In order to understand the effects of the government assurance programs we study, it is useful to briefly summarize the underlying technology, the risks it entails, and what "taking care" to prevent accidents means in this setting.

A. Technology

Most underground fuel tanks are located at retail gasoline stations. A small gas station typically has two tanks, and a large station may have five or six. From a regulatory and an insurance standpoint, they are treated as one system consisting of the tanks and underground piping, pumps, and ancillary equipment. The most common and serious cause of accidental underground fuel leaks is long-term corrosion (oxidation) of the tank or pipes by groundwater in the surrounding soil.[8]

While leaks underground are not directly visible, they are readily detected by several means. These include inventory monitoring and reconciliation, automatic leak sensors located in the tank system, and groundwater monitoring wells located near the tank system. Since 1993 all tank systems in the United States have been required to have some leak detection system in place. However, tank system owners can invest in more accurate detection systems than the minimum regulatory requirement, which enables a leak to be identified and rectified more rapidly.

The rapid detection of a tank system leak is essential to minimize its cost and avoid consequential damage that can be severe. Small leaks can be resolved by removing the remaining fuel, replacing the tank and piping, and cleaning (e.g., excavating) any surrounding contaminated

[8] Other, less common causes include improper installation, structural collapse, and uncontained surface fuel spills during fuel deliveries.

soil. Although total costs vary, typical expenses in these situations are about $90,000 per leak.[9] In contrast, a leak that remains unresolved will not stop on its own accord and tends to grow progressively worse over time, spreading into groundwater systems that may extend well beyond the station site. Once it has contaminated groundwater off-site, the total cost of remediating the leak can rise by a factor of ten or more. In severe cases, fuel from leaking tanks can contaminate drinking water sources, forcing the permanent closure of municipal and private wells and acquisition of new water supplies.[10] For these reasons, investing in equipment and operating practices that can prevent accidental underground leaks—and detecting and remediating leaks with alacrity—is desirable to minimize the total social costs of underground fuel storage.

B. Preventing Leaks: Maintenance and Capital Investment

Since the mid-1980s, new technologies have enabled tank system owners to greatly reduce the likelihood of an accidental underground fuel leak. Prior to 1990, near all underground fuel tanks were single-walled and constructed of bare steel that is prone to corrode. Two types of capital investments can greatly reduce this risk. The first, and most effective, is to replace a steel tank with one constructed of, or coated with, non-corroding materials (such as reinforced fiberglass). Installing a double-walled tank will further reduce the corrosion risk, to negligible levels. Short of replacing an existing bare steel tank, a tank system owner can invest in corrosion-attenuating equipment that will reduce the likelihood of underground tank leaks. A variety of anti-corrosion technologies are available, with more effective systems carrying higher installation and ongoing maintenance costs.[11]

Tank system leaks can also be reduced, in severity and in likelihood, through assiduous operations and maintenance activities. These include weekly pressure testing the tank system, calibrating inventory monitoring systems after each fuel delivery, replacing sacrificial anodes (a means of corrosion resistance in steel tanks), and the like. All of these activities are costly, and some require periodic closure of the station and attendant lost revenue.

---

[9] *State Financial Assurance Funds Survey* (2003, 2004)

[10] Benzene and other compounds in gasoline are hemotoxic and neurotoxic to humans in high doses, and carcinogenic with long-term, low exposure levels. Ingestion via contaminated water is an especially damaging vector due to rapid absorption into the bloodstream. See ATSDR (2005) and references therein.

[11] A summary of technologies and their attributes is provided in the US EPA's Office of Underground Storage Tanks technical information website; see, e.g., http://www.epa.gov/OUST/fsprevnt.htm#corrosion.

During our study period, changes in federal and state regulations altered the incentives for tank system owners to adopt these measures. We address these changes next.

III. REGULATION AND ITS INCENTIVES

A. Federal Regulations and Owners' Responsibilities

In response to mounting scientific evidence and public concern over adverse health consequences of leaking underground fuel tanks, in 1984 Congress directed the US Environmental Protection Agency (EPA) to regulate public and private underground fuel storage tanks.[12] The EPA's final regulations, issued in 1988, had several distinct provisions: Financial responsibility requirements, tank-system technical standards, and disclosure and corrective action obligations. The first of these provisions is the impetus for the state-level policy variation we examine in this paper.

Financial Responsibility Requirements. The EPA's financial responsibility requirements require tank system owners either to (*i*) purchase environmental liability and site remediation insurance for fuel tank leaks from a qualified insurer, with a minimum coverage of $1 million per occurrence, or (*ii*) participate in a state-level underground storage tank financial assurance program providing comparable coverage. Current compliance documents must be supplied to regulatory agencies, and the penalty for noncompliance or lapsed coverage is high. State and federal regulators believe that compliance with financial responsibility requirements is (essentially) universal.[13]

In creating these new obligations, Congress did not alter any tort system remedy available to third parties injured by a tank leak. Rather, Congress effectively concluded that such remedies

[12] 40 CFR §280-1, implementing the Resource Conservation and Recovery Act Subtitle 1 Amendments of 1984. Underground fuel tanks were not a public concern until the early 1980s; in 1983, the CBS program *60 Minutes* story "Check the Water" brought national attention to the potential problem of leaking underground gasoline storage tanks and public health.

[13] Email communications with Sammy Ng (US EPA Office of Underground Storage Tanks, 5/19/2006) and Kevin Wieber (Michigan Department of Environmental Quality, 6/15/2006). Penalties for noncompliance are stipulated per diem in RCRA, Subtitle 1, §9006(d)(2).

alone are apt to be (1) administratively and socially costly relative to prophylactic regulation,[14] and (2) that the desired incentive effect of a pure liability rule for owners to "take care" to avoid leaks may be adversely tempered by the limited liability provisions of the bankruptcy code. This second concern is particularly extreme with respect to the risk posed by underground fuel storage tank leaks at gasoline stations, as many are small businesses and the cost of cleaning up a major tank leak can easily exceed the present value of an individual station's future profit stream (Kunreuther, Pfaff and Yin, 2007).[15]

Technical Requirements. Although regulatory standards for tank system technical attributes are not the focus of our analysis, they affect the interpretation of our data. The EPA chose compliance dates for technical standards that differed for new versus existing ("grandfathered") underground fuel tanks. Any *new* tank or system installed after the EPA's final regulations issued in 1988 was required to have one or more leak detection systems, and to meet a basic requirement for corrosion resistance. In contrast, existing (grandfathered) tanks were obligated to meet the leak detection technology requirement within five years (by December 1993), and the corrosion-resistance requirement within ten years (by December 1998). In both cases, the corrosion resistance requirement could be met by retrofitting an existing steel tank with technology readily available in 1988.

The principal consequence of these technical regulations is that, even in the absence of any state-level policy variation, we would expect the frequency of underground storage leaks to decrease over time as older, sub-standard tanks are upgraded or closed to meet the 1998 deadline.

Reporting and Corrective Action Requirements. The 1988 federal regulations stipulate prompt reporting of underground storage tank leaks in any detectable quantity to federal and/or state regulatory agencies, and specify required corrective actions in detail. Importantly for our

[14] The administrative inefficiency of a pure liability rule rests on the observation that tank leak litigation centers on competing expert testimony in geology, epidemiology, engineering, and other scientific areas that courts are often ill-equipped to evaluate. In addition, Congress recognized that time is of the essence in acting to resolve an underground fuel storage tank leak, for reasons discussed in Section II.A. This makes corrective action and assured financing for it stipulated *a priori* by a regulatory agency preferable to the delay of judicial decisions regarding clean-up programs made in the course of civil litigation or a bankruptcy proceeding.

[15] Although it is not essential to our interpretation of the data, questions commonly arise regarding the division of liability between owner and operator at franchised gasoline stations. Liability in these cases varies, depending upon applicable state franchising law, who holds title to the tank system, and any provisions regarding these contingencies in the specific franchise agreement.

purposes, the penalty for failing to report a suspected underground tank leak is extraordinarily high, at $11,000 per (leaking) tank *per day*.[16] We discuss this and other incentives facing owners to disclose tank leaks in Section IV.C, below. First, it is useful to summarize state policy responses to the federal regulations.

B. State Responses: Government Assurance Funds

The federal financial responsibility requirements generated a storm of political protest from gasoline retailers and small business advocates. Petroleum marketers argued that many stations would not survive because private insurance was not readily available, and expensive when available (GAO, 1987).[17] In response to these political pressures, many state legislatures created financial assurance funds for underground fuel tank leaks.

These state assurance funds function as a publicly-financed insurance program for tank system owners. In the event of a tank leak, the state assurance fund pays for the cost of cleanup at the site and third-party consequential damages. To participate in a state assurance fund program, a tank system owner must (1) pay a nominal registration fee (typically $100 per tank per annum), and (2) comply with the applicable regulatory requirements for leak detection systems and tank standards noted earlier; and (3) promptly report (usually within 24 hours) any detected or suspected underground fuel leaks. Most state assurance fund programs, including all examined here, were crafted so that participating tank owners thereby achieve full compliance with all federal financial responsibility requirements.

There are two important observations about these programs to note. First, most states' assurance funds are financed by an incremental excise tax on motor fuel (typically about one cent per gallon). The nominal fee that a tank system owner pays to participate in a state assurance fund is a small fraction of the actuarially fair price of underground fuel leak cleanup and

[16] 42 USC 6991(e).

[17] According to GAO's 1987 report, firms claimed it was extremely difficult for them to obtain adequate pollution liability insurance for tanks. One firm said it contacted 44 insurance companies and was unable to find coverage. Others said their insurance brokers had to contact as many as 20 insurance companies before they were able to obtain insurance. Firms also said that, when available, tank insurance became more expensive over time. One small firm testified that between 1986 and 1987, its premium tripled from $3,000 to $10,000 and for coverage that was reduced from $4 million to $2 million by the same insurer. In another example, a firm's premium increased from $10,000 in 1985 to $73,000 in 1987, even though what was included under the coverage declined significantly (GAO 1987).

liability insurance. As a consequence, in states with assurance fund programs the participation rate of tank system owners is close to 100%, and the use of private market cleanup and liability insurance is virtually zero.

Second, the fee that tank owners pay to qualify for state fund benefits is the same to everyone. It does not vary with respect to the age of the tanks being insured, their capacity, prior leak histories, groundwater proximity, whether or not a tank system has been retrofit with advanced corrosion protection equipment, whether or not a tank is single- or double-walled to contain a leak, or with any of a host of quantifiable factors that directly affect the chance of a tank leak or the cost of remediating it. Consequently, the structure of state fund programs provides no incentive for an owner to invest in or maintain leak prevention equipment beyond the bare minimum necessary to meet federal tank-system technical standards.

Indeed, it is possible that state assurance fund programs actually attenuate the incentives of tank owners to comply with federal tank-system technical regulations. Our discussions with regulatory officials indicated that while state assurance funds nominally require participants to comply with federal technical regulations, that requirement is not well-enforced. William Foskett, an official at the EPA's Office of Underground Storage Tanks, indicates how administrators view the problem:

> Anecdotes that have come to my attention indicate that where a state has the authority to limit coverage based on compliance, that authority is not necessarily exercised. Withholding payment for non-compliance poses state fund administrators two very practical problems: 1) both the owner/operator and state legislators tend to think of payment for cleanups as an entitlement, except in the most egregious violations; and 2) the public interest (public welfare) purpose of protecting the environment and health by cleaning up release sites is not served if the public monies allocated for cleanups are not in fact applied to accomplishing that public goal expeditiously. … Assured financing for cleanups is a higher goal than bringing non-compliers to justice.[18]

In practice, this perspective has a potential to create mal-aligned incentives for tank owners to comply with tank technical standards. Still, whether or not the absence of strong incentives to prevent accidental leaks among state assurance fund participants is manifest in more adverse outcomes is an empirical matter. We now turn the policy variation that informs this question.

[18]Email communication with William Foskett, US EPA, August 18, 2004.

IV. POLICY VARIATION AND MARKET INSURANCE

A. State Policy Changes

Our empirical analysis examines three states for which comprehensive facility- and tank-level data are available: Michigan, Illinois, and Indiana. All three established substantively-identical state assurance fund programs in 1998 or 1999. Indiana initially chose a high (relative to subsequent claims) gasoline excise tax to finance its assurance fund, and has operated its program without major changes since that time. However, claims in both Michigan and Illinois significantly exceeded their initial funding levels and rendered both states' assurance funds insolvent by the mid-1990's (Cowans, 1995).

In response, Illinois raised its (wholesale) motor fuels tax by approximately 0.8 cents by gallon and has continued to operate its state assurance fund without major changes. In contrast, Michigan conducted several studies that concluded a similar increase in funding would be necessary to restore its program's solvency. Facing public opposition to further gasoline taxes and encouraged by a newly-emerging private insurance market for environmental liability coverage, the state legislature elected to close its state assurance fund program (EPA, 1997). Michigan made the transition to the private market by requiring tank owners to obtain private-market insurance after June 30, 1995. In the analysis below, we refer to the years before 1995 as the *pre-transition period* and years after 1995 as the *post-transition period;* we will identify the transition year separately.

B. Market Insurance and Incentives

Environmental liability and cleanup insurance for underground fuel tank releases is available on similar terms from a number of commercial insurance companies. In contrast to state assurance fund programs, these commercial insurance policies are explicitly structured to encourage risk reduction efforts. For example, insurance premiums are designed to reward owners for replacing tanks constructed of corrosive-prone material (bare steel) and aging tanks generally. A review of several major insurers' policies indicates that the primary factors determining commercial tank insurance premiums are the age of the tank system, tank material and coatings, construction (single- or double-walled), contents, capacity, and the history of prior leaks at the facility. Premiums are also based on the number and types of leak detection systems in place, with lower premiums offered for more sophisticated detection systems.

Some evidence regarding the magnitudes involved is provided in Tables 1 and 2. Table 1 shows several key rate factors for one major commercial environmental liability insurer (the Zurich Company N.A.) .[19] Base premia vary with tank construction and age by a factor of *ten*, from $185 p.a. for a new, double-walled tank to $1850 p.a. for a single-walled, 35+ year-old tank. Premiums are discounted by 10% each for installation of an advance leak detection system, additional corrosion protection equipment, and other preventive measures that exceed federal tank-system technical standards. In addition, this firm will not insure corrosion-prone tanks (bare steel tanks that lack corrosion protection equipment) at any price. Insurers monitor compliance with the asserted equipment and system attributes of insured tank owners (generally *ex post*), and are known to deny compensation if mis-reporting of tank attributes is evident.[20]

Table 2 shows the total insurance premium for four typical three-tank system configurations in 1997, which is approximately the mid-point of our study period. Comparing the rows, the table shows that premiums vary significantly across tank systems. Lower premiums apply if owners invest in systems that are less likely to corrode and leak, and that have better monitoring and inventory control. Table 2 also reveals considerable variation in premia across insurers in the mid-1990s, when the market was fairly new; this price dispersion has disappeared over time as the market has matured.

A second contrast to state assurance funds is that commercial insurance contracts motivate tank system owners to "take care" with experience-rated prices. For instance, the bottom row of Table 1 indicates that a prior accidental fuel release (a tank leak or spill) will increase the premium per tank charged by this insurer by 10-to-20 percent per annum. To our knowledge, no state assurance fund program has incorporated even this most basic form of risk-related information into its program.

Last, private market insurers engage in a variety of activities designed to promote risk-reducing activities by tank system owners. Some insurers issue newsletters that identify cost-effective technologies to prevent or detect leaks, which could conceivably reduce owners' costs

[19] These data represent prices as of 2004. Discussions with Zurich indicate its premia during the mid-1990's were generally higher but structured similarly with respect to tank attributes. See also EPA (1997) and PSC (1995).
[20] Telephone interview with Michele Schroeder of the Zurich Company N. A., March 3, 2005.

of searching for and processing related information. Insurers also offer premium discounts and rebates to tank system owners who purchase leak detection and tank system maintenance services from specific third-party providers. For example, the American Insurance Group's Environmental Insurance unit provides substantial premium discounts to tank system owners who purchase compliance management and monitoring services from Tanknology-NDE International, a company that specializes in tank system engineering and equipment (NPN, 1998). While purchasing these third-party services does not necessarily change an owner's investment decisions, they are viewed by insurers as a cost-effective way to reduce moral hazard in operations and maintenance activities by small gasoline station retailers and other tank owners.

In sum, because the price of commercial insurance is closely tied to tank systems' attributes, leak history, and tank owner's risk-reducing activities, we hypothesize that with commercial insurance, a facility that operates underground fuel tank is less likely to have an accidental leak compared to facilities participating in state assurance fund programs. Before turning to the data that can inform this conjecture, however, it is important to first describe how the leaks that do occur are reported.

C. About Leak Disclosure Compliance

For the states we examine, our data include all underground tank fuel leaks and spills (formally known as *accidental releases*) reported to, or discovered by, state regulatory agencies and commercial insurers. The issue we confront is whether this number of reported releases reflects the true number of releases discovered by tank system owners each year.

As noted earlier, federal law requires the owner or operator of an underground fuel storage tank to report a suspected accidental release within 24 hours to regulatory authorities (40 CFR §280.50). If a tank owner and its operator fail to report a suspected release within this period, they are subject to civil penalties of up to $11,000 per tank, per violation, *per day* (RCRA Subtitle I §9006(d)(2)). The question here is whether tank owners and operators, subject to this penalty, have an incentive to hide a suspected or known accidental release.

For tank systems covered by a state assurance fund program, there is little or no incentive to hide an accidental release and a considerable incentive to report it. Because these owners are insured for cleanup costs (without limit) *and* state fund programs are not experience-rated, the cost to a tank owner of reporting an accidental leak is only the program's deductible (commonly $5,000 to $10,000 per incident, depending on the state). This cost is quite small relative to the costs of *not* reporting a leak, for two reasons. First, as noted above the tank system owner is subject to penalties that accrue at a rate $11,000 per day. Second, a state assurance fund may bring suit to have the tank system owner cover the cleanup costs in excess of what the state would have incurred if the leak had been reported in a timely fashion. Both of these costs can be quite high, and are easily avoided by reporting a tank system leak promptly upon detection. For these reasons, tank owners covered by state assurance funds have little incentive to not disclose accidental releases promptly.

Of greater concern to our analysis is the possibility that tank system owners covered by private insurance may fail to report tank system accidental releases. Here the cost an owner incurs from reporting a leak is its policy deductible *and* future increases in its experience-rated premiums. This increase is typically 20% or less of the total annual premium (or several hundred dollars per tank per year), and continues for the entire service life of the insured system. Balanced against these costs of reporting a leak are the considerably higher costs of not reporting it. Commercial tank insurance is renewed on a yearly basis. A tank owner has to make a detailed declaration of whether its tanks have experienced an accidental release in the past when purchasing or renewing its policy. Non-disclosure of a prior release at the site is a breach for which the insurer may legally rescind coverage, which leaves the tank system owner liable for the cost of the cleanup. At this point, the tank system owner is also immediately subject to the federal civil penalty for non-compliance with timely accidental release reporting requirements (of $11,000 per diem, cumulated back to the date of the prior release). Compared to these potential losses, the benefit of hiding an accidental release is extraordinarily small.

Two other technological and temporal features also argue against the possibility that reported releases and actual releases (detected by owners) would differ. As noted in Section II, underground fuel tank leaks do not stop of their own accord but tend to grow over time as the plume of fuel disperses through surrounding soil and into groundwater. As leaks progress, maintaining fictitious accounts showing continuously balanced inventories of fuels and fuel sales becomes increasingly untenable due to the progressive leak losses (this is especially true for electronic data produced by automating monitoring systems that tally cumulative net inventory changes over time in on- and off-site databases, a system preferred by commercial insurers).

Suspicious inventory-balance records invite on-site inspections from state tank regulatory agencies, and on-site inspections of a station's leak detection systems will reveal an ongoing leak.

Moreover, a leaking underground tank cannot remain hidden indefinitely. When an underground fuel tank is ultimately closed and retired, state inspectors require site testing by outside parties to verify that the tank is demonstrably removed (or rendered unusable *in situ*) and that the tank owner no longer needs to maintain insurance and compliance documents for it. The closure testing and final leak detection system inspections are diagnostic—that is, highly unlikely to falsely conclude a site is clean if, in fact, a sustained leak has occurred.

These features of accidental underground fuel leaks and their monitoring imply that not disclosing a suspected leak can—at best—simply postpone the inevitable costs of a cleanup. In such an event, all or some of the costs of the now-expensive cleanup will shift from the insurer (whether private or a state program) to the negligent tank system owner—who, at this point, is now retroactively subject to the $11,000 per day penalty for not reporting the leak in the first place. A tank owner in such a position may well declare bankruptcy, thus foregoing all future profits. In sum, under any conceivable scenario, the costs to a tank owner from proceeding down this path vastly exceed the comparatively minor expense of reporting a tank leak promptly.

Given the totality of these incentives, we do not believe that tank system owners with commercial insurance are less likely to report an accidental release (after one occurs) than owners participating in state-fund assurance programs. In fact, it is conceivable that reporting might increase with commercial insurance, since private insurers provide financial incentives (premium discounts) for tank owners to install more sophisticated leak detection systems. This implies that the likelihood an actual leak remaining completely undetected by the tank system owner is likely to be lower. Nevertheless, regulatory officials at the US EPA who oversee compliance policies nationally indicate there is no evidence to date that tank owners in states with assurance programs and those using commercial insurance differ systematically in reporting accidental releases.[21]

V. DATA AND METHODOLOGY

[21] Email communications with Sammy Ng (Director, US EPA Office of Underground Storage Tanks) and Mark Barolo (US EPA Office of Underground Storage Tanks), May 25, 2005.

A. Data

Data were provided by the Illinois Office of the State Fire Marshal, the Illinois Environmental Protection Agency, the Indiana Department of Environmental Management and the Michigan Department of Environmental Quality. Two databases are available from each state. One is the underground tank database, in which tank-level attributes are reported, such as tank status, tank installation and closure date, tank capacity, name of tank owners and tank location. Another one is the tank release database, which records all the releases that have ever occurred, release date and clean up progress. Because the tank release database only notes which facility (but not which tank at the facility) had a release, the finest level on which we could perform our analyses is at the level of facility (including gasoline stations and other sites with underground fuel tanks). Data span the years 1990 to 2003.

Illinois and Indiana are selected to form a counterfactual for the evolution of the tank release risk in Michigan. As Illinois and Indiana are in the same EPA region as Michigan, they experience the same regional policy changes. Another practical reason Illinois and Indiana are chosen is that they, like Michigan, have comprehensive, computerized databases which include not only currently active facilities, but also closed facilities. Without knowledge of what facilities are closed, we will not have an accurate account of the total facility population in each year. [22]

Illinois has more attractive features than Indiana for serving as a control state. Michigan and Illinois have similar numbers of tanks initially (see table A1). Indian had fewer tanks. As discussed in Section VII.B, Michigan and Illinois also made similar efforts to enforce technical standards, more than Indiana did. Michigan and Illinois experiences similar financial difficulties around the same time, while Indian did not. Both Illinois and Michigan started processing underground fuel tank claims in 1990, while Indiana waited until January 1993. Lastly but not least, Indiana has a missing data problem far more serious than Illinois (see Appendix). For these reasons this paper primarily focuses on comparisons between Michigan and Illinois. The comparison between Michigan and Indiana serves as a robustness check for the major findings.

[22] The EPA's regulations also cover underground fuel storage tanks at airports, farms, railroad yards, municipal service lots, manufacturing facilities, and so on. All such underground fuel tanks (regardless of ownership or use) in the states we examine are included in our data. Federal law excludes residential heating oil tanks from the financial responsibility regulations studied here, and as such are not included in our analysis. In the data, the overwhelming majority of underground fuel storage tanks are used for motor gasoline and located at retail gasoline stations.

B. Measuring Facility Release Risk

The central task of this paper is to investigate how the release risk of facilities that operate underground fuel tanks in Michigan is changed by switching from a state assurance program to private insurance. When measuring the Facility Release Risk, one may want to focus on active facilities and define it as the probability that an active facility *i* has at least a release in year *t*, which can estimated by

$$\hat{P}(R_{it} | Active_{it}) = \frac{Number\ of\ Active\ Facilities\ with\ Release\ in\ Year\ t}{Number\ of\ Active\ Facilities\ in\ Year\ t} \qquad (1)$$

We define (1) as active release rate. Although straightforward, the active release rate is misleading. If more facilities are taken out of service, both the number of active facilities and the number of releases from active facilities become smaller. As a result, the estimates of the active release rate in year *t* depend on how many facilities were taken out of service before year *t*. As such the active release rate does not accurately reflect the facility release risk. This concern is particularly relevant if the policy change influences both the facility release risk and how many facilities are taken out of service, which is likely the case here. Tank owners/operators under private insurance have more incentives to close their old tanks because they need to pay a high premium for those tanks. Therefore, to measure the facility release risk more appropriately, we need to account for the different speed at which facilities are taken out of service in different states.

Let R_{it} denote that at least one release[23] occurs at facility *i* in year *t*
Let $Active_{it}$ denote that facility *i* is in service in year *t*
Let $Inactive_{it}$ denote that facility *i* is not in service in year *t*

The probability that at least one release occurs at facility *i* in year *t*, $P(R_{it})$, can be decomposed as

$$P(R_{it}) = \underbrace{\underbrace{\underbrace{P(R_{it} | Active_{it})}_{\text{Active Release Rate}} P(Active_{it})}_{\text{Ajusted Active Release Rate}} + P(R_{it} | Inactive_{it})\, P(Inactive_{it})}_{\text{Total Release Rate}} \qquad (2)$$

[23] It is very rare that one facility reported two or more releases in a year.

The first term in equation (2), $P\ (R_{it} \mid Active_{it})$ is the active release rate. The active release rate adjusted by the probability that a facility stays in service [$P(Active_{it})$] is defined as the adjusted active release rate. We defined $P(R_{it})$ as the total release rate, that is, the probability that any facility *i* has at least a release in year *t*.

To get the adjusted active release rate, we need estimate $P(Active_{it})$. Conceptually, $P(Active_{it})$ can be estimated by the percentage of active facilities – dividing the total number of active facilities in year *t* by the total facility population in year *t*. The challenge is how to define the total facility population in year *t*. In this paper, we define the total facility population in year *t* as the set of facilities that have ever been in service between 1986 and year *t*.[24] According to this definition, if a facility had all its tanks taken out of service before 1986, it is excluded from the total facility population. Let POP_{it} denote that facility *i* had ever been in service between 1986 and year *t*, that is, facility *i* is in the total facility population of year *t*. $P(Active_{it})$ can be estimated by (3).

$$\hat{P}(Active_{it}) = \frac{Number\ of\ Active\ Facilities\ in\ Year\ t}{Number\ of\ POP_{it}\ Facilities\ in\ Year\ t} \tag{3}$$

The adjusted active release rate can be estimated by multiplying equation (1) by equation (3). That is,

$$\hat{P}(R_{it} | Active_{it}) * \hat{P}(Active_{it}) = \frac{Number\ of\ Active\ Facilities\ with\ Release\ in\ Year\ t}{Number\ of\ POP_{it}\ Facilities\ in\ Year\ t} \tag{4}$$

The difference between the estimates of the adjusted active release rate (equation (4)) and the active release rate (equation (2)) is that the estimate of the adjusted active release rate use total facility population instead of active facility population as the denominator. Whether or not a facility has been taken out of service in year *t*, it will still be counted in the total facility population as long as it has been active between 1986 and year *t*. As a result, the denominator in (4) is not affected by how many facilities were taken out of service before year *t*.

[24] Why is the year of 1986 chosen? Federal regulations require owners/operators of underground storage tank systems that were in the ground on or after May 8, 1986 to notify the designated state or local agency (40 CFR §280.22).

However, the numerator in the estimate of the adjusted active release rate (equation (4)) is still confounded by how many facilities have been taken out of service, in that the more out-of-service facilities, the less number of active facilities, and the less releases from active facilities. Total release rate can remedy this problem by incorporating inactive facility releases.[25] At aggregate level, the total release rate can be estimated by the percentage of facilities, among the total facility population, that have at least a release in year *t*. That is,

$$\hat{P}(R_{it}) = \frac{Number\ of\ POP_{it}\ Facilities\ with\ Release\ in\ Year\ t}{Number\ of\ POP_{it}\ Facilities\ in\ Year\ t} \tag{5}$$

Both the numerator and the denominator in equation (5) do not depend on how many facilities are taken out of service. Hence the total release rate is an accurate measure of the facility release risk and therefore conceptually preferred.

VI. Empirical Evidence

This section presents empirical evidence showing that the policy change to a private insurance market has helped Michigan reduce its facility release rate by about 1.14 percentage points. The data also suggest that tank owners/operators in Michigan tend to take more care of their tanks after the policy change than those in Illinois.

A. Investigating the Total Release Rate

Figure 1 shows how the difference in the total release rate between Michigan and Illinois changed over time. It shows that Michigan had a higher total release rate than Illinois before the policy transition. However, for most years thereafter Michigan had a total release rate lower than Illinois. Table 3 summarizes the observations in Figure 1. Table 3 (difference column) reveals that the average total release rate dropped by 4.16 % in Michigan from the pre- to the post-transition period, while it dropped only by 2.63 % in Illinois. This suggests that Michigan's pol-

[25] Inactive facility could have a release because of two reasons. The major reason is that there are still petroleum products in underground tanks after the facility was taken out of service. It is also possible, although rare, that release occurred in the past and was discovered during site assessment in a later year.

icy change helped to reduce the total release rate by 1.53 percentage points, which accounts for 23% of Michigan's average total release rate in the pre-transition period.

These observations do not account for other factors that may have an impact on facility release risk such as facility size, tank quality, and other facility-specific characteristics. To consider these factors, we generate the conditional total release rate in each year by running a logit regression. It is called "conditional" because it explicitly accounts for facility size, facility tank quality, and other facility-specific characteristics. In contrast, we call the total release rate without adjusting for these factors the unconditional total release rate. Both Figure 1 and Table 3 show the unconditional total release rate.

A random-effects model is employed to consider facility-specific characteristics that do not change over time. Facility size is measured with the total number of tanks that a facility had. The number of pre-1989 installed tanks is used as a proxy of facility tank quality because the tanks installed after December 22, 1988 must meet the requirements concerning correct installation, leak detection, and spill, overfill, and corrosion protection (EPA, 1995). Tanks installed after December 22, 1988 are therefore much less likely to have a release than pre-1989 installed tanks. The logit regression model with random effects of facility is depicted by (6).

$$P(R_{ikt}=1)=F(\beta_0+\alpha_i+\beta_1 * TN_{ikt}+\beta_2 * TO_{ikt}+\beta_3 * MI_k \\ +\gamma * year\_dummy_t+\phi * MI_k * year\_dummy_t) \quad (6)$$

where F is the cumulative probability of a logistically distributed random variable

A logit regression is a standard approach when the dependent variable is dichotomous (release or no release in our study). In (6), the dependent variable, R_{ikt}, is equal to 1 if facility *i* in state *k* had a release in year *t*, and 0 otherwise. We use TN_{ikt} to denote the total number of tanks facility *i* in state *k* had in year *t*. It is included in the regression to account for the impacts of facility size on facility release rate. The total number of pre-1989 installed tanks facility *i* in state *k* operated in year *t*, denoted as TO_{ikt}, is included to account for the fact that having more pre-1989 installed tanks would raise facility release risk. A state dummy, MI_k, which is equal to 1 if the facility is in Michigan, is used to account for the baseline difference between Michigan and control states that may be correlated with the likelihood of facility releases. The $year\_dummy_t$ are used to trace out the time trend of facility release risk in Illinois. The interaction term $MI_k * year\_dummy_t$ captures the difference of the facility release rate between Michigan and Illinois in each year.

Marginal effects of explanatory variables on the probability that a facility has an accidental release are evaluated after estimation. The difference in the conditional total release rates between Michigan and Illinois in 1995, for example, is estimated as follows. The estimated coefficient of the Michigan state dummy, $\hat{\beta}_3$, captures the difference in the baseline year -1990. The estimated coefficient of the interaction term between the Michigan state dummy and the 1995 year dummy $\hat{\phi}_{1995}$ captures how the difference in 1995 differs from the baseline year. Therefore, $\hat{\beta}_3 + \hat{\phi}_{1995}$ captures the difference of the conditional total release rate between Michigan and Illinois in 1995.

Figure 2 shows how the difference of the conditional total release rate between Michigan and Illinois changed over time. Similar to Figure 1, it shows that Michigan had a higher conditional total release rate than Illinois before the policy transition. However, for most years after the policy transition, Michigan had a lower conditional total release rate than Illinois. To have an assessment of the average impact of Michigan's policy transition over years, we also estimate equation (7).

$$\begin{aligned} P(R_{ikt}=1) = F(&\beta_0 + \alpha_i + \beta_1 * TN_{ikt} + \beta_2 * TO_{ikt} + \beta_3 * MI_k \\ &+ \beta_4 * Post_t * MI_k + \gamma * year\_dummy_t) \end{aligned} \tag{7}$$

where F is the cumulative probability of a logistically distributed random variable

In this equation, the coefficient on $Post_t * MI_k$ is the one of interest. The term $Post_t * MI_k$ is a state and year specific dummy variable, which is equal to 1 for facilities in Michigan after the policy transition and 0 otherwise. It in fact indicates whether private insurance is the major compliance mechanism with financial responsibility requirements in state *k* and year *t*. The coefficient of this variable assesses whether the transition to risk-based pricing mechanisms (or private insurance market) reduced facility release risk significantly, after controlling other variables. The changes in the total release rate in Michigan, relative to control states, are the variations to identify this impact.

Table 4 reports the estimation results from model (7), with and without controlling facility size and facility tank quality. The coefficient of $Post_t * MI_k$ is negative with a small standard error. As shown in row 1 and column 2 of the Table 4, after controlling for facility size and facility tank quality, it is estimated that the policy change had helped reduce the conditional total release rate by 1.14 percentage points. It accounts for 21.5% of Michigan's average conditional total release rate in the pre-transition period.[26]

B. Discussion on Risk Reduction Mechanism

A priori, we expect that pre-1989 installed tanks give rise to the most problems. This is confirmed by the estimated coefficient of TO_{ikt} in the regression analyses performed earlier (Table 4, row 2 column 2), which is positive (0.89) with a very small standard error (0.02). It is of interest to know whether the use of private insurance (risk-based pricing mechanisms) encourages tank owners/operators to take better care of their pre-1989 installed tanks. For example, they may upgrade these tanks with corrosion protection or make more efforts to maintain tank equipment and operate them appropriately. To look at this, we ran the following logit regression with random effects of facility.

$$P(R_{ikt}) = F(\beta_0 + \alpha_i + \beta_1 * TN_{ikt} + \beta_2 * MI_k + \gamma * year\_dummy_t + (\beta_3 + \beta_4 * MI_k + \beta_5 * Post_t + \beta_6 * Post_t * MI_k) * TO_{ikt}) \quad (8)$$

where *F* is the cumulative probability of a logistically distributed random variable

The coefficient of $Post_t * MI_k * TO_{ikt}$, β_6, captures whether Michigan's policy change helped reduce the facility release risk, given the number of active pre-1989 installed tanks. A negative coefficient suggests that after the policy change, a facility in Michigan is less likely to have a release than an Illinois facility with the same number of pre-1989 installed tanks. The marginal effects are evaluated at a typical facility with one pre-1989 installed tank. The results are shown in Table 5. It suggests that because of the policy change, Michigan facilities with one pre-1989 installed tank further reduced the total release rate by 0.22 percentage points. This observation suggests that tank owners/operators in Michigan have made more efforts to take care of their pre-1989 installed tanks after the policy change.

---

[26] Michigan's average conditional total release rate in the pre-transition period is estimated based on the estimates from regression model (7). For a typical facility (three tanks in total with one of them installed before 1989), the estimated Michigan's conditional total release rate in year 1990 is $\hat{\beta}_0 + \hat{\beta}_3$, and $\hat{\beta}_0 + \hat{\beta}_3 + \hat{\gamma}_{1991}$ for year 1991, where $\hat{\gamma}_{1991}$ is the estimated coefficient of the 1991 year dummy. Thus, Michigan's average conditional total release rate in the pre-transition period is estimated to be $\hat{\beta}_0 + \hat{\beta}_3 + [(\hat{\gamma}_{1991} + \hat{\gamma}_{1992} + \hat{\gamma}_{1993} + \hat{\gamma}_{1994})/4]$ = 0.053. The coefficients of the year dummies are not reported in Table 4 for the sake of conciseness.

C. Robustness Check

This section checks the robustness of the findings in previous sections — using Indiana instead of Illinois as a control state. As discussed in section IV, Indiana is not as good as Illinois to serve as a counterfactual for Michigan. With this caveat in mind, we redo all the analyses with Indiana as a control state. Similar findings are observed on the impacts of the policy change. Table 4 shows that because of the policy change, facilities with underground fuel tanks in Michigan further reduced their conditional total release rate by 0.84 percentage points, relative to Indiana. This accounts for 17% of Michigan's average conditional total release rate in the pre-transition period. Table 5 shows that compared to Indiana, Michigan facilities with one pre-1989 installed tank further reduced its total release rate by 0.72 percentage points after the policy change.

One should note that when Indiana is employed as a control state, the regression model (column 3, Table 4) and the aggregate data analysis (row 3, Table 3) suggest different assessments of the impacts of the policy change. The regression model suggests that the policy change reduced the unconditional total release rate by 1.11 percentage points, while the aggregate data analysis suggests 2.25 percentage points. The reason is that Indiana has a far more serious missing data problem than Michigan and Illinois, as discussed in the appendix. We developed a matching procedure to deal with the missing data problem. But the more information available, the more accurate the matching procedure is. The large missing data problem in Indiana has an impact on the matching procedure, and therefore on the estimates.

Despite the data problem, various analyses on the total release rate in Michigan and Indiana provide the same insights as when we compared Michigan and Illinois. That is, the policy change to risk-based pricing mechanisms effectively reduced the facility release risk. This is a confirmation of the previous findings. Meanwhile, we suggest that the analysis with Illinois as a control state is more likely to be an accurate evaluation of the impacts of the policy change.

VII. Alternative Explanations

There are competing explanations for the observation that Michigan had lower release rate after the policy change, compared to what would happen if it had not made this change. In this section, we discuss these alternative explanations, and argue that the policy change to risk-based pricing mechanisms is the most likely explanation.

A. Michigan Expected Less of a Tank Problem

One may argue that Michigan had made the policy change because it expected less of a problem with tank releases in 1995 and therefore believed the state assurance fund program was no longer needed. If this is the case, the smaller number of tank releases after the policy transition may not be attributable to the policy change to private insurance market which fully utilizes risk-based pricing mechanisms.

Documents advocating Michigan's policy change (Public Sector Consultants, Inc. 1995; EPA, 1997) suggest that the solvency problem is the major impetus for moving Michigan along the transition route. The report by Public Sector Consultants, Inc. (1995) concluded that "the current MUSTFA (Michigan Underground Storage Tank Financial Assurance) is already insolvent with an expected shortfall of $235.34 million to meet expected costs for existing claims." Expecting fewer tank releases is not mentioned as a reason for the transition in any of these documents. On the contrary, the report by Public Sector Consultants, Inc. predicted that more than 3000 additional claims for reimbursement were expected between March 1995 and December 1998. This represented a significant amount of financial and environmental liability. Avoiding this potential financial burden is clearly stated as one reason for transition. "This option would eliminate the need to appropriate dollars to subsidize new claims." (Public Sector Consultants, Inc. 1995)

B. Michigan Enforced Technical Standards

Well-enforced technical standards will help reduce tank releases. Therefore, one could argue that the reason that Michigan had a relatively lower release rate is because they are making more efforts to enforce technical standards, especially after 1995.

In 2000, the Government Accountability Office (GAO) did a survey of 50 state Underground Storage Tank programs. As summarized in Table 6, this survey showed that Michigan, Illinois and Indiana made similar efforts to enforce technical standards. They made similar progress in installing required equipment. The percentage of active tanks which installed required equipments reached the category of "91%-95%" in each of these three states. When it came to inspection, Illinois was doing a better job than Michigan. A tank gets inspected every two years in Illinois, but every three years in Michigan. Therefore, the observation that Michigan had a lower facility release rate than Illinois after the policy change cannot be explained by the argument that Michigan was doing a better job in enforcing technical standards.

The same survey also showed that Indiana made fewer efforts in inspecting tanks, at least in year 2000 (see the percentage of tanks that were inspected in year 2000). However, given Indiana's response of "a tank normally gets inspected every three years" in the same survey, the low percentage of tanks inspected in year 2000 may be explained by the possibility that inspection was not a priority of the Indiana Department of Environmental Management in 2000. In spite of this, we suggest that we need to be cautious when comparing Michigan and Indiana because the higher tank release rate in Indiana may be due to its laxer enforcement of technical standards.

IX. Policy Implications and Conclusions

This study shows that the policy transition to risk-based pricing mechanisms in Michigan helped reduce the facility release rate by about 1.14 percentage points, accounting for approximately 21% of Michigan's average conditional total release rate in the pre-transition period. Because of this transition, approximately 2,500 releases have been avoided from 1996 to 2003. To clean up these releases, Michigan would have had to pay nearly $240 million (in 2003 dollars). Those are the direct costs for cleanups and do not include administrative, legal and business interruption costs that may have been associated with cleanup activities. More importantly, the environmental harms those 2,500 tank releases may have caused has been avoided. The policy transition to risk-based pricing mechanisms has thus rewarded Michigan with significant financial and environmental benefits.

According to the latest State Financial Assurance Funds Survey (2004), state funds of eleven states have outstanding claims greater than current balance with a total of more than $1 billion deficits. What's more, the US EPA estimates that 12,000 new underground fuel tank releases occur each year in the United States.[27] Given these, this study suggests that it may be a

[27] US EPA Office of Underground Storage Tanks, *2006 Corrective Action Performance Measures Data.*

good policy choice to make the transition from state assurance fund programs to the private insurance market, or incorporate some sort of risk-based pricing mechanisms in state assurance fund programs. This can not only help with the financial problems plaguing many of the state tank assurance fund programs, but also encourage risk reduction behaviors on the part of tank owners/operators and help reduce the tank release risk.

Similar suggestions are appropriate for designing other government assurance programs such as deposit insurance and pension benefit guaranty programs. The fact that these programs are normally subsidized with general tax and exclude risk-based pricing mechanisms has led two adverse outcomes. First, moral hazard is a serious concern due to the absence of risk-based pricing mechanisms. With pension benefit guaranty funds, for example, unions and firms have an incentive to agree to lucrative retirement benefit packages knowing the government will bail the firm out if it cannot pay the pensions (Cooper and Ross, 1999). Similarly, given the presence of federal deposit insurance, financial intermediaries may decide to take extensive financial risks that they would not consider if they did not have a federal backstop (Kareken and Wallace, 1978; Wheelock and Wilson, 1995). Second, because the cost to participate in government assurance programs is usually much cheaper than buying private insurance, the existence of a government assurance program often eliminates the opportunity of using the private insurance market to promote risk reduction efforts.

This study suggests that risk-based pricing mechanisms can effectively mitigate moral hazard by promoting risk reduction efforts. When politically feasible, policy makers should consider the option of private insurance market. In this vein, Boyd and Kunreuther (1997) suggested that “prospective liability should be coupled with privately-demonstrated financial responsibility”. At least, government assurance programs should incorporate some risk-based pricing mechanisms to encourage risk reduction efforts. One policy change that has been discussed to address moral hazard problem associated with deposit insurance fund is to condition federal deposit insurance premiums paid by intermediaries on a measure of portfolio risk (Meltzer, 1967). According to this principle, the 1991 Federal Deposit Insurance Corporation Improvement Act (FDICIA) required the Federal Deposit Insurance Corporation (FDIC) to have in place an assessment system wherein each bank’s assessment would be reflective of the risks it posed to the insurance fund. The FDIC had backed such a change and implemented a risk-based premium system on January 1, 1993, a year ahead of schedule.

Several other interesting questions have been left unexplored in this paper and should be investigated in future research. First, it is of interest to look at how small businesses responded to Michigan's policy change. One concern with the private insurance market is that the risk-based pricing mechanisms will drive small businesses out of the market, especially those in remote and rural areas, because small businesses have financial difficulties in keeping their tanks up-to-date, or paying an unsubsidized insurance premium. Second, this paper focused on the ex ante moral hazard problem, that is, whether a tank owner/operator takes extra risk reduction efforts in response to risk-based pricing mechanisms. There is also an ex post moral hazard problem, that is, whether a tank owner/operator has an incentive to exaggerate the losses under tank state fund programs. Finally, public and private partnerships have been utilized in insuring against tank release risk in other states. For example, Washington implemented a state-financed reinsurance program in which the state sells reinsurance to the underground fuel tank insurers at prices well below the private market price for similar reinsurance. The insurers are required to pass this discount to the tank owners/operators (EPA, 1997). It would be interesting to investigate whether Washington state fund program represents a better model balancing the need to promote risk reduction efforts and the interests of small businesses.

REFERENCES

Akerlof, G. A. and P. M. Romer. (1993). Looting: The Economic Underworld of Bankruptcy for Profit. *Brookings Papers on Economic Activity,* Vol. 1993, No. 2., pp. 1-73.

ASTDR (2005). *Toxicological Profile for Benzene.* Agency for Toxic Substances and Disease Registry. Atlanta, GA: U.S. Public Health Service.

Boyd, J. and H. C. Kunreuther (1997). Retroactive Liability or the Public Purse? *Journal of Regulatory Economics*, 11: 79-90.

Cooper, R. and T. W. Ross (1998). Bank Runs: Liquidity Costs and Investment Distortions, *Journal of Monetary Economics*, 41(1): 27-38.

Cooper, R. and T. W. Ross (1999). Public and Private Guarantee Funds with Market Fragility. *The Journal of Risk and Insurance*, 66(2):163-184.

Cowans, D. S. (1995). State Assurance Funds Faltering: Recent Developments Cast Doubt on Reliability of State Funds. *Business Insurance*, 29 (40): 3-4.

Freeman, P. K. and H. C. Kunreuther (1997). *Managing Environmental Risk through Insurance*. Boston: Kluwer Academic Publishers.

Government Accountability Office. (1987). Availability of Insurance for Petroleum Underground Storage Tank.

Government Accountability Office. (1988). *Superfund: Insuring Underground Petroleum Tanks*.

Hopkins, S. and M. Kidd (1996). The Determinants of the Demand for Private Health Insurance Under Medicare. *Applied Economics*, 28: 1623-1632.

Kareken, J. and N. Wallace (1978). Deposit Insurance and Bank Regulation: A Partial-Equilibrium Exposition. *The Journal of Business*, 51(3): 413-438.

Kunreuther, H., A. Pfaff, and H. Yin (2007). Can Environmental Insurance Succeed Where Others Fail? Conceptual Framework and the Case of Underground Storage Tanks. *The Wharton Risk Management and Decision Processes Center Working Paper # 2007-10-16*.

Meltzer, Allan H. (1967). Major Issues in the Regulation of Financial Institutions. *The Journal of Political Economy*, 75 (4): 482-501.

National Petroleum News (1998). AIG Environmental offers reductions for Tanknology customers. *National Petroleum News*, 90(12): 9.

Public Sector Consultants, Inc. (1995). *An Analysis of the Michigan Underground Storage Tank Financial Assurance Program: Assessment of Solvency, Opportunities for Cost Containment, and Future Options.*

Sapelli, C. and A. Torche (2001). The Mandatory Health Insurance System in Chile: Explaining the Choice between Public and Private Insurance. *International Journal of Health Care Finance and Economics*, 1(2): 97- 110.

U.S. Environmental Protection Agency (1995). Musts for USTs. *EPA 510-K-95-002.*

U.S. Environmental Protection Agency (1997). State Funds in Transition: Models for Underground Storage Tank Assurance Funds. *EPA 510-B-97-002.*

Wheelock, D. and P. W. Wilson (1995). Explaining Bank Failures: Deposit Insurance, Regulation, and Efficiency. *The Review of Economics and Statistics*, 77 (4), 689-700.

Appendix: Missing Data Problem

A challenge in determining the release rates from equations (1) – (5) is that we do not observe the status (*active* vs. *inactive*, POP_{it} vs. *non* POP_{it}) of a large number of facilities because of missing data. This appendix explains why missing data is a challenge to this study, and discusses how we meet this challenge by developing a matching procedure.

1. The Missing Data Problem

Equations (1)-(5) reveal that to estimate the active release rate, the adjusted active release rate and the total release rate, we need to know 1) the $Number\ of\ Active\ Facilities\ with\ Release\ in\ Year\ t$; 2) the $Number\ of\ Active\ Facilities\ in\ Year\ t$; 3) the $Number\ of\ POP_{it}\ Facilities\ with\ Release\ in\ Year\ t$; and 4) the $Number\ of\ POP_{it}\ Facilities\ in\ Year\ t$.

However, we cannot directly observe these numbers in the data. For a large number of facilities, we are not sure if they are active (or POP_{it}) in a particular year because of the missing data problem as detailed below. To address this problem, if a facility's status (*active* vs. *inactive*, POP_{it} vs. *non* POP_{it}) cannot be directly observed in year *t*, we estimate the probability that this facility is in each status. The estimated probability is used in place of this facility's true status when computing the total count values entering the right-hand sides of equations (1) through (5).

Let $P(Active_{it})$ denote the probability that facility *i* was active in year *t* and $P\ (POP_{it})$ denote the probability that facility *i* had ever been in service between 1986 and year *t*. A facility is defined as active in year *t* if at least one tank at the facility is in service in year *t*, and a facility is included in POP_{it} if at least one tank at the facility had ever been in service between 1986 and year *t*. we index tank by subscript j and define the probability that a facility is *active* (POP_{it}) in year *t* as the maximum probability that any tank at the facility is *active* (POP_{jt}) in year *t*. That is $P(Active_{it}) = \max_{j\in facility\ i}\{P(Active_{jt})\}$ and $P\ (POP_{it}) = \max_{j\in facility\ i}\{P(POP_{jt})\}$. This definition presumes that tank status positively covaries across tanks within a given facility. Now the problem of estimating facility status, $P(Active_{it})$ and $P\ (POP_{it})$, boils down to examining tank status $P(Active_{jt})$ and $P\ (POP_{jt})$.

We do not observe $P(Active_{jt})$ and $P\ (POP_{jt})$ for a large number of underground tanks because we do not know the installation year, the out-of-service year or both for those tanks. Table A1 reveals the data problem of missing installation and/or out-of-service year in Michigan, Illinois and Indiana. For example, the fourth cell in the last second row indicates that in Illinois for 3.95% of all the tanks, both the installation date and the out-of-service date are missing although it is observed that they were closed before 2004. This number is almost zero in Michigan while 28.90% in Indiana. This suggests that Indiana has a more serious missing data problem.

2. Addressing the Missing Data Problem – A Matching Procedure

We develop a simple matching procedure to address the missing data problem. The idea is to match the tanks with missing information with the tanks with complete information based on the observed dimensions. We then estimate the status of the tanks with missing information with the status of the tanks with complete information.

Here we illustrate how to estimate $P(Active_{jt})$. $P(POP_{jt})$ can be estimated in the same fashion. We decompose $P(Active_{jt})$ as follows:

$$P(Active_{jt}) = P(Active_{jt} \mid Active\ in\ 2004)\, P(Active\ in\ 2004) \\ + P(Active_{jt} \mid Inactive\ in\ 2004)\, P(Inactive\ in\ 2004)$$

Terms $P(Active\ in\ 2004)$ and $P(Inactive\ in\ 2004)$ can be observed directly. However, as indicated above, for many tanks, both $P(Active_{jt} \mid Active\ in\ 2004)$ and $P(Active_{jt} \mid Inactive\ in\ 2004)$ can not be observed from the data directly because we do not observe their installation and/or out-of-service year. Again, Table A1 reveals the data problem of missing installation and/or out-of-service year in Michigan, Illinois and Indiana, for tanks active in 2004 and taken out of service before 2004 separately. Below we illustrate how to estimate $P(Active_{jt} \mid Inactive\ in\ 2004)$. The term of $P(Active_{jt} \mid Active\ in\ 2004)$ can be estimated in the same fashion. Let $Y_j^{Installation}$ denote the year tank *j* was installed and $Y_j^{Out\_of\_Service}$ the year tank *j* was taken out of service.

$$\begin{aligned}
& P(Active_{jt} \mid Inactive\ in\ 2004) \\
&= P(Active_{jt} \mid Inactive\ in\ 2004,\ Y_j^{Installation} observed,\ Y_j^{Out_of_Service} observed) \\
&* P(Y_j^{Installation} observed\ \&\ Y_j^{Out_of_Service} observed \mid Inactive\ in\ 2004) \\
&+ P(Active_{jt} \mid Inactive\ in\ 2004,\ Y_j^{Installation} observed,\ Y_j^{Out_of_Service} unobserved) \\
&* P(Y_j^{Installation} observed\ \&\ Y_j^{Out_of_Service} unobserved \mid Inactive\ in\ 2004) \\
&+ P(Active_{jt} \mid Inactive\ in\ 2004,\ Y_j^{Installation} unobserved,\ Y_j^{Out_of_Service} observed) \\
&* P(Y_j^{Installation} unobserved\ \&\ Y_j^{Out_of_Service} observed \mid Inactive\ in\ 2004) \\
&+ P(Active_{jt} \mid Inactive\ in\ 2004,\ Y_j^{Installation} unobserved,\ Y_j^{Out_of_Service} unobserved) \\
&* P(Y_j^{Installation} unobserved\ \&\ Y_j^{Out_of_Service} unobserved \mid Inactive\ in\ 2004)
\end{aligned}$$

Terms like $P(Y_j^{Installation} observed \ \& \ Y_j^{Out\_of\_Service} observed \ | \ Inactive \ in \ 2004)$ can be estimated from Table A1. However, terms like $P(Active_{jt} \ | \ Inactive \ in \ 2004, \ Y_j^{Installation} observed, \ Y_j^{Out\_of\_Service} observed)$ should be investigated case by case.

Case 1: Inactive in 2004; both $Y_j^{Installation}$ and $Y_j^{Out\_of\_Service}$ are observed

$$
\begin{aligned}
& P(Active_{jt} \ | \ Inactive \ in \ 2004, \ Y_j^{Installation} observed, \ Y_j^{Out\_of\_Service} observed) \\
&= P(Y_j^{Installation} \leq t \leq Y_j^{Out\_of\_Service} \ | \ Inactive \ in \ 2004, \ Y_j^{Installation} observed, \ Y_j^{Out\_of\_Service} observed) \\
&= \begin{cases} 1 & if \quad Y_j^{Installation} \leq t \leq Y_j^{Out\_of\_Service} \\ 0 & Otherwise \end{cases}
\end{aligned}
$$

Case 2: Inactive in 2004; $Y_j^{Installation}$ observed and $Y_j^{Out\_of\_Service}$ unobserved

$$
\begin{aligned}
& P(Active_{jt} \ | \ Inactive\_in\_2004, \ Y_j^{Installation} observed, \ Y_j^{Out\_of\_Service} unobserved) \\
&= P(Y_j^{Installation} \leq t \leq Y_j^{Out\_of\_Service} \ | \ Inactive \ in \ 2004, \ Y_j^{Installation} observed, \ Y_j^{Out\_of\_Service} unobserved) \\
&= \begin{cases} \sum_{Y_j^{Installation} \leq t} \begin{array}{l} P(t \leq Y_j^{Out\_of\_Service} \ | \ Y_j^{Installation} = s, \ Inactive \ in \ 2004, \ Y_j^{Out\_of\_Service} unobserved) * \\ P(Y_j^{Installation} = s \ | \ Inactive \ in \ 2004, \ Y_j^{Installation} observed, \ Y_j^{Out\_of\_Service} unobserved) \end{array} \\ 0 \quad if \quad Y_j^{Installation} > t \end{cases}
\end{aligned}
$$

where *s* indexes years.

Term $P(Y_j^{Installation} = s \ | \ Inactive \ in \ 2004, \ Y_j^{Installation} observed, \ Y_j^{Out\_of\_Service} unobserved)$ is observed. However, $P(t \leq Y_j^{Out\_of\_Service} \ | \ Y_j^{Installation} = s, Inactive \ in \ 2004, \ Y_j^{Out\_of\_Service} unobserved)$ cannot be obtained from the data directly because the out-of-service year is missing. In this paper, we will estimate this probability by making a "conditional independence assumption". That is,

$$
\begin{aligned}
& P(Active_{jt} \ | \ Y_j^{Installation} = s, \ Inactive \ in \ 2004, \ Y_j^{Out\_of\_Service} unobserved) \\
&= P(t \leq Y_j^{Out\_of\_Service} \ | \ Y_j^{Installation} = s, \ Y_j^{Out\_of\_Service} < 2004, \ Y_j^{Out\_of\_Service} unobserved) \\
&= P(t \leq Y_j^{Out\_of\_Service} \ | \ Y_j^{Installation} = s, \ Y_j^{Out\_of\_Service} < 2004, \ Y_j^{Out\_of\_Service} observed) \\
&= P(Active_{jt} \ | \ Y_j^{Installation} = s, \ Inactive \ in \ 2004, \ Y_j^{Out\_of\_Service} observed)
\end{aligned}
$$

The conditional independence assumption means that for all the tanks installed in year *s* and closed before 2004 in a given state, the probability distribution of the out-of-service year (between year *t* and

2003) does not differ with respect to whether the out-of-service year is recorded in the data or not. Similarly,

Case 3: Inactive in 2004; $Y_j^{Installation}$ unobserved and $Y_j^{Out\_of\_Service}$ observed

$$
\begin{aligned}
& P(Active_{jt} \mid Inactive\ in\ 2004,\ Y_j^{Installation} unobserved,\ Y_j^{Out\_of\_Service} observed) \\
&= P(Y_j^{Installation} \le t \le Y_j^{Out\_of\_Service} \mid Inactive\ in\ 2004,\ Y_j^{Installation} unobserved,\ Y_j^{Out\_of\_Service} observed) \\
&= \begin{cases} \sum_{Y_j^{Out\_of\_Service} \ge t} \begin{array}{l} P(Y_j^{Installation} \le t \mid Y_j^{Out\_of\_Service} = s,\ Inactive\ in\ 2004,\ Y_j^{Installation} unobserved) * \\ P(Y_j^{Out\_of\_Service} = s \mid Inactive\ in\ 2004,\ Y_j^{Installation} unobserved,\ Y_j^{Out\_of\_Service} observed) \end{array} \\ 0 \quad if \quad Y_j^{Out\_of\_Service} < t \end{cases} \\
&= \begin{cases} \sum_{Y_j^{Out\_of\_Service} \ge t} \begin{array}{l} P(Active_{jt} \mid Y_j^{Out\_of\_Service} = s,\ Inactive\ in\ 2004,\ Y_j^{Installation} observed) * \\ P(Y_j^{Out\_of\_Service} = s \mid Inactive\ in\ 2004,\ Y_j^{Installation} unobserved,\ Y_j^{Out\_of\_Service} observed) \end{array} \\ 0 \quad if \quad Y_j^{Out\_of\_Service} < t \end{cases}
\end{aligned}
$$

Case 4: Inactive in 2004; $Y_j^{Installation}$ unobserved and $Y_j^{Out\_of\_Service}$ unobserved

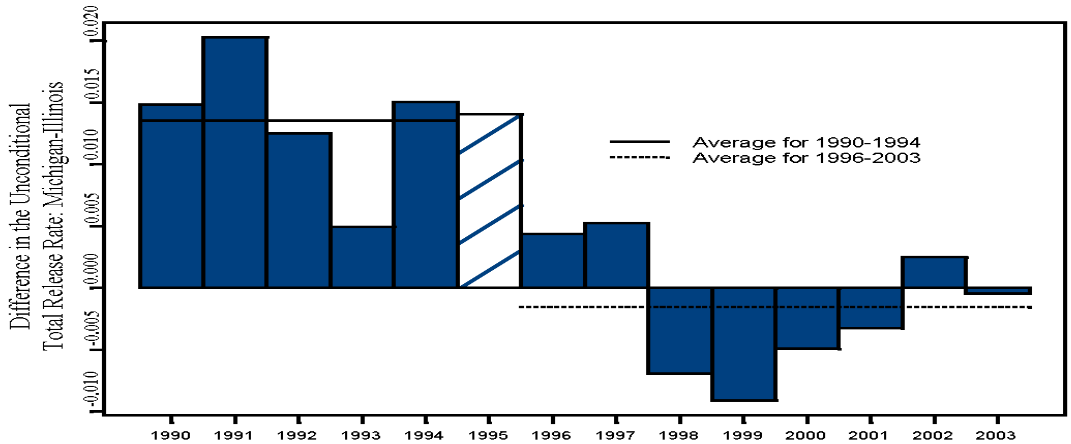
$$
\begin{aligned}
& P(Active_{jt} \mid Inactive\ in\ 2004, Y_j^{Installation} unobserved\ \&\ Y_j^{Out\_of\_Service} unobserved) \\
&= P(Y_j^{Installation} \le t \le Y_j^{Out\_of\_Service} \mid Inactive\ in\ 2004, Y_j^{Installation} unobserved\ \&\ Y_j^{Out\_of\_Service} unobserved) \\
&= P(Y_j^{Installation} \le t \le Y_j^{Out\_of\_Service} \mid Inactive\ in\ 2004, Y_j^{Installation} observed\ \&\ Y_j^{Out\_of\_Service} observed) \\
&= P(Active_{jt} \mid Inactive\ in\ 2004,\ Y_j^{Installation} observed\ \&\ Y_j^{Out\_of\_Service} observed)
\end{aligned}
$$

3. Conditional Independence Assumption

As indicated earlier, the proposed matching procedure hinges on the assumption of conditional independence. Is this a reasonable assumption? My interview with Jan Spoor, the database manager at the Illinois office of the State Fire Marshall indicated that the major reason for missing information is that the office is understaffed and the missed information is not viewed essential (May 19, 2005). Another reason is that when the tank owners/operators did not report or reported obviously wrong information (e.g., installation year is 2040), the office codes it as missing. Given these comments, the conditional independence assumption seems plausible.

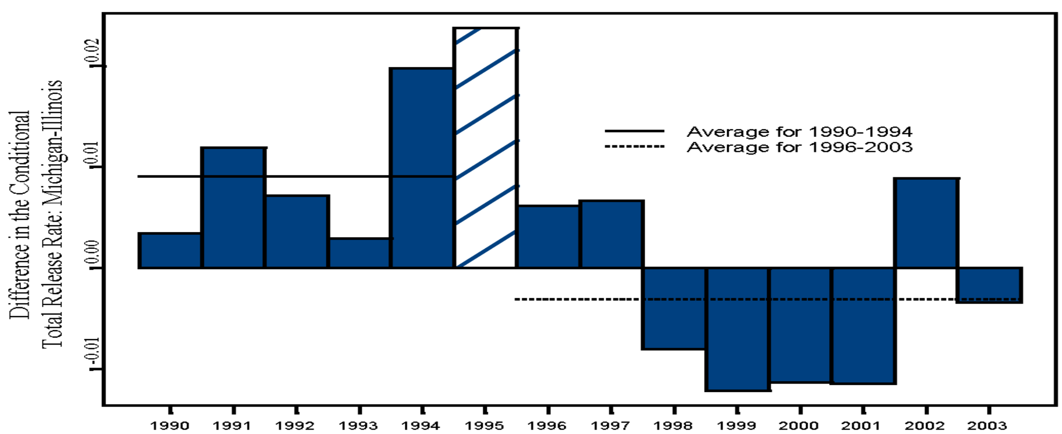
As a further verification of the conditional independence assumption, we compare all the observable dimensions between tanks closed before 2004 with observed installation year but unobserved out-of-service year and tanks closed before 2004 with observed installation year and observed out-of-service year. Table A2 shows that the distribution of installation year is roughly the same between these two groups of tanks. It also reveals that conditional on installation period, the average capacity of tanks with an observed out-of-service year is different from tanks with an unobserved out-of-service year. The difference in average capacity is less than 1000 gallons. An ANOVA analysis suggests the difference is significant except for the category of “installed between 1960 and 1969”. However, this does not invalidate our matching procedure. An analysis on the tanks with complete information suggests that given the tank installation year (and that the tank is taken out of service before 2004), an extra 1000 gallons capacity is expected to extend a tank’s out-of-service date by 0.15 year. Since the difference in the average tank capacity is less than a thousand gallons between the two groups, and we use an annual time unit in our analysis, the available evidence suggests that the conditional independence assumption is plausible and the proposed matching strategy is a reasonable procedure.

Figure 1: Difference in the Unconditional Total Release Rate: Michigan-Illinois



Note: Figure shows the difference in the unconditional total release rate between Michigan and Illinois.

Figure 2: Difference in the Conditional Total Release Rate: Michigan-Illinois



Note: Figure shows the difference in the conditional total release rate between Michigan and Illinois.

Table 1: Private Insurance Rate Factors and Premia
For Underground Fuel Tank Accidental Release Coverage

Base Insurance Premium by Tank Age and Type, per Tank per Annum

Age	0-5	6-10	11-15	16-20	21-25	26-30	31-35	>35
Single Wall	$284-$339	$350-$470	$500-$700	$760-$1030	$1100-$1380	$1450-$1690	$1750	$1850
Double Wall	$185-$221	$228-$302	$320-$356	$365-$426	$441-$509	$441-$509	$526-$582	$620

Impact of Preventive and Detective Measures on Private Insurance Premiums

	Yes	No	Unknown
Advanced Leak Detection	0%	+10%	+10%
Overfill Detection	0%	+10%	+10%
Additional Corrosion Protection	0%	+10%	+10%

Impacts of Prior Releases on Private Insurance Premiums:

	Yes, Claim Closed	Yes, Claim Open	No
Location Prior Release	10%	20%	0%

Notes: Table shows insurance premia from Zurich N.A. for environmental liability and tank pollution insurance for $1 million coverage at $5,000 deductible. This is a partial list of all rate factors used by one major insurer. Data from 2004. *Sources:* Zurich N.A. and the Michigan Office of Financial and Insurance Services.

Table 2: Variation in Private Insurance Premia
For Underground Fuel Tank Accidental Release Coverage (1997)

Underground Tank System Attributes (3 tanks per site)	**Premium** Insurer A	Insurer B	Insurer C
Fiberglass reinforced tank (new); double wall piping; suction pump system; automated monitor & inventory	$1,350 ($5,000 deductible)	$825 ($5,000 deductible)	$1,320 ($10,000 deductible)
Coated (STI-P3) steel tank (installed 1991) with cathodic anti-corrosion protection; single wall piping and suction pumps; automated monitor & inventory	$1,500 ($5,000 deductible)	$1,250 ($5,000 deductible)	$1,320 ($10,000 deductible)
Single wall steel tank (installed 1985); cathodic protection; single wall piping; pressurized system; statistical inventory reconciliation; no overfill or spill prevention	$3,500 ($10,000 deductible)	$1,500 ($5,000 deductible)	$2,563 ($10,000 deductible)
Single wall steel tank (installed 1975); no cathodic protection; single wall piping; pressurized system; stat. inventory reconciliation; no overfill or spill prevention	Decline Coverage	$3,800 ($5,000 deductible)	$5,610 ($10,000 deductible)

Source: EPA, 1997.

Table 3: Difference in Changes in the Unconditional Total Release Rate Between Michigan, Illinois and Indiana

		Pre-transition (1990-1994)	Post-transition (1996-2003)	Difference	Difference-in-Difference	Percentage Decrease
Total Release Rate (%)	Michigan	6.74	2.59	-4.16		
		(0.0036)	(0.0028)	(0.0046)		
	Illinois	5.37	2.74	-2.63	-1.53	23%
		(0.0038)	(0.0029)	(0.0047)	(0.0066)	
	Indiana	3.78	1.88	-1.90	-2.25	33%
		(0.0039)	(0.0029)	(0.0049)	(0.0062)	

Note: Table shows the average facility release rates (and their standard errors) in Michigan, Illinois and Indiana.

Table 4: Effect of Policy Change on the Probability that A Facility Has an Accidental Release

	Illinois as Control State (1)	Illinois as Control State (2)	Indiana as Control State (3)	Indiana as Control State (4)
MI*Post	**-1.57**	**-1.14**	**-1.11**	**-0.84**
	(0.12)	(0.10)	(0.10)	(0.06)
Number of Active Pre-1989 installed tanks		0.89		0.71
		(0.02)		(0.02)
Number of Tanks		-0.003		-0.10
		(0.01)		(0.01)
State Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Excluding 1995	Yes	Yes	Yes	Yes
Observations	673758	673758	582571	582571
Number of Facilities	53374	53374	45945	45945

Note: Table shows random effects logit estimates (and standard errors) of the marginal effect of policy change on the probability that a facility has an accidental tank release, evaluating at a typical facility that has three tanks in total with one of them installed before 1989. Estimates are presented in percentage points.

Table 5: Effect of Policy Change on the Probability that A Facility Has an Accidental Release

(Given the Number of Active Pre-1989 Installed Tanks)

	Illinois as Control State (1)	Indiana as Control State (2)
MI*Post* TO_{ikt}	**-0.22**	**-0.72**
	(0.05)	(0.04)
MI* TO_{ikt}	0.57	0.06
	(0.04)	(0.02)
Post* TO_{ikt}	0.48	0.93
	(0.05)	(0.04)
Number of Active Pre-1989 installed tanks	0.52	0.70
	(0.03)	(0.02)
Number of Tanks	0.006	-0.13
	(0.015)	(0.01)
State Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Excluding 1995	Yes	Yes
Observations	676288	582571
Number of Facilities	53576	45945

Note: Table shows random effects logit estimates (and standard errors) of marginal effect of the policy change on the probability that a facility has an accidental tank release, given the number of active pre-1989 installed tanks. The marginal effects are evaluated at a typical facility that has three tanks in total with one of them installed before 1989. TO_{ikt} is the number of active pre-1989 installed tanks. Estimates are presented in percentage points.

Table 6: Regulatory Enforcement in Michigan, Illinois and Indiana

	Michigan	Illinois	Indiana
Percentage of active tanks which installed required equipment	91%-95%	91%-95%	91%-95%
Percentage of active tanks which properly operated and maintained required equipment	71%-80%	81%-90%	Not Available
Number of full-time employees that were used to conduct field Underground Tank inspections (Oct. 1, 1999 through Sept. 30, 2000)	21	17 (state) + 6 (local)	6
Frequency of state Underground Tank inspections	Every 3 years	Every 2 years	Every 3 years
Percentage of Underground Tanks that were inspected (Oct. 1, 1999 through Sept. 30, 2000)	31%-40%	31%-40%	11%-20%

Source: GAO's survey of 50 state Underground Storage Tank programs (2000)

Table A1: Summary of Missing Installation and Closure Date Data

	Michigan		Illinois		Indiana	
	# Tanks	% Tanks	# Tanks	% Tanks	# Tanks	% Tanks
Tanks Active in 2004	24,002	26.67	23,742	26.67	16,537	29.50
Known Installation Date	22,582	25.09	22,554	25.34	10,728	19.14
Missing Installation Date	989	1.10	1,188	1.33	5,809	10.36
Tanks Closed before 2004	66,006	73.33	65,272	73.33	39,518	70.50
Known Installation and Closure Date	53,485	59.42	33,312	37.42	8,762	15.63
Known Installation, Missing Closure Date	32	0.04	18,023	20.25	398	0.71
Missing Installation, Known Closure Date	11,404	12.67	10,425	11.71	14,158	25.26
Missing Installation and Closure Date	2	0.00	3,512	3.95	16,200	28.90
Total Observations	90,008	100.00	89,014	100	56,055	100

Table A2: Attributes of Closed Tanks by Installation Year

Installation Year	Tanks Inactive in 2004, with Observed Installation Year, and with Observed Out-of-Service Year				Tanks Inactive in 2004, with Observed Installation Year and with Missing Out-of-Service Year			
	No. Tanks	% of Tanks	Mean Tank Capacity	SD Tank Capacity	No. Tanks	% of Tanks	Mean Tank Capacity	SD Tank Capacity
Before 1959	2,106	6.32	4568.31	5041.33	824	4.57	5536.45	5578.68
1960-1969	5,229	15.70	4261.15	4358.98	2,327	12.91	4460.89	4448.99
1970-1979	11,083	33.27	4656.97	3986.31	5,768	32.00	4294.82	4005.74
1980-1989	11,390	34.19	4745.14	4326.20	6,813	37.80	4257.11	4263.71
1990-2004	3,504	10.52	4727.94	4577.28	2,291	12.71	3860.05	4056.34
Total	33,312	100.00	4627.65	4300.11	18,023	100.00	4300.28	4258.57