ENVIRONMENT

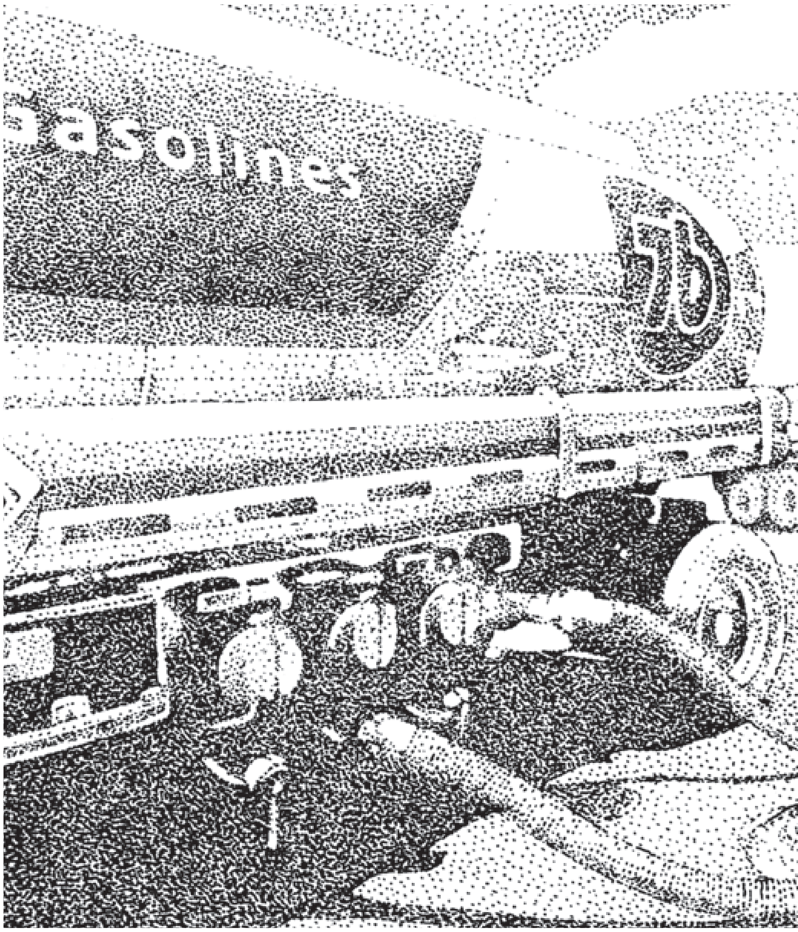
Does Private Insurance Reduce Environmental Accidents?

Gas station underground tank leaks decreased when states switched from state-managed assurance programs to mandatory private insurance.

By HAITAO YIN, HOWARD KUNREUTHER, and MATTHEW W. WHITE

Many of the risks faced by firms and individuals are spread across the economy through government assurance programs. Prominent examples include bank deposit insurance, pension benefit guarantee funds, and hazardous material cleanup funds. A salient feature of these government assurance programs is the absence of risk-based pricing: they do not charge insured individuals a premium commensurate with the specific risk that each one poses. As a result, the programs protect beneficiaries from adverse events at a subsidized price. The absence of an actuarially-based pricing structure may exacerbate moral hazard, raising the frequency of adverse events by lessening incentives for risk-reducing efforts.

An example of this can be found in government-managed assurance programs for gas station fuel leaks. In the late 1980s, new federal regulations required gas stations and owners of underground fuel tanks to demonstrate they are financially capable of cleaning up underground fuel leaks and compensating third parties for consequential damages. Michigan, Illinois, and Indiana soon created state assurance programs to subsidize firms'



Haitao Yin is an associate professor in the Antai College of Economics and Management at Shanghai Jiao Tong University (China).

Howard Kunreuther is the James G. Dinan Professor of Decision Sciences and Public Policy in the Wharton School at the University of Pennsylvania.

Matthew W. White is the senior economist for ISO New England Inc.

This article is based on the authors' paper "Risk-Based Pricing and Risk-Reducing Effort: Does the Private Insurance Market Reduce Environmental Accidents?" *Journal of Law and Economics*, Vol. 54, No. 2 (2011).

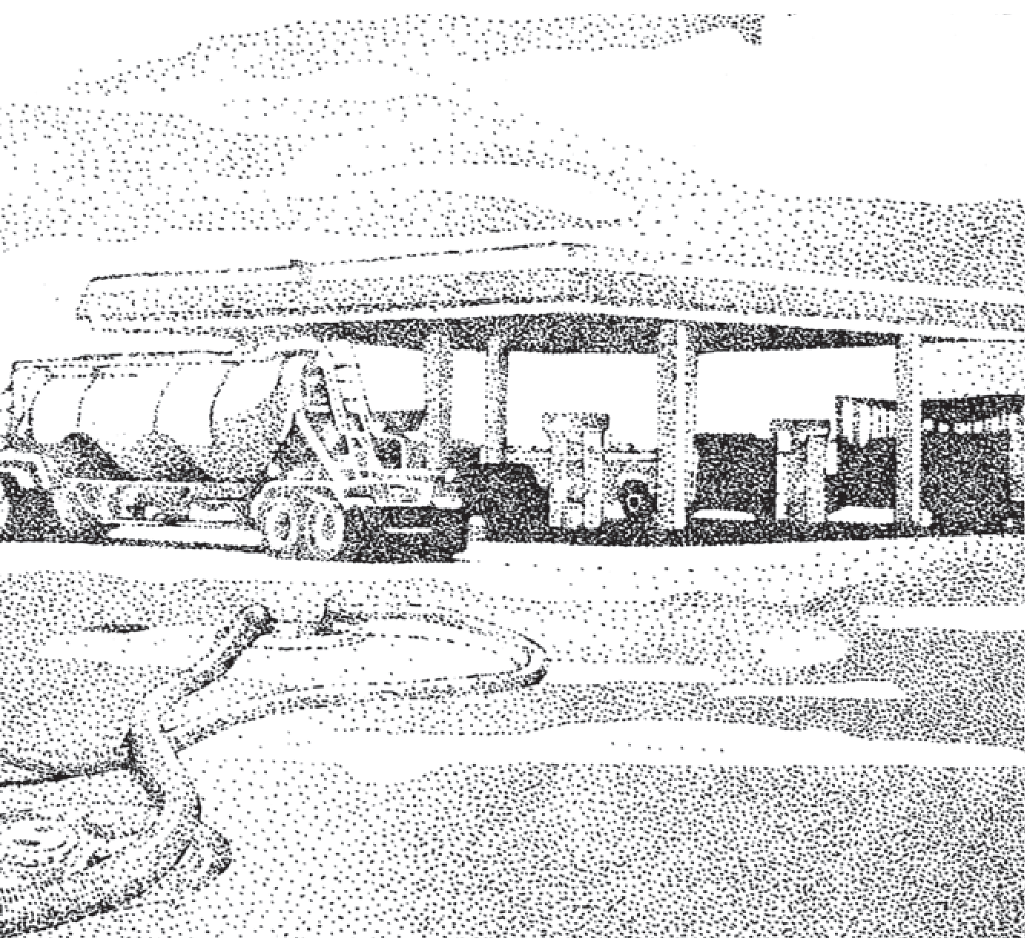
costs of complying with the new federal regulations. Although the risk of an underground fuel tank leak varies greatly with a tank owner's operating and investment decisions, the price to participate in these state cleanup assurance funds did not vary with the individual station's risk. Consequently, station owners could have costly tank leaks and their consequential damages covered at state expense, while facing little program-related incentives to take care to prevent such leaks.

By the mid-1990s, Michigan's and Illinois' assurance funds became insolvent. However, they took different approaches to their insolvency crises. While Illinois raised its gasoline excise tax to restore its program's solvency, the Michigan legislature terminated its state assurance program. Tank owners in Michigan subsequently had to purchase 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 economic incentives to invest in equipment that reduces the chance of accidental fuel tank leaks.

After Michigan's policy change, the number of underground fuel tanks with accidental releases dropped by more than 20 percent, relative to surrounding states that maintained state assurance fund programs. This reduction corresponds to more than 3,000 avoided fuel tank releases in Michigan over the following eight years. At an average cleanup cost of $125,000 per release, this represents an aggregate cleanup cost savings for that state on the order of $400 million.

These findings have a practical policy implication. The U.S. Environmental Protection Agency estimates that 6,300 new underground fuel tank releases occur each year in the United States. For the more than 30 states that presently operate state assurance fund programs, risk-based pricing mechanisms similar to private insurance markets may reduce the costly burden of future accidents and alleviate ongoing solvency crises.

ILLUSTRATION BY MORGAN BALLARD



Gasoline Storage Technology

Most underground fuel tanks are located at retail gasoline stations. A small gas station typically has two tanks; a large station may have five or six. The most common and serious cause of accidental underground fuel leaks is long-term corrosion (oxidation) of the tank or pipes, catalyzed by groundwater in the surrounding soil.

Prior to 1990, nearly 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, a non-corroding material such as fiberglass. Installing a double-walled tank further reduces the corrosion risk to negligible levels. A tank system owner also can keep a steel tank and invest in corrosion-attenuating equipment that will reduce the likelihood of underground tank leaks. Several anti-corrosion technologies are available, with more effective systems carrying higher installation and ongoing maintenance costs.

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

Gasoline Tank Regulation

In response to mounting scientific evidence and public concern over adverse health consequences of leaking underground fuel tanks, in 1984 Congress directed the EPA to regulate public and private underground fuel storage tanks. The agency's regulations, issued in 1988, had three 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.

The EPA's financial responsibility requirements require tank system owners either to 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 participate in a state-administered underground storage tank financial assurance program providing comparable coverage. Other mechanisms for complying with the financial responsibility requirement, such as self-insurance, surety bonds, or letters of credit, are permitted but uncommon. State and federal regulators believe that compliance with financial responsibility requirements is (essentially) universal.

Although changes in tank-system technical standards are not the focus of our analysis, they affect the data interpretation. The EPA's compliance deadlines for technical standards for new underground fuel tanks differed from those of existing ("grandfathered") underground fuel tanks. Any new tank installed after 1988 was required to have one or more leak detection systems and 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 10 years (by December 1998). 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 standards is that, even in the absence of any state-level policy variation, we would expect the frequency of underground tank leaks to decrease over time as older, substandard tanks are closed or upgraded to meet the 1998 deadline.

The 1988 federal regulations stipulate prompt reporting to federal and/or state regulatory agencies of underground storage tank leaks in any detectable quantity, and specify required corrective actions in detail. Importantly for our purposes, the penalty for failing to report a suspected underground tank leak is extraordinarily high, at $11,000 per tank per day.

State Government Assurance Funds

The federal financial responsibility requirements generated political resistance from gasoline retailers and small-business advocates. They argued that many stations would not survive the requirement because private tank insurance was not widely available in the 1980s and the available coverage was expensive. In response to these political pressures, many state legislatures created financial assurance funds for underground fuel tank leaks. In the event of a tank leak, the state assurance fund would pay for the cost of cleanup and third-party consequential damages.

Two features of these programs are important. First, most states' assurance funds are financed by an incremental excise tax on motor fuel. The nominal registration fee that a tank owner pays to participate in a state assurance fund is a small fraction of the actuarially fair price of underground fuel leak cleanup and liability insurance. As a consequence, in states with assurance fund programs, the participation rate is effectively 100 percent.

Second, the fee that tank owners pay to qualify for state fund benefits is the same for everyone. It does not vary with respect to the age of the tank being insured, its capacity, prior leak history, groundwater proximity, whether or not the tank system has been retrofitted with advanced corrosion protection equipment, whether or not it is single- or double-walled to contain a leak, or with any other factors that directly affect the chance of a leak and the cost of remediating it. Consequently, the structure of state fund programs provides little incentive for an owner to invest in or maintain leak prevention equipment beyond the minimum necessary to meet federal technical requirements.

State Policy Variation and Market Insurance

Michigan, Illinois, and Indiana established substantively identical state assurance fund programs in 1988 or 1989. 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-1990s.

In response, Illinois raised its (wholesale) motor fuels tax by 0.8 cents per gallon and continued to operate its state assurance fund. Facing public opposition to further gasoline taxes, in 1994 the Michigan legislature elected to close its state assurance fund program to new claims. All tank owners operating in Michigan needed to obtain private-market insurance starting July 1, 1995.

In contrast to state assurance fund programs, commercial insurance policies are explicitly structured to encourage risk reduction efforts. For example, insurance premiums reward owners for replacing tanks constructed of corrosive-prone material (bare steel) and aging tanks generally. The primary factors determining commercial tank insurance premiums are the age of the tank system, tank and piping material and coatings, construction (single- or double-walled), contents, capacity, and the history of prior leaks at the facility.

Some evidence on the magnitudes involved is summarized in Tables 1 and 2. Table 1 lists several rate factors for one major commercial environmental liability insurer (Zurich Company, N.A.). Annual premiums vary with tank construction and age by a multiple of 10, from $185 for a new double-walled tank to $1,850 for a single-walled tank more than 35 years old. The commercial insurance premium structure makes it cost-effective for facility owners to replace aging tanks sooner than they would have with public insurance through the state assurance fund.

Similarly, commercial premium structures create economic incentives for facility owners to purchase leak-resistant equipment when they replace tank systems. For example, the data in Table 1 Panel A imply the 30-year present value (at 5 percent

TABLE 1

Private Insurance Rate Factors and Base Premiums for Underground Fuel Tank Accidental Release Coverage

Panel A: Base Insurance Premiums by Tank Type and Age (Years). In Dollars per Tank per Year

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

Panel B: Impact of Preventive and Detective Equipment on Insurance Premiums

	YES	NO	UNKNOWN
Advanced leak detection	0%	+10%	+10%
Overfill detection	0%	+10%	+10%
Supplemental corrosion protection system(s)	0%	+10%	+10%

Panel C: Impact of Prior Accidental Releases on Insurance Premiums

	YES, CLAIM CLOSED	YES, CLAIM OPEN	NO
Prior release at same facility (adjustment per release)	+10%	+20%	0%

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

TABLE 2

Variation in Private Insurance Premiums in 1997 For Typical Tank System Configurations of Several Vintages

Tank System Attributes						Insurance Premiums for a 3-Tank System (1997 $)		
VINTAGE	TANK MATERIAL	PIPING CONSTRUCTION	ANTI-CORROSION EQUIPMENT	OVERFILL PROTECTION	INVENTORY MONITORING	INSURER A	INSURER B	INSURER C
1997	Reinforced fiberglass	Double wall	N/A	Yes	Automated	$1,350 ($5K ded.)	$825 ($5K ded.)	$1,320 ($10K ded.)
1991	Coated steel	Single wall	Yes	Yes	Automated	$1,500 ($5K ded.)	$1,250 ($5K ded.)	$1,320 ($10K ded.)
1985	Bare steel	Single wall	Yes	No	Manual	$3,500 ($10K ded.)	$1,500 ($5K ded.)	$2,563 ($10K ded.)
1975	Bare steel	Single wall	No	No	Manual	Decline coverage	$3,800 ($5K ded.)	$5,610 ($10K ded.)

Notes: Minimum deductibles noted in parentheses (where K=1,000). All tanks are single-walled construction, unless noted. Anti-corrosion equipment applies only to steel tanks. Source: EPA (1997).

annual interest) of the insurance premium savings from installing a double- versus single-wall tank exceeds $5,300. In practice, the procurement cost differential between a basic single-wall (cathodically protected) steel tank and a non-corroding double-wall composite (fiberglass-steel) tank at standard size is approximately $2,600–$3,000; the latter carry 30-year manufacturer warranties against corrosion. Thus, for reasonable discount rates, commercial insurance pricing creates incentive to install higher quality, non-corroding tanks when a facility replaces them. The state assurance fund lacks similar incentives.

Table 2 shows insurance premiums for several common three-tank system configurations of different vintages as of 1997, which is approximately the midpoint of our study period. Table 2 shows that premiums vary significantly; lower premiums apply if owners invest in tank and piping equipment that is less likely to corrode, and for systems with superior monitoring and inventory control. Similarly, Table 1 (Panel B) indicates commercial insurance premiums are reduced for advanced leak detection systems, additional corrosion-protection equipment, and other preventive measures that exceed federal technical standards.

Commercial insurance contracts provide additional incentives for tank owners to take care through experience-rated prices. The bottom row of Table 1 indicates that a prior accidental fuel release (a tank leak, or surface spill exceeding 25 gallons) will increase the premium per tank charged by this insurer by 10–20 percent per year. To our knowledge, no state assurance fund program incorporates experience-rating—the most basic form of risk-related information—into its program participation fee. Commercial insurers also provide incentives for tank owners to purchase detection and maintenance services from specific third-party providers, an arrangement that insurers view as a means to reduce moral hazard in gasoline retailers' maintenance and operations activities.

Because the price of commercial insurance is closely tied to tank systems' attributes, leak history, and risk-reducing activities at the station level, we hypothesize that stations with commercial insurance are less likely to have accidental fuel tank leaks than stations participating in state assurance fund programs.

Is Leak Disclosure Reporting Unbiased?

The data we examine include all underground fuel tank leaks and spills (formally known as accidental releases) reported to, or discovered by, state regulatory agencies and commercial insurers. We are interested in whether the true number of releases discovered by tank system owners differs from the reported number of releases. If underreporting is more prevalent with private insurance than public insurance through the state assurance fund, then our conclusions about the incentive effects of private insurance may be inaccurate.

Three observations argue against this possibility:

- There is a high likelihood that a non-reported release will ultimately be detected.
- The costs imposed by the marketplace and the legal system upon discovery of a non-reported release are severe.
- The costs of reporting an insured accidental release are comparatively small.

As a result, a tank owner's interests are best served by reporting and cleaning up any leaks promptly, regardless of the insurance system in place.

With respect to the likely detection of non-reported releases, there are two mechanisms at work: routine inspections and onsite testing when a tank is replaced or a facility is closed. Table 3, which summarizes information from a U.S. General Accounting Office study of state tank regulations during the 1990s, indicates Michigan and Illinois inspected between 30 and 40 percent of facilities in each state annually; Indiana inspected somewhat fewer (less than 20 percent). A primary purpose of routine state inspections is to detect previously unreported leaks. In addition, when a facility owner closes or replaces a tank, state regulators require its removal and inspection for leaks. The site assessment at closure is designed to be diagnostic—that is, highly unlikely to erroneously conclude a site is clean if a release has in fact occurred.

Regarding the high costs of non-reported releases, market mechanisms provide considerable incentive to report and clean up leaks. It is standard practice for a prospective buyer of any site with underground fuel storage tanks to have the site tested (via direct soil sampling and monitoring wells) prior to purchase. A facility that does not test clean becomes difficult, if not impossible, to sell and to insure by a future owner (absent cleanup). Consequently, unless the market value of the site is already negligible before an accidental release, it is in the facility owner's best interest to have any leak cleaned up promptly—at the current insurer's expense—so as to preserve the asset's future value.

Failing to report an accidental release also has significant legal consequences. First, federal law stipulates that a tank owner or operator who fails to report a suspected accidental release within 24 hours is subject to civil penalties of $11,000 per day. Second, to renew commercial tank insurance, a facility owner must make a detailed declaration of whether it experienced an accidental release in the past. Nondisclosure of a prior release is a breach for which the insurer might legally rescind coverage, leaving the tank owner liable for the full cost of the cleanup. In contrast, by reporting the release promptly, a facility owner can avoid this loss

TABLE 3

Regulatory Compliance and Facility Inspection Rates

	MICHIGAN	ILLINOIS	INDIANA
Percentage of tanks inspected annually(actual)	30 - 40 %	30 - 40%	10 - 20 %
Frequency of state inspections (nominal)	Every 3 years	Every 2 years	Every 3 years
Percent of active tanks with required leak detection equipment	91 - 95	91 - 95	91 - 95
Number of full-time employees that conduct field inspections	21	23	6

Source: Government Accounting Office (2000)

TABLE 4

Facility Statistics and Trends by State

	MICHIGAN	ILLINOIS	INDIANA
Vehicle miles traveled (in billions), 1990	81.1	83.3	53.7
Growth rate, 1990 to 2003 (per year)	2%	2%	2%
Number of active facilities, 1990	25,253	22,809	17,089
Growth rate, 1990 to 2003 (per year)	-7%	-7%	-6%
Average number of tanks per facility, 1990	2.8	2.7	2.4
Growth rate, 1990 to 2003 (per year)	-0.2%	0.8%	-0.4%
Average tank capacity (in gallons), 1990	4,428	4,732	4,248
Growth rate, 1990 to 2003 (per year)	5%	4%	5%
Median active tank age (in years)			
1990	14	11	10
2003	16	13	13

Notes: Growth rates are average annual compound rates from 1990 to 2003. Tank-level attributes are means for active facilities.
Sources: Authors' calculations and Highway Statistics 1990, 2003, Table VM-2.

and have the release cleaned up at the insurer's expense.

In contrast, the costs that the owner of an insured facility bears after reporting an accidental release occurs are only the deductible and future increases in experience-rated commercial premiums.

Although hard data on the prevalence of unreported tank leaks remain elusive, the totality of these considerations leaves us skeptical that tank owners with private insurance are systematically less likely to report an accidental release than owners participating in state assurance fund programs. Similarly, EPA officials who oversee compliance policies nationally assert there is no evidence tank owners using state assurance funds behave differently from those using commercial insurance in reporting accidental releases.

Data

We examine accidental release rates over a 14-year period at all facilities in Michigan, Illinois, and Indiana. All three states developed substantively identical assurance fund programs at the same time (either in 1988 or 1989). Second, each of these states maintains comprehensive data on all underground fuel storage tanks and accidental releases in the state. These databases have been continuously updated as old tanks exit and new tanks enter service. Third, as indicated in Table 3, each of these states' on-site inspections of tank facilities shows a similarly high compliance rate (between 91 and 95 percent) with leak detection system installation requirements. Last, these neighboring states have similar climates, a contributing long-term factor to tank corrosion.

Two databases are maintained by each state's environmental protection and tank regulatory agencies. One is the tank database, which reports a tank's installation date, closure date (if applicable), facility, and location. The second database contains information on all reported releases in the state, including the facility, release date, and clean-up progress. A central feature of all three states' databases is that they retain information on tanks closed since 1986. Information on closed facilities allows us to avoid attrition and survivor biases that would otherwise confound measurement of release rate changes over time. In total, there are approximately 236,000 individual underground fuel storage tanks in the data.

Table 4 summarizes facility attributes and trends by state. Michigan and Illinois are quite similar with respect to the number of facilities with underground fuel storage tanks, vehicle miles traveled (an indicator of fuel storage demand), and most tank-level attributes. Indiana, which has two-thirds as many residents, has commensurately fewer facilities and vehicle-miles, but similar tank-level attributes. All three states exhibit similar growth rates (within one percentage point) on these dimensions over our 14-year study period. One noteworthy difference in Table 4 is that Michigan's tanks are slightly older than the other two states.

A striking feature of the data is the dramatic facility exit rate in all three states. Some 65 percent of the 25,253 active facilities in Michigan in 1990 closed permanently over the following 14 years. Entry (that is, *de novo* new facilities) was slight over this period, resulting in a net facility exit rate of 61 percent from 1990 through 2003. Net exit rates are similarly high in Illinois and Indiana over the same period (61 and 56 percent, respectively). There has also been a trend to larger stations: the mean tank capacity of active facilities increased steadily over time, by 4–5 percent per year. These trends mirror the industry's view that only the most profitable, high-volume gas stations can cover the fixed cost of upgrading their tank systems to meet the regulatory requirements phased-in during the 1990s.

The empirical task is to measure how accidental release rates changed in Michigan relative to other states after Michigan's policy change. To do so, we distinguish between an active and closed facility. A facility is classified as active if it has at least one active tank; otherwise, the facility is classified as closed. We classify a tank as active from installation date until closure as recorded by state regulatory agencies.

After Michigan changed to a private insurance market, release rates in the state fell by 20 percent more than in adjacent states. Tank owners tended to take more care to prevent leaks than in Illinois or Indiana.

This distinction is important because there are two ways in which a facility owner might respond to risk-based insurance pricing. One is to make capital investments and improve maintenance practices that reduce the chance of a tank system leak. Such actions are not obligatory, however; a station owner might choose to pay higher insurance premiums and not undertake any risk-reducing activities. Alternatively, a station owner might opt to close a leak-prone facility entirely. This avoids the need for additional capital expenditures and/or higher insurance expenses after a state requires commercial insurance, and will be preferred if these expenses are high relative to the station's profit stream.

Results

After Michigan changed to a private insurance market, overall release rates in the state fell by 20 percent more than in adjacent states. The data also suggest that after the change, tank owners in Michigan tended to take more care to prevent leaks than in Illinois or Indiana.

Table 5 summarizes the three states' average annual release rates before and after 1995, when Michigan switched to private insurance. It omits 1995 because Michigan's policy change took

TABLE 5

Changes in Total Release Rates over Time by State

(Standard errors in parentheses)

	Releases per 100 Facilities		Absolute Risk Reduction		Relative Risk Reduction[a]	
STATE	PRE-TRANSITION (1990-1994)	POST-TRANSITION (1996-2003)	POST – PRE DIFFERENCE	CONTRAST VS. MICHIGAN	POST VS. PRE	ETIOLOGIC RATIO[b]
Michigan	6.51 (0.09)	2.56 (0.06)	-3.95 (0.10)		-60.6% (1.0)	
Illinois	5.23 (0.09)	2.82 (0.06)	-2.42 (0.11)	-1.53 (0.15)	-46.2% (1.5)	1.31 (0.05)
Indiana	3.62 (0.09)	1.84 (0.06)	-1.77 (0.11)	-2.18 (0.15)	-49.0% (2.2)	1.24 (0.06)

Notes: Standard errors assume a (symmetric) misclassification error rate of 5 percent. [a] Relative risk reduction is 100 × ($rate^{post}$ / $rate^{pre}$ – 1). [b] The etiologic ratio is RRR^{MICH} / $RRR^{OtherState}$, where *RRR* is relative risk reduction. Source: Authors' calculations.

effect mid-year; we show 1995 separately.

The data indicate that on an average annual basis, Michigan's total release rate fell from 6.51 to 2.56 per 100 facilities before versus after the policy change, a drop of 60.6 percent. By contrast, the total release rate in Illinois was lower initially and declined by less: 5.23 to 2.82 per 100 facilities, a reduction of 46.2 percent. The ratio of relative risk changes, known generally as the etiologic ratio, is 1.31. It indicates that Michigan's relative risk reduction exceeded Illinois' by 31 percent. The relative risk reduction in Michigan exceeded Indiana's by a similar amount, 24 percent.

Reductions in environmental risks also should be considered in absolute terms. On an average annual basis, Michigan's total release rate fell by 3.95 per 100 facilities after its policy change. In contrast, the total release rate in Illinois declined by only 2.42 per 100 facilities. The absolute risk reduction in Michigan exceeds that in Illinois by 1.53 (3.95 – 2.42) releases per 100 facilities, which is 23 percent of Michigan's initial (1990–1994) average annual release rate.

Is a reduction of 1.53 releases per 100 facilities economically significant? Yes. The number of facilities in Michigan after its policy change averages approximately 26,000. So an annual reduction of 1.53 releases per 100 facilities corresponds to about 400 fewer accidental releases per year and approximately 3,200 fewer releases over our eight-year post-transition study period. Table 5 also indicates that Michigan's "excess" absolute risk reduction (the difference-in-differences) is even greater compared to Indiana: 2.18 releases per 100 facilities annually. Taken together, these data suggest that Michigan had between 3,000 and 4,000 fewer underground tank leaks over the eight years following its policy change than the number predicted by neighboring states' experience over the same time period. Given an average cleanup cost of $125,000 per release, this represents an aggregate cleanup cost savings for that state on the order of $400 million over eight years.

Figure 1 shows the difference in total release rates between Michigan and Illinois at an annual frequency. It indicates that the greater drop in Michigan's pre- versus post-period release rate relative to the change in Illinois is not driven by the data for any one particular year. Michigan's total release rate was consistently higher than Illinois' through 1995. The difference in release rates between the two states falls in 1996, after Michigan requires private insurance. (A drop is also observed in 1993, the federal deadline to install or upgrade leak detection at "grandfathered" facilities. All states' release rates fell that year, Michigan's slightly more than the others.) After Michigan's policy change in 1995, its release rate not only falls relative to Illinois, but is actually lower than Illinois' most years thereafter.

Mechanisms and Closure Rates

Why did accidental release rates fall more in Michigan than neighboring states after 1995? Conceptually, it is useful to distinguish among three distinct possible explanations:

- ***Greater facility closure rate.*** Because releases at closed facilities are rare, shifting facilities from active to closed status will tend to reduce a state's overall release rate. A greater closure rate in Michigan—for any reason—would tend to reduce its total release rate more than neighboring states.
- ***Greater selective attrition*** of the most leak-prone facilities into closed status in Michigan than in adjacent states. Note that selective attrition may reduce release rates in Michigan more than other states even if overall facility exit rates are similar—that is, even if the explanation immediately above does not hold.
- ***Greater risk-reducing effort at active (surviving) facilities*** in Michigan than in adjacent states. Tangibly, this means replacing or re-lining older tanks, improving maintenance practices, installing anti-corrosion equipment, and similar activities after Michigan's insurance policy change.

The first of these explanations is potentially problematic because high closure rates of gas stations during the 1990s could have come about for a number of reasons unrelated to insurance reform: adverse demand conditions, the federal tank-system technical standards phased-in during the 1990s, the industry's trend to replace smaller stations with larger facilities that have convenience stores, and so on. These pose a potential concern if they resulted in higher facility closure rates in Michigan than in comparison states after 1995. We consider this possibility in light of the next set of data and the other two explanations.

Facility closings | Figure 2 displays the total number of facilities and the number of active facilities from 1986 to 2003 in Michigan and Illinois. A state's total and active facilities are the same in 1986, when record-keeping requirements began. In both states, the total number of facilities (solid lines) grows incrementally over time because of modest *de novo* entry by new gasoline stations. However, the number of active facilities (dashed lines) plummets in both states. The decline in Indiana's active facilities is substantively the same (see Table 4).

Figure 2 reveals several important points. First, the decline in the number of active facilities commences in 1988–1989, when the EPA issued its final regulations regarding financial responsibility requirements (effective in 1988) and tank technical requirements (effective a decade later, in 1998, for existing facilities). Second, there is an abrupt drop in the number of active facilities in Illinois (and Indiana) in 1999, the year "grandfathering" of existing facilities ends. We do not observe an abrupt decline in Michigan at the same time, indicating most of its grandfathered facilities had either exited or upgraded by then. Third, there is a slightly greater rate of *de novo* entry in Illinois than in Michigan. Since newly installed tanks are unlikely to corrode, this difference in entry rates should tend to reduce Illinois' overall release rate relative to Michigan's over time. That is, the difference in new entry rates does not help account for Michigan's greater drop in release rates—it makes Michigan's greater decline more remarkable.

Last, and perhaps most importantly, there is little evidence that closure rates in Michigan exceeded those in Illinois. From 1990 to 2003, the proportion of facilities that were active declined by essentially identical amounts in both states: 56 percentage points (from 90 percent to 34 percent) in Michigan and 57 percentage points (from 88 percent to 31 percent) in Illinois. The proportion of active facilities fell 59 percentage points (from 97 percent to 38 percent) in Indiana over the same period, nearly the same as in Michigan.

FIGURE 1

Difference in Overall Release Rates for Michigan and Illinois, 1990-2003

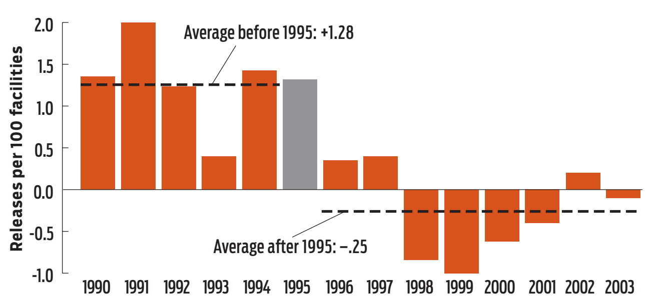
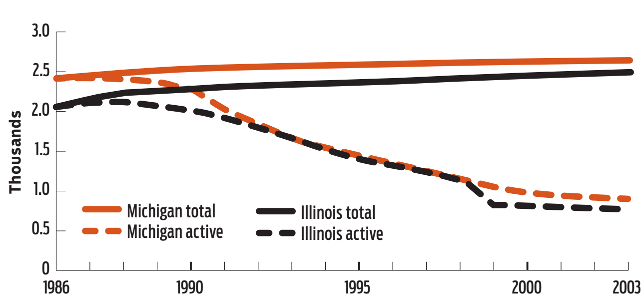


FIGURE 2

Number of Facilities and Active Facilities in Illinois and Michigan, 1986-2003



These data support two intermediate conclusions:

- The net exit of stations in Michigan over time was not induced by that state's private-market insurance requirement in 1995.
- The difference in absolute risk reduction between Michigan and its neighbors is not attributable to a greater rate of facility closure over time in Michigan.

The second conclusion is important because it is inconsistent with confounding factors—that is, something other than insurance reform—causing different release rate changes between states by inducing different facility closure rates.

It is (perhaps) puzzling that Michigan's overall closure rate from 1996 to 2003 is essentially the same as in Illinois and Indiana. After all, the cost of operating a facility in Michigan rose in mid-1995; why not greater exit after a cost shock? The likely explanation lies in the magnitudes. Gasoline retailing entails an up-front sunk cost (upward of $100,000 to $200,000 for initial site acquisition and development), which owners expect to recoup on annual gross margins. Insurance cost increases of $1,000 to $3,000 annually (Table 2, rows 1–3) are too small to turn this expected annual gross margin negative, so are unlikely to induce exit among compliant facilities.

Of course, the cost of commercial insurance for older, noncompliant facilities could be substantially higher. That might drive out marginally profitable noncompliant establishments and induce more-profitable ones to accelerate replacement of leak-prone tanks in order to reduce their insurance premiums. This may explain why Michigan's exit rate declines steadily over the 1995–1999 period in Figure 2, but Illinois exhibits an abrupt drop in the number of active facilities in 1999. Both states' noncompliant facilities could not operate after the federal "grandfathering" provision expired in 1998 (without costly upgrades), but in Illinois there was less incentive to close a noncompliant facility before 1998.

Changes in active release rates | The greater-selective-attrition and greater-risk-reduction-effort explanations above point to the possibility of changes in release rates at active facilities as a result of insurance reform. Table 6 summarizes each state's active facility release rate. Note this is not a fixed set of establishments; the number of active facilities declines steadily over time, as shown in Figure 2 above.

After 1995, Michigan's active release rate falls by 3 percentage points, from 8.81 to 5.78 per 100 active facilities. By contrast, Illinois' release rate declines by slightly more than 1 percentage point and Indiana's falls by less than 1. The excess absolute risk reduction among active facilities in Michigan versus Illinois is 1.78 per 100 facilities, and 2.09 per 100 facilities compared to Indiana.

Because the set of active facilities is declining steadily over time in each state, changes in active facility release rates may arise from two conceptually different mechanisms. The first is direct risk-reducing effort at facilities that continue to operate, and involves investment in risk-reducing technologies and their maintenance. Alternatively (or in combination), selective attrition of the most leak-prone active facilities over time would result in a progressively lower-risk set of surviving active facilities. Note the latter mechanism would reduce active release rates, as measured in Table 6, even if firms made no efforts at all to reduce release risks at ongoing establishments.

Which of these mechanisms accounts for the larger reduction in release rates in Michigan, relative to the other states, after its policy change? The most compelling data to address this question would be information on facility-level investments in specific risk-reducing technologies before and after 1995 (such as corrosion protection equipment, tank re-linings, maintenance logs showing more frequent pressure testing, and so on). To our knowledge such data have not been systematically collected, and it is far from clear that they could be assembled reliably in retrospect. Nevertheless, we can draw useful inferences about whether or not these activities must have occurred by separately examining facilities that survived and those that closed due to attrition.

TABLE 6

Changes in Active Facility Release Rates over Time by State
(Standard errors in parentheses)

	Releases per 100 Facilities		Absolute Risk Reduction		Relative Risk Reduction[a]	
STATE	PRE-TRANSITION (1990-1994)	POST-TRANSITION (1996-2003)	POST – PRE DIFFERENCE	CONTRAST VS. MICHIGAN	POST VS. PRE	ETIOLOGIC RATIO[b]
Michigan	8.81 (0.11)	5.78 (0.10)	-3.03 (0.15)		-34.4% (1.4)	
Illinois	5.74 (0.10)	4.48 (0.10)	-1.25 (0.14)	-1.78 (0.21)	-21.8% (2.3)	1.58 (0.18)
Indiana	4.20 (0.10)	3.36 (0.10)	-0.95 (0.14)	-2.09 (0.20)	-22.5% (3.0)	1.53 (0.21)

Notes: Standard errors assume a (symmetric) misclassification error rate of 5 percent. [a] Relative risk reduction is 100 × ($rate^{post}$ / $rate^{pre}$ – 1). [b] The etiologic ratio is RRR^{MICH} / $RRR^{OtherState}$, where *RRR* is relative risk reduction. Source: Authors' calculations.

TABLE 7

Release Rates at Continuously Operated Facilities 1990-2003
(Standard errors in parentheses)

	Releases per 100 Facilities		Absolute Risk Reduction		Relative Risk Reduction[a]	
STATE	PRE-TRANSITION (1990-1994)	POST-TRANSITION (1996-2003)	POST – PRE DIFFERENCE	CONTRAST VS. MICHIGAN	POST VS. PRE	ETIOLOGIC RATIO[b]
Michigan *n*=6,985	8.08 (0.18)	3.51 (0.12)	-4.57 (0.21)		-56.6% (1.7)	
Illinois *n*=4,103	6.27 (0.22)	3.72 (0.15)	-2.55 (0.26)	-2.02 (0.34)	-40.6% (3.2)	1.39 (0.12)
Indiana *n*=2,606	6.04 (0.27)	3.84 (0.19)	-2.20 (0.33)	-2.37 (0.42)	-36.4% (4.3)	1.55 (0.19)

Notes: Standard errors assume a (symmetric) misclassification error rate of 5 percent. [a] Relative risk reduction is 100 × ($rate^{post}$ / $rate^{pre}$ – 1). [b] The etiologic ratio is RRR^{MICH} / $RRR^{OtherState}$, where *RRR* is relative risk reduction. Source: Authors' calculations.

Continuously operated facilities | The majority of the facilities active at the end of our study period were active since (at least) 1990. Table 7 summarizes the average annual release rates for these continuously operated facilities. The average annual release rate in Michigan decreases by 4.57 releases per 100 facilities after 1995 (from 8.08 to 3.51). In contrast, the rate in Illinois falls by about half as much: 2.55 per 100 facilities (from 6.27 to 3.72). The situation in Indiana is similar to Illinois, with a decline of only 2.20 per 100 facilities (from 6.04 to 3.84). In absolute terms, the reduction in Michigan's release risk exceeds that in Illinois and Indiana by 2.02 and 2.37 per 100 facilities, respectively; the relative risk falls 39 percent and 55 percent more in Michigan than the adjacent states. These magnitudes are substantial, greater than the excess absolute risk reduction and etiologic ratios for facilities overall, as shown in Table 5.

The facilities in Table 7 are unlikely to be representative of all facilities, as surviving facilities are apt to be more profitable than average. Still, these facilities operated underground fuel storage tanks in the same location, with the original or replacement tanks and equipment, for many years before and after Michigan's policy changed. There are three possible explanations for Michigan's substantially greater decline in release rates among these states' continuously operated facilities:

- Greater direct risk-reducing activity among facilities in Michigan, whether through closing or replacing old tanks, re-lining existing tanks, improving maintenance practices, or similar efforts.
- Greater nondisclosure of releases in Michigan after 1995, financial penalties and insurer monitoring efforts notwithstanding.
- A change in the rate at which steel tanks corrode underground in Michigan relative to other Midwest states, for other reasons.

TABLE 8

Number of Tanks in Service at Continuously Operated Facilities, 1990-2003

	MICHIGAN (1)	ILLINOIS (2)	INDIANA (3)	MI / IL RATIO (4)	MI / IN RATIO (5)
Panel A: Active Tanks per Facility					
Pre (1990-1994)	3.6	2.9	3.0	1.2	1.2
Post (1996-2003)	3.1	2.9	3.1	1.1	1.0
Percent Change	-16%	-1%	3%	-15%	-18%
Panel B: Active Tanks Over 20 Years Old per Facility					
Pre (1990-1994)	1.0	0.5	0.6	1.9	1.7
Post (1996-2003)	1.0	0.7	0.7	1.5	1.5
Percent change	0%	31%	15%	-23%	-13%

Notes: Count data are annual averages. Ratios calculated before rounding. Source: Authors' calculations.

Although we cannot completely rule out greater nondisclosure of releases, we find it difficult to support. The facilities in Table 7 are long-term operators at (presumably) profitable locations, and therefore should have high opportunity costs of violating release-reporting laws—including significant civil penalties and the potential denial of insurance coverage. We can identify no evidence (nor reason) to support a change in tank corrosion rates, which would seem to require a heretofore undocumented change in Michigan's geology—and in the same year as its insurance reform.

In contrast, there is some evidence of greater risk-reducing activity. Table 8 Panel A shows that after 1995, the number of tanks in service at continuously operated facilities in Michigan falls 16 percent (from 3.6 to 3.1 per facility). In contrast, the corresponding changes are close to zero in Illinois and Indiana (2.9 to 2.9 and 3.0 to 3.1, respectively). Continuously operated facilities in Michigan thus reduced the number of tanks in service—in absolute number and relative to adjacent states—as one would expect after the tank insurance costs increased.

More pointedly, Panel B shows the number of older tanks in service (per facility) at continuously operated facilities. Column (4) indicates that prior to 1995, facilities in Michigan had nearly twice as many tanks over 20 years old in service (per facility) as Illinois. Michigan had 70 percent more than Indiana. The greater prevalence of older tanks in service helps explain Michigan's higher initial release rate (Tables 5, 6, and 7). The final row in Panel B reveals that after 1995, this ratio declines 23 percent (from 1.9 to 1.5) relative to Illinois and 13 percent (from 1.7 to 1.5) relative to Indiana. In sum, after Michigan's policy change, the continuously operated facilities in Michigan closed not only more tanks overall, but disproportionately more of their older—and more leak-prone—tanks than Illinois and Indiana.

Interestingly, the proportion of active tanks over 20 years old *increases* in both Illinois and Indiana, but not in Michigan. This seems consistent with increases in new tank installation costs during the 1990s and the limited incentive to replace old tanks under a public insurance system relative to the incentive to replace old tanks under the commercial insurance system in Michigan starting in 1995. On the latter, some simple calculations are informative. Consider a commercially insured three-tank facility, which is the modal size, with tanks that are 25 years old. The data in Table 1 Panel A indicate that replacing the tanks now—instead of one year hence—reduces the facility's insurance premium by $3,300 this year ($1,380 – $284 = $1,096 per tank). With 30-year-old tanks, the savings exceed $4,200. For a continuously operating facility, accelerating the tank system's replacement to capture this benefit also entails a cost, which is primarily the forgone interest on the non-deferred capital expense. That can run several thousand dollars, but this cost is independent of the insurance system. Thus the insurance savings benefit creates an economic incentive for commercially insured tank owners to replace their aging, potentially leak-prone tanks proactively—perhaps after as little as 20–25 years of service. Owners with public insurance through the state fund do not receive a similar incentive for precautionary behavior.

Selective facility attrition | The forgoing leaves open the possibility that part of Michigan's greater overall risk reduction is due to selective facility attrition. In precise terms, selective attrition means facilities that ultimately closed in Michigan were more leak-prone (prior to closure) than facilities that closed in Illinois or Indiana. Table 9 tabulates empirical frequencies that address this. It reveals that the facilities that ultimately closed in Michigan had significantly higher historical release rates—over 8 percentage points higher than Illinois (18.11 versus 10.07 releases per 100 facilities), and 4.5 percentage points higher than Indiana (18.11 versus 13.67 releases per 100 facilities).

Note these frequencies do not say how much selective attrition contributed to the overall absolute risk reduction in Table 5. For this we require a more detailed decomposition of the relative magnitudes. In principle, we can decompose a state's absolute risk reduction into the release rate changes at continuously operated facilities ("stayers"), at facilities that ultimately close ("attritants"), and at new facilities ("entrants"), weighted by their

TABLE 9

Release Rates at Attriting Facilities

(Subsample of facilities closed by 2004. Releases per 100 active facilities.)

	MICHIGAN (1)	ILLINOIS (2)	INDIANA (3)	MI / IL RATIO (4)	MI / IN RATIO (5)
Overall rate, 1990-2003	18.11	10.07	13.67	1.8	1.3
Pre-transition (1990-1994)	9.89	5.86	5.37	1.7	1.8
Post-transition (1996-2003)	24.25	13.41	19.59	1.8	1.2

Notes: Data are annual averages. Source: Authors' calculations.

population shares.

Table 10 displays the detailed calculations. Here we include an additional group of "unknown" facilities that are operational in 2004 but have missing entry/installation dates (and thus cannot be unambiguously categorized as entrants or stayers). Panel B weights each group's conditional release rate reduction by its population share.

Subtracting the rows in Panel B and expressing the difference by group as a percentage of Michigan's overall excess risk reduction gives the decomposition in Panel C. It shows that half of Michigan's excess absolute risk reduction over Illinois is attributable to the greater risk reduction at continuously operated facilities in Table 7. The balance is attributable to the fact that facilities that ultimately closed in Michigan had higher historical release rates than did closing facilities in Illinois. The proportions for Indiana are somewhat greater for attritants and smaller for stayers. (Combining Indiana's "unknown" group with the stayers they likely represent lowers the stayers' contribution to about one quarter.)

We conclude that not only did ongoing establishments make greater risk-reducing efforts in Michigan than in other states after 1995, but tank owners in Michigan also tended to permanently close facilities that had a high propensity to leak. Note this second, selective attrition mechanism is not based on overall facility closure rates, which the data indicate were similar in each state. Rather, it attributes part of the differential change in total release rates between Michigan and neighboring states to *which* facilities were closed. Greater sorting of leak-prone tanks into closure in Michigan than neighboring states seems a particularly plausible result of the switch to private-market insurance, since tank attributes that predict future accidental releases (such as tank age) are a major determinant of commercial insurance premiums (Tables 1 and 2).

TABLE 10

Decomposition of Absolute Risk Reduction by Facility Duration Status, 1990-2003

	ALL (1)	ATTRITANTS (2)	STAYERS (3)	ENTRANTS (4)	UNKNOWN[a] (5)
Panel A: Absolute Risk Reduction by Group, Post- vs. Pre-1995. Rate per 100 Facilities.[b]					
Michigan	-3.95	-4.63	-4.57	0.31	-2.98
Illinois	-2.42	-3.19	-2.55	0.06	-1.18
Indiana	-1.77	-1.70	-2.20	0.17	-2.49
Panel B: Contribution of Each Group to Absolute Risk Reduction. Rate per 100 Facilities.[b]					
Michigan	-3.95	-2.70	-1.21	0.01	-0.05
Illinois	-2.42	-1.91	-0.42	0.00	-0.08
Indiana	-1.77	-1.03	-0.30	0.01	-0.43
Panel C: Decomposition of Michigan's Excess Absolute Risk Reduction by Group					
Michigan – Illinois		51%	51%	-1%	-2%
Michigan – Indiana		76%	42%	0%	-17%

Notes: [a] "Unknown" are facilities operational in 2004 that cannot be definitively classified as entrants or as stayers from 1990-2003 due to missing installation year data. These are 2% (MI), 7% (IL), and 17% (IN) of each state's total (active and closed) facilities.
[b] Panel A reports conditional release rate changes $\Delta P(R_{ft} / group)$, and Panel B reports share-weighted changes, $s^{group} \times \Delta P(R_{ft} / group)$.
Source: Authors' calculations.

Conclusion

After Michigan's transition to private-market environmental liability insurance, overall accidental release rates from underground fuel storage tank systems declined by over 20 percent, or by about 1.5 releases per 100 facilities, more than in adjacent states. This is a substantial change, amounting to 3,000 to 4,000 fewer accidental releases over the following eight-year period. At an average cleanup cost of approximately $125,000 per release, this corresponds to aggregate avoided cleanup costs exceeding $400 million in that state. Those are the direct costs of cleaning up affected sites and do not include business interruption costs associated with cleanup activities. More importantly, it also excludes the cost of any adverse health effects of contaminated water supplies.

Is Michigan's policy change and its use of risk-based insurance pricing the cause of its greater decline in accidental release rates? We believe so; however, we would like to analyze other, similar cases elsewhere. Specifically, nine states have followed Michigan's lead in closing their state-fund assurance programs to new claims: Wisconsin (1996), Texas (1998), Florida (1999), West Virginia (2000), Iowa (2000), Delaware (2001), Alaska (2004), Arizona (2006), and Maryland (2007). Since federal financial responsibility requirements are mandatory, tank system owners are obligated to switch to commercial environmental liability contracts like those in Michigan. If the main findings we report are confirmed independently for other states undertaking similar insurance reforms, the policy ramifications would be compelling.

According to the *State Financial Assurance Funds Survey* 2007, eight states' underground storage tank financial assurance funds are insolvent with outstanding liabilities totaling $2 billion. Moreover, the EPA estimates that 6,300 new underground fuel tank releases occur annually. This study indicates that risk-based pricing structures similar to those studied here may help reduce the frequency of accidental releases and alleviate the ongoing solvency crises. The potential is significant: a 20 percent reduction in release rates nationally would reduce future cleanup expenses on the order of $3 billion over the next decade. R

READINGS

- "Can Environmental Insurance Succeed Where Other Strategies Fail? The Case of Underground Storage Tanks," by Haitao Yin, Alexander Pfaff, and Howard Kunreuther. *Risk Analysis*, Vol. 31, No. 1 (2011).
- *Managing Environmental Risk through Insurance*, by Paul K. Freeman and Howard Kunreuther. Kluwer Academic Publishers, 1997.
- "Retroactive Liability or the Public Purse?" by J. Boyd and H. C. Kunreuther. *Journal of Regulatory Economics*, Vol. 11 (1997).