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Accidents Waiting to Happen: Liability Policy and Toxic Pollution Releases

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Abstract

Proponents of environmental policies based on liability assert that strict liability imposed on polluters induces firms to handle hazardous wastes properly. We run regressions relating unintended pollution releases to strict liability imposed on polluters, exploiting variation across states and over time in the liability provisions of state mini-Superfund laws.

Strict liability reduces the frequency and severity of pollution releases, provided it is modeled endogenously with the latter. Its effects vary with firm size. Partially sheltered from liability, small firms may have specialized in riskier production processes, but their number has not necessarily grown in response to the states' liability policy.

Key Words: strict liability, negligence, hazardous waste, state environmental policy, endogenous policy adoption

JEL Classification Numbers: Q28, D72, K13

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Accidents Waiting to Happen: Liability Policy and Toxic Pollution Releases

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1. Introduction

This paper examines whether imposing strict liability for the cost of cleaning up contaminated sites has increased the level of care taken by firms to avoid uncontrolled releases of pollutants into the environment and thus reduced the frequency and/or severity of such events.

Proponents of environmental policies based on strict liability, such as the federal Superfund and the states' "mini-Superfund" legislation, contend that when faced with the prospect of disbursements over cleanup or to compensate third parties, firms will avoid improper disposal of pollution into the environment. Economic theory, however, warns that several factors may dilute the incentives of legal liability. Firms with relatively limited assets may be sheltered from the economic incentives created by strict liability (Shavell 1984). Firms may even select their asset level or corporate financial structure to minimize payment of damages in the event of an accident (Pitchford 1995), or spin off into (or subcontract risky operations to) smaller, judgment-proof companies in hopes of avoiding liability (Ringleb and Wiggins 1990). Making it even more difficult to anticipate the behavioral responses of firms under liability laws, Beard (1990) shows that when the size of the damages is uncertain, it is unclear whether care against pollution releases would increase or decrease with the wealth of the firm.

In this paper, we empirically explore the effects of strict liability on uncontrolled releases of pollutants into the environment, exploiting differences across the states in the liability

structure imposed by their mini-Superfund programs. These programs typically confer authority on the regulator to force responsible parties to conduct or pay for initial feasibility studies and remediation activities at nonpriority sites, and they establish financing mechanisms to pay for such activities when the responsible party is insolvent or no longer in existence (EPA 1989). As in the federal Superfund program, responsible parties are sought among the generators of the waste that ended up contaminating the site, and the owner(s) and operator(s) of the site. In contrast to the federal Superfund program, however, not all state programs impose strict liability on responsible parties. As of 1995, 40 states had instituted strict liability provisions, and the remainder relied on negligence-based liability.

Absent data on firms' expenditures on care, we use data on accidents and spills involving hazardous substances to establish whether their frequency per state per year has been systematically affected by the introduction of strict liability. Because our spill data cover 1987 through 1995, we are unable to establish how the previous passage of the federal Superfund law affected accidental releases. Instead, we examine whether the strict liability feature of state cleanup programs has had any *additional* influence on accidental events, above and beyond that of the federal Superfund.

The very fact that the liability policy addressing hazardous waste site cleanup varies across states suggests that it might be endogenous with the outcome we wish to model. Presumably, the state legislature selects the liability structure and other aspects of its hazardous waste program to maximize the net benefits of the program. These are defined as the reduction in expected health damages for the population exposed to accidental toxic releases at contaminated sites where mitigation is subsequently undertaken, minus litigation costs and the share of unrecovered cleanup costs borne by the state (Alberini and Austin 1999a).

The health benefits should depend on the population exposed and on the value the state places on avoiding morbidity, which in turn should be a function of educational attainment, income, and environmental awareness of residents. The liability structure presumably affects both the program's benefits, through the expected reduction in health damages if firms adjust their level of care in response to the liability policy, and its costs, which depend on the size of the firms in the state and on their use of toxic substances.

Unobserved factors could influence both the net benefit calculus and the outcome we wish to model, resulting in their endogeneity. Such factors could include the state legislature's perception of the difficulty of establishing a standard of negligence or determining when it has been breached, or its knowledge of hard-to-document firm practices.

In our econometric analyses, we account for endogeneity of pollution releases and the liability structure, and for the possibility of structural differences in firms' behaviors across regimes. We find that states with more serious spills *are* more likely to adopt strict liability, and this policy *does* reduce the frequency of spills. We also find evidence consistent with different behavioral responses by large and small firms, the latter being partially sheltered from liability.

The remainder of the paper is organized as follows. Section 2 presents the data and the econometric model, and section 3 discusses the independent variables of the econometric model. Section 4 presents the results, and section 5 concludes.

2. The Data and the Econometric Model

To measure the effect of strict versus negligence-based liability on care against releases of pollution, we estimate econometric equations for pollution releases, which we measure as the frequency of spills and accidents involving toxic chemicals.¹

A. The Data

Our data come from the Emergency Response Notification System (ERNS) of the Environmental Protection Agency (EPA). Spills and releases of specified substances covered by certain environmental statutes must be reported to ERNS. For each release of a toxic substance, the ERNS database documents the date and place of the discharge, the substance spilled, and the number of fatalities, people injured, and evacuations from a facility. The quantity of pollutants released is also available, but this variable is unreliable and affected by so many missing values that we prefer to work with spill frequencies. We focus on spills of chemicals listed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), better known as Superfund.

In this paper we take an aggregate approach, examining spills of all CERCLA-listed chemicals per state per year, from 1987 to 1995.² We include in our counts only the spills and accidents occurring at a plant, as opposed to offshore or during transportation, to avoid the complexity of the federal, state, and local regulations affecting chemical transport (Wentz 1989).

¹ We focus on accidental chemical spills for three reasons. First, data on firm expenditures on safety and release prevention are not publicly available. Second, chemical spills have the potential to trigger the federal and state Superfund statutes. Third, using chemical spills avoids the problems associated with examining contaminated waste sites recently listed on the federal or state priority lists, which may be the result of manufacturing activity many years ago, as opposed to the response to the current liability incentives.

The spills data were merged with manufacturing, mining, and population variables, and with variables describing the liability structure in the state and its evolution over time. This produced a panel data set following the 50 states plus the District of Columbia for nine years (1987–1995).

B. Main Equations

Spills of CERCLA substances are relatively common and can be reasonably modeled using a regression equation where the dependent variable is log spill counts:

$$(1) \ln y_{it} = \mathbf{x}_{it}\beta + S_{it}\gamma + \mathbf{A}_{it}\delta + \varepsilon_{it},$$

where the vector \mathbf{x} contains state-level socioeconomic variables; β , γ , and δ are vectors of parameters; S and \mathbf{A} are a strict liability indicator and other associated policy variables, respectively; ε is the error term; and i and t denote state and year.

We initially run regressions that include the liability policy variables in the right-hand side of the model to see whether they explain spills beyond what is predicted by the intensity of manufacturing and state sociodemographics. It is clear that these initial regressions assume that the presence of strict liability is exogenous to the dependent variable.

If the liability structure within a state is endogenous with the spill outcome, it is necessary to specify an additional equation expressing (the probability of) adoption of strict liability as a function of a set of instruments. Once this additional equation is estimated, a two-stage procedure yielding a consistent estimate of γ is obtained by replacing S in the right-hand side of equation (1) with a state's predicted probability of adopting strict liability.

² An alternative approach is to group spills by chemical, or families of chemicals (Alberini and Austin 1999b).

To build the equation explaining the presence or absence of strict liability, we assume that a state adopts the liability structure that maximizes the net benefits of its hazardous waste cleanup program. The net benefits of regime k are expressed as:

$$(2) NB_k = \mathbf{w}\alpha_k + \eta_k,$$

where the coefficients are allowed to vary with the liability structure ($k \in \{\text{S(strict), N(egligence)}\}$), \mathbf{w} is a set of variables influencing the state's benefit-cost calculus, and η is a standard normal error term. Although we do not observe NB_k , we do observe whether the state mini-Superfund program imposes strict or negligence-based liability. A state's adoption of strict liability therefore implies that it deems its expected net benefits to be greater than the net benefits from a program without that provision, leading to a probit equation.³

³ In reality, the state legislature selects the liability structure not alone but in concert with other liability and program attributes meant to influence firms' exposure to cleanup and damages claims. For example, the state may uphold joint-and-several liability and impose punitive damages on recalcitrant firms. This suggests that k should really denote one of the many possible combinations of indicators and real-valued variables capturing liability and other attributes of the state's program, and that the appropriate econometric model is a multinomial logit model explaining the choice of one combination of attributes over all other possible combinations. However, Alberini and Austin (1999a) show that a multinomial logit model explaining adoption of several liability attributes (strict versus negligence-based liability; proportional versus joint-and-several liability; presence or absence of provisions authorizing punitive damages against recalcitrant responsible parties) can be collapsed to a simple binary model describing just the presence or absence of strict liability. The latent variable in the probit model is the difference between the net benefits of strict liability and those of the alternative regime. Strict liability is adopted if this difference is greater than zero. The coefficients of the probit model are the difference between the α s of the two regimes in equation (2).

3. Independent Variables and Instruments

A. Determinants of Spill Frequency

The vector \mathbf{x} in equation (1) includes state socioeconomic variables thought to influence aggregate spill rates and/or quantities released. Descriptive statistics and data sources for these variables and those discussed in the next subsection are reported in table 1.

An obvious determinant of toxic spills is the extent of economic activity involving chemicals. We use numbers of production units in the manufacturing and extractive sectors in each state, distinguishing between large and small plants (having more than, and fewer than, 20 employees, respectively).⁴ We are forced to proxy for firm size using numbers of employees because data on the number of firms by asset size are not available at the state level.

Small and large firms may contribute to pollution releases at a different rate for various reasons. Firms with limited assets, sheltered from liability, may have less incentive to take precautions against pollution releases. On the other hand, large firms or plants may use and store large amounts of chemicals or hazardous wastes, with more potential for accidental discharges of larger quantities. Larger spills or more “visible” plants may make it more likely that a spill is reported to ERNS. In addition, the Occupational Safety and Health Administration requires large companies handling dangerous chemicals or hazardous wastes to prepare formal plans to handle emergencies but waives this requirement for small plants (Wagner 1999).

To further capture the toxics riskiness of manufacturing processes in the state, we also control for the amount of hazardous waste generated *per capita* (HAZWASTE).

The regressor STRICT (S_{it}) is a dummy indicator for whether the state mini-Superfund program prescribes strict liability. Many of the northeastern states passed strict liability provisions relatively early, shortly after passage of CERCLA. In some states, such as New Jersey and Rhode Island, strict liability has been in place since the late 1970s. In the industrial Midwest, some states adopted liability relatively early (Ohio, Missouri), others later (Michigan), and some repealed strict liability in the mid-1990s.⁵ Mountain states (where the mining industry may be politically powerful, or where the state legislature did not deem strict liability appropriate to handle contaminated sites, many of which are associated with past mining activities) generally have elected not to implement strict liability, but there are some exceptions (e.g., Montana).⁶

In most cases, liability standards are subject to interpretation by the state courts, based on statutory language and common law arguments (ELI 1995). States upholding strict liability typically give enforcement authority to their environmental protection agency, which has the authority to issue unilateral orders to responsible parties and to refer cases to the state attorney general. The burden of proof is on the firm alleged to be responsible for the release.

By contrast, under negligence-based liability the burden of proof is on the state agency to show that the responsible party committed a negligent, reckless, or intentionally wrongful act. The negligence standards are established by the courts on a case-by-case basis. It is generally argued that under negligence-based liability, the state agency will have to spend more resources

⁴ We repeated our analyses for other size breakdowns (e.g., establishments with fewer and more than 50 or 100 employees) and obtained qualitatively similar results.

⁵ In the early 1990s, Ohio briefly reverted to a policy based on negligence but had reinstituted strict liability in its mini-Superfund program by 1995. Illinois repealed strict liability in 1995.

⁶ See Alberini and Austin (1999a) for more on the pattern of strict liability adoption.

investigating the intent of involved parties and will face a smaller universe of parties on which liability may attach. This may lessen the incentive of firms to take care (ELI 1995).

Although many responsible parties avoid litigation by reaching consent agreements with the state agency, under either liability regime firms' incentives should be influenced by the expected outcome of litigation. This may depend on the aggressiveness of the state agency in prosecuting polluters, on the perceived efficiency of the state court system, and on the perception of the courts' tendency to rule in favor of the defendant or the plaintiff in toxic tort lawsuits.

We measure prosecutorial aggressiveness as the number of state lawyers working on state Superfund cases per million residents (LAWYERS). A state's court efficiency, CORTEFF, is captured by the ratio of all civil cases disposed of to all civil cases filed in any given year. We assume that the state's preferences toward business activity and environmental quality are generally reflected in its courts. We proxy for these preferences with the percentage of votes for the Democratic candidate in the most recent presidential elections (PCTDEMPR), a widely used political variable. Other provisions of the state mini-Superfund laws that might influence the breadth of the state prosecutorial authority and the outcome of litigation are included in the vector \mathbf{A}_{it} .

Two additional explanatory variables are population density (POPDENS), and membership per 1,000 residents in any of three major environmental organizations (ENVORG). These factors may encourage firms to avoid releases for fear of causing greater damages or being reported to authorities by residents. However, since these factors may also influence the reporting of spills to ERNS, the sign of their coefficients is uncertain a priori.

Firms' responses to the imposition of liability should depend in part on their ability to deflect some or all damage payments to insurance companies, and on the safety standards

imposed by their insurers. Ideally, one would like to model pollution insurance coverage, preferably broken down by firm size, endogenously with accidental pollution events.

Unfortunately, data on firms' pollution insurance, and claims paid in relation to spills and contaminated sites, are not available, forcing us to omit this variable altogether.

B. Determinants of Liability Structure

In equation (2), the vector \mathbf{w} of instruments for the liability policy includes predetermined economic and political characteristics that influence the net benefit calculus of the state agency or legislature, and hence the decision to adopt one or the other type of liability. We assume that the state chooses the type of liability that maximizes the net benefits of the cleanup program. We define the benefits of the program as the value of resulting reductions in human morbidity or mortality. This should depend on the population exposed and on the value placed on avoiding morbidity and reducing mortality risks. These in turn should be a function of the educational attainment, income, and environmental awareness of residents. The costs of the state cleanup program include administrative costs, plus the share of cleanup costs that cannot be recovered from responsible parties and must be borne by the state.

We assume that a state's liability structure affects both benefits—through the reduction in health damages as firms adjust their level of care in response to the liability policy—and costs,⁷ which should depend on the sizes of firms in the state and on their use of toxic substances.

⁷ On a per case basis, it should be more expensive to build the case against the alleged polluter under a negligence regime than it is under a strict liability regime, where the burden of the proof is on the defendant. In addition, under the two liability regimes the state can be expected to shoulder different amounts of unrecoverable cleanup costs. Total costs will depend on how many cases the agency decides to pursue.

States' propensity to adopt strict liability is ultimately a function of their assessment of their risk of toxics cleanup. This is related to the amount of uncontrolled toxics in the state, proxied by the numbers of existing hazardous waste sites on the federal and state priority lists (NPL and SITES, respectively), past spills of CERCLA chemicals (SPILLS), and past injuries in spills of these chemicals (INJURIES). The numbers of small and large production units in manufacturing (LESS20 and MORE20) and in mining (MINLESS20 and MINMORE20) should capture both the toxics risk of manufacturing activity as well as the likely costs of the state's remediation program.

We proxy for the size of the exposed population using the state's population density. State residents' educational attainment levels are likely to affect public perception of the hazardous waste problem in their state, and their value of avoiding the illnesses associated with exposure to hazardous wastes (Tolley et al. 1994). Absent information about the administrative costs of the state hazardous waste programs, we assume that a program's net benefits are influenced by the state resources available to the mini-Superfund program, here measured by state expenditures per capita and the percent of state budgets dedicated to environmental programs.

Finally, the state legislature's net benefit calculus may be influenced by interest group pressure, attitudes of residents toward environmental quality, and attitudes of the state agencies toward the environment. These considerations suggest that a political variable—here we also use PCTDEMPR—be considered among the determinants of net benefits.

4. Results

A. Preliminary Data Analyses

We first compare the incidence of spill events across states with and without strict liability in place. In states with strict liability, the average annual number of spills of CERCLA substances of any severity is 114.2 (standard error around the mean 10.7), versus 70 (s.e. 4.6) in negligence-based states. Strict liability states average 3.6 (s.e. 0.4) spills involving at least one injury—an indicator for severe spills—compared with 2 (s.e. 0.2) in negligence states. These differences are statistically significant.

To determine whether they indicate a link between strict liability and elevated rates of pollutant releases, however, we must control for state-level differences in manufacturing base, population, use of toxics, and environmental awareness.

B. Initial Regressions

The results of several variants of regression (1), all of which include year dummies, are reported in table 2. Column A presents our basic specification, in which the indicator for strict liability is included in the right-hand side and treated as econometrically exogenous. In column B we add three more indicator variables describing other features of the state mini-Superfund programs. These include state provisions for victims' compensation, punitive damages if the state is forced to initiate the cleanup itself, and actions initiated by private citizens against responsible parties. The first two variables capture additional aspects of firms' liability exposure; the citizen-suit provision effectively broadens the reach of the state environmental agency by "deputizing" private citizens on its behalf. This may permit closer effective oversight over firms' behavior, possibly increasing the probability of being targeted by the state agency.

Treating strict liability as exogenous, the frequency of CERCLA spills appears to increase with the number of small manufacturing units (with elasticity 0.4) but is relatively insensitive to the number of large units. Even controlling for manufacturing and mining units, spill counts rise with the quantity of hazardous waste generation and with population density, the latter possibly reflecting reporting effects.

The number of state lawyers assigned to mini-Superfund cases and the efficiency of the state courts have negative but insignificant effects on spills. The higher the popular support for Democratic presidential candidates in general elections, the lower the incidence of spills, but this effect is not statistically significant at the conventional levels.

The strict liability effect is positive and significant in both specifications A and B. All else the same, a state with strict liability experiences about 20 percent more spills than a comparable state maintaining negligence-based liability. The inclusion of the other three policy variables in B has little effect on this coefficient, and only the victim-compensation effect is negative, suggesting a slight deterrent on the total number of spills.

C. Unobserved Heterogeneity and Endogeneity of Liability

Why is strict liability positively associated with the frequency of spills, even after controlling for economic activity, population characteristics, and state agency and courts?

One possible explanation is that strict liability per se is not responsible for the greater spill frequency but is correlated with omitted factors that are. To test this, we fitted state fixed-effect models to see whether omitted factors were driving the result. An insignificant strict liability effect would support this hypothesis. An advantage of the fixed-effects model is that its

coefficients are robust to unobserved state-specific factors that are correlated with the state's liability structure and make the dependent variable endogenous with the liability regime.

The fixed-effects regression, reported in column C of table 2, indeed produces an insignificant strict liability effect. It is striking that this coefficient is negative, and that those of most of the other variables are insignificant.⁸ However, the efficiency of these estimates might be improved by explicit modeling of strict liability as endogenous, as we do next.

In column D we adopt a two-stage model that allows for endogeneity of spill frequency and liability laws. The first stage is a probit equation for states' liability adoption decisions, where the dependent variable is the presence or absence of strict liability in state i in year t (with t ranging from 1988 to 1995)⁹ and all independent variables are lagged one year.¹⁰

The fitted probit equation is as follows:

$$(3) \Pr(\text{strictliab}_{it}) = \Phi(1.17 + 0.09 \cdot \text{LogNPL}_{i,t-1} + 0.05 \cdot \text{LogSITES}_{i,t-1} + 0.50 \cdot \text{LogSPILLS}_{i,t-1} \\ + 0.23 \cdot \text{LogINJURIES}_{i,t-1} - 0.082 \cdot \text{LogDENSITY}_{i,t-1} + 0.56 \cdot \text{LogMORE20}_{i,t-1} \\ - 0.99 \cdot \text{LogLESS20}_{i,t-1} - 1.11 \cdot \text{LogMINMORE20}_{i,t-1} + 0.29 \cdot \text{LogMINLESS20}_{i,t-1} + 0.04 \text{HIGH SCH}_{i,t-1} \\ - 0.06 \cdot \text{LESSTHS}_{i,t-1} + 0.30 \cdot \text{LogEXPEND}_{i,t-1} - 0.10 \cdot \text{ENVPROG}_{i,t-1} + 0.19 \cdot \text{PCTDEMPR}_{i,t-1}).$$

The t statistics associated with the estimated coefficients are (in order) 0.44, 0.53, 0.55, 3.04, 3.35, -0.59, 1.24, -1.68, 1.26, 1.16, 1.32, -2.89, 0.89, -1.11, and 1.20. The numbers of hazardous waste sites on the federal and state lists are thus positively associated with the likelihood of imposing strict liability, although the respective coefficients are not statistically

⁸ An F statistic equal to 12.67 rejects the pooled data model in favor of the fixed effects at the conventional significance levels.

⁹ Our probit model treats all observations as serially independent within a given state. Alberini and Austin (1999a) fit fixed-effects logit equations and obtain qualitatively similar results.

¹⁰ Additional lags did not improve the explanatory power of the model.

significant. Importantly, the past frequencies of spills of CERCLA chemicals and the past severity of such spills (measured by the number of injuries) *are* positively and strongly associated with adoption of strict liability. This suggests that strict liability provisions are passed in response to numerous and potentially severe releases of pollutants into the environment.¹¹

States are less likely to adopt strict liability the more numerous their *small manufacturing* plants and *large mining* establishments. States with many small firms may anticipate that it will be difficult to get such firms to pay for cleanup under strict liability. Strict liability may also be deemed better suited to deterring or correcting after-the-fact pollution from manufacturing firms than from mining firms.¹² By contrast, the number of *large manufacturing* plants and *small mining* establishments is positively associated with the presence of strict liability, but this association is not statistically significant.

Of the remaining variables in this model, only education seems to have an effect: states with relatively low educational attainment levels appear less likely to impose strict liability. Collinearity may reduce the efficiency of these estimates—many are insignificant—but the model fits the data well, correctly predicting more than 79% of the observations.

¹¹ Past spills and chemical-spill injuries remain strong predictors of the liability policy even when the number of NPL and non-NPL sites in the state are omitted from the equation. When past spills and injuries are omitted, the coefficients of the numbers of existing hazardous waste sites are positive and statistically significant. Although we believe that the number of existing hazardous waste sites, past spills and past spill-related injuries are *all* related to the adoption of strict liability policies, the effect of hazardous waste sites is probably muted by the collinearity between these variables.

¹² An alternative interpretation for the negative and significant coefficient of large mining establishments is that the extractive industry has effectively lobbied against imposition of strict liability.

When we use the predicted probability that strict liability is in place in state i in year t , $\hat{\Phi}_{it} = \Phi(\mathbf{w}_{it}\hat{\alpha})$,¹³ in the original equations for spill frequencies, instead of the strict liability dummy, the strict liability effect becomes *negative* and significant at the 6% level.¹⁴ In column D of table 2, the estimated γ is -0.27 , implying that all else the same, imposition of strict liability lowers the incidence of spills by 24%.¹⁵ The model predicts that a representative strict liability state will experience on average 98.3 spills per year (s.e. 5.7). Were strict liability removed, the number of spills would rise to 126.8.

The number of small plants continues to be positively associated with spill frequency, while the state Superfund litigation outcome proxies remain insignificant. We had no prior expectations about the sign of the court efficiency effect. An inefficient state court system may favor either alleged polluters or the regulator, depending on the circumstances. The prospect of lengthy litigation and related expenses can deter certain firms from improperly handling hazardous substances, but it could also be welcomed by others hoping to delay cleanup activities and disbursements. It is possible that the lack of significance for court efficiency reflects such heterogeneous tastes across firms. Alternatively, it is possible that the court efficiency variable,

¹³ Of the alternative features of state cleanup programs, only the strict liability policy is retained in these specifications, because of the difficulty of modeling several policy dummies as endogenous and the small effect that the other policy dummies had on spill outcomes.

¹⁴ Replacing S_{it} with $\hat{\Phi}_{it}$ introduces heteroskedasticity in the equations for spill frequency, and requires appropriately correcting the standard errors of the estimates, following the general expressions in Murphy and Topel (1985). Neither our own algorithms nor packaged routines produced the appropriate covariance matrix, forcing us to resort to the general heteroskedasticity-robust covariance matrix $V^{-1}R_2V^{-1}$, where V is the outer product of the first derivatives of the log likelihood function (Fahrmeir and Tutz 1994).

¹⁵ A formal test of the null hypothesis that the strict liability indicator is exogenous with respect to log CERCLA spills rejects the null at the 1% significance level. The test statistic is the square of the t statistic associated with the

and perhaps also the number of lawyers and the Democratic presidential vote, is not a very good proxy. However, adding EPA region dummies to further control for differences in enforcement across states did not change results appreciably, and only two region dummies are significant.¹⁶

To further understand the strict liability effect, we also ran a regression (not reported) on a subsample of states that at some point passed strict liability provisions. In this regression, the number of years since strict liability was adopted has a negative and significant coefficient, showing that spill frequency slowly declines over time (at a rate of 4% to 5% a year) once strict liability is in place.

We conclude that rather than causing an increase in spill rates, strict liability has been introduced by states already experiencing numerous chemical spills or having a substantial contaminated site problem, and it has helped lessen such problems. Even with this decline, spills remain more numerous in strict liability states, which tend to have greater manufacturing intensity and more small manufacturing plants, which in turn have a greater propensity to spill. (On average, there are 5,402 small manufacturing plants in strict liability states, versus 3,792 in negligence-based states).

Despite its reasonable R^2 (0.65), the equation of column D slightly overpredicts spills in negligence-based states and underpredicts spills in strict liability states. This discrepancy prompted us to investigate whether there were structural changes across the two liability regimes.

inverse Mills' ratio from the first-stage probit, entered in the log spills regression as an additional variable. Its value here is 8.96, leading to the rejection of the null hypothesis that S is exogenous at traditional significance levels.

¹⁶ In the regression with EPA region dummies, $\hat{\gamma}$ is equal to about -0.27 and is significant at the 10% level.

D. Structural Changes

If the different liability structures alter firms' behavioral responses, a switching regression model with endogenous switching is intuitively appealing. We assume that:

$$(4) \ln y_{it} = \mathbf{x}_{it} \beta_N + \varepsilon_{it}^N \text{ if } S_{it} = 0 \text{ (under negligence),}$$

$$(5) \ln y_{it} = \mathbf{x}_{it} \beta_S + \varepsilon_{it}^S \text{ if } S_{it} = 1 \text{ (under strict liability),}$$

with $S_{it} = 1$ if $S_{it}^* = \mathbf{w}_{it} \alpha + \eta_{it} \geq 0$, and 0 otherwise, and η jointly normally distributed with ε^N and ε^S . The model is estimated by limited-information maximum likelihood (i.e., in two steps), with the first step producing inverse Mills' ratios for use in the second-step equations, which separate the data by liability regime.

Results for the switching regression model are reported in column E of table 2. The model fits the data well, predicting that a representative strict liability state has a total of 100.0 spills per year (s.e. 6.4), and a representative negligence-based state has 75.6 (s.e. 4.1).

In states with strict liability the number of spills is increasing in the number of small manufacturing establishments but unrelated to the number of large manufacturing plants. By contrast, in states imposing negligence-based liability, the number of large manufacturing establishments is positively associated with chemical spills. Strict liability reduces accidental releases, but it is less effective at doing so the greater the number of small firms. This suggests that the small-firm effect of column D in table 2 is probably due to the prevalence of strict liability observations, and of small firms in strict liability states, in the combined sample.

The magnitude of the manufacturing plant coefficients suggests that in strict liability states, a 1% rise (fall) in the number of small plants results in a 0.7% rise (fall) in the number of accidents, but in negligence-based states, a 1% change in the number of *large* plants results in a

1.4% change, of the same sign, in the number of spill events. No such large-firm effect is seen in strict liability states.

These results support the hypothesis that under strict liability, small firms may engage in lower levels of care, presumably because they are partially sheltered from liability. Risky production activities may have devolved from or been delegated by large firms to small ones in hopes of avoiding liability. We explore below the possibility that these incentives might overlap with those created by extending liability to lenders, and that small firms' demand for pollution insurance may differ from that of large firms.

E. Additional Robustness Checks

Liability incentives may be stronger where there is greater risk to human health, which suggests that we check the effects of liability on the subset of CERCLA spills involving human injury. The average number of spills per state per year in which injury occurs is three, prompting the use of Poisson regressions.¹⁷ The results, reported in table 3, specifications A and B, are for the most part similar to those of table 2. In particular, strict liability is associated with 39% more injury spills, but other aspects of the state liability structure are not significantly related to severe spills. In contrast to the all-spills results, here the number of lawyers working on state mini-Superfund cases does appear to have a deterrent effect, as does the level of popular support for Democratic presidential candidates.

¹⁷ The Poisson model postulates that state i 's probability of experiencing y severe spills in year t is $\exp(-\lambda_{it})\lambda_{it}^y / y_{it}!$ with $\lambda_{it} = \exp(\mathbf{x}_{it}\beta + S_{it}\gamma + \mathbf{A}_{it}\delta)$. λ_{it} is both the mean and the variance of y_{it} .

To address the potential for overdispersion of the dependent variable, we also fit a negative binomial model.¹⁸ The estimated coefficients (column C, table 3) are relatively close to those of the Poisson model, though a likelihood ratio test rejects the latter in favor of the negative binomial. The strict liability coefficient in the negative binomial model is pegged at 0.29, versus 0.33 in the Poisson.

The fixed-effects regression (Hausman et al. 1984) reported in column D of table 3 produces a negative, insignificant coefficient for the strict liability dummy. Its absolute magnitude (−0.23) is larger than its all-spills counterpart (column C of table 2). In column E we repeat our two-stage instrumental variables regression, finding that a state will experience 28% fewer severe spills if strict liability is introduced, compared with 24% for all spills.¹⁹

To estimate our structural change model, we fit the switching regime Poisson model suggested by Greene (1995), which is estimated in two steps. This gives results that are qualitatively similar to those for all CERCLA spills, except that the elasticities are even larger for severe spills: with respect to small plants the strict liability elasticity is 0.9, and the negligence-based elasticity with respect to large plants is 2.0. The predictions for the annual number of spills are 3.9 (s.e. 0.4) under strict liability and 2.2 (s.e. 0.2) under negligence-based

¹⁸ In a negative binomial λ_{it} is no longer a fixed parameter but a draw from a gamma distribution with parameters (γ_{it}, θ) , with $\gamma_{it} = \exp(\mathbf{x}_{it}\beta + S_{it}\gamma + \mathbf{A}_{it}\delta)$, while θ is the same across sample units and over time, and the draws λ_{it} are independent over time. The negative binomial model allows for overdispersion, a problem frequently encountered in practice, and reduces to the Poisson as θ tends to infinity, or $(1/\theta)$ tends to zero.

¹⁹ Here the difference between the fit of the Poisson and that of the negative binomial becomes blurred, and a likelihood ratio test finds the Poisson equation acceptable. In both the Poisson and the linear regression models, small and large mining establishments were found insignificant and were hence dropped from the endogenous liability models.

liability; those predictions compare very favorably with the actual frequencies (4.0 and 2.2, respectively).

To proxy for spill severity, we also fit negative binomial models explaining the number of injuries associated with spills (rather than the number of spills with injuries). In these equations, the liability regime is not a significant determinant of the number of injuries. However, injuries do increase at a higher rate with the number of small firms under strict liability, but under negligence-based liability, large firms appear to be associated with injury outcomes. This is consistent with our earlier results for spill counts, again suggesting that strict liability for hazardous waste cleanup may have encouraged companies to spin off, or delegate riskier operations, to small firms, which are presumably sheltered from liability because of their limited assets.

F. Why Structural Changes?

There are various possible reasons why, in the presence of strict liability, accidental releases of pollutants are associated with small production units. One reason might be, as in Shavell's (1984) model (later questioned by Beard 1990), that small firms' limited assets cap the disbursements they would have to make in the event of a spill, muting their incentives to take appropriate care. Strict liability regimes may induce small firms to specialize in riskier processes, either because a niche opens up when large firms cease those activities to avoid liability, or because the large firms have spun them off to the small firms. Anecdotal evidence suggests that this may have happened in a number of cases. Ringleb and Wiggins (1990) find that small firms were drawn to sectors with high occupational exposure to toxics when firms began to be held liable for the long-term health effects of toxics on workers.

The divergent rates of accidental releases may also be related to the corporate financial structures of small firms or the extent to which liability has been extended to lenders. Potentially responsible parties at Superfund and state mini-Superfund sites are sought among the owner(s) and operator(s) of the contaminated site, but CERCLA specifically excludes from the definition of owner or operator “a person who, without participating in the day-to-day management of a vessel or facility, holds indicia of ownership [including mortgages] primarily to protect his security interest in the vessel or facility.”

It is not clear whether a lender foreclosing on contaminated property loses its status as a secured creditor, or what constitutes participation in day-to-day management. In some well-known court cases, lenders have been held to be owners or were otherwise held liable. In one case (*US v. Fleet Factors, 1991*) a lender not involved in day-to-day management was found to have participated in financial management to a degree indicating the capacity to influence the corporation’s treatment of hazardous wastes. To end confusion over the status of lenders, EPA in 1992 issued a final rule reiterating the exclusion of secured creditors from liability and providing a specific procedure for lenders wishing to divest themselves of foreclosed property (Fogleman 1992).

Where liability has extended to the lender, firms have had an incentive to rely more on debt financing and to underinvest in care against pollution releases (Pitchford 1995; Ulph and Valentini 2000). Empirical studies show that small firms borrow primarily from banks, but large firms have access to public borrowing (bonds) (Johnson 1997; Titman and Wessels 1988).²⁰

²⁰ These findings hold for firm sizes defined in terms of both sales and assets.

Thus, small firms would be in a better position to shift liability to their lenders by increasing their reliance on borrowed capital if they perceived banks to be liable, and therefore to underinvest in care. We expect that any such behavior would have declined after 1992, the year of the EPA rule.

To test this behavior, we reestimated the switching regression model of table 2 with an interaction term between the number of small manufacturing establishments (in logs) and a post-1992 indicator variable. Under strict liability, small firms continue to be positively and significantly associated with spills. Compared with the switching regression results in tables 2 and 3, the small-firm effect increases by 15% to 25%, to 1.02, with a *t* statistic of 4.5. However, the interaction term is negative (−0.16) and significant at the 10% level, providing moderate evidence of the dampening effect of the 1992 EPA rule. We expect no such effect in negligence-based states, and indeed the interaction effect is quite negligible in those states, the coefficient being 0.05 and its associated *t* statistic 0.05.

We also examined the possible role of the availability of pollution insurance as a cause of structural change. We do not believe that this is the case, although we cannot formally test the effect of pollution insurance on care and releases because of a lack of data. In 1986 insurance companies modified their comprehensive general liability policies specifically to exclude coverage for sudden and accidental releases of pollution (previously covered by such policies). Now, such coverage is offered through expensive, specialized pollution insurance policies with standards of care prescribed by the insurance companies. Insurance industry representatives estimate they take in from \$0.5 to \$1 billion a year in premiums on such policies. Government reports have emphasized that small companies are effectively excluded from access to this coverage (US General Accounting Office 1987).

In general, firms will purchase pollution insurance if it lowers their total expected costs. This depends on rates, deductibles, expected cleanup costs, and required standards of care—which in turn influence the likelihood of an accident.²¹ If insurance companies compel otherwise similar firms to take greater care in strict liability states, and if only large firms buy pollution insurance, this would be consistent with large firms' tending to have lower pollution-release probabilities in strict liability states.

However, this argument remains an unsatisfactory explanation for our findings. Conversations with insurance company representatives indicate that they do not write policies that depend on states' liability regimes. Pollution insurance rates and standards of care depend instead on firms' past environmental performance and on their expected future exposure (based on conditions at their facilities). Even substandard facilities can be deemed insurable because of favorable site hydrogeology or low population density nearby. Rates and standards of care depend neither on the stringency of state environmental policies and enforcement nor on the state's liability regime.

Insurance representatives indicate, further, that manufacturing firms historically have not purchased much specialized pollution insurance unless specifically required to under the Resource Conservation and Recovery Act (RCRA) by virtue of their storing or managing on-site

²¹ To illustrate, consider a solvent firm under an ideal strict liability regime where liability attaches perfectly. Expected costs with insurance are $\pi + e' + p(e')(1 - \alpha)D$, where D is the damage, π the premium, α the fraction of total cleanup costs paid for by the insurance company ($D(1 - \alpha)$ being the deductible), and e' the standard of care the firm must adhere to. Without insurance, the firm's expected costs are $e^* + p(e^*)D$, where e^* is both the firm's private optimal amount of care and the social optimum. Clearly, whether it is better to choose insurance or to go without it will depend on the sizes of α , e' , e^* and π . Under negligence-based liability, firms without insurance have the incentive to choose a level of care exactly equal to the standard of negligence imposed by the courts (Tietenberg 1989), in which case their expected cost equals their expenditure on care (firms are not liable if they have taken the

hazardous wastes, or owning underground storage tanks. Such firms are typically larger and wealthier (Stafford 1999), however, and can often satisfy financial assurance requirements by self-insuring.²² Specialized pollution insurance coverage does not appear to be widespread, and there are, in any case, no readily available data to assess differences in coverage propensities across liability regimes.

Because specialized coverage is priced beyond the reach of small firms (US General Accounting Office 1987), differences in pollution insurance policies across liability regime (if any) still could not explain small firms' higher accident rates in strict liability states unless it is further assumed that they do indeed specialize in riskier activities in these states.

G. Does Strict Liability Encourage the Formation of Small Firms?

Although we control for the numbers of small and large firms, our analyses so far have not addressed whether the introduction of strict liability at the state level encourages the formation of small firms, as suggested by Ringleb and Wiggins (1990). To answer this question, we separated our 1987–95 data into adopters and nonadopters of strict liability. We reason that if wealthier firms are actually spinning off their risky activities to small companies as a way of protecting themselves from potential liability, or abandoning such activities and leaving a void into which small firms then enter, the ratio of small to large firms should increase in the presence of strict liability.

prescribed level of care). In that case, firms will buy insurance only if it allows them to exercise a lower level of care while keeping their expected disbursements at a level less than that implied by the standard of care.

²² California Department of Toxic Substance Control.

The data do not support this hypothesis. We find that there are more establishments of *both* size classifications in strict liability states. The ratio of small to large plants varies across industries and, if anything, appears to be higher in negligence-based states. There are, on average, 2.4 small manufacturing plants for each large plant in strict liability states, against 2.5 in negligence-based states (the *t* statistic for the no-difference null hypothesis is -1.95). Within the chemical industry, these ratios are 1.8 and 2.2, respectively (*t* statistic: 2.6), and in petroleum refining (which typically involves large quantities of chemicals and hazardous wastes), the small-to-large plant ratios are 2.8 to 2.6 (*t* statistic: -0.82). In the instruments industry (reported in Ringleb and Wiggins 1990 to have the highest levels of worker exposure to carcinogens), small plants outnumber large ones by 2.0 and 2.4 times, respectively (*t* statistic: 1.65).

These ratios followed a linear time trend between 1987 and 1995. In both manufacturing and in the instruments sector, small plants have become relatively more common, but in the highly polluting chemical and refining industries, large plants are the norm. Within each industry, the time trends are statistically indistinguishable across the two liability regimes. Finally, we perform *F* tests on the ratios of small to large plants before and after adoption of strict liability but find no evidence of structural change.

It is possible that changes in the relative numbers of small and large firms followed the establishment of the *federal* Superfund law in 1980. To test this hypothesis, we extended our plant-size data back to 1977. We find that in general, the federal Superfund statute appears to have increased the ratio of small plants to large plants by about 25%. The effect is particularly strong in the chemical industry but is insignificant among oil-refining plants (possibly because of their considerable capital and equipment requirements).

In none of the sectors we examine do states' post-CERCLA initiation of their own strict liability regimes further affect the proportions of small and large plants. The state hazardous waste liability laws still may have induced vertical reorganization of processes, whereby small firms may have tended to specialize in riskier activities, taking advantage of limitations in their environmental liability exposures, *without* altering the relative numbers of small and large plants.

5. Conclusions

We have estimated models of chemical spill frequencies and severity to see whether they are influenced by liability-based state environmental policies. We find that all else the same, unintended pollution releases are reduced by imposition of strict liability. It appears that states adopted strict liability *because* they experienced numerous spills, and that strict liability has subsequently reduced spills. Our results emphasize the importance of checking for the endogeneity of environmental policies in analyses that exploit policy differences across states.

We find evidence consistent with the hypothesis that firms have developed behavioral responses to avoid liability when they are strictly liable for releases of hazardous chemicals into the environment. In states with strict liability, greater spill severity and frequency are associated with small production units (our proxy for firms with fewer assets), whereas this association is not present in states with environmental liability laws based on negligence.

We offer two possible explanations for this finding: (1) in a strict liability regime, firms deliberately select their corporate structures and asset levels to avoid liability, or (2) small firms have tended to specialize in riskier processes while underinvesting in safety. The first explanation suggests that firms with manufacturing processes involving significant risk to the

environment may, if their state adopts strict liability, spin off those activities to smaller firms. Small firms are partially protected from potential liability if their book values are less than the expected environmental damages from a spill or accident. We find no evidence of an increase in the ratio of small to large firms as a response to state-level adoption of strict liability for environmental damages. If anything, the ratio has tended to be *lower* (and often declining over time) in these states, even in manufacturing sectors most heavily involved with the use of toxic chemicals, generation of hazardous waste, and nomination as responsible parties at contaminated sites.

The phenomenon we have observed, that small firms in strict liability states have greater propensity to be involved with spills of toxic substances, may therefore be due to the second explanation. The tendency of small firms in strict liability states to specialize in environmentally risky processes does not necessarily require that they knowingly exploit their effective limited-liability status, or even that they be familiar with the liability regime under which they operate. To the extent large firms have abandoned some risky activities to reduce their liability exposures, small firms may simply take them up in response to resulting business opportunities. Whatever industry restructuring has been induced by state-level imposition of strict environmental liability, however, it does not appear to bear on the relative numbers of small plants.

Our results complement those reported in an earlier paper (Alberini and Austin 1999a), in which the spill analyses were specific to individual families of chemicals, rather than aggregated. In the earlier analyses, the evidence about the effects of strict liability was mixed, in the sense that it seemed to affect the spills of some substances (e.g., acids and ammonia) but not others (halogenated solvents). Where liability did matter, small firms tended to experience more numerous spills under strict liability regimes. Evidence for policy endogeneity was weak (for

acids) or absent altogether (for ammonia or chlorine). Comparison with the present paper suggests that states' choices of liability regime have been made in response to *overall* patterns of pollution releases into the environment, rather than in reaction to spills of specific toxic chemicals.

References

- Alberini, Anna, and David Austin. 1999a. "Off and On the Liability Bandwagon: Explaining State Adoptions of Strict Liability in Hazardous Waste Programs," *Journal of Regulatory Economics*, 15 (1), 41–63.
- Alberini, Anna, and David Austin. 1999b. "Strict Liability as a Deterrent in Toxic Waste Management: Empirical Evidence from Accident and Spill Data," *Journal of Environmental Economics and Management*, 38, 20–48.
- Beard, Randolph T. 1990. "Bankruptcy and Care Choice," *RAND Journal of Economics*, 21 (4), 626–634.
- Environmental Law Institute. 1993. "An Analysis of State Superfund Programs: 50-State Study. 1995 Update," prepared for the US Environmental Protection Agency, Washington, DC, December.
- Environmental Law Institute. 1995. "An Analysis of State Superfund Programs: 50-State Study. 1993 Update," prepared for the US Environmental Protection Agency, Washington, DC, December.
- Fahrmeir, Ludwig, and Gerhard Tutz. 1994. *Multivariate Statistical Modelling Based on Generalized Linear Models* (New York: Springer-Verlag).
- Fogleman, Valerie M. 1992. *Hazardous Waste Cleanup, Liability, and Litigation. A Comprehensive Guide to the Superfund Law*. Westport, CT: Quorum Books.
- Greene, William H. 1995. *LIMDEP 7.0 User's Manual*, Plainview, NY: Econometric Software, Inc.
- Hall, Bob, and Mary Lee Kerr. 1992. *The 1991–92 Green Index*. Covelo, CA: Island Press.
- Hausman, Jerry, Bronwyn H. Hall, and Zvi Griliches. 1984. "Econometric Models for Count Data with an Application to the Patents–R&D Relationship," *Econometrica*, 52, 909–937.
- Johnson, A. 1997. "An Empirical Analysis of the Determinants of Corporate Debt Ownership Structure," *Journal of Financial and Quantitative Analysis*, 32(1), 47–69.
- Murphy, Kevin M., and Robert H. Topel. 1985. "Estimation and Inference in Two-Step Econometric Models," *Journal of Business and Economics Statistics*, 3(4), 370–379.
- Pitchford, Rohan. 1995. "How liable Should a Lender Be? The Case of Judgment-Proof Firms and Environmental Risk," *American Economic Review*, 85, 1171–1186.

- Ringleb, Al H., and Steven N. Wiggins. 1990. "Liability and Large-Scale, Long-Term Hazards," *Journal of Political Economy*, 98 (31), 574–595.
- Shavell, S. 1984. "A Model of the Optimal Use of Liability and Safety Regulation," *RAND Journal of Economics*, 15, 271–280.
- Stafford, Sarah L. 1999. "Vertical Integration of Hazardous Waste Management in the United States," Department of Economics, College of William and Mary, Williamsburg, VA, October.
- Tietenberg, Tom H. 1989. "Indivisible Toxic Torts: The Economics and Joint and Several Liability," *Land Economics*, 65 (4), 305–319.
- Titman, S., and R. Wessels. 1988. "The Determinants of Capital Structure Choice," *Journal of Finance*, 43(3), 689–702.
- Tolley, George, Donald Kenkel, and Robert Fabian, eds. 1994. *Valuing Health for Policy: An Economic Approach*. Chicago: The University of Chicago Press.
- Ulph, Alistair, and Laura Valentini. 2000. "Environmental Liability and the Capital Structure of Firms," paper presented at the annual EAERE meetings, Crete, Greece, July.
- U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. 1989. "An Analysis of State Superfund Programs: 50-State Study." Washington, DC.
- U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. 1990. "An Analysis of State Superfund Programs: 50-State Study. 1990 Update." Washington, DC.
- U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. 1991. "An Analysis of State Superfund Programs: 50-State Study. 1991 Update." Washington, DC.
- U.S. General Accounting Office. 1987. "Hazardous Waste. Issues Surrounding Insurance Availability," Report to the Congress, PB88-123138, Washington, DC.
- Wagner, Travis P. 1999. *The Complete Guide To Hazardous Waste Regulations. RCRA, TSCA, HMTA, OSHA*. 3rd edition (New York: Wiley & Sons).
- Wentz, Charles A. 1989. *Hazardous Waste Management* (New York: McGraw-Hill).

Table 1. Data Description and Descriptive Statistics.

All variables are state-level annual figures, except where noted.

Variable	Description and source of data	Mean	Std. devn.
COUNT	Spills of all CERCLA substances per state per year; Emergency Response Notification System (ERNS) Database	100.28	158.74
LCOUNT	Log COUNT	3.99	1.12
NUMBINJ	Count of accidents resulting in at least one injury (ERNS)	3.02	5.36
LESS20	Number of manufacturing establishments with fewer than 20 employees; US Statistical Abstracts, various years.	4845.39	5804.42
MORE20	Number of manufacturing establishments with more than 20 employees; US Statistical Abstracts, various years.	2633.13	2731.75
LLESS20	Log LESS20	7.94	1.08
LMORE20	Log MORE20	7.12	1.25
SMALL-M	Number of establishments in the mining sector with fewer than 20 employees; US Statistical Abstracts, various years.	466.78	912.28
LARGE-M	Number of establishments in the mining sector with more than 20 employees; US Statistical Abstracts, various years.	116.77	187.98
LSMALL-M	Log SMALL-M	5.30	1.31
LLARGE-M	Log LARGE-M	3.96	1.43
HAZWASTE	Hazardous waste generated in the state per capita (thousand lbs.); Hall and Kerr, <i>The Green Index</i> , 1992. Based on 1991 data.	1.58	2.91
LPOPDENS	Log population density. Calculated by the authors as log(population/area); population and area figures come from the US Statistical Abstracts, various years.	-2.58	1.53
ENVORG	Membership in three major environmental organizations per 1,000 residents; Hall and Kerr, <i>The Green Index</i> , 1992. Based on 1991 data.	8.48	3.54
LAWYERS	Number of lawyers working on state mini-Superfund program cases per million state residents; calculated by the authors as Number of lawyers working on state mini-Superfund program cases (EPA 1989, 1990, 1991; ELI 1993, 1995) divided by state population.	1.38	1.72
CORTEFF	Civil cases disposed divided by civil cases filed in the state. Civil cases disposed and civil cases filed are from the Court Statistics Project, National Center for Court Statistics, Williamsburg, VA.	0.95	0.10
PCTDEMPR	Percentage of popular votes for the Democratic candidate in the most recent presidential elections; US Statistical Abstracts, various years.	0.48	0.09
STRICT	Strict liability dummy (EPA 1989, 1990, 1991; ELI 1993, 1995).	0.68	0.47
JOINT-SE	Joint and several liability dummy (EPA 1989, 1990, 1991; ELI 1993, 1995).	0.56	0.50
CITSUIT	Provision allowing citizen suit dummy (EPA 1989, 1990, 1991; ELI 1993, 1995).	0.32	0.46
PUNDAMAG	Provision allowing imposition of punitive damages.	0.27	0.44

Table 2. OLS regressions.

Dependent variable: Log CERCLA spills. T statistics in parentheses. All specifications include year dummies

	A. Base specification	B. Other liability features	C. State fixed effects	D. Endogenous liability ^a	E. Switching regression model ^a	
					Strict liability	Negligence
Constant	-0.8021 (-1.572)	-0.6502 (-1.251)	-22.4239 (-2.283)	-1.3029 (-2.119)	-1.3994 (-2.179)	-4.3908 (-1.296)
Log manuf. firms 20+ employees	0.0784 (0.576)	0.0595 (0.431)	0.8036 (1.496)	0.0443 (0.255)	0.0661 (0.415)	1.3662 (3.596)
Log manuf. firms 20 or less employees	0.4090 (2.755)	0.4259 (2.823)	1.1269 (1.145)	0.7341 (4.112)	0.7369 (4.350)	-0.6829 (-1.990)
Log mining firms 20+ employees	0.1203 (1.862)	0.1548 (2.313)	-0.0707 (-0.555)			
Log mining firms 20 or less employees	0.1900 (2.910)	0.1564 (2.310)	0.3630 (1.376)			
HAZWASTE	0.0316 (2.249)	0.0330 (2.333)		0.0617 (4.014)	0.0724 (2.669)	0.0750 (2.478)
LPOPDENS	0.0874 (2.105)	0.1001 (2.352)	-2.4850 (-2.109)	-0.0503 (-1.124)	0.0024 (0.047)	-0.4681 (-1.599)
ENVORG	-0.0490 (-3.648)	-0.0420 (-3.056)		-0.0699 (-4.243)	-0.0922 (-4.283)	0.0536 (1.629)
Strict liability dummy	0.1864 (2.523)	0.1778 (2.234)	-0.0356 (-0.393)			
Citizen suit allowed dummy		0.1509 (2.401)				
Punitive damages		0.1090 (1.277)				
Victim compensation		-0.1344 (-1.539)				
Predictor for strict liability				-0.2686 (-1.899)		
LAWYERS	-0.0059 (-0.304)	-0.0103 (-0.532)	0.0123 (0.689)	0.0071 (0.318)	-0.0304 (-1.190)	0.0401 (1.068)
CORTEFF	-0.1523 (-0.479)	-0.2525 (-0.792)	-0.0723 (-0.307)	-0.2330 (-0.595)	-0.0503 (-0.170)	0.9293 (1.177)
PCTDEMPR	-0.7049 (-1.097)	-0.7976 (-1.222)	-0.1289 (-0.107)	-0.7964 (-1.033)	-0.9432 (-1.243)	2.7289 (2.219)
Sample size	362	0.7394	362	313	313	
Adjusted R square	0.7345	0.7394	0.9082	0.6563		

^a: Heteroskedasticity-corrected t statistics.

Table 3. Poisson regressions.

Dependent variable: Number of spills with at least one injury. T statistics in parentheses. All specifications include year dummies.

^a: Heteroskedasticity-consistent t statistics.

	A. Base specification	B. Other liability features	C. Negative binomial	D. State fixed effects	E. Endogenous liability ^a	F. Switching regression model ^a	
						Strict liability	Negligence
Constant	-6.8577 (-11.407)	-6.4044 (-9.581)	-5.8346 (-7.042)		-7.2083 (8.652)	-7.8248 (-9.050)	-6.4831 (-0.924)
Log manuf firms 20+ employees	0.1079 (0.699)	0.2308 (1.351)	0.1195 (0.488)	-1.3679 (-0.978)	0.4369 (2.304)	0.2887 (1.421)	1.9901 (2.222)
Log manuf. firms 20 or less employees	0.6562 (4.104)	0.5387 (3.078)	0.5882 (2.321)	2.3522 (1.013)	0.7282 (3.898)	0.8734 (4.279)	-1.2042 (-1.491)
Log mining firms 20+ employees	0.3571 (3.884)	0.2514 (2.565)	0.1286 (1.332)	-0.3595 (-0.966)			
Log mining firms 20 or less employees	-0.0634 (-0.749)	0.0369 (0.411)	0.1134 (1.178)	-0.1901 (-0.296)			
HAZWASTE	0.0096 (0.596)	0.0139 (0.843)	0.0260 (1.047)		0.0567 (3.064)	0.0494 (2.195)	0.1117 (2.242)
LPOPDENS	-0.0751 (-1.406)	-0.0802 (-1.396)	-0.0049 (-0.065)	-1.1238 (-0.375)	-0.2403 (-3.260)	-0.1651 (-2.207)	-0.4978 (-0.699)
ENVORG	0.0477 (3.159)	0.0666 (3.771)	0.0142 (0.612)		0.0643 (2.531)	0.0746 (2.914)	0.0187 (0.333)
Strict liability dummy	0.3296 (4.179)	0.2302 (2.475)	0.2860 (2.600)	-0.2331 (-0.980)			
Citizen suit allowed dummy		0.0450 (0.592)					
Punitive damages		0.0749 (0.804)					
Victim compensation		0.0951 (0.976)					
Predictor for strict liability					-0.3155 (-1.645)		
LAWYERS	-0.0776 (-2.207)	-0.0964 (-2.685)	-0.0574 (-1.296)	0.0591 (0.597)	-0.0805 (-1.566)	-0.0902 (-1.305)	0.0888 (1.163)
CORTEFF	-0.0031 (-0.008)	0.0832 (0.202)	-0.1484 (-0.245)	1.2669 (1.880)	-0.2299 (-0.365)	0.3025 (0.482)	0.2320 (0.108)
PCTDEMPR	-1.5401 (-2.237)	-4.0194 (-4.405)	-1.3908 (-1.459)	-8.4698 (-2.039)	-4.0720 (-3.447)	-4.5019 (-3.522)	-0.0397 (-0.007)
Sample size	362	362	362	362	313	313	
Log likelihood	-703.58	-694.32	-669.64	-511.26	-637.89	-610.81	

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