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The winding road to industrial safety. Evidence on the effects of environmental liability on accident prevention in Germany.

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Abstract:

The German Environmental Liability Law (ELL) of 1991 has introduced far-reaching civil liability for environmental damages with the aim to increase firms' efforts to prevent accidents. Previous studies find poor evidence that this goal has actually been achieved. One and a half decades after the introduction of that law, we undertake a new attempt to investigate the impact of the ELL on accident prevention.

Our analysis is based on annual data on the number of environmental accidents per year, reported to the monitoring agency ZEMA, and the risk premium imposed by a large German insurer on environmental liability insurance (ELI). As reliable accident reporting has begun only after the implementation of the new law into practice, pre- and post-reform levels of accident prevention cannot be directly compared. However, the time series of ELI premiums cuts across these two periods. Once we examine the relationship between the ELI premium and accident prevention and observe the effect of the reform impulse on the former, we are able to model the dynamics of the adjustment process induced by the ELL.

According to our results, the average number of environmental accidents per year has decreased from 29 before to 17 and a half after the reform. Our dynamic analysis reveals an overshooting of the insurance premiums in the first years after the reform and a successive decrease from 1997 onwards. The premiums and firms' prevention efforts achieved a new equilibrium in 2000.

Keywords: Environmental liability, accident prevention, empirical analysis, Germany.

JEL-Classification: **K32, K13, Q58**

1. Introduction

Environmental liability serves a dual objective in the economic theory, namely: Preventing environmental damage and charging external costs - that is, costs previously borne by the injured party - to the polluter. The latter is also called the goal of internalization. The preventive effect of environmental liability is evident in the number and range of measures taken to prevent accidents or in the changes of the frequency and/or severity of accidents. The internalization effect of the law is evident in the number of successful court cases and the increase of the density of environmental liability insurance. The number of successful suits shows whether claims for damages can easily be won in court. But it tells us little about the preventive effect of liability. A low number of suits can be both an expression of disinclination to sue, and so regarded as failure of prevention, or as reflecting a reduction in damages. This question can only be clarified empirically through observation of accident data, and this procedure is followed below in this paper.

Numerous studies have previously looked into the prevention and internalization effects of environmental liability law, mostly theoretically. The theoretical literature is generally concerned with transaction costs and the various legal barriers to successful environmental claims of private parties. With few exceptions[1], experts believe that environmental liability is largely ineffective and comparatively costly in reaching its goals (for an overview: Dewees 1992). Empirical findings are also little in favor of environmental liability when it comes to its effects on internalisation and prevention. Ringleb and Wiggins (1990), for example, find evidence on evasion from liability by means of undercapitalisation in the toxic substance transport and disposal in the U.S. In a complementary finding, Ulph and Valentini (2004) show that firms, with limited liability, evidently increased their bank borrowing by 15 to 20% in the face of environmental liability. Austin and Alberini (1999, 2000) examine the preventive effect of environmental liability in a study commissioned by DG ENV of the European Commission. They look at annual changes in state-level emissions reported in the Toxics Release Inventory, relating them to the liability imposed on polluters by state laws, and state characteristics. Their main finding is 'that states' liability policies toward environmental damages may exert some slight, additional pressure to reduce emissions of the most toxic industrial chemicals. The evidence of the effect of strict liability is suggestive but

[1] Katzman (1985) provides examples of safety enhancing effects of environmental liability in the chemical industry while Panther (1992) demonstrates in a rigorous economic model that “environmental liability is an almost ideal instrument to stimulate research and development in environmental safety” (ibid., p. 239).

not strongly significant statistically' (loc. cit., pp. 26/7). In a later study[2] the same authors examine how accidental releases of pollution into the environment (in the U.S.) was affected by the imposition of strict liability on the polluter, using variation across states in the liability provisions of Superfund laws in the period 1987 to 1995. They find that only after explicitly modelling the endogeneity of states' liability laws, strict liability is seen to reduce the seriousness of spills and releases. They also confirm the finding that under strict liability, firms may delegate risky production processes to smaller firms, which are partially sheltered from liability. Blancard and Laguna (2006), in a recent paper, examine the stock market response to 76 petrochemical accidents to find that there is no stock market penalty for chemical substances releases if only ecological damages result. Previous studies on stock market responses to environmental accidents and toxic torts (e.g., Muoghalu, Robison and Glascock (1990), Salinger (1992), Lanoie and Laplante (1994), White (1996), Bartsch (1998), Ananathanaryanan (1998)) discover similar negligible, often only day of announcement effects on stock values with very few exceptions (Bhopal and Exxon Vadez). The latter can be explained by unprecedented, long-lasting lawsuits. Despite this generally discouraging evidence, the EU has, after a ten-year political debate[3], delivered benchmark European rules for environmental liability. The conceptual basis for this law making was the so-called 'Green Paper' of the EU Commission in 1993, which was followed by a 'White Paper' in 2000 and, finally, enshrined into the 2004 EU directive on environmental liability. This directive passed the European legislation in 2005 and is due to be implemented into national law in this year (2007).

Considerable experience with environmental liability has been made in Germany where an early first move towards strict liability has been made in 1990. This paper examines whether the German Environmental Liability Law, which proceeded the EU law making, has been successful in reaching its economic objectives, i.e. whether it led to an internalization of environmental damage and increased standards of accident prevention. The following section reviews the specifics of this legislation and the results that surfaced from it.

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[2] Alberini, A. and Austin, D. H. (2002): Accidents waiting to happen: Liability and toxic pollution releases, Review of Economics and Statistics, Vol 4(4), pp. 729–41.

[3] A comprehensive overview on this history of law making is provided at (http://ec.europa.eu/environment/liability/index.htm).

2. The German Environmental Liability Law and its immediate effects

Germany has a multi-tiered system of environmental liability. Regulation on environmental liability can be found under general civil law (§ 823 of the Civil Code), in the Law on Neighbourhoods (§§ 906, 1004 of the Civil Code) as well as various environmental legislations, e.g. the Federal Water Act (§ 22) and the Federal Soil Conservation Act (§ 24). The Environmental Liability Law (ELL) stands out as it is the only legislation that is expressedly and primarily geared to prevent environmental damages and to internalise social cost. The justification by the legislature on the ELL states that the legislation is intended 'to bring lasting improvement to the legal position of the injured party, inducing those who cause damage to the environment to take efforts'. Moreover, it shall 'impose cost on environmentally damaging production processes, help making the products and services involved more expensive on the market'. It should also 'aid to implement measures to avoid damage where they are most cost-effective'.[4]

The key rule in the law is a strict liability for environmental risk, although it is limited to specific named installations and their operation.[5] Its effect is strengthened by a presumption of causality, making it easier for the plaintiff to bring evidence.[6] The presumption of causality can only be refuted by the defendant with specific arguments that are precisely defined in the law. Chief among them are maintaining 'normal operation', that is, operation without disruption.[7] The injured party's position is also improved in that the ELL requires the plant operator and the environmental authorities to give the plaintiff information to establish his claim. In addition, a mandatory insurance for plant operators ensures that claims for damages can be met. Prima facie, therefore, the ELL would appear to be a stringent and appropriate set of regulations that will achieve its objectives.

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[4] Draft environmental liability law of 1990, Bundestagsdrucksache 11/7104 - Begründung zu A, Allgemeiner Teil (Justification on A, General Section).

[5] The law states: 'If a person is killed, if he suffers physical injury or impairment to his health, or if an item is damaged through an environmental effect caused by one of the plants listed in Annex A the owner of the plant is obliged to compensate the injured party for the injury or damage thus caused'. (§ 1 ELL).

[6] 4 The law states: 'If a plant could be deemed in the circumstances of the individual case to have caused the damage in question it is presumed that the damage has been caused by that plant. Whether a plant may be so deemed will depend in any individual case on its operation, the facilities used, the type and concentration of the substances used and released, the meteorological conditions, the time and place of the damage incurred, the nature of the damage and all the other factors that indicate the cause of the damage in any individual case'. (§ 6, Para. 1 ELL)

[7] § 6, Para. 2 ELL states: 'Para. 1 does not apply if the plant has been operated in accordance with its design and purpose and if no disruption to its operation has occurred'.

A look at the jurisdiction in the last fifteen years disappoints this expectation, however. Since the ELL was passed altogether only six court decisions have been given on the basis of this legislation. Only one was for the plaintiff, while five were for the defendant.[8] The response to this jurisdiction in the legal literature is divided. Some commentators see it as progress, while others complain of stagnation or even regression.[9] In essence, legal practice has not changed in fifteen years, for environmental cases were also rare before the ELL came into force, and few were successful.

By contrast, insurance practice has changed considerably. This applies both to the policy structure and the density of insurance. Whereas in the 1970s the environmental risk was not specified and sometimes just added on to the general third party insurance as a free 'extra', we now find, in the environmental liability insurance model offered by industrial insurers, a differentiated system of insurance for individual plants with strict regulations to prevent the misuse of insurance, and with appropriate amounts to be paid by the claimant (e.g. for damage to his own property). The contract is only signed when a safety audit has been carried out and risk consultations have been given on the spot.[10] Many German industrial insurers have set up their own or independent risk consultancy firms, and developed computerized risk analysis models to be used on the spot, even in small and medium-sized firms.[11] The readiness of companies to take out environmental liability insurance is high, although there has not been a wave of lawsuits. By 2003, insurance policies had been taken out for around 130,000 installations.[12] Insurance is compulsory only for less than 1% of these, in other words almost all the insurance is voluntary. This raises the question how a law, that imposes only a low liability risk on companies, could give rise to such a comprehensive demand for insurance. One possible explanation is that companies are not at all sure of the exact legal implications or the practical consequences of the ELL. This uncertainty is increased by the fact that the ELL is embedded in a dynamic liability and insurance policy context; for example, it is

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[8] Neue Juristische Wochenschrift _ Rechtsprechungsreport 1993, pp. 598ff; Versicherungsrecht 1995, p. 551; Neue Juristische Wochenschrift 1997, pp. 2748ff; ibid 1998, pp. 3720ff.; ibid, Rechtsprechungsreport 2002, pp. 26ff.

[9] Salje (2000) concludes that 'the efforts of the Federal Environment Ministry to extend the concept of liability for hazard on the ground and in the air have not borne fruit', while Wagner (1998) sees the one successful case as a 'valuable guideline in the process of environmental liability,' but Gottwald (1992) believes that the ELL has given plaintiffs 'stones not bread.'

[10] For more details see Schwarze (1997), pp. 331-353.

[11] Cf. e.g. Vogel (1995), pp. 1207-1212.

[12] A total of 104,915 insurance contracts has been reported to the German Insurance Association in 2003. Based in the market shares of the non-reporting firms it can be set at 128,070 contracts in that year. The number of installations must not be confused with the number of plants. Most plants, e.g. in the chemical industry, compass a large number of installations and, thus, carry several insurance contracts for that purpose.

backed up by numerous new regulations on firm owner and product liability. For example, the Law on Control and Transparency (KonTraG) of 1998 introduced a directors' liability for a breach of the duty to establish an organizational 'early warning system' to detect business risk, including environmental liabilities, at the earliest possible stage.

In the immediacy of the ELL, several empirical analyses of its preventive effects were undertaken. Feess-Dörr, Prätorius and Steger (1992) examined companies' strategies to cope with environmental liability risks before the introduction of the new law and changes in view of the introduction of environmental liability. They used structured interviews in ten large chemical industry plants between November 1988 and January 1989. Their most important results are:

1. The companies questioned were not planning any fundamental changes to their risk provision for their plants, production and products. Nor would their present efforts in this field be intensified in view of the coming legislation, as they regarded their present safety level as already very high.
2. Companies varied in their estimate of the need for additional risk provision. While big companies pointed to their functioning safety management, some smaller and midsize firms still saw considerable shortcomings here. But in the view of the firms themselves this was chiefly a result of shortcomings in implementing the existing legal requirements.
3. Companies expected the more stringent liability requirements to involve growing expenditure to deal with environmental ligitation with a rise in claims for damages. As a result, the ELL was only expected to bring changes in damage regulation but not in damage prevention.

Several studies undertaken for the European Commission have examined the economic effects of environmental liability.[13] In the study on Germany (Kuepper 1996), a survey was carried out of the investment behavior of firms in the iron, sheet metal and metals processing industry in view of the new ELL. The most important result is that, with the high level of investment already reached, the ELL did not give rise to any additional voluntary environmental protection investment.[14]

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[13] See http://ec.europa.eu/ environment/liability/background.htm.

[14] Voluntary environmental protection investment in this study is investment 'not enforced by the legislature (emission protection, industrial supervision etc.)'.

Herbst (1996) examined the stimulus to companies' risk policy from the ELL. This study is based on surveys of industrial firms and associations from 1992 to 1993. It showed that only a few companies were expecting the changes in the liability norms to lead to changes in production or an improvement in corporate risk policy. This scepticism was based on the widespread separation of liability and safety technology in companies' organization, and on the fact that the legislation on environmental liability only covers a small part of environmental damage (less than 1% of the average pollution costs).[15]

Bartsch (1998) analyzed the movements in share prices after three major events connected with the ELL. They were the Sandoz accident of 1986, the announcement of more stringent environmental liability in Germany in 1989 and the passing of the Environmental Liability Law in 1990. The author examined the share prices of selected firms in the chemical industry that might be assumed to be particularly strongly affected by more stringent environmental liability requirements. The two most important results of the study are:

1. The prices of the shares of the companies affected did not show any significant deviation from the normal trend close in time to the events named.
2. The investment risk in buying chemical industry shares did not change significantly close in time to these events.

Schwarze (1998, 2001) measured the preventive effect of the ELL on the basis of the trend in damages claims and accidents in environmental liability insurance and the trend in accidents reported to the Central Registration Office for Breakdowns and Accidents in Industrial Installations (ZEMA) at the Federal Environment Agency (FEA). This study showed that the likelihood of accidents fell from 1993 to 1997, while at the same time take up of the new environmental liability insurance accelerated. However, this result faced critique because of the very short time period on which it is based (Salje 1999). Table 1 gives a survey of these early results.

[15] The share is actually less than 1% of total environmental protection costs, which in turn only account for a small part of a company's total costs (less than 5%).

Table 1: *Empirical Analyses of the Preventive Effect of the Environmental Liability Law*

Author(s)	**Period**	**Method**	**Sample**	**Results**
Feess-Doerr, Praetorius, Steger (1992)	1988-1989	Questions on risk provision and expected liability	10 largest chemical firms	No changes in risk provision as present safety level is high, but expected raise in claims
Kuepper (1996)	1991-1994	Questions on investment in environmental Protection	30 firms in the iron, sheet metal and metals processing industry	No additional voluntary environmental protection investment
Herbst (1996)	1992-1993	Questions on risk provision and insurance practice	27 firms in industry and insurance	No changes in production or risk provision as liability and production are organised separately and costs of liability are not considerable
Bartsch (1998)	1986-1993	Movements in share prices after events related to the ELL	Chemical industry	No significant influence on share prices and profit expectations, no increase in investment risk
Schwarze (1998)	1993-1997	Trends in industrial liability for damage and breakdowns, correlation with the spread of environmental insurance	Insurance industry statistics on damage, Federal Environment Agency and StatBA statistics on breakdowns	Significant decline in frequency of breakdowns correlates with the acceptance of the environmental liability insurance model

3. The effects of the German Environmental Liability Law after fifteen years

In this section, we look at the effects of the German ELL based on longer period (15 years) and new data available from the insurance industry and the FEA. The insurance data is of a leading German industrial insurer. It gives the annual premium turnover in the branch of environmental liability insurance (ELI) based on the new environmental insurance policy (decribed above). The market turnover of this policy has been estimated on the basis of the market share of this insurer. The new ELI was introduced in 1993 by the German Insurance Association and consequently adopted by all national and foreign insurers in the German market. It can be seen as the institutional transmitter of the ELL into the 'world of insurance and business'. The series of insurance premiums covers a time period of fifteen years (1988 to

2002), five years of which report the premium income of the pre-existing policy (1988-1992), while ten years are based on the sale of the new ELI (1993-2002). The ZEMA statistics of the FEA reports the number of accidents with release of dangerous substances into the plant's environment as defined in Annex VI, Part 1, of the German Breakdowns Ordinance (Stoerfallverordnung). Accidents of this sort are rare in Germany (about ten per year on average) but they are reliable as a source of data because of the fact that they are backed by publicly available single accident reports in the internet (http://www.umweltbundesamt.de/zema/download.html).

Figure 1: Insurance Premiums and Number of Accidents (1988-2006)

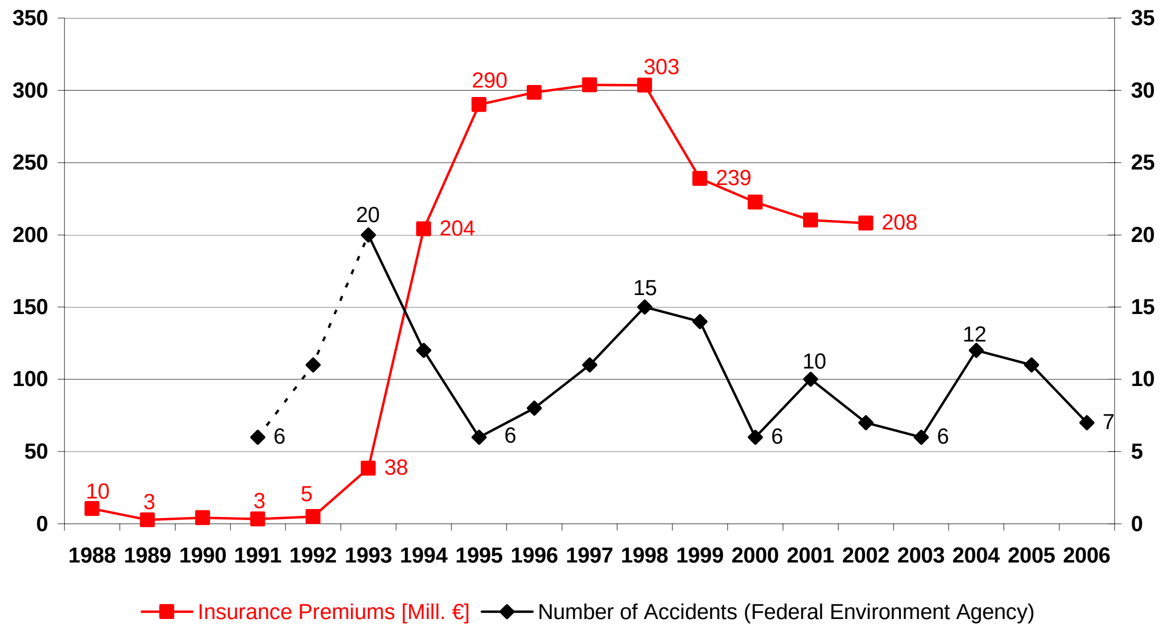


Figure 1 depicts both time-series for the period of 1991 to 2006. The development of insurance premiums shows a strong path-dependency. The huge rise immediately after the introduction of the ELI from 1993 to 1995 seemingly led to an overshooting and subsequent readjustment in the second half of the 1990s. After a maximum was reached in 1997, the amount of the premium lowered, probably because the insurees corrected their demand in the light of the unchanged number of successful court suits, or because emerging competition on the market for ELI forced the insurers' to lower their mark-ups on market prices.[16] The time

[16] Indeed, in 1999 a giant U.S. industry insurer (AIG.) introduced a new, more costumer-orientated policy (covering seld-sustained damages to soils) into this so far self-regulated, German insurer dominated line of insurance. This so-called 'Bodenkasko' was then quickly adopted and even extended by several German insurers. See Ruetz, N. (2001) for the full story.

series of accidents shows an initial strong increase of reported events in the set-up and enforcement period of this new reporting duty from 1991 to 1993. The ZEMA supposes that it is the result of the initial improvement of the survey methods.[17] Since that time the number of reported events follows an oscillating path with diminishing amplitude. A slightly downwards sloping trend can be observed. However, part of this trend might be the result of a major change of reporting rules, which occurred in 2000, following the implementation in Germany of the SEVESO II-directive of the European Union[18], the effect of which was an immediate decrease in the number of reported events. [19]

To summarize, we see indeed a strong increase in premium turnover following the introduction of new liability rules into the 'world of insurance and business' (1993). An effect of the reform on the number of accidents, however, is difficult to observe on first sight. In the following, we will improve our understanding of the distortions in the data and the processes driving the firms' efforts for accident prevention and find strong evidence for such effect on the basis of econometric techniques.

3.1. An economic model of accident prevention

For modelling the impact of the ELL on accident prevention, we assume that a firm's cost of prevention of environmental accidents (*C*) is a convex function of prevention efforts (*X*), such as

(1) $$C = \frac{b}{2} X^2, \quad \text{with } b>0.$$ [20]

[17] ZEMA: Jahresbericht 2004, Berlin, 2006, p. 7.
[18] Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances (avaiable at: ec.europa.eu/environment/seveso/index.htm)
[19] There is a good reason to expect the number of accidents reported to decrease as a result of the new reporting rules as the reporting unit has been changed to the higher, more aggregated level of sector of production ("Betriebsbereich") compared to the previous reporting of installations ("Anlagen"). A sector of production usually contains a large set of installations. However, the change in accidents reported after 2000 can also be due to other reasons.
[20] We chose a generalized functional form to simplify our theoretical exposition in this paper and to allow for a smooth econometric approach. This is conducted in a way to avoid any loss of generality of the results.

Furthermore, we assume that prevention reduces the expected loss arising from the liability to compensate for environmental damage caused by the firm (L). We describe this relationship by the cost function

(2) $L = e^{\gamma R - \alpha X}$, with $\alpha>0$ and $\gamma>0$.

R measures the strictness of the legal framework. The higher is R, the more restrictive is the environment liability legislation and the higher is the firm's loss in case of an accident at any given level of prevention. Moreover, in a stricter legal framework, firms can avoid a greater loss by extending prevention by one unit. As firms seek to minimise total costs, $TC=C+L$, they chose an equilibrium level of prevention, X^*, at which the marginal cost of prevention equals the negative marginal expected liability:

(3) $$\min_X TC \Leftrightarrow \frac{\partial C}{\partial X} + \frac{\partial L}{\partial X} = 0 \Leftrightarrow \log X^* + \alpha X^* = \log \alpha - \log b + \gamma R\,.$$

We assume that firms lack the informational capacities for assessing the true expected loss resulting from potential environmental accidents. This risk assessment is the primary competence of insurance companies. They translate the expected cost arising from being held liable for environmental damages into insurance premiums which they deduct from insurees. Hence, from the firm's perspective, the prevention level X^* is not directly dependent on R, but transmitted by the premium, L, reflecting the expected liability in a given legal environment for a given level of prevention. In the equilibrium, insurers impose the premium $L^*=L(R,X^*)$ and firms set their equilibrium level of prevention on the basis of that premium: $X^*=X^*(L^*)=X^*(L(R,X^*))$. In the short run, however, the premium is determined on the basis of the *currently* observed prevention level and firms decide upon their prevention activities on the basis of the premium *currently* imposed. We define the premium set in the short run as $L^S=L(R,X^S)$, where X^S is exogenous to the insurers. The short-run prevention level is $X^S=X^*(L^S)$, where L^S is exogenous to the firm. We obtain this latter function by solving equation (2) for γR and putting it into equation (3).

(4) $$\log X^S = \log \alpha + \log L^S - \log b \Leftrightarrow X^S = \frac{\alpha}{b} L^S$$

Differentiating over L^S, we obtain the short-run change in prevention:

(5) $$\mathrm{d}X^S = \frac{\alpha}{b}\mathrm{d}L^S .$$

The short-run change in expected liability is given by the total differential of equation (2) over R and X^S:

(6) $$\mathrm{d}L^S = \frac{\partial L^S}{\partial R}\mathrm{d}R + \frac{\partial L^S}{\partial X^S}\mathrm{d}X^S = \gamma e^{\gamma R - \alpha X^S}\mathrm{d}R - \alpha e^{\gamma R - \alpha X^S}\mathrm{d}X^S .$$

As we see from equation (6), the overall change in expected liability can be decomposed into a legal and a preventive effect. The legal effect is represented by the first summand and measures the change in expected liability under the condition that the prevention level remains constant. The prevention effect is represented by the second summand and measures the change in expected liability purely caused by changes in the firms' prevention levels.

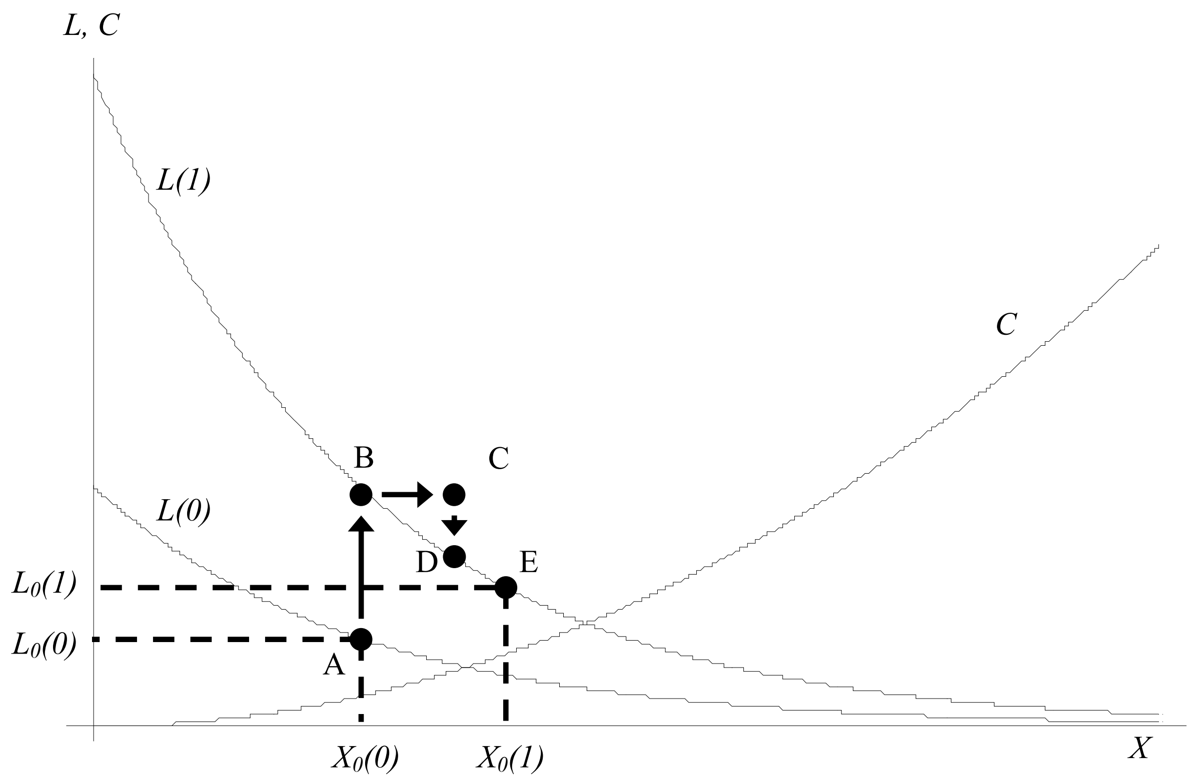
The equations (5) and (6) reveal the reciprocal nature of the adjustment process. Companies adjust their prevention levels to changes in the premium levels while insurance companies consequently take this adjustment into account in the determination of the premiums. From this follows a dynamics which is caused by a sequence of changes:

- In the *first stage*, as an immediate consequence of the ELL reform, the expected liability and the degree, to which liability can be avoided by means of prevention, increases for each level of prevention. Accordingly, the liability curve in figure 2 shifts from *L(0)* to *L(1)*. As a consequence, insurers impose a higher premium, even though the prevention level remains the same. The arrow AB represents this direct legal effect.
- In the *second stage*, companies realise that they can save costs by extending their accident prevention, because the expenses for additional prevention efforts will be overcompensated by the reduction of the expected loss in case of an accident, as signalled by the premium they pay.[21] This behavioural adjustment is represented by the arrow BC.
- In the *third stage*, insurance companies, under the pressure of competition, notice that they can reduce their premiums – and thereby achieve an advantage to their competitors – because expected liability has lowered as a result of the increase in prevention. Accordingly, the premium level falls from C to D.

[21] Throughout this paper we assume that premiums are fair, i.e. reflecting expected damages. There are no loadings except for temporary rents that result from a lagged adjustment of premiums to the reduction in the number of industrial accidents (explained below).

If, after this adjustment, companies realise that the marginal expected liability, in absolute terms, is still higher than the marginal cost of prevention, they further extent their precautionary efforts, and the stages 2 and 3 will be repeated until the point E is reached. In that point, the marginal expected liability equals the negative marginal cost of prevention, and the insurance premium accurately reflects the expected loss to be covered in case of an accident.

Figure 2: *Adjustment of insurance premiums and prevention efforts*



3.2. Data

We measure the expected liability, *L*, to the average firm in terms of the total of insurance premiums firms paid each year for the ELI police offered by a leading German industry insurer (see figure 1).[22] This time series has one unit root, which is confirmed by the Dickey-

[22] We thereby abstract from possible effects on the aggregate insurance premium which could eventually result from the change of the size of the sector of firms facing a positive risk of being assumed liable for environmental damage. An increase (a decrease) in the total of insurance premiums can be interpreted as either higher (lower) prices for any given contract or an increase (decrease) of the rate of coverage, e.g. extended or new sold

Fuller (p-value: 0.163) and Phillips-Perron tests (p-value: 0.736).[23] Its first difference is autoregressive of order one. The autoregression coefficient, in the following *ρ,* amounts to 0.44. A t-test on this coefficient leads a p-value of less than 0.1. Accordingly, we assume the following data generation process:

$$(7) \qquad \Delta \log L_t = \rho \Delta \log L_{t-1} + u_t \Leftrightarrow \log L_t = \log L_{t-1} + \rho(\log L_{t-1} - \log L_{t-2}) + u_t \ ,$$

where u_t is distributed with zero mean and constant variance. No serial correlation has been found in u_t. The process described by equation (7) is typically caused by adaptive expectations, as they often occur, for example, in stockkeeping or investment decisions (Metzler 1941). Insurance companies do not immediately adjust their premiums from one period to the next. Instead, in period *t*-1, the premium level of the next period, L_t, is chosen by taking into account the change in the period before, which is (log L_{t-1}−log L_{t-2}). u_t represents the 'innovation', e.g. the component of the premium which is independent from the development in the past.

We use the number of accidents (A_t), reported to the monitoring agency ZEMA, as an inverse indicator for the level of prevention:

$$(8) \qquad A_t = c - X_t ,$$

where *c* represents some hypothetical base level of accidents to be expected if no prevention would be undertaken at all. The time series of the accidents is free from auto-correlation both in levels and differences.

R, the strictness of environmental liability regulation, is modelled by means of a jump function which is 1 from 1993 onwards and 0 in the years before. As noted above, the year 1993 can be regarded as the point in time where the new liability regime (of 1990) was translated into 'the world of insurance and business'.

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insurance policies, in the sector. In both cases, the average premium to be paid by a firm in that sector rises (falls).

[23] Of course, the size of these p-values should be interpreted with care, as these tests are based on only 15 observations. However, the shape of the curve in figure 1 strongly supports our belief that the time series of the insurance premium is integrated.

3.3. Econometric specification

Equation (2) expresses the dependence of the insurance premium on the legal rules and prevention levels. Using the number of accidents as an indicator of prevention, it turns into

(9) $$\log L = \gamma R - \alpha c + aA$$

Taking into account the nature of the data generation process, as described in equation (7), we estimate equation (9) in first difference and include the lagged values of $\Delta\log L_t$:

(10) $$\Delta \log L_t = \gamma \Delta R_t + \alpha \Delta A_{t-1} + \rho \Delta \log L_{t-1} + u_t \, .$$

We thus assume the premium level to react to changes in the number accidents that occurred in the year before.

The relationship between the change in insurance premiums and the firms' efforts for accident prevention is described by equation (4). We use A_t as an indicator of these prevention efforts, (see equation (8)) and define $\beta=-\alpha/b$. Furthermore we generate a jump variable, B_t^{00}, which is equal 1 from the year 2000 onwards and 0 in the years before, in order take into account a structural shift in the time series of accidents in 2000, possibly resulting from the change of reporting rules. We estimate equation (4) in first difference, in order to cope with the non-stationarity of the logarithmic premium levels also in that regression,[24] and assume that firms adjust their prevention to premiums with a time lag of one year. The resulting econometric model is given by

(11) $$\Delta A_t = \beta \Delta \log L_{t-1} + \delta \Delta B_t^{00} + v_t \, .$$

γ in equation (10) represents the change taking place in the *first stage* of the adjustment process described above, caused purely by the modification of the legal framework. β in equation (11) represents the effect of the *second stage*, in which firms adjust their prevention efforts to the change of the premiums. Finally, α in equation (10) is associated with the *third*

[24] Initially, we also included a one-period lag of $\Delta\log L_{t-1}$ as an independent variable. Its coefficient turned out to be insignificant at the 10-percent level (p-value: 0.829).

stage and measures the degree to which insurers readjust their premiums to the changed prevention levels under the condition of a stable legal environment.

3.4. Results

For the estimation of the legal effect on the premium level, γ, we can use all observations in L, including the years from 1990 to 2002. By contrast, the observations available for the estimation of α are limited to the shorter time span, during which the time series of L and A overlap. For not loosing information on the former effect, we split equation (10) into two separate equations: one in which α, another in which γ is restricted to zero. They are estimated simultaneously together with equation (11) as a SURE system.[25] The results are presented in table 2. They reveal that one percentage point of growth of the ELI premium leads, on average, to the prevention of 0.038 environmental accidents. In turn, each avoided accident makes the insurance premium fall by 3 percentage points. The immediate legal effect on the logarithmic premium, at given prevention level, is estimated to be 1.82. This implies an increase of the insurance premium by 5.23 ($e^{1.82}$-1) times as an immediate response to the introduction of the ELL in 1993.

Table 2: Regression results

	Equation 1	Equation 2	Equation 3
Dep. var.	$\Delta \log L_t$	ΔA_t	$\Delta \log L_t$
ΔR_t	1.829721 ***	/	/
ΔA_{t-1}	/	/	0.030291 **
$\Delta \log L_{t-1}$	0.470226 ***	-3.756379 ***	0.470226 ***
ΔB_t^{00}	/	-9.040491 ***	/
R^2	0.620	0.682	0.833
Obs.	13	10	9
Period	1990-2002	1994-2003	1994-2002

***/ **/ *: significant at the 1/ 5/ 10 percent level.

The predicted development from 1993 to 2002 is shown in table 3. It is based on the models

$$(11) \qquad \Delta \log \hat{L}_t = \gamma \Delta R_t + \alpha \Delta \hat{A}_{t-1} + \rho \Delta \log \hat{L}_{t-1}$$

[25] Note that the residuals from the two equations based on (10) and from equation (11) are supposed to be correlated. The equality of the ρ in the two equations based on (10) has not been refuted by a Wald test on the 10 percent level (p-value: 0.192). It has been restricted to equality in the final regression.

and

(12) $\Delta \hat{A}_t = \beta \Delta \log \hat{L}_{t-1}$,

with t=1, 2, ..., 10 and $\Delta\log L_0=0$ and $\Delta A_0=0$,

It thus documents the change in the number of accidents, which we would expect if the old reporting rules had been applied during the entire period of time. A rapid growth of the premium is predicted for the first years after the reform. It levels off in the following time and becomes negative after 1996. The number of accidents falls from 1994 onwards. The absolute yearly changes steadily diminish, and after 1998 they are even positive, though small, corresponding with the fall of the premium level during that time. In 2000 and the following years, the predicted growth of the ELI premium amounts to less than 0.1 percent, and the change in the expected number of accidents per year is less than 0.01. The adjustment process induced by the reform can thus be regarded as completed in that year.

Table 3: Predicted development of accidents and insurance premiums in response to the ELL

t	year	ΔR	ΔA_t	$\Delta\log L_t$	$\Delta L/L$ [%]
1	1993	1	0.000	1.8297	523.2
2	1994	0	-6.646	0.8604	136.4
3	1995	0	-3.125	0.2033	22.5
4	1996	0	-0.738	0.0009	0.1
5	1997	0	-0.003	-0.0219	-2.2
6	1998	0	0.080	-0.0104	-1.0
7	1999	0	0.038	-0.0025	-0.2
8	2000	0	0.009	0.0000	0.0
9	2001	0	0.000	0.0003	0.0
10	2002	0	-0.001	0.0001	0.0

How much lower is the number of yearly accidents in the pre-reform compared to the post-reform equilibrium? Putting the estimated coefficients into equation (3), we obtain a prevention level of 3.4 before (R=0) and of 14.9 after the reform (R=1). Thus $\Delta X^* = -\Delta A^* = 14.9 - 3.4 = 11.5$. After 2000, the year which we identified as the point where risk prevention has attained its new equilibrium, the average number of accidents per year, published on the basis of the *new* reporting standards, is 8.4. These should be 8.4 + 9.0 = 17.4 accidents if the *old* reporting rules were applied. Accordingly, we would have observed on average 29 accidents per year before the introduction of the ELL, provided that the ZEMA had effectively carried out its surveillance at that time.

4. Conclusion

The Environmental Liability Law (ELL) has partly achieved its declared objectives. It has brought a fundamental change in insurance practice while legal practice has remained largely unchanged. With the high density of insurance now reached, the internalization effect of environmental liability insurance is considerable. Its effect on accident prevention is evidently positive but works through a staggered process of interaction between insurees and insurers. This process occurs in exactly the way that the economic model proposes, i.e. higher premiums and/or a greater take out of insurance policies incite firms to increase their effort to reduce environmental accidents. This result is challenging the common belief that insurance as an 'institution in the middle' is reducing the preventive incentive of liability. Based on our findings, it is the premium signal of insurers which ultimately triggers the signal of increased environmental liability to the target group of industry and makes them move towards greater precaution. However, the path of adjustment to the post-reform equilibrium is driven by adaptive expectations on the side of the insurer. They lead to an overshooting of the insurance premium in the first years after the reform. The increased precaution of firms is taken into account in their determination with a time lag, so that it takes seven years until the information about the equilibrium premium and precaution levels is readily processed and the new equilibrium reached. This slackening intermediation between regulation and business response is supposed to create a temporary rent to the insurers.

Interestingly, this preventive effect of insurance works out even if it is decoupled from the legal underlying. Assuming that legal practices remained unchanged by the ELL so that environmental claims are difficult to make and often unsuccessful, we have an interesting legal-political effect: a legal impetus which, taken by itself, has little or no real impact, but by being situated in a thriving legal and insurance context is able to shape expectations in a way that the intended effects are nevertheless achieved. Such kind of self-fulfilling prophecy is well known in the field of monetary policy ("money illusion") and can be long-lasting.[26] The precondition for this effect to occur in a legal context is that the legal practice, which flows from the law, is uncertain.

[26] Fehr and Tyran (2001, 2006) show in series of experiments that different effects of money illusion can cause lasting nominal price inertia.

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Onno Hoffmeister and Reimund Schwarze

The winding road to industrial safety. Evidence on the effects of environmental liability on accident prevention in Germany.

Abstract
The German Environmental Liability Law (ELL) of 1991 has introduced far-reaching civil liability for environmental damages with the aim to increase firms' efforts to prevent accidents. Previous studies find poor evidence that this goal has actually been achieved. One and a half decades after the introduction of that law, we undertake a new attempt to investigate the impact of the ELL on accident prevention.

Our analysis is based on annual data on the number of environmental accidents per year, reported to the monitoring agency ZEMA, and the risk premium imposed by a large German insurer on environmental liability insurance (ELI). As reliable accident reporting has begun only after the implementation of the new law into practice, pre- and post-reform levels of accident prevention cannot be directly compared. However, the time series of ELI premiums cuts across these two periods. Once we examine the relationship between the ELI premium and accident prevention and observe the effect of the reform impulse on the former, we are able to model the dynamics of the adjustment process induced by the ELL.

According to our results, the average number of environmental accidents per year has decreased from 29 before to 17 and a half after the reform. Our dynamic analysis reveals an overshooting of the insurance premiums in the first years after the reform and a successive decrease from 1997 onwards. The premiums and firms' prevention efforts achieved a new equilibrium in 2000.

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