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## Economic consequences of the German environmental liability act: Capital market response for the chemical industry

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# Kiel Working Papers

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ECONOMIC CONSEQUENCES OF THE GERMAN ENVIRONMENTAL  
LIABILITY ACT – CAPITAL MARKET RESPONSE FOR THE CHEMICAL  
INDUSTRY

by  
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## **Abstract**

The Environmental Liability Act (Umwelthaftungsgesetz) enacted January 1, 1991 is claimed to have substantially tightened the environmental liability regime in Germany. The economic consequences of the amendment of the German environmental liability legislation initiated by the Sandoz accident are investigated for a portfolio of firms in the chemical industry. By means of an event study it is determined whether the UmweltHG has led to a revision of expectations regarding the profitability of the German chemical industry. If sizeable precautionary pollution control measures and liability payments were to be induced by the UmweltHG, both the returns and the risk attached to investing in the chemical industry should be negatively affected. The findings of this study, however, do not indicate that the German Environmental Liability Act induced such a negative impact on the chemical industry.

## 1. Overview

In January 1991, the Environmental Liability Act (Umwelthaftungsgesetz, UmweltHG) brought about what was thought to be a major change in the German environmental liability regime. The UmweltHG introduced a strict liability for damages caused by the pollution of certain environmentally significant facilities.<sup>1</sup> The strict liability covers air, water and soil pollution. Moreover, the law reverses the burden of proof and provides for a causality presumption such that if the operation of a certain facility is inherently suited to cause the harm incurred, it is presumed that this facility has actually caused the damage, unless the facility's operator can prove otherwise. In addition, the UmweltHG provides the claimant with a right to obtain certain information from both the operator of the facility and government authorities (Hoffman 1991). Given these far-reaching provisions, the Federal government expected the law to constitute an effective means of preventive environmental policy. Six years after the introduction of the UmweltHG, the question arises to what extent these ambitions have been accomplished.

The UmweltHG is subject to a substantial debate both from a legal and an economic perspective. From a legal point of view, the interpretation of the UmweltHG diverges until the present. Some scholars take the view that the law brought about a dramatic legislative change (e.g. Schmidt-Salzer [1996, 63]). Others doubt that liability for environmental damages has in fact been tightened by the UmweltHG (e.g. Hoffman [1991, 28]). From an economic point of view, it is debated whether civil liability for environmental damages constitutes an appropriate means of preventive environmental policy. Whereas Siebert [1991] argues that liability can generate ex ante incentives to take precautions against uncertain environmental damages, for instance Schwarze [1996, 100 ff.] takes

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<sup>1</sup> Note, that rather than the compensation paid by the defendant 'damages' refers to the harm incurred. Compensatory payments will be referred to as 'liability payments'.

the view that various obstacles to the enforcement of legal claims prevent the civil liability from having significant allocative effects.

The purpose of this paper is to evaluate the economic consequences of the legislative change brought about by introduction of the UmweltHG. In order to do so, ideally it were necessary to obtain data on precautionary pollution control measures and estimates of the environmental risk generated at the firm level. Although, a rough measure could possibly be deduced from environmental protection investments and reserves appropriated for environmental protection as stated in the balance sheets, accounting data suffers from several shortcomings. First, it is often impossible to separate environmental protection items. More importantly, however, the evaluation of balance sheet positions differs from economically correct costs. Under German accounting and tax law numerous choices left to the firm's management as to the evaluation and the appropriation of reserves for environmental protection. Alternatively, the consequences of the UmweltHG could be assessed by looking at actual compensation as recorded in legal disputes. Recorded legal disputes, however, remain confined to ex post compensation which is estimated to correspond to approximately one per cent of actual environmental damages in Germany.<sup>2</sup> Furthermore, recorded legal disputes omit substantial out-of-court settlements (Feess-Dörr, Prätorius, Steger [1992, 39]). So far, no legal dispute of litigation where compensation was claimed under UmweltHG has been recorded. In the so-called PCB-case the UmweltHG only served as a reference. The court decision was not based on the UmweltHG since the emitting plant was not among those listed in Appendix 1 to the Act (Hohloch [1994, 20]). The observed lack of claims under the UmweltHG could point to the fact a failure of the law to provide a means of environmental protection. Alternatively, it could imply that the UmweltHG provides such a clear-cut legal framework, that parties settle their legal disputes out of court.

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<sup>2</sup> Neue Züricher Zeitung, February 2, 1996 *Umwelthaftung ein immer dringlicheres Thema.*

In order to circumvent, the lack of appropriate data, this paper adopts an event study approach and uses capital market data to assess the impact of the UmweltHG's legislative change. The event study presented in this paper evaluates the stock market response of the German chemical industry to a series of events related to the change in the German environmental liability regime. It is first analysed whether the expected profitability of chemical firms has been affected by the revision of the legal framework. If the UmweltHG induced additional precautionary measures to be implemented and if firms would now face sizeable liability payments, one should observe a decline in the returns to chemical stocks. Secondly, it is examined whether the risk attached to future profits in the chemical industry has been affected. If firms were facing a substantial liability risk due to the UmweltHG, one should see an rise in the investment risk attached to chemical stocks.

So far, no empirical study on the stockmarket response of environmental policy issues has been carried out for Germany. Yet, a number of event studies on environmental issues have been conducted for the United States.<sup>3</sup> Some studies however fail to discern a negative impact on the industry under study contemporaneous to an amendment in environmental law. Whereas, e.g. Doyle [1985] finds a negative impact of the EPA Air Pollution Regulation on the copper industry, the same regulation had a positive effect on returns in the cement industry. This somewhat surprising result that the profitability has increased is also obtained by Maloney, McCormick [1982]. Maloney, McCormick find that the textile industry's stock value rose with the introduction of the OSHA cotton dust standard. Similarly, an increase in the stock value of non-ferrous metal smelting plants occurred at the time of a major air pollution control ruling by the Supreme Court. For environmental litigation similar positive abnormal returns are observed as the legal dispute evolves. Investigating a series of events in

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<sup>3</sup> Wallace, Watson and Yandle [1988], Moreschi [1990] for water pollution regulations and Muoghalue, Robison and Glascock [1990] or Laplante and Lanoie [1994] for environmental litigation.

the highly publicised Agent Orange and Diethylstilbestrol (DES) litigation, Viscusi and Hersch [1990] find a substantial negative impact of the announcement of litigation. But as the litigation continued positive abnormal returns were found, e.g. at the announcement of the settlement amount. For large scale environmental accidents, typically an adverse impact on the stocks of firms other than one subject to the incident, is only observed once the market starts to expect a revision of safety regulations. As to the impact of the Bhopal accident on the stock market performance of US chemical firms other than Union Carbide Blacconiere, Patten [1994] found a significant negative stock market reaction. Thus, even if abnormal returns are identified that are associated with an environmental policy incident, these abnormal returns do not necessarily indicate an decline in the profitability as conventional wisdom would suggest.

The remainder of this paper proceeds as follows. A first attempt to evaluate the role of environmental liability is made in Section 2. Section 3 describes the event study methodology used here. Section 4 presents the empirical analysis of the stockmarket response for the German chemical industry. Section 5 concludes.

## 2. A First Evaluation of the Role of the UmweltHG

### a. *Civil Liability Prior to the Enactment of the UmweltHG*

As to the role of environmental liability prior to the UmweltHG compensation was mainly claimed under Section 22, par. 2 of the Water Resources Act (*Wasserhaushaltsgesetz*, WHG, Feess-Dörr, Prätorius, Steger [1992]).<sup>4</sup> According to Feess-Dörr, Prätorius, Steger [1992], the negligence-based tort

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<sup>4</sup> Surprisingly, no instance was reported where a claim was made under Section 22, par. 1 WHG. Thus, despite the heated public debate on liability based on conduct (*Handlungshaftung*), it does not seem to relevant in practise (Feess-Dörr, Prätorius, Steger [1992, 41]).

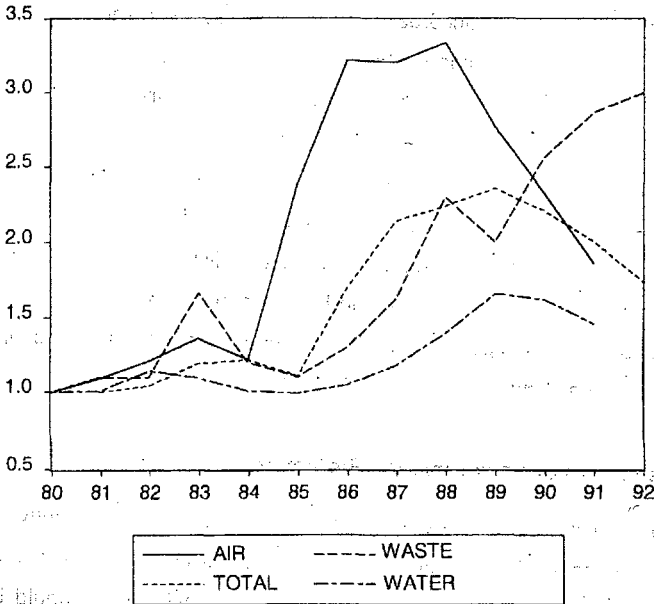


provisions of the Civil Code (*Bürgerliches Gesetzbuch*, BGB) do not bear much relevance for environmental damages. The reason for the prevalence of the WHG is seen in the strict liability it provides for in contrast to the tort law provisions which are based on negligence. The role of the strict liability rule is also supported by the evidence on litigation under the private nuisance law which also follows a strict liability rule. Although under German nuisance law claims are restrained by the requirement of land-related damages, the confinement to neighbourhood, and non-accordance with local use, nuisance claims are prominent vis-à-vis the negligence based tort rules. To sum up, prior to the enactment of the UmweltHG environmental litigation concentrated on water pollution. The prominence of water pollution could be due to the strict liability rule applying to water pollution. In addition, the characteristics of water pollution which are alleviated to prove causation compared to air pollution might have played a role. Therefore, the extension of strict liability to air pollution and soil contamination by the UmweltHG should have a substantial impact on environmental litigation. This impact is further enhanced by the causality presumption introduced by the UmweltHG.

**b. *The Pattern of Environmental Protection Investment***

If the UmweltHG has generated substantial precautionary incentives, this should be reflected by the pattern of environmental protection investment. In particular, an increase in environmental protection investment should be observed prior to the enactment of the UmweltHG in 1991. Moreover, such an increase should be mainly found for air pollution control and waste management (taken as a proxy for soil contamination) since for water pollution a strict liability already applied before. A rise in water pollution control investment would point to the importance of UmweltHG provisions other than the strict liability rule, such as the causality presumption. Figure 1 shows an index of the environmental protection investment undertaken by the private sector.

Figure 1 — Pattern of Environmental Protection Investment in Real Terms by Different Environmental Media in the Private Sector, 1980-1992, (1980 = 1.00)



Source: Own calculation.

During the pre-enactment period 1987-1990, air pollution control investments were falling rapidly in real terms. Since air pollution is the dominating environmental protection investment by the private sector, total environmental protection investment also started to decline beyond 1988. Water pollution related investments were approximately constant during the pre-enactment period. Only waste management related investments increased from 1989 onwards. These stylised facts do not suggest that the UmweltsHG generates sizeable precautionary incentives for air and water pollution. Only for waste related investment

a hike contemporaneous to the revision of the German environmental liability legislation can be noted. However, the observed pattern is not exclusively determined by the UmweltHG. Waste related environmental protection investment is also shaped by the 1986 amendment to the Waste Act (*Abfallgesetz* AbfG) and the Packaging Ordinance (*Verpackungsordnung*) of 1991. Substantial additional precautions might not have been induced because of the stringent German environmental protection standards already in place. Yet, under the UmweltHG's strict liability further economic consequences could be brought about by the liability payments polluter face even they took adequate precautions. The event study presented in the following is able to identify such an impact of the UmweltHG even if no additional precautions were taken.

### 3. The Event Study Methodology

This section briefly outlines the event study methodology adopted in this paper. Basically an event study investigates the relationship between stock prices and economic, political, or legislative events.<sup>5</sup> It starts out from the premise of rational expectations which implies that an unanticipated event affects investors' expectations regarding the future profitability of firms' (Fama [1970], [1976]) and hence stock prices (Schwert [1981, 123]). In this study the (single index) market model is used to characterise normal returns in the absence of the event (Strong [1992]). The market model presumes a linear relationship between return of a given security and the market return

$$[1] \quad R_{it} = \alpha_i + \beta_i R_{mt} + v_{it} \quad \text{with } i=1, \dots, N \text{ and } t=1, \dots, T,$$

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<sup>5</sup> The event study method was first described by Fama, et al. [1969]. An early discussion of the use of capital market data to measure the effects of regulation is given by Schwert [1981]. An overview of the methodological issues is provided, for instance, by Henderson [1990] and Strong [1992]. The simulation studies by Brown and Warner [1980], [1985], Dyckman, Phibrick and Stephan [1984], Collins and Dent [1984] and Bernhard [1987] point to some of the econometric problems involved.

where  $R_{it}$  denotes the return on security  $i$  in period  $t$  and  $R_{mt}$  the return on the market index. The regression coefficient  $\alpha_i$  reflects the security specific return component and  $\beta_i$  the market dependent return component. The unpredictable component is denoted by  $v_{it}$ , with  $v_{it} \sim N(0, \sigma^2)$ . The regression coefficient  $\beta_i$  can be interpreted as the risk of security  $i$  relative to the risk of the market portfolio.<sup>6</sup>

Event and non-event periods are distinguished by means of dummy variables (Maloney and McCormick [1982], Binder [1985]). Shifts in extra-market factors and changes in the investment risk are captured by a differential intercept coefficient  $\gamma_1$ , and a differential slope coefficient  $\gamma_2$  (see equation [2]), respectively.

$$[2] \quad R_{it} = \alpha_i + \beta_i R_{mt} + \gamma_{1i} D_t + \gamma_{2i} R_{mt} D_t + v_{it} \quad i=1, \dots, N, t=1, \dots, T, T_1, \dots, T_2$$

where  $D_t$  represents the dummy variable being equal to one during the event period and zero otherwise. If the marginal probability value of the t-statistic indicates that the estimates of the dummy coefficients are statistically significant, we can reject the null hypothesis that (on average) no abnormal returns were experienced. Similarly, the hypothesis that the investment risk was unchanged during the event period can be rejected for a significant t-statistic.

When analysing events that evolve over a longer period of time such as legislative changes, it might be helpful to distinguish different subperiods.<sup>7</sup> Let there be  $k$  announcements and let each dummy variable be denoted by  $D_{kt}$  equal to one during the period of the  $k$ th announcement and zero otherwise.

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<sup>6</sup> In an empirical estimation, the slope coefficients of the market model and the Capital Asset Pricing Model (CAPM) are the same. The CAPM, however, places an additional constraint on the extra market return component  $\alpha_i = (1-\beta_i)R_{ft}$  and requires that the slope coefficient is greater than zero. For the purpose of this study the market model is sufficient.

<sup>7</sup> In the following, the expressions events and announcements are used synonymously.

$$[3] \quad R_{it} = \alpha_i + \beta_i R_{mt} + \sum_{k=1}^K \gamma_{1ki} D_{kt} + \sum_{k=1}^K \gamma_{2ki} R_{mt} D_{kt} + v_{it}$$

Again,  $\gamma_{1ki}$  measures the abnormal return and  $\gamma_{2ki}$  the investment risk shift. The distinction of different announcements relating to the same event allow, along with a significance test at any individual announcements, to test a joint hypothesis on whether abnormal returns are zero at all announcement dates.

Especially for legislative changes, which evolve over a longer period of time, event date uncertainty poses a problem. Event date uncertainty is accommodated by successively extending the event window starting out from the coverage in major newspapers. For none of the windows, a significant dummy coefficient indicating abnormal returns for that window should be found.

If firms belong to the same industry and events are contemporaneous in calendar time, cross-sectional correlation (Henderson [1990, 294ff.]) can render the estimates inefficient. Instead of setting-up a Multivariate Regression Model, cross-sectional correlation can be accounted for by examining a portfolio of affected firms (Schwert [1981, 129ff.])

$$[4] \quad R_{pt} = \sum_{i=1}^N x_i R_{it}, \quad \sum_{i=1}^N x_i = 1$$

where  $x_i$  is the weight attached to a security  $i$  in the portfolio. Reformulating the market model for a portfolio of assets yields

$$[5] \quad R_{pt} = \alpha_p + \beta_p R_{mt} + \gamma_{pt}$$

The hypothesis that the average abnormal return in the event period is equal to zero can then be estimated by the following equation

$$[6] \quad R_{Pt} = \alpha + \beta R_{mt} + \gamma_{1p} D_t + \gamma_{2p} R_{mt} D_t + \varepsilon_{pt}$$

The estimated dummy coefficient  $\gamma_{pk}$  in equation [6] is equal to the arithmetic average of the abnormal returns. Doyle [1985] compares the Multivariate Re-

gression Model (Binder [1985]) to the portfolio model by means of simulated events and finds that the portfolio method is as least as powerful as a Multi-variate Regression Model.

#### **4. The Sandoz Incident, Ensuing Revision of the German Environmental Liability Legislation and the Chemical Industry**

Having outlined the event study methodology, this section describes the set-up of the empirical analysis. Subsequently, the estimation results for the German chemical industry are presented. The empirical analysis has tested the effect of a series of events related to the change in the environmental liability regime on the stock prices of a sample of firms in the German chemical industry. The chemical industry is one of Germany's major industries. It accounts for about 5 per cent of the Gross Domestic Product, for about 13 per cent of German exports, 10 per cent of German import, and for 8 per cent of the workforce in manufacturing (OECD [1993, 153ff.], VCI [1991, 17]). The chemical industry is a rather polluting industry. In 1990, the chemical industry has accounted for 62 per cent of sulphur dioxide emissions, 42 per cent of waste water discharged directly, 17 per cent of production related waste, and 57 per cent of hazardous waste of overall pollution generated by industry (OECD [1993]).<sup>8</sup> At the same time, the chemical industry undertakes considerable environmental protection. It accounts for about 40 per cent of the total environmental protection investment by manufacturing. The share of environmental protection investment in total investment by the chemical industry is more than twice of the average of manufacturing (DIW [1988, 375f.]). When the German liability legislation was tightened considerable economic risks were expected for the German chemical industry.<sup>9</sup>

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<sup>8</sup> Note that for sulphur dioxide the fraction refers to all sectors, for water pollution only to manufacturing. The figure for waste generation refers to 1987.

<sup>9</sup> Handelsblatt, March 10, 1987 "*Gegen übertriebene Gefährdungshaftung*".

## b. The Data

The data employed in this study are the indices of German stock prices published by the Federal Statistical Office (see Federal Statistical Office, Fachserie 9, Reihe 2).<sup>10</sup> The indices are calculated on the basis of the stock prices of about 300 German companies listed at the Frankfurt Stock Exchange. Compared to other indices, the index computed by the Federal Statistical Office reflects the structure of the different industries more accurately, since the stock prices are capital weighted (Richard [1992]).<sup>11</sup> Furthermore, the index focuses on the development of stock prices.<sup>12</sup>

Returns are computed in continuously compounded form,

$$[7] \quad R_{it} = \log (P_{it} / P_{i,t-1})$$

on a monthly basis using end of the month values. The reason for choosing a monthly return interval is twofold. First of all, in analysing legislative events, the high degree of uncertainty regarding the event date renders daily returns superfluous. Moreover, the distribution of monthly returns appear to be closer to a normal distribution than daily or weekly returns (Ulschmid [1994, 280ff.]).<sup>13</sup>

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<sup>10</sup> A detailed discussion of the computation of the indices is given by Lützel, Jung [1984].

<sup>11</sup> In a value weighted index, by contrast, the firms are weighted by their stock price. Thus, firms with higher stock prices have more weight in the index. When looking at economic consequences, however, there is no reason for attaching more weight to firms with higher stock prices. Unless the weights vary with stock prices, different weighting schemes do not change the abnormal performance detected.

<sup>12</sup> Many of the widely used indices do not consider cash dividends. Richard [1992] argues that stock prices already reflect dividend payments and one should therefore beware of double-counting. The fact that the indices have not been adjusted for dividend payments should have little effect on the estimates if the dates at which the dividends are paid differ among firms contained in the portfolio.

<sup>13</sup> Serial correlation is substantially reduced if monthly stock returns are used. Daily data also is more prone to display conditional heteroskedacity (Ulschmid [1994]). Autoregressive Conditional Heteroskedacity effects typically vanish if monthly data is used instead of daily data.

## b. The Legislative Process

The legislative process leading to the enactment of the UmweltHG is summarised in the calendar of events (Table 1).

Table 1 — Calendar of Events, November 1986–January 1991

Date	Event
November 1, 1986	Sandoz Incident
December 1986	Extension of strict liability publicly discussed
March 18, 1987	Federal Government announces extension of strict liability to air and soil pollution
October 19, 1987	World-wide Stockmarket Crash
May, 24 1989	Cabinet agrees on cornerstones of UmweltHG
November 1989	Presentation of a UmweltHG proposal
February 1990	First Reading in Bundestag
October 1990	Bundesrat refuses to approve UmweltHG
December 10, 1990	Passing of the UmweltHG
January 1, 1991	UmweltHG enters into force

The legislative process was initiated by the Sandoz accident on November 1, 1986. On November 1, 1986, a warehouse near Basle went on fire where chemical products, basic substances, and high powered pesticides were stored. Subsequently, heavy contamination of the Rhine river was experienced.<sup>14</sup> Along the Rhine river, large fish populations died. Waterworks had to stop their drinking water supply and on top of that breweries had to stop their beer production.<sup>15</sup> Compensation paid to German claimants alone was in excess of Sfr 71 million. Immediately, a heated public debate began whether

<sup>14</sup> A detailed description is given by FME [1987].

<sup>15</sup> The Federal Government claimed compensation on behalf of the German victims. In 1988, an out of court settlement was reached by which Sandoz accepted to pay 71 million Swiss Francs as compensation (Schwarze [1996, 93].



German safety regulations were appropriate to prevent a similar accident in Germany. In the following, a sequence of events signalled an increasing probability of a tightening of environmental liability provisions. In March 1987, the Federal Government formally announced its plans to extend strict liability to air pollution and soil contamination. Following the formal announcement, the Federal Ministry of the Environment (FME) and the Federal Ministry of Justice (FMJ) worked out separate proposals for an Environmental Liability Act. The proposals, which differed in a number of points, were presented in summer 1988.<sup>16</sup> On May 24, 1989, the cabinet decided on the cornerstones of the Environmental Liability Act. These cornerstones included a strict liability based on plant-type, a reversal of the burden of proof by introducing a causality presumption, the right to obtain information from the operators of polluting plants and government authorities. Moreover, it was decided that liability insurance should only be compulsory for a subset of plants. In the following, the Federal government presented a formal draft. This draft was debated for the first time in parliament (*1. Lesung*) in February 1990. The Act, did not pass the upper house in October 1990 though, and the mediation committee (*Vermittlungsausschuß*) had to be called in. On December 10, 1990, the Act was finally passed. It came into force January 1, 1991. The main difference between the draft and the final UmweltsHG is the provision limiting liability in case of multiple plaintiffs to prorata-liability for damages caused within proper operation which has been deleted.

The legislative process is characterised by three different stages: the Sandoz incident, the agreement on the cornerstones of the draft, and the final enactment of UmweltsHG. The event window for the Sandoz incident, the Sandoz-window, begins in November 1986. It ends in March 1987 when extension of

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<sup>16</sup> The main differences were that the FME disapproved a liability limited to specific plant types, and did not regard the liability for ecological damages appropriate.

strict liability was officially announced.<sup>17</sup> The official government announcement is the last plausible point in time where it became obvious that the German legislation would change. The second event window, which captures the announcement of the basic characteristic of UmweltHG in May 1989, was chosen to end with the announcement of the cornerstones and to extend back to January 1989. It is likely that the basic characteristics of the compromise were known sometime before the official announcement. For the same reason, for the enactment, a window of six months before the final passing of the Act on December 10, 1990 was chosen.<sup>18</sup>

### c. The Impact of the Environmental Liability Act

In estimating normal returns for portfolio of chemical firms, equation [8] was estimated beginning 60 months prior to the Sandoz incident.

$$[8] \quad \text{CHEM}_t = \alpha + \beta \text{GESAMT}_t + v_t$$

For the chemical industry, the sectoral index *Sonstige Chemie* was chosen. A complete list of the firms contained in the portfolio is given in the Appendix.<sup>19</sup>

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17. Interestingly, no significant stock market reaction was found for November 1986. The reason might be that it took the market some time to realise that the Sandoz accident would have consequences for German chemical firms. It even took the Swiss stock market about 10 days to react to the accident (Frankfurter Allgemeine Zeitung, "Sandoz-Aktien gefallen", November 11, 1986, p. 15). Moreover, it seems to be a general characteristic of the chemical industry that its stock prices react rather slowly to new information (May [1994, 283ff.]).

18. The length of windows was checked for sensitivity. The chosen periods are those for which the most pronounced stock market reaction was found. Estimating for event windows of different length should never yield a significant dummy coefficient. The results are very similar if other environmentally significant industries are considered. The highest significance for the Sandoz dummy coefficient was obtained for 1986:11 to 1987:2 and the window was adjusted accordingly.

19. The sample does not include the three very large multinational chemical firms (BASF; Hoechst, Bayer). These firms are among the ten largest chemical firms in the world and account for about one third of the turn-over of the German chemical industry (VCI [1991, 17]). The reason for excluding these three stocks is twofold. First, given their size these firms would dominate the portfolio. Second, given their internationally diversified structure other factors outside the German legislation might be inferring so that the effects of UmweltHG cannot be disentangled.

For the market index the index *Insgesamt* was chosen. With an adjusted coefficient of determination of 0.81, the market model offers a fairly good explanation for the stock price movements in the chemical industry (see Table 2).

Regarding the profitability of the chemical industry two types of hypothesis are tested. The first hypothesis tests whether substantial changes in the expected costs were induced by tightened environmental liability are expected. Since revision of German liability provisions was expected to be costly for the firms,

Table 2 — Estimates of the Impact of the Revision of Environmental Liability on the Chemical Industry's Specific Return Component, October 1981–December 1990

	MARKET Model	JOINT DUMMY model	SEPARATE DUMMY model			
Estimation Period	81:10–86:10	81:10–90:12	81:10–90:12	82:2–87:2	84:5–89:5	85:12–90:12
Windows		86:11–87:2 89:1–89:5 90:8–90:12	86:11–87:2 89:1–89:5 90:7–90:12	86:11–87:2	86:10–87:2 89:1–89:5	86:10–87:2 89:1–89:5 90:7–90:12
VARIABLE						
Intercept	-0.001 (-0.324)	0.001 (0.357)	0.002 (0.706)	-0.001 (-0.407)	0.000 (0.057)	0.001 (0.311)
Market Return	0.831 (16.146)***	0.721968 0.758 (21.812)***	0.4816 0.742 (21.581)***	0.68541 0.818 (16.647)***	0.954536 0.743 (16.564)***	0.756672 0.726 (15.897)***
Event Dummy		0.010 (1.561)				
Sandoz–Event		0.12157	0.017 (1.565)	0.022 (2.189)**	0.018 (1.579)0.11999	0.164 (0.309)
Cornerstone–Event			0.1204 0.017 (1.862)*		3 0.019 (1.867)*	0.19602 0.018 (1.617)0.11052
Enactment–Event			0.0654 -0.014 (-1.590)	0.03266	0.067053	-0.014 (-1.350)0.18250
Adjusted R <sup>2</sup>	0.812	0.812	0.823	0.824	0.823	0.824
Durbin-Watson	1.784	2.001	2.010	1.775	1.846	2.173
SEE	0.019	0.021	0.020	0.019	0.0215	0.237
Degrees of Freedom	59	108	106	58	57	56
F-Statistic	260.679	239.216	128.784	141.385	93.692	71.056

t-statistics in brackets — \*significant at the ten per cent level — \*\*significant at the five per cent level — \*\*\*significant at the one per cent level — SEE — standard error of estimate.

the null hypothesis is that the incidents had no effect on the stock returns of chemical firms. This null hypothesis would be rejected if the events had a considerable impact across firms in the chemical industry. The second hypothesis tests whether changes in the investment risk attached to future profits in the chemical industry was affected by uncertain future environmental liability payments. Accordingly, the second null hypothesis poses that the events did not affect the market dependent return coefficient. If the slope coefficient for the chemical industry shifted, it could be concluded that the event contained unanticipated information on the investment risk of the chemical industry.

#### *Estimation of Changes in Costs Attributed to UmweltHG*

In order to estimate whether a significant reduction in the profitability can be attributed to one of the announcements, first an equation over the whole time span 1981:1 to 1990:12 was estimated. Two different versions of this regression were estimated. The first regression tests whether the overall effect of all three events is zero. The coefficient on the dummy variable estimates the average effect of the legislative change.

$$[9] \quad \text{CHEM}_t = \hat{\alpha} + \hat{\beta} \text{GESAMT}_t + \hat{\gamma} D_t + \hat{v}_t$$

where  $\hat{\cdot}$  indicates estimated parameters. The second regression tests whether there was a significant stock market reaction at each event date. This is done by estimating equation [10]

$$[10] \quad \text{CHEM}_t = \hat{\alpha} + \hat{\beta} \text{GESAMT}_t + \sum_{k=1}^3 \hat{\gamma}_k D_{kt} + \hat{v}_t$$

The regression coefficients and the respective t-statistics are reported in Table 2. Employing three different dummy variables allows to separate the distinct features of the event windows. The Sandoz incident points to the revision of environmental liability in Germany. If there were expected increases in total environmental costs, this should show up in lower stock returns. As first, a compulsory liability insurance was put forward, in the Sandoz event period, the in-

vestment risk should not have changed. The formal announcement of the cornerstones of the UmweltHG proposal revealed that a more conservative approach was going to be adopted. At this point it became clear that liability would be limited to specific plant-types and that the causality presumption would not include plants that have been operated according to safety regulations. It also became apparent that damage caused within proper operation would be subject to liability. This package might have been good news, bad news, or no news to the capital market compared to previous expectations. With the cornerstone compromise it also became clear that insurance would not be compulsory in general. Hence, the perception of investment risk of chemical firms might have changed. The enactment, finally, conveyed information regarding multiple defendants when the provision limiting liability to pro rata in case of compliance to proper operation was deleted. Instead now courts have to rely on the joint and several liability doctrine under the Civil Code. This increases both the potential costs and the risk attached to liability.

The size of the dummy coefficients corresponds to what has been found by other studies. For the joint estimation of all three events, it turns out that the dummy coefficient is insignificant. Thus, investors may have viewed the additional costs imposed by the UmweltHG to be minor relative to the assets and earnings of the chemical industry. This insignificance might also be due to offsetting effects of the different windows. If one of the events leads to pessimistic revision of expectations and another to an optimistic revision, the test of a joint hypothesis would falsely support the hypothesis that there was no effect. In fact, if events are represented by individual dummy variables, the signs of the dummy coefficients differ. Two events, the Sandoz incident and the Cornerstone window lead to an increase in the profitability of chemical firms. Now, the Cornerstone event's misses the 5 per cent significance level only narrowly and the Sandoz event misses the 10 per cent significance level by a small degree. Only for the Enactment window, the coefficient has the negative sign that one would expect when liability is tightened. Only that, the coefficient is

insignificant. Whereas it seems to be plausible that the compromise among the Federal Ministry of Justice and the Federal Ministry of the Environment was in fact good news in the view of the market, the positive effect of the Sandoz accident is harder to explain. The sign of the coefficient indicates that there are abnormal gains following the Sandoz incident, which are sustained even during the period over which safety regulations regarding chemical plants and liability provisions in Germany were questioned publicly. It could be argued that the German chemical industry had already taken adequate precautions. Indeed in the public discussion the impression was conveyed that a similar accident could not happen in Germany. If adequate precautions had already been taken by German chemical firms, this would imply that the capital market did not expect potential liability payments to result in a substantial cost increase.<sup>20</sup>

Another reason for the insignificance of the dummy coefficients could be that the parameters of the underlying model are unstable. A stylised fact found by many empirical studies is that parameter instability can only be rejected for estimation periods up to five years (Ulschmid [1994]). Therefore, in addition, three separate five-year regressions were run each ending with the event under study. Although, regression results (reported also in Table 2) support the general pattern identified above, there are some noteworthy changes. First, the coefficient on the Sandoz event dummy becomes highly significant. At the same time, the coefficient increases. Hence, positive impact for the Sandoz accident is more pronounced in the five-year estimation. The results for the Enactment window also change. The Enactment window now misses the ten per cent significance level more clearly. For the Cornerstone window, the estimates are similar to those obtained before. Again significant abnormal profits were not found. Thus, taking parameter stability of the market model over five year pe-

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<sup>20</sup> The capital market could have perceived the Sandoz accident as pointing only to a potential increase in the pollution control costs of foreign competitors. But even if the German chemical industrial was already in good shape in terms of precautionary pollution control measures, this would also rule out substantial liability payments.

riod as granted, it can be concluded that the observed shifts are related to environmental liability rather than to changes in the underlying model.

#### *Change in the Investment Risk Attributed to Environmental Liability*

The coefficients reported in Table 2 point to a decline in the market related return component. This suggests a potential reassessment of the risk in the chemical industry. In order to test whether there were changes in the risk of the chemical portfolio, the following equation was estimated,

$$[11] \quad \text{CHEM}_t = \hat{\alpha} + \hat{\beta} \text{GESAMT}_t + \hat{\gamma}_2 \text{GESAMT}_t D_t + \hat{\gamma}_1 D_{kt} + \hat{v}_t.$$

A second regression was run with three different event dummy variables

$$[12] \quad \text{CHEM}_t = \hat{\alpha} + \hat{\beta} \text{GESAMT}_t + \sum_{m=1}^3 \hat{\gamma}_{1k} D_{kt} + \sum_{m=1}^3 \hat{\gamma}_{2k} \text{GESAMT}_t D_t + \hat{v}_t$$

If the differential slope coefficient were significant during one of the event windows, the market viewed the event as revealing unanticipated information on the investment risk attached to returns in the chemical industry.

Testing first for the joint effect, the event slope shift coefficients turns out to be insignificant. This result is independent of whether the change in industry specific return factors are captured jointly or separately (see Table 3). Only for the Cornerstone window a significant differential slope coefficient is found. This is consistent with the fact that in Spring 1989 it became obvious that liability insurance would not be easily obtained nor be compulsory in all cases. However, the sign of the dummy coefficient points to a decrease in the risk attached to investment in chemical stocks. The decreased risk might be due to fact that it become obvious that chemical plants are among those who have to seek compulsory coverage against liability risk. For the Sandoz incident no significant change in the slope is found. This is consistent with the fact that initially a compulsory liability insurance scheme was planned.



Table 3 — Estimates of The Impact of the Revision Environmental Liability on the Chemical Industry's Market Dependent Return Component, October 1981 – December 1990

	JOINT DUMMY model	SEPARATE DUMMY model			
Estimation Period	81:10 – 90:12	81:10 – 90:12	81:10 – 90:12	81:10 – 90:12	81:10 – 90:12
Variable	86:11 – 87:2, 89:1 – 89:5 90:8 – 90:12	86:11 – 87:2 89:1 – 89:5 90:7 – 90:12	86:11 – 87:2 89:1 – 89:5 90:7 – 90:12	86:11 – 87:2 89:1 – 89:5 90:7 – 90:12	86:11 – 87:2 89:1 – 89:5 90:7 – 90:12
Intercept	0,001 (0,444)	0,001 (0,654)	0,002 (0,695)	0,002 (0,717)	0,002 (0,674)
Market Return	0,745 (19,068)*** 0,00000	0,749 (19,497) 0,00000***	0,4886 0,742800 (21,126)***	0,4751 0,741 (21,841)***	0,5018 0,746 (19,897)***
Event	0,011 (1,702)0,0915				
Sandoz-Event		0,016 (1,437)	0,015 (1,236)	0,017 (1,058)	0,017 (1,574)
Cornerstone-Event		0,153569 0,018 (1,890)*	0,2193 0,017 (1,854)*	0,057 (2,516)**	0,017 (1,855)*
Enactment-Event		0,061502-0,015 (-1,634)* 0,1053	0,0666-0,014 (-1,574) 0,1185	0,11630,0134 -0,014 (1,612) 0,1101	-0,015 (-1,580) 0,1170
Event Slope Shift	0,068 (0,783) 0,43515	-0,036 (-0,408) 0,68429	Sandoz -0,034 (-0,176) 0,8605	Cornerst. -1,194 (-1,911)* 0,0588	Enactmt. -0,026 (-0,272) 0,7864
Adjusted R <sup>2</sup>		0,822	0,821	0,827	0,821
Durbin-Watson	2,031	2,098	2,102	2,115	2,093
Degrees of Freedom	107	105	105	105	105
SEE	0,020	0,021	0,021	0,020	0,021
F-Statistic	162,498	102,250	102,091	106,334	102,142

t-statistics in brackets — \*significant at the ten per cent level — \*\*significant at the five per cent level — \*\*\*significant at the one per cent level —  
SEE – standard error of estimate

Besides the dummy variable estimation reported in Table 3, Chow tests (Chow [1960]) for structural breaks were performed.<sup>21</sup> The Chow-test only rejected the hypothesis of no structural break for Cornerstone window and hence confirms the aforementioned results.

#### **d. Evaluation of the Regression Results**

Summarising the regression results, no significant decrease in the profitability of German chemical firms has been found as a consequence of the plans to introduce a comprehensive strict liability for environmental damages. On the contrary, increases in the stock market returns were experienced contemporaneous to the Sandoz accident and the subsequent revision of liability and safety regulations in Germany. An increase in returns was also found for the agreement on a more conservative approach to environmental liability. The only event for which a decrease in the profitability was established is the enactment of the UmweltHG. However, the differential intercept coefficient is insignificant. The regression results also convey the impression that the riskiness of investing in the chemical industry compared to the market in fact decreased despite the intentions to impose liability irrespective of the precautions taken. However, a significant differential slope coefficient was found only for the cornerstone agreement. At this time it became apparent that liability insurance would not be compulsory in general. The capital market might however have expected that chemical plants were among those for which precautionary coverage was still planned to be compulsory and hence perceived this to lower the investment risk.

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<sup>21</sup> For October 1986, the hypothesis of no structural break could not be rejected (F-statistic: 1,518 (0,062)). For January 1989, however, the Chow-test indicates a structural break (F-Statistic 1,89 (0,019)), whereas for July 1990 (F-statistic 0,588 (0,709)) a structural break seems unlikely.

In evaluating these results critically, two sets of issues have to be considered. The first set of issues is related to the details of the set-up of the event study. The second set issues refers to statistical adequacy of the econometric model.

### *The Adequacy of the Event Windows*

The first issue is the appropriate choice of the event windows. The correct determination of the event window might in fact be a problem for later stages of the legislative action. However, for the Sandoz incident, there can be little doubt about the correct choice of the beginning of the event window. For November no significant reaction was found. In order to accommodate event date uncertainty, the window was then successively extended. Note that for none of the windows, a significant dummy variable should be found.

Another concern is that of overlapping events. For instance, following the Sandoz accident a catalogue of policy strategies to improve the safety of chemical plants was presented by Federal Government on December 4, 1986. Subsequently, the Hazardous Incident Ordinance (*Störfall-Verordnung*, 12th BImSch-VO) was revised in May 1988 and reamended in 1991 to transform the EU Directive on the Major Accident Hazards of Certain Industrial Activities into German law. The direction of the abnormal profits is even more surprising if these overlapping effects are considered.

Another potential source of error is that the event studied might have already been anticipated at an earlier state. Again, this is not plausible for the Sandoz accident. For the announcements during the legislative process, by contrast, we cannot exclude that some developments were not anticipated at an earlier stage. In particular, since the German government is obliged to cooperate with the affected social groups when putting forward changes in environmental legislation, some developments might have in fact been anticipated earlier.

Finally, the portfolio method suffers from a weakness if the event studied has differentiated effects on individual firms (Binder [1985]). Then the effects by cancelling out each other, falsely support the hypothesis that the regulation had no effect. In the case of environmental liability, however, the direction of the effect should be homogenous within the German chemical industry even if it differed from the impact on Sandoz itself.<sup>22</sup>

### *The Adequacy of the Econometric Model*

A number of studies show that the assumptions underlying the market model might not hold (e.g. Coutts, Mills, Roberts [1994]). Therefore, the statistical assumptions underlying the market model were tested. The results of these tests are reported in the Appendix. Only the results obtained by using different method to detect heteroskedacity are ambiguous in that some reject homoskedacity. Whereas testing for heteroskedacity by the Goldfeld-Quandt test (Goldfeld, Quandt [1965]), did not indicate a rejection of homoskedacity, the White test rejects homoskedacity at least for period 1981.10 -1986.10. The reason for the rejection of homoskedacity are probably two outliers, 1986:5 and 1986:8, (see Figure A2). Equally, Ramsey's Regression Specification Error Test (RESET, Ramsey [1969]) rejected linearity for the period 1981.10 to 1986.10. Again, the test statistic becomes insignificant, once the full period is analysed. Therefore, although outliers might give rise to econometric problems for the estimation period, over the longer time span 1981.10 to 1990.12 for which the event study is conducted this problem resolves. Overall the econometric model chosen to estimate the impact of environmental liability announcements on the chemical industry seems to be appropriate.

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<sup>22</sup> Asymmetric effects can be caused by an environmental accident, if the firm where the accident occurred is also contained in the portfolio (Dowdel et al. [1990]). Recent major environmental accidents in the German chemical industry show that the stock prices of the firm where the accident occurred dropped, whereas the stock prices of other firms in the industry rose (Frankfurter Allgemeine Zeitung, January 30, 1996 "Zwei Chemieunfälle in kurzer Folge setzen Hoechst unter Druck").

## 5. Summary and Conclusions

Given the nature of its production processes and the hazardous substances used, the chemical industry was supposed to be severely affected by the introduction of the German Umwelthaftungsgesetz. The empirical evidence presented in this paper, however, suggests that the legislative change (if any) created by the UmweltHG did not have a substantial adverse effect on the chemical industry. This result is in line with the impression conveyed by the pattern of environmental protection investment which does not point to a significant impact of the UmweltHG on the aggregate level of environmental protection.

In particular, two sets of issues have been examined. First, it has been analysed whether the revision of the German environmental liability legislation following the Sandoz accident has had significant effects on the stock returns of a portfolio of German chemical firms. Secondly, it has been investigated whether this revision significantly affected the investment risk attached to these firms. If environmental liability were to provide an effective means of internalising environmental risks, one would expect the profitability of affected firms to decline for two reasons. First of all, if additional precautionary measures are induced this should raise costs. In addition, if firms have to face future liability payments despite having taken appropriate precautions – as under the strict liability the UmweltHG provides for – this should also lower profits. Yet, the performance of chemical stocks suggests that rather abnormal profits were expected contemporaneous to the revision of the German environmental liability legislation. Besides from raising costs, the risk associated with future cash flows in the chemical industry should rise if chemical firms face substantial uncertain liability payments. But instead of an increase in the chemical industry's investment risk, the estimates point to a decline in the investment risk contemporaneous to the introduction of a strict liability for environmental damages.

There are two potential explanations for the absence of an adverse effect on chemical industry. First, the legal framework might not have changed to the extent that was feared initially such that the UmweltHG was perceived as a favourable outcome. But even shortly after the Sandoz accident such a downward revision of expectations could not be detected. Secondly, various obstacles might prevent the enforcement of environmental liability claims under the UmweltHG. Problems of enforcing liability claims, notably the difficulty of proving causation, impede the internalisation of environmental risks. Hence, in presence of such impediments to enforcing legal claims neither significant preventive measures nor liability payments will be generated. If the problems of enforcing environmental liability claims were anticipated by the market, the enactment of the UmweltHG could have been good news compared to a substantial tightening in safety regulation applying to chemical plants which was also debated as an alternative at the time.

Thus, the findings of this paper do not indicate that there was a substantial negative impact of the UmweltHG on the profitability or the investment risk of a portfolio of German chemical firms. This result is even more surprising because extensive media coverage of the Sandoz accident raised the public awareness of the potential risk of chemical plants and also led to a decrease in the time it takes chemical stocks to react to unanticipated disruption of chemical plants. Hence, the findings of event study presented in this paper support a rather pessimistic view on the economic consequence of the UmweltHG.

**Appendix**

**Table A1 — Environmental Protection Investment in the Goods Producing Industry, 1980–1993 (Million DM)**

	1980		1985		1990		1993	
	DM	per cent	DM	per cent	DM	per cent	DM	per cent
Electricity, district heating and water supply	482	2.8	2,665	13.2	4,250	9.6	3,313	9.8
Mining and Quarrying	110	4.4	315	10.4	656	14.9	415	14.5
Manufacturing industry including	2,066	3.9	2,627	4.3	2,797	5.2	4,710	5.1
– Mineral oil refining	134	10.2	134	10.1	140	11.4	419	22.0
– Quarrying and Processing of Stone and clay	175	7.4	116	6.6	101	6.2	313	5.4
– Iron Production	283	10.1	446	12.4	153	8.0	185	7.8
– Non-ferrous metal industry	39	5.5	189	21.4	89	16.9	103	6.4
– Foundries	33	5.8	35	6.0	51	13.7	68	8.1
– Chemical Industry	573	8.8	585	7.9	1,067	14.9	1424	13.0
– Wood processing	24	6.8	18	6.1			46	6.2
– Manufacture of pulp, paper and board	87	7.1	72	6.8	112	10.1	269	17.0
– Mechanical Engineering	53	1.0	60	1.0	81	1.5	152	2.1
– Manufacturing of Road Vehicles	162	2.1	433	4.6	254	3.6	309	2.6
– Consumer goods industry including	158	2.2	164	2.0	241	3.4	442	3.2
– Textiles	31	2.4	34	2.2	51	3.1	108	6.9
– Leather production	3	1.9	3	5.3	5	14.1	7	26.5
– Food and luxury food industry	145	2.8	157	3.1	166	3.2	405	3.3
Building Trade	36	0.7	29	0.9	44	1.4	114	1.1
TOTAL Goods producing industry	2,674	3.5	5,635	6.4	7,746	5.9	8553	6.1

Source: Federal Statistical Office Statistical Yearbook, current volumes. For 1993 Pan-German Figures.

*The Adequacy of the Econometric Model*

Testing for stationarity of returns by using an Augmented Dickey-Fuller test (Dickey, Fuller [1981] showed that a unit root was rejected for returns to the

chemical portfolio nor to the market portfolio at the 1 per cent level (using MacKinnon critical values).

Autocorrelation of residuals does not seem to pose an econometric problem in estimating the market model with data used here. However, as the Durbin-Watson test reported in Table 2 an 3 presupposes homoskedacity and structural constancy which turn out to pose a problem here, the Breusch-Godfrey Lagrange Multiplier test (Breusch [1978], Godfrey [1978]) and the Ljung-Box Q-statistics for residual serial correlation were performed. Both confirmed that no autocorrelation cannot be rejected (see Table A2).



Table A2 — Tests of the Adequacy for the Market Model, 1981–1990

Estimation Period	1981:10–1986:10	1981:10–1990:12
<b>Adequacy- Test</b>		
<b>SERIAL CORRELATION</b>		
Breusch Godfrey LM Test		
$\chi^2$ distributed		
AR(1) <sup>a</sup>	0,551 (0,458)	0,004 (0,947)
AR(3)	5,491 (0,139)	2,148 (0,542)
AR(12)	15,135 (0,234)	13,826 (0,312)
<b>HETEROSKEDACITY</b>		
Goldfeld Quandt		
F distributed	0,398 (0,981)	0,718 (0,845)
White Test		
$\chi^2$ distributed	9,614 (0,008)	0,355 (0,838)
<b>STRUCTURAL CONSTANCY</b>		
Ramsey Reset (4)		
F distributed	3,325 (0,016)	0,9171 (0,457)
ARCH Test AR (1)		
$\chi^2(1)$ distributed	2,809 (0,094)	0,000 (0,989)
<b>NORMALITY</b>		
Jarque-Bera test		
$\chi^2$ distributed	0,394 (0,820)	1,254 (0,534)
Q Ljung Box		
$\chi^2$ distributed	39,507 (0,073)	38,227 (0,369)
<sup>a</sup> Marginal probability values in brackets		

Often, for the market model the assumption of homoskedastic error terms is not given. Missong and Seppelfricke [1993] find that for monthly data, the German stock market the assumption of homoskedastic residuals has to be rejected. Testing for heteroskedacity by the Goldfeld-Quandt test (Goldfeld, Quandt

[1965]), did not indicate a rejection of homoskedacity.<sup>23</sup> Another heteroskedacity test – the White test – rejects the hypothesis of homoskedacity at the one per cent level for the estimation period 1981.10 – 1986.10.<sup>24</sup> Unlike the Goldfeld Quandt test, the White test does not presuppose an ordering of the observations with respect to the explanatory variable the supposedly causes heteroskedacity. The rejection of homoskedacity vanishes, however, once the full ten year period is analysed. The reason for the rejection of homoskedacity is probably the outliers 1986:5 and 1986:8 (see Figure A1). In the larger sample, the importance of these outliers diminishes and so does heteroskedacity (see Coutts, Mill, Roberts [1994, 156ff.]). Equally, the Regression Specification Error Test (RESET) as proposed by Ramsey [1969] equally rejected linearity for the period 1981.10 to 1986.10. Again, the test statistic becomes insignificant, once the full period is analysed. Thus, although outliers might give rise to econometric problems for the estimation period, over the longer time span 1981.10 to 1990.12 for which the event study is conducted this problem resolves.

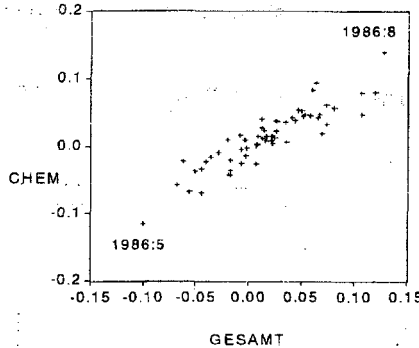
It is essential for the event study methodology that the estimated model parameters are stable over the estimation period and the event period. The CUSUM-test (Brown, et al. [1975]) was performed, since it does not require to specify exact breakpoints. The CUSUM-test did not indicate parameter instability for the estimation nor for the full period. A particular point in time at which

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<sup>23</sup> The Goldfeld Quandt test seems appropriate, because the variance in the error terms is likely to be driven by the rates of change in the market index. The values reported in Table A2 refer to omitting 20 observations in the middle.

<sup>24</sup> The White test is also regarded as a general misspecification test. If the parameters of the market model are varying over time, but are estimated as being constant, residuals are heteroskedastic. Therefore, a test for heteroskedacity can be interpreted as a test for parameter constancy.

Figure A1 — Relationship between Rates of Returns to the Chemical Industry and the Market Index, 1981:10–1986:10



a structural break might have occurred is the world wide stock market crash. Testing for a structural break in 1987:10 by means of the Chow test, the hypothesis of no structural break cannot be rejected.

The prevalence of so-called AutoRegressive Conditional Heteroskedacity (ARCH) effects frequently constitutes a problem in empirical research into financial time series (see for instance Funke [1994], Dankenbring and Misssong [1996]).<sup>25</sup> ARCH refers to the fact that often a period with a high volatility of the returns is followed by more stable return patterns. In this case the variance in error terms depends on last period's error term variance and heteroskedacity follows an autoregressive conditional process. Figure A1 indicates that there might be some variation in the volatility of the monthly rates of change of the stock price index both for the chemical industry and of the market as a whole. Yet, the Lagrange-Multiplier test proposed by Engle [1982] for ARCH (1), however, did not reject no autocorrelation for one of the periods.

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<sup>25</sup> Dankenbring and Misssong [1996] find significant ARCH effects for monthly returns German stocks.

Testing, finally, for normality of the distribution of the residuals, the Jarque-Bera statistic (Bera, Jarque [1981]) cannot reject normality.<sup>26</sup> Overall, the regression model chosen to estimate the impact of different environmental liability events on the German chemical industry seems to be appropriate.

Table A3— Firms contained in the portfolio for the Chemical Industry  
(December 30, 1991)

Akzo Faser AG
Altana Industrie-Aktien und Anlagen AG
Beiersdorf AG
C.H.A. Chemie Holding AG
Cassella AG
Degussa AG
Feldmühle Nobel AG
Fuchs Petrolub AG Öl
Gehe AT
Goldschmidt AG
Kali-Chemie AG
Rieder-De Haen At
Ruberoidwerke AT
Ruetgerswerke AG
RWE-DEA AG
Schering AG
Süd-Chemie AG
Veba AG
Wasag-Chemie AG

Source: Federal Statistical Office Fachserie 9, Reihe 2, S.1, Index der Aktienkurse – Lange Reihen.

<sup>26</sup> Similar results have been obtained by Ulschmid [1994].

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