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CONTAGION EFFECTS IN THE CHEMICAL INDUSTRY FOLLOWING THE BHOPAL DISASTER

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Abstract

This study examines the returns of Union Carbide and other chemical producers around the time of the Bhopal disaster. As might be anticipated, there were significant contagion effects. These effects were, however, economically small. There is also some evidence of over-reaction effect—larger initial losses moderated by later offsetting gains. For the firms other than Union Carbide, the later gains completely offset the initial losses.

INTRODUCTION

Contagion refers to spillover effects of an economic shock from one firm to others—typically others in the same industry. Contagion studies have been done on the shocks to the sale of both products (e.g., Tylenol, see Dowdell, et al. [7]) and services (e.g., airplane crashes, see Chalk [4] and Karels [12]). There have been studies of the intra-industry effects of firm failures (see Lang and Stulz [15]).

One industry has been repeatedly examined for contagion effects. Bank research has frequently looked for contagion effects following bank failures (see, e.g., Swary [20] and Aharony and Swary [1]). Policy considerations make it important to understand whether failure of a prominent bank could cause runs on other banks.[1]

Such studies can also assess the informational efficiency of markets. For example, if a bank failed for a particular reason, such as bad energy loans, the failure of one bank could alert investors to the riskiness of other banks involved in similar operations. Indeed, several studies have found such information effects.[2]

In addition to providing insights about intra-industry relationships, contagion studies are interesting methodological problems. Typically run as event studies, contagion studies generally must content with all of the forms of clustering that an event study might encounter—calendar clustering (all firms share the same event date), industry clustering (all firms are in the same SIC classification) and risk clustering (most of the firms would have similar betas).

We study the chemical disaster that happened at the Union Carbide plant in Bhopal, India. We compare the stock returns of chemical companies that manufacture isocyanates (similar to the deadly toxin involved in the Bhopal accident) and those of chemical companies that do not produce isocyanates.

The Bhopal Disaster

On December 4, 1984, at approximately 12:40 a.m., the worst industrial accident in history occurred. A highly toxic methyl isocyanate (MIC) gas leak from the Union Carbide plant in Bhopal, India, killed at least 2,000 people (some estimates run as high as 5,000) and injured tens of thousands of others (many of whom later died).

Union Carbide sent an investigative team to India to provide assistance and to determine the cause of the accident. The team had difficulty interviewing plant employees or obtaining access to records concerning the accident. According to Union Carbide, the investigative team was prohibited from interviewing the employees

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because the Indian Central Bureau of Investigation (CBI) was conducting its own investigation; CBI considered that interviewing the employees would be tampering with evidence in a criminal investigation.

No investigation thus far has conclusively determined events leading up to the discharge. It is agreed, however, that the leak was the result of human error. Whether the accident was the result of intentional sabotage, as claimed by Union Carbide, or the result of a mistake of an inadequately trained employee and poor maintenance, the result was the same—the death of thousands of people.

The Product

MIC is a highly volatile toxin. It is a chemical intermediate. It is combined with other chemicals to produce a pesticide. Phosgene, which is made by combining carbon monoxide and chlorine, is reacted with monomethylamine to form MIC. MIC is used in the production of the agricultural pesticides carbaryl and aldicarb, generally known as carbamates. Union Carbide's trade names for these pesticides are Sevin and Temik. Dupont's Lannate, and Shell Chemical Co.'s Nudrin make up more than half of the pesticide market for soybean producers. Carbamates are also used by corn and cotton farmers, but are not nearly as important to them as they are to the soybean producers. Union Carbide is not the only company to produce MIC, but is the only company in the United States to produce MIC. Companies in Japan, Germany, Israel, Taiwan, and Korea also produce MIC. Union Carbide halted production and distribution of MIC after the accident on December 4, 1984.

Calls for investigations into the safety of the plants in the United States that use or manufacture hazardous chemicals resounded from environmentalists, union groups, and other concerned groups including Congress. Shortly after the disaster, manufacturers looked at alternative methods of manufacturing pesticides to avoid use of toxic raw materials such as methyl isocyanate.

THE EVENT STUDY

This study follows a classic event study format. We define an event date, then examine the excess returns of (1) the firm experiencing the disaster, i.e., Union Carbide, (2) other similar firms using isocyanates in their manufacturing process, and (3) control firms (other chemical manufacturers who do not use isocyanates).

The Event Day

December 4, 1984, the day when UPI and the *Wall Street Journal* (*WSJ*) carried the news of the Bhopal accident, is defined as the event day (t=0). Given the nature of the event, anticipation of the accident was impossible.

The Sample

All U.S. chemical firms listed on the Center for Research in Security Prices (CRSP) tapes were potential members of the sample. The stocks of these firms trade on the NYSE or the AMEX, and they claim manufacture and/or distribution of chemicals as their main business activity.

The list was examined to identify those firms whose stock was not trading during the study period, that is, during t-250 to t+20; the non-trading firms were dropped from the study. The remaining firms were split into three portfolios: (1) firms that use cyanates or isocyanate in their products (hazardous), (2) firms that do not use cyanates or isocyanate, and (3) Union Carbide. Firms are classified according to information available in Moody's industrial manual and the reports appearing in the *WSJ* following the Bhopal accident.

METHODOLOGY

In order to control for contemporaneous covariance associated with a common event date, this study uses the multivariate regression model (MVRM) suggested by Binder [2] and Malatesta [16]. Use of dummy variables allow

statistical evaluation of variation in the intercept and slope during the event period and study of the share price reaction to the accident news.

The shifts in alpha and betas were measured using the return generating model:

Equation 1

$$R_{it} = \alpha_i + \alpha_{i\Delta}D_{0,t} + \beta_i R_{mt} + \beta_{i\Delta}R_{mt}D_{0,t} + \varepsilon_{it}$$
$$R_{jt} = \alpha_j + \alpha_{j\Delta}D_{0,t} + \beta_j R_{mt} + \beta_{j\Delta}R_{mt}D_{0,t} + \varepsilon_{jt}$$
$$R_{kt} = \alpha_k + \alpha_{k\Delta}D_{0,t} + \beta_k R_{mt} + \beta_{k\Delta}R_{mt}D_{0,t} + \varepsilon_{kt}$$

where:

i, j, and k represent the three portfolios of firm(s) discussed above (i = Union Carbide, j = hazardous chemical manufacturers, and k = non-hazardous control firms),
R_{it} = the average of the daily realized returns on securities in portfolio i on day t. Daily returns on individual securities are taken from the CRSP daily return tape,
α_i = the intercept term for portfolio i,
$\alpha_{i\Delta}$ = shift in the intercept term for portfolio i during the event period,
$D_{0,t}$ = a dummy variable, which is equal to 1 during the event interval, and zero otherwise,
β_i = the systematic risk of portfolio i,
R_{mt} = the return on the value-weighted market portfolio on day t, taken from the CRSP daily return tape,
$\beta_{i\Delta}$ = Shift in the systematic risk of portfolio i during the event period, and
ε_{it} = a random disturbance term.

To measure the effect of the Bhopal accident on share prices, the return generating model used is:

Equation 2

$$R_{it} = \alpha_i + \beta_i R_{mt} + \sum_{n=-2}^{+20} \Gamma_{in} D_{in} + \varepsilon_{it}$$
$$R_{jt} = \alpha_j + \beta_j R_{mt} + \sum_{n=-2}^{+20} \Gamma_{jn} D_{jn} + \varepsilon_{jt}$$
$$R_{kt} = \alpha_k + \beta_k R_{mt} + \sum_{n=-2}^{+20} \Gamma_{kn} D_{kn} + \varepsilon_{kt}$$

where all terms are defined as before except:

$D_{n,t}$ = a dummy variable, which is equal to 1 on observation n and zero otherwise, and
Γ_{in} = estimated coefficient on dummy variable $D_{n,t}$, or excess return on portfolio i on observation n.

Daily prediction error on portfolio i on event day n (PE_{in}) would normally be computed as:

Equation 3

$$PE_{in} = R_{in} - (\alpha_i + \beta_i R_{mt})$$

In this approach the prediction error is directly estimated as the coefficient of the dummy variable, Γ_{in}.

The standardized prediction error (SPE_{in}) is then computed as the prediction error divided by the regression standard error:

Equation 4

$$SPE_{in} = PE_{in} / s_{in}$$

where:

s_{in} = standard error of the excess return for portfolio i for observation n.

With the event parameter model, as this approach is sometimes called, SPE_{in} is simply the t value for the dummy coefficient Γ_{in}. Under the null hypothesis of no abnormal returns, the prediction errors are assumed to be normally distributed with zero mean, so the standardized prediction errors, SPE_{in}, are normally distributed.

The test statistic, Z, for various sub periods is found as:

Equation 5

$$Z = \sum_{t=T_1}^{T_2} SPE_t / \sqrt{T_2 - T_1 + 1}$$

where T_2 and T_1 are portfolio-specific days.

RESULTS

The results of the parameter shift tests are presented in Table 1. These results indicate whether the event was of such a magnitude so as to alter the relationship between the firm (or portfolio) and the market. That is, were the alpha and/or beta significantly different during the event window from their values during the estimation period?[3]

TABLE 1
Parameter Shifts

	Union Carbide	Hazardous	Non-Hazardous
Alpha	-0.001	0.000	0.000
t Value	-1.00	-0.62	-1.06
p Value	0.319	0.534	0.289
Beta	1.077	0.831	0.875
t Value	8.25	20.03	35.01
p Value	0.000	0.000	0.000
Alpha Shift	-0.011	0.001	0.000
t Value	-3.37	0.54	0.25
p Value	0.001	0.590	0.805
Beta Shift	-0.539	-0.223	-0.151
t Value	-1.11	-1.44	-1.61
p Value	0.269	0.151	0.108

Not surprisingly, Union Carbide had a significant alpha shift of -1.096. This means that Union Carbide's stock lost an extra 1.096 percent per day, on average, for the 22 days in the event window.

Union Carbide's beta shift, although not significant at normal research thresholds, also has a simple economic interpretation. The implied shift of -0.539 does not mean the firm became less risky. It means, instead, that the event destroyed the firm's normal market-sensitivity relationship. During this period Union Carbide's stock was reacting to firm-specific events instead of moving in concert with the market.

The alpha and beta shifts for the hazardous and non-hazardous chemical producers are not significant at normal research threshold. There is weak evidence that Bhopal disrupted the normal market sensitivity of chemical producers—as indicated by the negative beta shifts at p values of 0.15 and 0.11, respectively. The low significance of these shifts, however, allows us to rely on daily prediction errors estimated using parameter coefficients from a prior estimation period. Because the purpose of this study is to examine the shortterm contagion effects of the Bhopal accident, there is no need to re-estimate regression parameters using a post-event period.

Table 2 presents the event-study statistics for Union Carbide. We note the large negative return on day t-1. This does not imply market clairvoyance. Because of time differences, 12:40 a.m. in Bhopal was late in the trading day of December 3 in New York. Union Carbide stock lost over 4 percent in value by the end of trading that day (a prediction error (PE) of -0.043). This is an indication of the speed of the market reaction.

TABLE 2
Prediction Errors For Union Carbide During The 23 Day Event Window

Event Day	PE	't'	p Value	CPE	Z
-2	-0.007	-0.66	0.512	-0.007	-0.66
-1	-0.043	-4.22***	0.000	-0.050	-3.45***
0	-0.015	-1.46	0.144	-0.065	-3.66***
1	-0.022	-2.14**	0.033	-0.087	-4.24***
2	-0.131	-12.82***	0.000	-0.218	-9.53***
3	-0.045	-4.43***	0.000	-0.264	-10.50***
4	-0.047	-4.54***	0.000	-0.310	-11.44***
5	-0.001	-0.13	0.900	-0.311	-10.75***
6	0.007	0.68	0.498	-0.305	-9.91***
7	0.051	4.99***	0.000	-0.253	-7.82***
8	-0.025	-2.41**	0.017	-0.278	-8.18***
9	-0.067	-6.56***	0.000	-0.345	-9.73***
10	0.026	2.49**	0.014	-0.319	-8.66***
11	-0.006	-0.55	0.580	-0.325	-8.49***
12	0.044	4.31***	0.000	-0.281	-7.09***
13	0.012	1.12	0.262	-0.269	-6.58***
14	0.024	2.34**	0.020	-0.245	-5.82***
15	-0.011	-1.04	0.299	-0.256	-5.90***
16	0.016	1.52	0.130	-0.240	-5.39***
17	-0.018	-1.80*	0.073	-0.259	-5.66***
18	-0.021	-2.06**	0.040	-0.280	-5.97***
19	0.018	1.72*	0.087	-0.262	-5.47***
20	0.005	0.50	0.618	-0.257	-5.24***

*Significant at the 10 percent level.
**Significant at the 5 percent level.
***Significant at the 1 percent level.

On the next day (t=0), Union Carbide stock lost another 1.5 percent; and on the day following it, lost over 2 percent (t+1; -0.022). On t+2, it lost 13 percent (-0.13134). By t+11, Union Carbide stock had dropped over 32 percent in value (a CPE of -0.325). Between t+11 and t+20, the loss was reduced to around 26 percent (a CPE of -0.257).

The t-values were negative and significant for every day between t-1 and t+4. There was a significant rebound of 5 percent on t+7 (0.051; t value 4.99). There were more statistically significant losses on t+8 and t+9, followed by rebounds on t+10, t+12, and t+14. The cumulative losses between t-1 and any day in the event window are significant at any normally applied level—Z values are more negative than -3.45 for every day after t-1.

A recovery after a big loss is not unusual. De Bondt and Thaler [5] suggest this is a recovery from an overreaction. Brown et al. [3] provide an alternative explanation, the "uncertain information hypothesis," which we find persuasive. It suggests that a negative information event has two effects on stock prices: (1) the value of the shares of a firm is written down because of the negative event, and (2) the markdown is greater because of the increased uncertainty about future prospects for the firm. As time passes, the uncertainty decreases because of resolution of the uncertainty. This explanation seems to fit the Bhopal incident.

At the time of the initial news, the potential loss of life was feared to be even more horrifying than what was reported. As time passed and the facts became better known, the write down of Union Carbide shares moderated somewhat.

Other hazardous chemical producers were affected only marginally by Union Carbide's problems. That is, there were only limited contagion effects. This can be seen by examining the PE's for the portfolio in Table 3.

TABLE 3
Prediction Errors For Hazardous Portfolio

Event Day	PE	't'	p Value	CPE	Z
-2	0.001	0.19	0.853	0.001	0.19
-1	-0.004	-0.84	0.401	-0.003	-0.46
0	-0.005	-1.01	0.315	-0.008	-0.96
1	-0.004	-0.90	0.367	-0.012	-1.28
2	-0.005	-1.11	0.267	-0.018	-1.64*
3	0.000	0.00	0.997	-0.018	-1.50
4	0.004	0.79	0.428	-0.014	-1.09
5	-0.002	-0.48	0.629	-0.016	-1.19
6	0.000	-0.01	0.994	-0.016	-1.12
7	0.004	0.81	0.419	-0.012	-0.81
8	-0.006	-1.32	0.187	-0.019	-1.17
9	-0.002	-0.34	0.735	-0.020	-1.22
10	-0.007	-1.33	0.185	-0.027	-1.54
11	0.010	2.07**	0.040	-0.017	-0.93
12	0.004	0.84	0.403	-0.013	-0.68
13	-0.001	-0.11	0.916	-0.013	-0.69
14	0.003	0.64	0.522	-0.010	-0.51
15	0.005	1.06	0.290	-0.005	-0.25
16	0.000	-0.02	0.985	-0.005	-0.25
17	0.003	0.55	0.583	-0.003	-0.12
18	0.008	1.57	0.117	0.005	0.23
19	0.003	0.59	0.559	0.008	0.35
20	0.003	0.66	0.508	0.011	0.48

*Significant at the 10 percent level.
**Significant at the 5 percent level.

On t+2, when Union Carbide lost 13.1 percent, the hazardous portfolio lost a statistically insignificant 0.53 percent. The cumulative losses on days t-1 through t+2 were enough to produce a significant Z value. That is, although none of the losses on t-1, t=0, t+1, and t+2 were significant, four losses in a row produced a cumulative loss that is significant.

The hazardous portfolio experienced, to a lesser extent, the same type of rebound as Union Carbide. The most noticeable day is t+11, when the portfolio had an abnormal return of (almost) 1 percent (PE = 0.010; t=2.07). Union Carbide had abnormal returns of 2.6 and 4.4 percent on days t+10 and t+12. By t+20, the CPE for the hazardous portfolio was, although not statistically significant, slightly positive.

The bad publicity surrounding the Union Carbide event appears to have had a small negative effect on other, less similar, chemical firms as well (see Table 4). On day t=0, these firms lost about 0.6 percent (PE = -0.006, t=-2.07). The portfolio also had small (insignificant) losses on days t+1, t+2, and t+3. The loss on t=0, plus the losses on these days, were enough to create significant Z values for the cumulative total. The small gain on t+4 was not enough to pull the cumulative total out of the significant range.

TABLE 4
Prediction Errors For Non-Hazardous Portfolio

Event Day	PE	't'	p Value	CPE	Z
-2	-0.003	-1.10	0.271	-0.003	-1.10
-1	-0.002	-0.52	0.602	-0.005	-1.15
0	-0.006	-2.07**	0.039	-0.011	-2.13**
1	-0.001	-0.21	0.833	-0.011	-1.95*
2	-0.001	-0.27	0.784	-0.012	-1.86*
3	-0.003	-1.01	0.315	-0.015	-2.11*
4	0.001	0.49	0.623	-0.014	-1.77*
5	0.000	0.08	0.935	-0.013	-1.63
6	0.000	-0.11	0.916	-0.014	-1.57
7	0.003	0.91	0.366	-0.011	-1.20
8	0.000	-0.15	0.879	-0.011	-1.19
9	-0.003	-1.05	0.295	-0.015	-1.45
10	-0.002	-0.84	0.402	-0.017	-1.62
11	0.005	1.76	0.079	-0.012	-1.09
12	0.003	1.09	0.276	-0.009	-0.77
13	0.000	0.11	0.914	-0.008	-0.72
14	0.001	-0.31	0.760	-0.009	-0.78
15	0.003	1.00	0.317	-0.006	-0.52
16	0.002	0.65	0.516	-0.005	-0.36
17	0.001	0.26	0.797	-0.004	-0.29
18	0.002	0.65	0.515	-0.002	-0.14
19	0.003	1.18	0.239	0.002	0.12
20	0.001	0.23	0.817	0.002	0.16

*Significant at the 10 percent level, two-tailed test.
**Significant at the 5 percent level, two-tailed test.

The non-hazardous portfolio, like the Union Carbide and the hazardous portfolio experienced a rebound after the initial losses. Like the hazardous portfolio, the most noticeable (significant) day is t+11. By t+20, the cumulative total, CPE, is a non-significant, positive, near zero amount.

Table 5 presents the results for various sub periods for the three portfolios. Union Carbide suffered almost a 6 percent (CPE = -0.058) loss during the two days t=-1,0. The other two portfolios had insignificant losses over the same period.

Over the t-1 to t+3 period, the losses on all three portfolios are significant. The size of the loss (almost 26 percent!) is much greater for Union Carbide, but the 1.9 percent and 1.2 percent losses, respectively, for the hazardous and non-hazardous portfolios are statistically significant. The losses are also significant for all three over the -1 to +10 period.

TABLE 5
Interval Statistics For Various Subperiods

	Union Carbide		Hazardous		Non-Hazardous	
Subperiod	**CPE**	**Z**	**CPE**	**Z**	**CPE**	**Z**
t-1 to t=0	-0.058	-4.11***	-0.009	-1.31	-0.008	0.33
t-1 to t+3	-0.257	-11.21***	-0.019	-1.73*	-0.012	-1.82*
t-1 to t+10	-0.313	-8.19***	-0.028	-1.66*	-0.014	-1.37
t+5 to t+10	-0.009	-0.38	-0.013	-1.09	-0.003	-0.47
t+10 to t+15	0.089	3.54***	0.015	1.29	0.008	1.01
t+10 to t+20	0.088	2.58***	0.031	1.97**	0.017	1.74*
t+15 to t+20	-0.012	-0.47	0.021	1.80*	0.012	1.62

*Significant at the 10 percent level.
**Significant at the 5 percent level.
***Significant at the 1 percent level.

The cumulative prediction errors over the t+5 to t+10 period are not significant for either Union Carbide or the other two portfolios. During t+10 to t+15, Union Carbide rebounded significantly—almost 9 percent (PE = 0.089; Z = 3.54). The rebounds on the other portfolios came slightly later.

During the period t+10 to t+20, all three portfolios had significant positive cumulative prediction errors. Union Carbide's had a CPE of 0.088, all of which was from the gains on t+10 to t+15. The hazardous portfolio gained 3 percent (CPE = 0.031; Z = 1.97) most of which was during the t+15 to t+20 period (CPE = 0.021; Z = 1.80). Most of the non-hazardous portfolio gains are from the later period also. Because of the smaller magnitude of the gains, however, the Z value for the five-day period (t+15 to t+20) is not significant, although the slightly larger gain for the ten-day period is significant.

FURTHER INTERPRETATION

A CPE chart helps to visualize the effects. Figure 1 presents the traditional CPE chart for the Bhopal incident. Because of the widely disparate magnitude of the reactions for Union Carbide and the two other portfolios, the chart is graphed on two different scales—Union Carbide on the right, the portfolios on the left.

By t=0, Union Carbide lost over 5 percent. The hazardous and non-hazardous portfolios had slipped only by about 1 percent. Union Carbide suffered high, almost immediate losses. By t+5, its losses were over 30 percent. The other two portfolios, experienced losses of about 1.5 percent with the hazardous portfolio losing slightly more than the non-hazardous.

The losses had reached their worst for all three portfolios by approximately t+10. Union Carbide was down about 32 percent, while the two portfolios were down 2.7 and 1.7 percent; as before, the hazardous portfolio lost more.

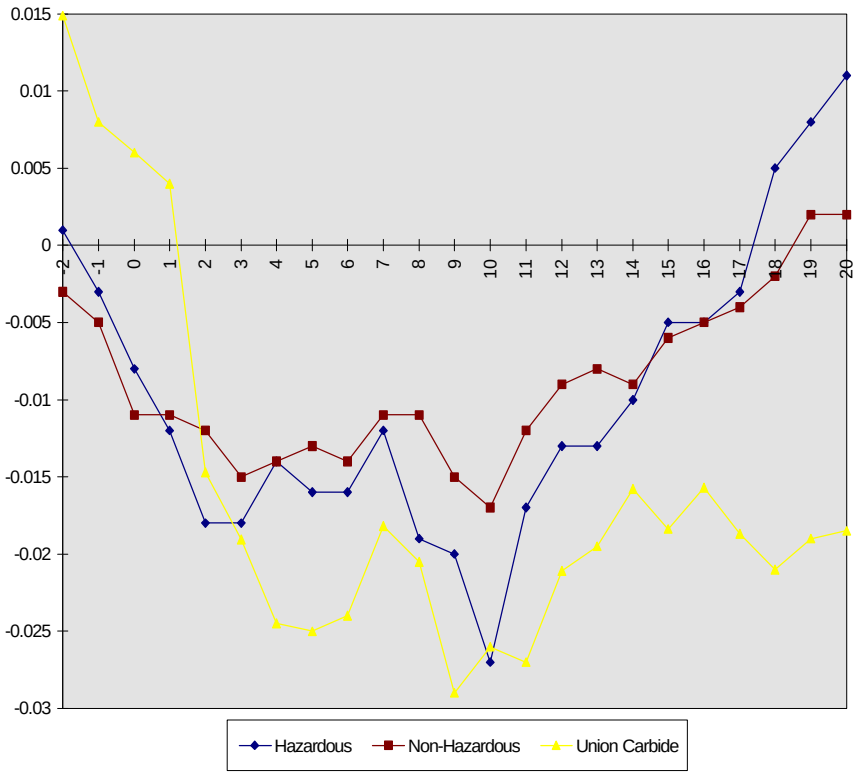
After t+10, all three showed improvement. Union Carbide regained about 6 percent, ending up with a loss of about 26 percent. The two portfolios recaptured all losses, finishing at positions not significantly different from zero.

SUMMARY AND CONCLUSIONS

This event study examines the returns of Union Carbide and the chemical industry during the period of the Bhopal disaster. This study must deal with most of the problems that researchers will encounter in carrying out event studies—calendar, industry and risk clustering.

As might be expected there were industry-wide contagion effects caused by the uncertainty created by the Bhopal disaster. Further, the impact was greater for the producers of hazardous chemical more similar to the product involved in the Bhopal accident. However, the uncertainty for these firms appears to have been resolved rather quickly and the share prices of the chemical producers rebounded rapidly—producing gains that wiped out the losses occurring at the time of the Bhopal incident.

FIGURE 1
CPEs For Three Chemical Portfolios During 23 Days Around Bhopal



Scaling For Union Carbide CPEs adjusted for clarity.

ENDNOTES

1. The bank contagion literature is reviewed by Kaufman [13].

2. Lamy and Thompson [14], Peavy and Hempel [18], and Karafiath and Glascock [11] study the information effects of the Penn Square failure (energy loans). Slovin and Jayanti [19] study the information effects of the Latin American debt moratoriums.

3. If a beta shift were detected, one should also run the study with parameter estimates from a post-event estimator period to see whether this would change the interpretation of the results.

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