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PAPER NO. 955

An Event-Time Analysis of the Three Mile Island Nuclear Accident

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April 1983

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ABSTRACT

The purpose of this paper is to examine the impact of the 28 March 1979 accident at the Three Mile Island (TMI) nuclear power facility on the systematic risk of General Public Utilities (TMI's owner) and other electric utilities heavily invested in nuclear power facilities. The results have implications for the returns required by investors and, therefore, on the economic viability of nuclear power for electricity generation. This paper compares the results of a traditional cumulative abnormal residual analysis (CAR) with the results of intervention analysis. It is found that the CAR analysis indicates abnormal negative returns occurred after the TMI accident. However, intervention analysis shows the assumptions necessary for the CAR method to be appropriate are violated. When adjustments are made for a shift in systematic risk and autocorrelation, no abnormal returns are generated.

An Event-Time Analysis of the Three-Mile Island Nuclear Accident

The March 28, 1979 Three Mile Island (TMI) nuclear accident added a new dimension to the ongoing debate over the private and social costs and benefits of nuclear power. Utility executives speculate "that the Harrisburg accident will add billions of dollars to nuclear generating costs that are already vastly higher than imagined" [18]. Some indication of TMI's "financial fallout" became apparent when General Public Utilities (GPU), which owns the TMI nuclear reactor, cut its quarterly dividend and told its stockholders on May 9, 1979 that unless governmental subsidies for the accident costs were forthcoming, GPU faced bankruptcy [1]. Not surprisingly, investment articles on the electric utility industry immediately began presenting utility data classified by the capacity percentage represented by nuclear power. Now, some four years after the accident the cleanup costs are estimated at $975 million and the expected completion date is mid-1988 [20].

The TMI accident made the cost-profit-risk dimensions of "nuclear risk" more apparent to investors and regulators. Whether the TMI incident altered the required rate of return of equity investors in electric utilities with nuclear generating capacity (hereafter nukes) is an important question. In an efficient capital market, a firm specific event such as the TMI accident would be hypothesized to have a negligible impact on nuke and non-nuke utility stocks. However, if nuclear generating capacity is perceived as increasing an investor's risk, then this will impact regulatory allowed rates of return and the cost-benefit choice between competing power generation sources.

The purpose of this paper is to examine the impact of the accident on the risk and return characteristics of (1) General Public Utilities, (2) other electric utilities heavily invested in nuclear power facilities, and (3) electric utilities without investment in nuclear power. Three empirical methodologies are used in the study: (1) cumulative abnormal returns (CAR) analysis, (2) intervention analysis and (3) beta decomposition analysis. Section I describes the models to be used and presents the empirical results of each model. Concluding remarks are presented in Section II.

I. The Models

Three empirical methodologies are used to examine the impact of the TMI accident on the returns and risks of the nuke and the non-nuke utility stocks. Risk and return are examined for (1) a portfolio of utilities which own and operate nuclear units, (2) a portfolio of utilities which have no investment in nuclear units, (3) General Public Utilities, the owner of the TMI nuclear unit, and (4) the five utilities with the largest investment in nuclear facilities.[1] All three methodologies utilize 121 weeks of return data; 60 weeks before and after the week of the accident.[2]

A. Cumulative Abnormal Return (CAR) Analysis

The traditional CAR method has been widely used in event-time studies to measure the impact of the announcement of new publicly available information (such as earnings, dividends, stock splits, mergers, accounting changes, etc.) on the risk-adjusted return of securities and to infer market efficiency or information content.[3] The method is based on the single-factor market model given by

$$\tilde{R}_{jt} = \alpha_j + \beta_j \tilde{R}_{mt} + \tilde{\varepsilon}_{jt} \quad (1)$$

where $\tilde{R}_{jt}$ = the rate of return on security or portfolio j over period t,

$\tilde{R}_{mt}$ = the rate of return on a value-weighted market portfolio over period t,

$\tilde{\varepsilon}_{jt}$ = the random disturbance term of the rate of return on security or portfolio j over period t, with $E(\tilde{\varepsilon}_{jt}) = 0$.

The residual term, $\tilde{\varepsilon}_{jt}$, represents the deviation of the actual return in period t from the return estimated by the market model and hence is a measure of risk-adjusted abnormal return.

In this study sixty weeks before and after the accident week are designated as the estimation period and the analysis period, respectively. The parameters estimated from equation (1) over the estimation period are presented in Table I. The t-statistics for the beta estimates are significant at the .01 level for all but one case, indicating that systematic risk is indeed an important factor in the return generating process for utility stocks.

[Insert Table I Here]

Given the market model parameter estimates, $\hat{\alpha}_j$ and $\hat{\beta}_j$, from the estimation period, abnormal returns for each period t within the analysis period are calculated as follows:

$$AR_{jt} = R_{jt} - (\hat{\alpha}_j + \hat{\beta}_j R_{mt}) \quad (2)$$

For a portfolio, the cross-sectional average abnormal return for period t is

$$\overline{AR}_t = \sum_{j=1}^{N} \frac{AR_{jt}}{N} \quad (3)$$

where N is the number of securities in the portfolio in period t. The cumulative abnormal return over the entire sample period is given by

$$CAR = \sum_{t=-60}^{60} \overline{AR}_t . \quad (4)$$

The CARs are plotted in Figure 1. In all but one (GPU) case, the CAR curves wander around zero and no persistent downward or upward drifts occur either before or after the accident week. These results suggest the firm specific TMI accident had negligible impact on other electric utilities, both nuke and non-nuke. However, the CAR curve for the GPU drifts downward persistently after the accident. The CAR reaches -121.6 percent fifty-two weeks after the accident and -86.8 percent at the end of the analysis period.

[Insert Figure 1 Here]

With regard to GPU, the unfavorable reaction of the market to the negative information content of the TMI accident causes the CAR curve to drift persistently downward after the accident. An investor who sold GPU stock short immediately after the accident could realize an 121.6 percent excess risk-adjusted return (before transaction costs) fifty-two weeks after the accident. Substantial excess risk-adjusted returns are generated even if transaction costs are considered.

However, these CAR results must be viewed with caution. CAR analysis assumes the beta coefficient estimated for the 60-week pre-TMI period

Table I

Parameters Estimated From Equation (1) Over the 60-month Estimation Period

$$\tilde{R}_{jt} = \alpha_j + \beta_j \tilde{R}_{mt} + \tilde{\varepsilon}_{jt} \qquad t = -60, \ldots .\ -1$$

	Nukes	Non-Nukes	GPU	5 Nuke Group	Five Major Nuclear Utilities				
					#1	#2	#3	#4	#5
$\hat{\alpha}$	-0.000	-0.000	-0.001	-0.000	0.001	0.000	-0.001	-0.001	-0.000
	(-0.176)	(-0.404)	(-0.485)	(-0.152)	(0.339)	(0.023)	(-0.403)	(-0.375)	(-0.103)
$\hat{\beta}$	0.346	0.368	0.442	0.366	0.304	0.433	0.347	0.270	0.477
	(5.896)**	(7.388)**	(3.984)**	(5.499)**	(3.288)**	(3.457)**	(4.747)**	(2.311)*	(4.257)**

Co. #1 Baltimore Gas & Electric
#2 Carolina Power & Light
#3 Commonwealth Edison
#4 Northeast Utilities
#5 Northern States Power

t-values are in parentheses.

** significant at 1%
* significant at 5%

Figure 1

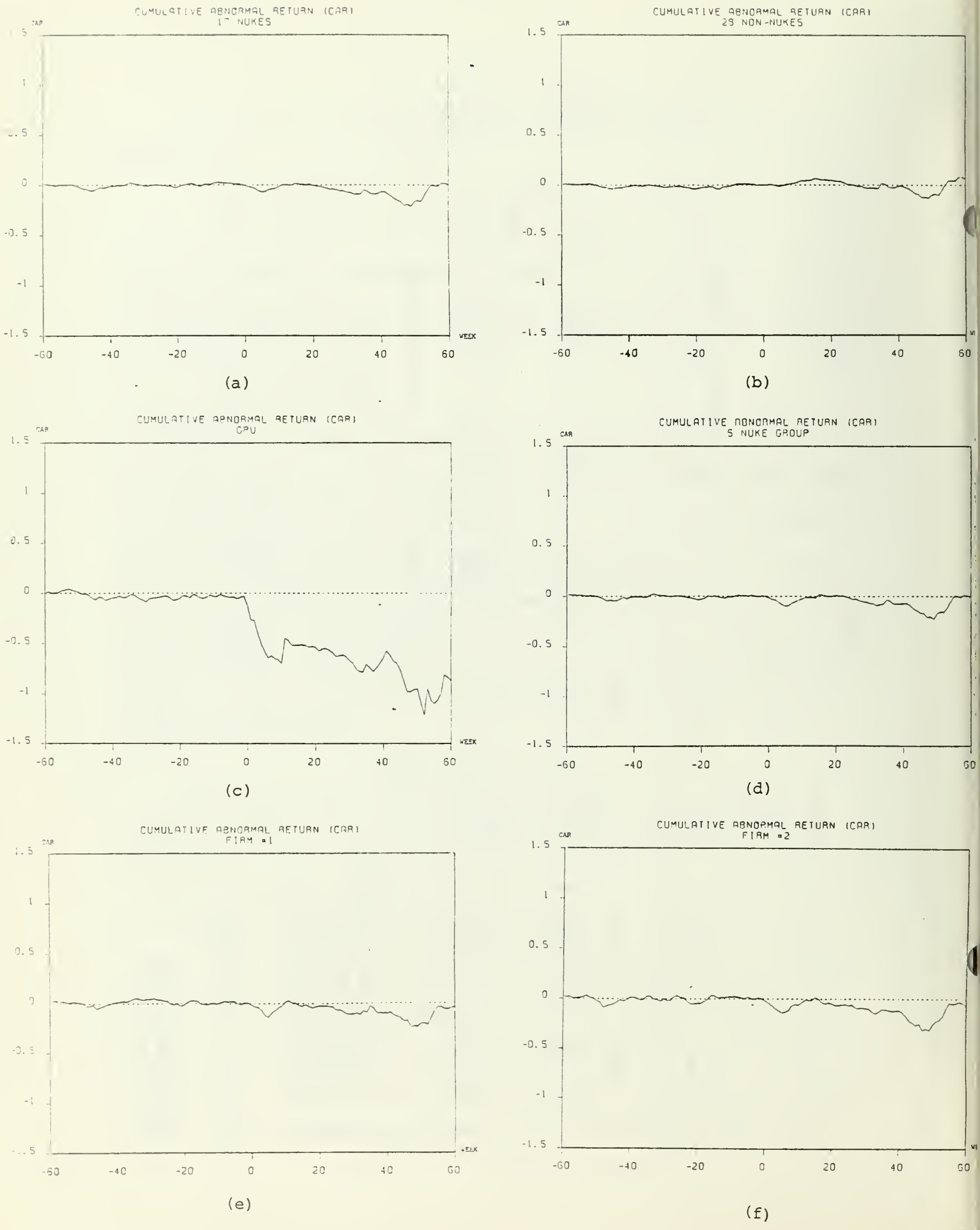
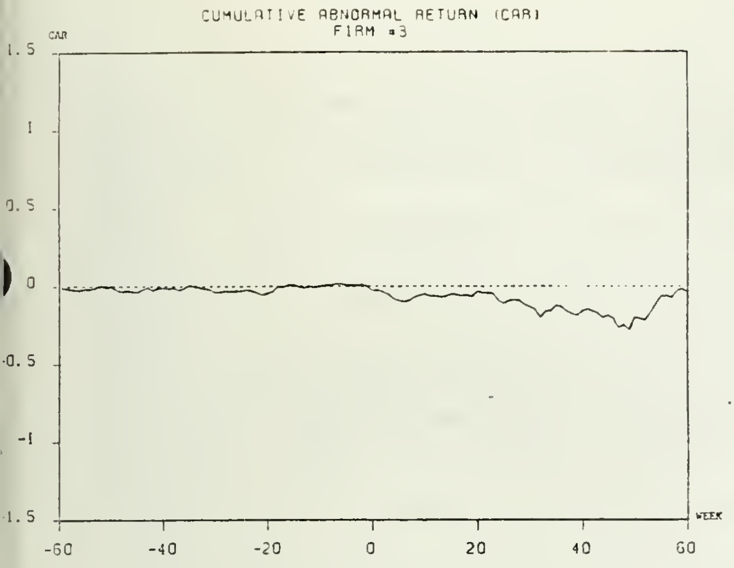
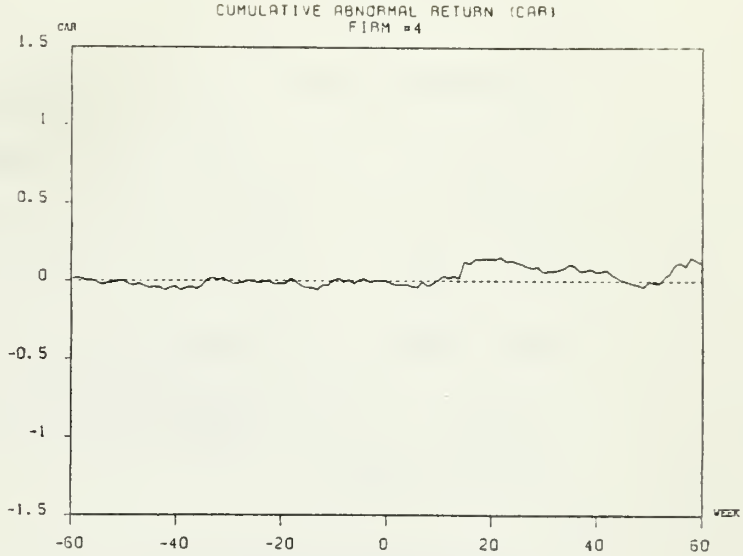

CUMULATIVE ABNORMAL RETURN (CAR)
17 NUKES
CAR
WEEK
(a)
CUMULATIVE ABNORMAL RETURN (CAR)
29 NON-NUKES
(b)
CUMULATIVE ABNORMAL RETURN (CAR)
CPU
(c)
CUMULATIVE ABNORMAL RETURN (CAR)
5 NUKE GROUP
(d)
CUMULATIVE ABNORMAL RETURN (CAR)
FIRM =1
(e)
CUMULATIVE ABNORMAL RETURN (CAR)
FIRM =2
(f)

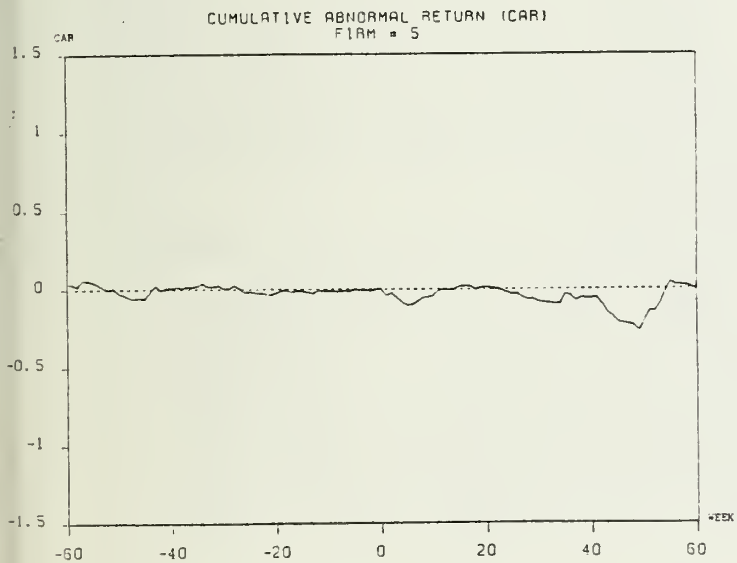
Figure 1 (continued)



(g)



(h)



(i)

remains constant during the analysis period. But the persistent drift in the CAR curve of GPU may be caused by changes in the systematic risk of GPU as the result of the TMI accident. If so, the result obtained from Figure 1c will be biased and lead to incorrect conclusions. For this reason, intervention analysis is employed to examine further the impact of the TMI accident on the performance of nuke and non-nuke utility stocks.

B. Intervention Analysis

Any financial announcement can be viewed as an intervention. Recently, based on Box and Tiao [7], Larcker, Gordon and Pinches [22] have proposed an alternative methodology, intervention analysis, for event-time studies. Intervention analysis provides a better test for market efficiency or information content than the CAR method on two counts. First, it is able to test specifically for a shift in the return series as distinct from systematic risk changes.[4] More precisely, intervention analysis can separate such risk changes from the information content of the announcement. Second, it allows the observed autocorrelation in the market model residuals to be removed.[5]

The following expanded market model is utilized to examine the impact of the TMI accident on the performance of nuke and non-nuke utility stocks during the 60-week pre-TMI and 60-week post-TMI periods.[6]

$$\tilde{R}_t = \alpha + \beta_1 \tilde{R}_{mt_1} + \beta_2 \tilde{R}_{mt_2} + \gamma D + \frac{\tilde{a}_t}{1-\phi B} \qquad (5)$$

$$\text{where } \tilde{R}_{mt_1} = \begin{cases} \tilde{R}_{mt} : & -60 \leq t < 0 \\ 0 : & \text{otherwise} \end{cases},$$

$$\tilde{R}_{mt_2} = \begin{cases} \tilde{R}_{mt} : & 0 \leq t \leq 60 \\ 0 : & \text{otherwise} \end{cases},$$

$$D = \begin{cases} 1 : & 0 \leq t \leq 60 \\ 0 : & \text{otherwise} \end{cases},$$

B = the backshift operator such that $B\tilde{R}_t = \tilde{R}_{t-1}$,

ϕ = the time series parameter of the noise model, and

$\tilde{a}_t$ = the random disturbance term.

The coefficients, β_1 and β_2, are measures of systematic risk before and after the accident, respectively. The coefficient γ measures the post-accident excess risk-adjusted return. Table II summarizes the results of the parameter estimates for equation (5).

[Insert Table II Here]

As expected, the t-statistics for $\hat{\beta}_1$ and $\hat{\beta}_2$ indicate the beta coefficients are significantly different from zero for most of the cases. This means that systematic risk was an important explanation of returns for most firms and portfolios both before and after the accident. More importantly, the t-statistics for $\hat{\gamma}$ are not significant for any case. Even the $\hat{\gamma}$ for GPU is insignificant which indicates no excess risk-adjusted returns occurred following the TMI accident after allowing for shifts in systematic risk and accounting for possible autocorrelation. Hence, the results for GPU obtained using intervention analysis conflict with the results obtained using the CAR method. GPU's post-accident β was nearly double its pre-accident value. However, this change in beta was not statistically significant due to the large standard errors of the estimates. None of the betas for the other nukes or utility portfolios were

Table II

Test of the Parameter Estimates for Equation (5)

$$\tilde{R}_t = \alpha + \beta_1 \tilde{R}_{mt_1} + \beta_2 \tilde{R}_{mt_2} + \gamma D + \frac{\tilde{a}_t}{1-\phi B}$$

$$\text{where } \tilde{R}_{mt_1} = \begin{cases} \tilde{R}_{mt} : & -60 \leq t < 0 \\ 0 : & \text{otherwise} \end{cases}$$

$$\tilde{R}_{mt_2} = \begin{cases} \tilde{R}_{mt} : & 0 \leq t \leq 60 \\ 0 : & \text{otherwise} \end{cases}$$

$$D = \begin{cases} 1 : & 0 \leq t \leq 60 \\ 0 : & \text{otherwise} \end{cases}$$

	Nukes	Non-Nukes	GPU	5 Nuke Group	#1	#2	#3	#4	#5
$\hat{\alpha}$	-0.000 (-0.071)	-0.000 (-0.115)	-0.001 (-0.137)	0.000 (0.029)	0.000 (0.230)	0.000 (0.018)	-0.000 (-0.194)	-0.001 (-0.384)	-0.000 (-0.021)
$\hat{\beta}_1$	0.346 (3.489)**	0.362 (4.050)**	0.443 (1.151)	0.342 (3.140)**	0.281 (1.938)+	0.389 (2.614)*	0.345 (2.425)*	0.291 (2.028)*	0.489 (3.206)**
$\hat{\beta}_2$	0.381 (4.307)**	0.357 (4.473)**	0.851 (2.475)*	0.374 (3.843)**	0.440 (3.396)**	0.204 (1.538)	0.512 (4.030)**	0.264 (2.058)*	0.364 (2.670)**
$\hat{\gamma}$	-0.000 (-0.018)	0.001 (0.255)	-0.015 (-1.385)	-0.001 (-0.139)	-0.001 (-0.248)	-0.001 (-0.166)	-0.001 (-0.293)	0.002 (0.593)	-0.000 (-0.002)
$\hat{\phi}$	-0.312 (-3.62)**	-0.293 (-3.366)**	-0.010 (-0.105)	-0.301 (-3.469)**	-0.188 (-2.106)*	-0.276 (-3.161)**	-0.042 (-0.459)	0.174 (1.948)+	-0.213 (-2.400)*
$(\hat{\beta}_2 - \hat{\beta}_1)$	0.035 (0.269)	-0.005 (-0.040)	0.408 (0.794)	0.032 (0.219)	0.159 (0.820)	-0.185 (-0.929)	0.167 (0.880)	-0.027 (-0.141)	-0.125 (-0.615)
R^2	0.209	0.239	0.073	0.175	0.117	0.074	0.161	0.069	0.131

t-values are in parentheses

** significant at 1%

* significant at 5%

\+ significant at 10%

statistically significantly different after the TMI accident. These results are presented as $(\hat{\beta}_2 - \hat{\beta}_1)$ in Table II.

C. Beta Decomposition Analysis

Some insights into the underlying characteristics of the observed betas of the utilities around the TMI accident may also be obtained through decomposition analysis. Francis [16] decomposed the beta coefficient in an effort to determine whether the source of beta instability arises from market return variability (σ_m), asset return variability (σ_j), or the correlation of asset and market returns $(\rho_{j,m})$.

Component values for the above three determinants of beta are shown in Table III for the 60 week pre-TMI and the 60 week post-TMI periods for the nuke and the non-nuke utility portfolios. The nuke and non-nuke portfolios displayed similar $\rho_{j,m}$, σ_j, and, thus, β values before TMI. The non-nuke total risk proxy, σ_j, increased significantly after TMI, but the systematic association of non-nuke returns and market returns fell sharply. Hence, slightly increased market variability and lower covariance with the market caused the non-nuke beta to be slightly lower in the post accident period. The beta for the nuke portfolio increased slightly due to the doubling of σ_j even as the $\rho_{j,m}$ declined.

[Insert Table III Here]

Component values for GPU and the five utilities that obtain 43 to 58 percent of their capacity through nuclear generation facilities are also presented in Table III. GPU's beta nearly doubled due to the fourfold increase in σ_j. GPU's $\rho_{j,m}$ declined by approximately 50%. Component data for the five utilities with the largest nuclear generation capacity show the $\rho_{j,m}$ for these utilities declined and the σ_j increased. As

Table III

Component Values of βs of Nukes and Non-Nukes in the 60 Week Pre-TMI and 60 Week Post-TMI Periods

	$\rho_{j,m}$		σ_j		β_j	
	Before TMI	After TMI	Before TMI	After TMI	Before TMI	After TMI
Nukes (17)	0.6122	0.3510	0.0108	0.0210**	0.3458	0.3501
Non-Nukes (28)	0.6963	0.3870	0.0101	0.0193**	0.3680	0.3530
GPU	0.4635	0.2297	0.0182	0.0787**	0.4426	0.8555
5 Nuke Group	0.5854	0.3215	0.0119	0.0226**	0.3663	0.3444
#1	0.3964	0.3223	0.0146	0.0283**	0.3041	0.4317
#2	0.4133	0.1508	0.0199	0.0264	0.4331	0.1881
#3	0.5289	0.3688	0.0125	0.0289**	0.3469	0.5040
#4	0.2904	0.2161	0.0178	0.0263+	0.2700	0.2685
#5	0.4879	0.2475	0.0186	0.0282+	0.4771	0.3299
Market (NYSE & AMEX)	1.000	1.000	0.0190	0.0211	1.000	1.000

Total risk in Post-TMI period is significantly different from Pre-TMI period at:

** 1% level (one-tailed test)
+ 10% level (one-tailed test)

a result, two of these firms showed higher betas and three exhibited lower betas.

To summarize, the correlation between electric utility returns and the market declined for both nuke and non-nuke portfolios while the standard deviation of returns increased for all utilities after the accident. The change in beta depends on whether the increased return variance was greater than, similar to, or less than the change in the correlation.

To examine whether a shift in total risk (variance) was caused by industry or firm specific effects or was due to changes in market-wide factors, the total variation of portfolio and company returns was divided into the proportion of variation explained by the market model and the proportion accounted for by the residuals. The total risk measure was decomposed into systematic and unsystematic components from equation (1)

$$\sigma^2 = \beta^2\sigma_m^2 + \sigma_e^2 \qquad (6)$$

where σ_e^2 is the unsystematic risk.

The results for the pre-TMI and post-TMI periods are presented in Table IV. It is observed that the proportion of the total variation explained by the market model fell sharply after the accident for all portfolios and individual utilities.

[Insert Table IV Here]

Thus, as the total variation of returns increased, the explanatory power of the market model decreased. This is additional evidence that the analysis of beta may be inadequate to describe the return series following the TMI accident. Before the accident, both nuke and non-nuke

Table IV

Estimates of Risk Shifts Due to the TMI Accident

Portfolio or Company	Pre-TMI		Post-TMI	
	$\beta^2\sigma_m^2/\sigma^2$	σ_e^2/σ^2	$\beta^2\sigma_m^2/\sigma^2$	σ_e^2/σ^2
Nuke	.370	.630	.124	.876
Non-Nuke	.479	.521	.149	.851
GPU	.213	.787	.053	.947
5 Nukes	.342	.658	.103	.897
#1	.157	.843	.104	.896
#2	.170	.830	.023	.977
#3	.278	.722	.135	.865
#4	.083	.917	.046	.954
#5	.238	.762	.061	.939

stocks possess a significant degree of unsystematic risk due to the regulatory environment in which the firms operate. After the accident the degree of unsystematic risk increased substantially. If diversification cannot eliminate all unsystematic risk, the CAPM is no longer an appropriate analytical tool to apply to both nuke and non-nuke utilities[7] in the sense that beta is an incomplete risk measure.[8] This incompleteness gives rise to obvious problems in determining the appropriate fully-risk-adjusted rate of return for rate making purposes.

II. CONCLUDING OBSERVATIONS

This paper has examined the impact the TMI accident had on the risk and return characteristics of electric utilities with and without nuclear generating capacity. Three methods of analysis were used to determine if the risk and return characteristics of utilities changed due to the TMI accident. The results of the CAR and intervention analysis methodologies were consistent for the non-nuke utilities and for all the nuclear utilities except GPU. The CAR methodology indicated substantial abnormal excess risk-adjusted (negative) returns occurred for GPU following the TMI accident. However, the intervention analysis, which adjusts for systematic risk changes and autocorrelation, indicated there were no excess risk-adjusted returns for GPU. The beta decomposition analysis indicated the betas for the utilities were not significantly changed because of relative changes in the correlation coefficient and total return variability. For GPU the increase in total return variability was nearly twice the decline in the correlation coefficient, but because of large standard errors of the estimates, the increase in beta was not statistically significant. Finally, the proportion of total return variation explained by the market model was substantially less after the TMI accident.

The observed level of total risk for both nuke and non-nuke portfolios was substantially higher in the post-TMI period while the total risk for the market index increased only slightly. Post-TMI systematic risk for both nuke and non-nuke utilities was not significantly different from the level of the pre-TMI period. Unsystematic risk increased substantially after the accident. As such, the impact of the TMI accident upon an electric utility's cost of equity capital revolves around whether investors' required return is based only upon systematic risk.

FOOTNOTES

[1]The electric utilities were classified using data contained in [32, 33] into five nuclear generation categories as of April 1, 1978: (1) operating nuclear units alone; (2) operating nuclear units jointly with other utilities; (3) building nuclear units alone; (4) building nuclear units jointly; and (5) no nuclear generation ownership. A utility that both operated its own nuclear unit as well as operated units jointly was classified in category 1. In this study "nukes" is used to refer to category 1 firms and "non-nukes" to refer to category 5 firms. There are 17 utilities in the nuke group and 28 utilities in the non-nuke group.

The five utilities with the largest nuclear capacity percentages are: (1) Baltimore Gas & Electric, 57%; (2) Carolina Power & Light, 47%; (3) Commonwealth Edison, 45%; (4) Northeast Utilities 58%; and (5) Northern States Power, 43%.

[2]Weekly rates of return are computed by compounding daily returns for each calendar week. Daily returns were obtained from the CRSP tapes. As Scholes and Williams [28] has shown, nonsynchronous trading of securities introduces into the market model a potentially serious econometric problem of errors in variables. With daily data, the problem is especially severe. Hence, weekly data are used in the study.

[3]See Ball and Brown [2],and Fama, Fisher, Jensen and Roll [15].

[4]Changes in systematic risk have been documented by Boness, Chen and Jutusipitak [4], Bar-Yosef and Brown [3], and Brenner and Smidt [9].

[5]Evidence on the negatively correlated market model residuals can be found in Ball and Brown [2], and Schwartz and Whitcomb [29].

[6]By examining the autocorrelations and partial autocorrelations of equation (5), we find a first-order autoregressive model is appropriate for the structural form of noise for most of the cases (see Box and Jenkins [5], page 79).

[7]Articles concerning the use of the capital asset pricing model in rate regulatory hearings include [8, 11, 12, 19, 23, 24, 25, 26, 27, 31].

[8]Brigham and Crum [11] reported electric utility security returns are skewed to the left.

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