CAT 48 (9/11) Event Study Data Analysis

Capital market and financial data relating to insurance companies circa CAT 48 (the 9/11/2001 attack) were gathered from CRSP and A. M. Best. Concurrent estimates of firm-specific losses sustained in the catastrophe were obtained from a Guy Carpenter client survey. The objective of the study was to test the theory that financial strength mediates the market value of an event loss. A statistically significant relationship between financial strength (Best's Capital Adequacy Ratio) and the market's response to an event loss was found.

1. The data

Financial and rating data from A. M. Best consisted of two types of records: parents and subsidiaries. Subsidiaries were associated with parents. Parent-level records held stock market from CRSP and estimates of losses in CAT 48 (the 9/11/2001 attack) from a Guy Carpenter client survey. In some cases, financial and rating data was not available at the parent level, but only at the sub level. Regression analysis required a data set with only parent records and the fields listed in table 1.

Table 1: Data fields

1.	Firm Identifiers	
2.	LOSS	amount of loss in CAT 48
3.	CAP831	market cap at 8/31/2001
4.	RSEP	stock market return from 8/31 to end of September 2001
5.	ROCT	" " " October "
6.	RNOV	" " " November "
7.	RDEC	" " " December "
8.	NPW	net written premium
9.	PHS	statutory policyholder surplus (capital & surplus)
10.	LOSSRSV	loss reserve/PHS in %
11.	LOBS	primary line of business
12.	LNPW	NPW attributed to primary line of business
13.	BCAR	A. M. Best BCAR score (Best's Capital Adequacy Ratio)
14.	RTG	numerical score for AMBest rating

Items 4-7 were to be the criteria (dependent variables); items 2 and 8-14 were to be considered as predictors (independent variables). Items 1-7 were always available at the parent level. An automated procedure to impute parent-level values of LOBS and RTG where needed was attempted. This turned out to be unworkable. The structure of subsidiaries involved overlapping definitions of ownership and double-counting of NPW and PHS. Therefore manual inspection of each case was used to identify (a) whether the parent data could be used as-is, and if not, (b) which subsidiaries should be combined together (added or averaged) to best represent the variables of the firm as a whole.

Of the 54 firms reporting a loss, 23 had credible data posted at the level of the parent. Of the remaining 31 firms, 14 were judged to be fairly represented by one subsidiary. Another 10 firms were represented by more than one subsidiary. The remaining 7 firms could not be resolved.

Of the 47 firms for which parent-level financials could be found or estimated, five firms showed unusual (and therefore suspect) relationships between market capital, premium, event loss, and surplus. Another three firms lacked BCAR scores. This left 39 firms that entered the study. They are listed in table 2.

Table 2: Firms entering the study

Ace Ltd
Allianz Aktiengesellschaft
Allstate Corp
American International Group Inc
Argonaut Group Inc
Berkley W R Corp
Berkshire Hathaway Inc Del
C N A Financial Corp
Chubb Corp
Cincinnati Financial Corp
Delphi Financial Group Inc
E M C Insurance Group Inc
Everest Re Group Ltd
H C C Insurance Holdings Inc
Harleysville Group Inc
Lincoln National Corp In
Markel Corp
Metlife Inc
Nationwide Financial Services In
Odyssey Re Holdings Corp
Ohio Casualty Corp
P X R E Group Ltd Bermuda
Philadelphia Consolidated Hlg Co
Pma Capital Corp
Prudential Plc
Qbe Insurance Group
Royal & Sun Alliance Ins Grp Plc
S C P I E Holdings Inc
Safeco Corp
Scor
St Paul Cos Inc
Stancorp Financial Group Inc
State Auto Financial Corp
Tokio Marine & Fire Ins Ltd
Transatlantic Holdings Inc
Trenwick Group Ltd
United Fire & Cas Co
Unumprovident Corp
Zenith National Insurance Corp

2. The model

The general form of the models being investigated was

$$M = f(L, B) + g(L, B) \cdot E$$

where

- M is market loss, measured over a one- to four-month horizon. Capital market returns from 8/31 to the end of each of the subsequent four months (RSEP, ROCT, RNOV, RDEC) were applied to market cap as of 8/31. Statistics are presented in table 3.
- E is event loss, i.e. the pre-tax loss amount reported in CAT 48.
- L is an index or measure of line of business. There were 42 distinct lines of business coded in the source data.[1] Various recoding schemata were tried.
- B is the Best's Capital Adequacy Rating (BCAR, discussed below).[2]
- M and E are scaled by Net Premiums Written or Policyholder Surplus.[3] Losses were scaled because of the large range of sizes among firms; the largest five firms had PHS averaging 67 times that of the smallest five firms.

Functional forms that were considered included constants subscripted by line of business or BCAR class intervals, linear forms in BCAR and proportion of business in reinsurance, a quadratic in BCAR, and linear forms in log(BCAR).

BCAR is defined as the ratio of a firm's (Absolute) Capital Adequacy Ratio (CAR) to the average CAR of its peer group, times 100. The CAR is defined as the ratio of adjusted surplus to required surplus. Adjusted surplus is surplus (PHS) less the greater of the 100 year net hurricane probable maximum loss (PML) and the 250 year net earthquake PML, plus or minus other adjustments relating to reserve adequacy, debt, capital impairment, etc. More detail is available from [A. M. Best]. Symbolically, we may write:

$$CAR = \frac{PHS - adj}{reqPHS},$$
$$BCAR = CAR / \overline{CAR}$$

or, more succinctly,

$$BCAR = k \cdot (PHS - adj)$$

where both the factor *k* and the adjustment *adj* are specific to the firm.

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[1] The 42 LOBs occurred among the 149 firms in the full financial database.

[2] Letter-grade ratings were also examined, but the numerical BCAR score consistently outperformed ratings.

[3] In preliminary work, Loss Reserves were also considered as scaling factors. Because Loss Reserves were so highly correlated with Policyholder surplus, this factor was subsequently dropped from the analysis.

Table 3: Statistics of returns

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Variable       Mean        Std Dev      Minimum       Maximum

RSEP        -0.0687561   0.1555903   -0.4607378    0.2639167
ROCT        -0.0624456   0.1651201   -0.4468070    0.4011043
RNOV        -0.0133424   0.1485389   -0.3626875    0.4087405
RDEC         0.0272933   0.1666599   -0.2976396    0.4174299
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3. Fitting the model

Well over 100 models were fitted to each of eight design blocks (four time horizons by two scale factors). A second-order variant of Akaike's Information Criterion, AIC_c [Burnham & Anderson], which is suited to low observation-to-parameter ratios, was used to adjudicate model specifications. While no one model was uniformly superior across all eight blocks, there was a comfortable regularity in performance, significance, and magnitudes of effects, as well as rankings of models.

The following model was chosen:

$$\frac{OneMonthMarketLoss}{PolicyholderSurplus} = \alpha + (\beta_{LOB} + \gamma \cdot BCAR) \cdot \frac{EventLoss}{PolicyholderSurplus}$$

The regression results for this model are presented in table 4.

Table 4: Regression results for selected model

Parameter	Estimate	StdErr	tValue	Probt
alpha	-0.0253	0.0700	-0.36	71.99%
beta[Comm, RE, Hlth]	4.6414	0.8987	5.1646	0.00%
beta[Pers, L&A]	9.2470	0.8990	10.2859	0.00%
gamma	-0.0202	0.0057	-3.56	0.11%

Firms are divided according to their primary line of business[4] into two categories:

- Commercial property, commercial liability, reinsurance, and health
- Personal property, personal liability, and life & annuities

Table 5 presents the fitted γ values and standard errors across all eight design blocks. In all cells, γ is significant at the 5% level or better.

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[4] Based on majority of Net Premiums Written.

Table 5: Gamma estimates and s. e. by horizon and scale factor

	Scale Factor			
Horizon	NPW		PHS	
SEP	-0.0058	(0.0024)	-0.0202	(0.0057)
OCT	-0.0050	(0.0023)	-0.0153	(0.0066)
NOV	-0.0051	(0.0027)	-0.0117	(0.0066)
DEC	-0.0102	(0.0028)	-0.0151	(0.0068)

4. Applying the model

We seek to examine a firm at a particular time and ask, what would happen to its market value if it experienced a sudden shock to its surplus? Since the alpha term is statistically indistinguishable from zero, we are left with a "market multiplier" equation: [5]

$$\frac{dMKT}{dPHS} = \beta_{LOB} + \gamma \cdot BCAR .$$

Putting this equation together with the definition of BCAR, we get the following linear ODE:

$$\frac{dMKT}{dPHS} = \beta_{LOB} + \gamma \cdot k \cdot (PHS - adj).$$

If we fix a point (PHS_0, MKT_0), then the solution (for a particular firm's *adj*, *k* and LOB's β) is given by

$$MKT = MKT_0 + (\beta - \gamma \cdot k \cdot adj) \cdot (PHS - PHS_0) + \frac{1}{2} \cdot \gamma \cdot k \cdot (PHS^2 - PHS_0^2).$$

This equation for MKT is a parabola in PHS. This is problematic in that with increasing PHS, at some point the market value goes down and eventually crosses zero to become negative. The problem can be traced to the first derivative dMKT/dPHS becoming negative with high PHS. A more realistic model would put a floor on dMKT/dPHS of some quantity $\delta \geq 0$ when PHS > $PHS_m = adj + (\delta - \beta)/\gamma k$.

We may scale the equation by dividing both sides by required surplus PHS_R. Required surplus is defined as the value for PHS that would put BCAR=100: $PHS_R = adj + 100/k$. Defining m = MKT/PHS_R, K = $kPHS_R$, A = adj/PHS_R, $p_m = A + (\delta - \beta)/\gamma K$, and p = PHS/PHS_R, the solution becomes

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[5] We will ignore the fact that the model as fitted deals with sizeable finite changes ΔPHS, and treat it as if it were estimating the effect of differential changes dPHS.

$$m^*(p) = \begin{cases} m_0 + (\beta - \gamma \cdot K \cdot A) \cdot (p - p_0) + \dfrac{1}{2} \cdot \gamma \cdot K \cdot (p^2 - p_0^2), & p \le p_m \\ m_0 + (\beta - \gamma \cdot K \cdot A) \cdot (p_m - p_0) + \dfrac{1}{2} \cdot \gamma \cdot K \cdot (p_m^2 - p_0^2) + \delta \cdot (p - p_m), & p > p_m \end{cases}$$

For applications, a value of $\delta = 0.95$ is suggested. At extremely high levels of PHS, additional PHS would add one-for-one to market value but for deadweight (tax) cost.

We may also readily see what would happen[6] to BCAR = k(PHS-*adj*) = K(p-A) upon a change of PHS. Not possessing information about the specifics of A. M. Best's evaluations of each firm, we first assume that the surplus adjustment A is zero, so we have the simple linear relation BCAR = kPHS = Kp. The coefficient K then simply reduces to K = 100, and $PHS_R = 100PHS_0/BCAR_0$.

5. Assessing the model

The preceding allows us to use the model to assess the changes in market value and BCAR of the 39 firms experiencing a loss in CAT 48. Figures 1 and 2 depict the m-BCAR phase space for the two LOB classes of firms. The pre-event status is labeled with a P (for Personal Lines) in figure 1 and a C (for Commercial Lines) in figure 2. The x-axis position is the BCAR as reported in the financial database. The y-axis position is the firm's market cap as of 8/31/2001 divided by the required surplus (defined above). A solid line segment connects that point to an unlabeled point representing the post-event status. The post-event BCAR is imputed based on the post-event PHS being the reported PHS less the amount of the firm's event loss. The post-event market cap is the old market cap with the one-month return applied to it. A family of dotted curves represents the model's solution curves. Plus signs occur one per curve, indicating the "starting point" used to generate the curve. In figure 1, the entire frame is within the quadratic portion of the solution curves. In figure 2, a vertical dotted line labelled "T" marks the transition from the quadratic (left) to the linear (right) portions of the solution curves.

According to the model, each firm should stay on its own solution curve. Event losses drive a change in the x position, and the model's theory of market response constrains the resulting y position. By comparing the line segments to the dotted curves, we can visually assess how well the model fits the data.

In figure 1 (Personal Lines), we can see that two firms, represented by long line segments in the upper left quadrant, show extraordinarily large[7] losses and dominate the regression for Personal Lines. Of the remaining nine firms, only one shows a line segment of substantial length. Seven of the eleven points show trajectories consistent with the model.

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[6] This is a theoretical exercise about what "should" happen to BCAR. Ultimately, it is up to A.M. Best to effect a change.

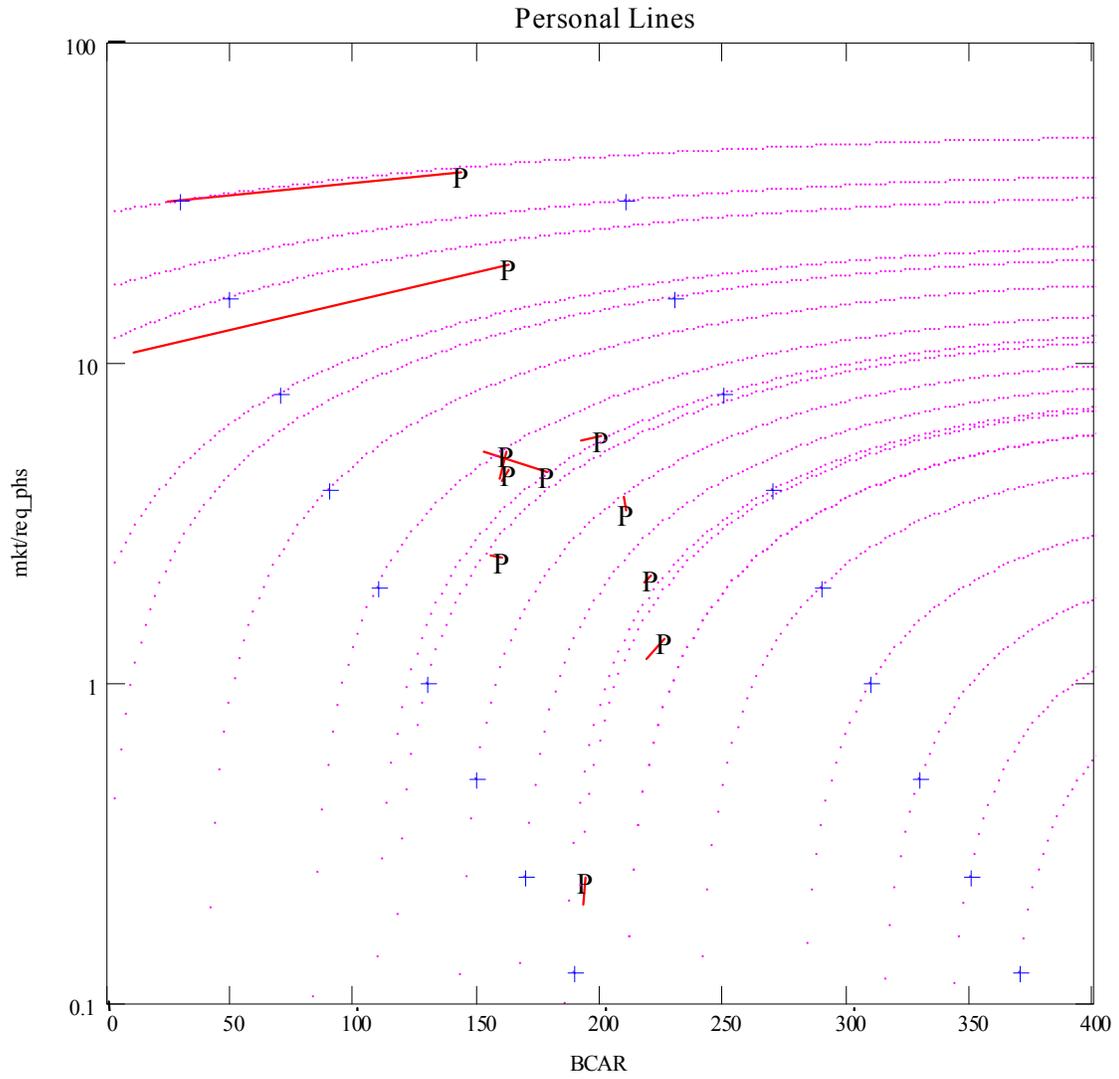[7] Large, that is, relative to surplus.

Figure 1: Personal Lines and Life & Accident firms' experience in CAT 48.

In figure 2 (Commercial Lines), model fitting depends on a much broader set of cases. Again, over half the firms – and a high proportion of firms with larger losses – show trajectories consistent with the model.
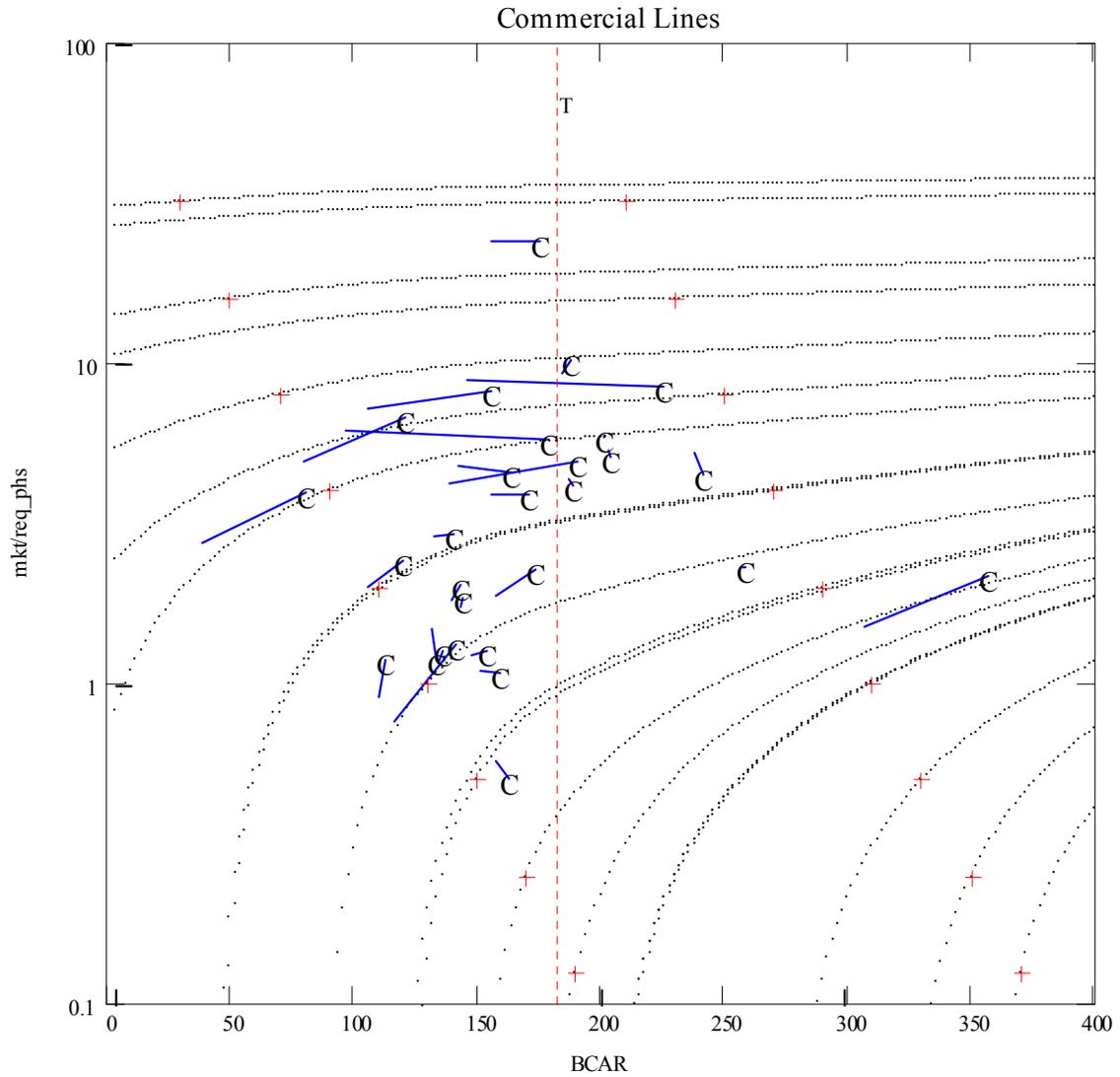

Figure 2: Commercial Lines, Reinsurance, and Health firms' experience in CAT 48.

6. Conclusion

A statistically significant relationship between financial strength (BCAR) and the market's response to an event loss, in the expected direction, was found. The marginal rate of change of market loss per unit of event loss appears to be in the range of 1 to 5 for most firms. This rate increases by at least 0.005 and possibly as much as 0.02 for every point decrease in BCAR.

7. References

A. M. Best (2003) "Understanding BCAR," http://www.ambest.com/ratings/bcar.pdf.

Burnham, Kenneth P. and David R. Anderson (1998) *Model Selection and Inference: A Practical Information-Theoretic Approach,* New York: Springer-Verlag.

8. Disclaimer