Large-Scale Disasters and the Insurance Industry

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Abstract

We investigate the impact of the 20 largest – in terms of insured losses – man-made or natural disasters on various insurance industry stock indices. We show via an event study that insurance sectors worldwide are quite resilient, in a market–value sense, to unexpected losses to capital: our data provide evidence that equity market investors believe that insurance companies will on average be able to make losses back over the foreseeable future, i.e. that the adverse shocks to equity which have resulted from these catastrophes will be compensated by either an outward shift of the demand curve or an ability to raise premiums, or both.

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1. Introduction

Large scale disasters, whether man-made such as the terrorist attack on the World Trade Center in 2001, or natural such as hurricane Katrina or the recent tsunami catastrophe in the Indian Ocean, need not necessarily imply a disaster for the insurance industry. There is a well documented tendency (see *e.g.* Shelor *et al.* 1992 or Cummins and Danzon 1997) for premiums to rise after such events which might or might not outweigh unexpected losses to capital, and a similar resilience to adverse effect is also reported for minor disaster such as denial of service attacks (Hovav and D'Arcy 2003).

The mechanism which establishes a new market equilibrium subsequent to such catastrophes is discussed in detail elsewhere (see *e.g.* Gron 1994, Froot and O'Connel 1999, or Cummins and Lewis 2003) and shall not concern us here. Rather, we answer the empirical question whether disaster-related factors which raise premiums, such as an outward shift of the demand curve or a decrease in the supply of insurance induced by an increase in the cost of capital (Cummins and Danzon 1997), are able to overcompensate the adverse shock to equity, at least in the eyes of investors. To this extent, we examine the 20 most costly disasters (in terms of insured property and business interruption losses) in the 30-year period from 1974 to 2004[2], and determine via an event-study whether insurance-industry stocks as a group experienced any positive or negative abnormal returns thereafter. Positive abnormal returns subsequent to a shock are seen as evidence that investors believe that premium increases will be sufficient to make up for capital losses resulting from the disaster for the industry, while negative abnormal returns are seen as evidence that investors think that such damage will not soon be repaired.

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[2] The first of these disasters – an explosion on a drilling platform – occurred however only in 1988, and there is a marked clustering of catastrophes at the end of this 30-year period.

There is ample evidence that the catastrophes in our study can indeed be viewed as unexpected shocks not fully anticipated in premium pricing. This is most obviously true for the September 11 terrorist attacks. Prior to these attacks, terrorism cover was generally not a separate line of insurance. Typically, it was not even mentioned in insurance policies and (all-risk physical damage) policies would automatically cover losses associated with such events, as the risk was perceived to be insignificantly low. Previous terrorist attacks in the United States like the first WTC bombing in 1993 or the Oklahoma City bombing in 1995 were discounted as non-recurring events in a world where attacks on United States life and property occurred exclusively outside the United States. In the case of natural catastrophes such as Hurricane Andrew or the Northridge earthquake, insurers were aware of the potential hazard, but seemed to underestimate both the probability and the severity of the events. This is what transpires from a perusal of the specialized insurance literature and it is also reflected in the large discrepancy between insured losses and premium incomes collected prior to the events. For example, it has been reported that insurance companies' pay-outs related to Hurricane Andrew in Florida exceeded by 50 per cent all premiums collected in that state for the past 22 years, while insured losses related to the Northridge earthquake alone were equal to the entire amount of premiums collected in the 20th century for earthquake insurance (Arnold 2002). Many industry observers have argued that in general the premiums collected during the 1990s were too low to compensate for the large pay-outs related to natural catastrophes during that decade, which included typhoons in Japan and winterstorms in Europe.

Therefore, it appears reasonable to interpret the disasters considered here as unexpected shocks, which caused unexpected losses. Below we investigate whether or not investors think that such unexpected losses are compensated by subsequent changes of parameters in the insurance industry. This question has so far been analysed mainly for single catastrophes and for individual stocks. Shelor *et al*. (1992) and Aiuppa *et al*. (1993), for instance, find that property-liability insurer stock values *increased* after the 1989 Loma Prieta earthquake in

California, despite substantial loss payments by insurers, whereas Lamb (1995), when investigating the aftermath of Hurricane Andrew, finds "a significant negative stock price reaction on property-liability insurers with direct premiums written in Florida and Lousiana."

Cummins and Lewis (2003) study the effects of three events – Hurricane Andrew, the Northridge earthquake from 1994, and the September 11 terrorist attacks. They likewise find a strong immediate negative impact of insurer stock prices in response to these events, which however dies out soon. The present paper is more in line with Chen and Siems (2004), who focus on stock price indices (rather than on individual stocks) and who also broaden the data base to include disasters and markets outside the United States. While Chen and Siems (2004) consider only terrorist and military attacks, we also consider natural disasters and use three different estimates of abnormal returns to make sure that our results are not an artifact of the procedure which is employed to isolate the effect of an event.

2. The models and the data

Table 1 lists the disasters included in our study. They are the 20 most costly events in terms of insured property and business interruption losses between 1970 and 2004,[3] as reported by *Swiss Re Sigma* (2006). The list is headed by Hurricane Andrew, which in August 1992 struck South Florida, Louisiana and the Bahamas with winds of up to 140 miles an hour, closely followed by the September 11 terrorist attacks in 2001, and the Northridge earthquake in 1994.[4] It does not

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[3] As the table only lists property and business interruption losses, excluding life and liability insurance losses, the overall insured losses from these catastrophes are of course much higher than indicated in the table. For example, estimates of all insured losses from the 11 September terrorist attacks are almost USD 40 billion, with claims to insurers totalling US$ 32.5 billion, and with payments by the U.S. federal Victim Compensation Fund equal to USD 5 billion (Kunreuther and Koo 2005).

[4] The ranking in table 1 does not correspond to catastrophes in terms of victims. The most costly disaster in this respect in modern times, the 1970 storm and flood catastrophes in Bangladesh and the recent tsunami in the Indian ocean, both with a cost of about 300,000 lives, are not even

include Hurricane Katrina, which at the time of this writing had just finished its course across the southern US, with damages which will eventually exceed those included in the present table by large amounts.

<div align="center">- table 1 about here -</div>

As regards the areas affected, the United States are the country most often hit by the catastrophic events shown in Table 1. They experienced eleven events from different categories, including hurricanes, terrorist attacks, earthquakes and storms, with four hurricanes occurring in 2004 alone. Japan experienced three typhoons and one earthquake. Europe was hit by three winterstorms in 1990 and 1999 and by storm and floods in 1987 which affected more than one country at a time, and an explosion on a drilling platform in 1988.

For each disaster, and for each country involved, we estimated normal and abnormal returns of the respective insurance industries in three different ways. First, via the conventional market model (MacKinlay 1997)

(1) $R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it}$,

where the subscript i identifies the disaster, R_{it} is the return of an index of the local insurance industry in period t, and R_{mt} is the return of a broad market index in that period, and where $\alpha_i + \beta_i R_{mt}$ is the "normal" return to be estimated from the data. Data are daily and range from event day t=– 199 to event day t = 0 (the event itself occurs on day t=1). Second, via the market-adjusted return model, where $\alpha_i = 0$ and $\beta_i = 1$. This is mainly to avoid the well known problem of correlation between the regressor and the disturbance term in (1) induced by non-synchronous trading (see *e.g.* Brown and Warner 1985), which renders

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included in table 1. Similarly, the earthquake in Tangshan in China in 1976, with 250,000 victims, or the tropical Cyclone Gorki in 1991, with 140,000 victims, although gigantic catastrophes in almost any sense, did not induce heavy insurance losses in absolute dollar terms, and are therefore also not included in the table.

conventional least squares estimates of β_i inconsistent. As we are using indices rather than data for individual firms, this potential bias does not seem to be very important here, but it is still useful to have alternative measures of abnormal returns. We therefore also used the constant expected returns model where we set normal returns equal to zero. In addition to providing yet another measure of abnormal performance, this also circumvents the problem that large-scale disasters may affect the market (which may be expected almost by the definition of such events), which would imply that both the market-model based and the market-adjusted abnormal returns do not capture all of the effects of an event.

Following the disaster, we therefore computed daily abnormal returns for the respective country insurance sector either as

$$(2) \qquad AR_{it} = R_{it} - \hat{\alpha}_i - \hat{\beta}_i R_{mt},$$

where $\hat{\alpha}_i$ and $\hat{\beta}_i$, respectively, are estimates for α_i and β_i from (1) (the market model), or as

$$(3) \qquad AR^*_{it} = R_{it} - R_{mt}$$

(the market adjusted returns model), or as

$$(4) \qquad AR^{**}_{it} = R_{it}$$

(the constant expected returns model). The subscript i (i=1,.., 20) indicates the disaster, R_{it} is the return of the local insurance sector (either United States, Japan or Europe) on event day t, and R_{mt} is the return of the local stock market. Both the total market and insurance industry indices were obtained from *Thompson Financial Datastream*.[5] In every case, the estimation window ranges from event

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[5] The stock market indices are the *Datastream Global Equity Indices* that are provided by the company *Thomson Financial Datastream*. The total market indices cover all sectors in each country (United States and Japan) or region (Europe). Indices for Europe cover mainly the EU (as of 1995) plus Switzerland, which include the countries affected by the disasters under study here. Thomson Financial Datastream calculates insurance sector indices using a list of companies,

day t=-199 to event day t=0 (which is the day before the event day), and the event window ranges from the event day t = 1 to day t = 30. The event itself occurs on day t=1. [Unsere bisherige Darstellung erschien mir etwas unklar; allerdings ist die neue Darstellung u.U. auch unklar; insofern mit der Bitte um Korrektur des vorangehenden Absatzes.]

Using indices for measuring the performance of insurance industry stocks of course obscures the differences in the performance of individual stocks, which was a main concern in Lamb (1995) or Cummins and Lewis (2003). Lamb (1995) for instance – not unexpectedly –in his investigation of Hurricane Andrew finds that investors discriminated among insurers based on the existence and magnitude of insurance written, and that the stock prices of insurers with premiums written in Florida or Louisiana suffered most (eight small companies folded altogether), whereas Cummins and Lewis (2003) reveal a "flight to quality": the stock prices of highly ranked insurers are less affected by catastrophes than the stock prices of lower rated firms. As the present paper is concerned with the performance of markets, not of firms, we disregard such differences among insurers here.

A potentially more important drawback is that insurance is a world-wide business. For example, among the 10 reinsurance companies most affected by the September 11 terrorist attacks, with claims in excess of US$ 500 million each, seven were *not* from the US (see *Oxford Metrika*, 2003, table 1). The two most affected were *Munich Re* from Germany (claims estimate: US$ 1,959 million) and *Swiss Re* from Switzerland (claims estimate US$ 1,777 million). Therefore, catastrophes in one country have an impact on the insurance industry also in other countries, which likewise is ignored in our analysis below. We will return to this point when discussing our results in section

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where inclusion in the list are based on market value and availability of data. The company reviews the list and weights of index constituents for each market/sector quarterly and re-sets it to represent the new relative importance of stocks in terms of market value. At the end of 2004, the total insurance sector indices reportedly comprised 46 firms in the case of the United States, 69 in Europe, and 8 firms in Japan, respectively.

3. Results

Table 2 gives the estimates of the respective market models (model (2) as described in previous section). It exhibits a considerable variation in regression estimates, even for a given market, which may not appear to be compatible with the assumption of a constant market model across the whole time period spanned by our data (*i.e.* 1987 to 2004). In the United States, for instance, the estimates for the intercept in the market model range from 0.45 (the OLS-estimate for β obtained from 200 daily returns prior to the September 11 terrorist attacks) to 0.95 (the OLS-estimate for β obtained from 200 daily returns prior to the tornadoes which hit the U.S. in May 2003).

- table 2 about here -

The are various ways in which one can formally test whether the observed variation in the estimated coefficients is due to a shift in the true underlying value of β. We first did a series of Cusum-tests, which reject the null hypothesis of parameter constancy whenever the cumulated sum of successive forecast errors deviates too much from what is expected under the null hypothesis, but could not reject the null hypothesis that the coefficients of the market model are constant throughout the 1987-2004 period which is spanned by the events under study. This failure is most probably due to the poor power of the Cusum-test in the present context, where structural changes are almost orthogonal to the mean regressor. It is well known (see Ploberger and Krämer 1990, 1992) that Cusum-tests have trouble detecting such changes in the regression coefficients.

We therefore also did various Chow-tests, which simply compare the estimated regression coefficients from different subsamples, and reject the null hypothesis of parameter constancy when the difference is too large. These tests showed that a constant market model for the whole 1987-2004 period can indeed not be

assumed. For the subsamples of lengths 230 which were used to both estimate the market model and to compute abnormal returns around a *particular* disaster, the assumption of parameter constancy, which is essential for a meaningful application of the market model, can however much more easily be maintained – attempts to refute this assumption failed no matter which formal statistical test was used. Also, the regression estimates for the market model prior to hurricanes Ivan, Charley, Jeanne and Frances, which all occurred in 2004, are very close together, indicating that there was no structural change in the market model in that year.

Figure 1 shows the cumulative excess returns, as computed according to the methods described in section 3. For each event day t, the 20 abnormal returns were averaged (arithmetic mean) prior to cumulating. The figure shows that, no matter which measure of abnormal performance is used, the insurance sector suffers on the day of the disaster, confirming the existing literature. However, according to the market-model returns and market-adjusted returns, the insurance sector soon recovers and is even outperforming the market about one week after the disaster, with a small and insignificant negative cumulative return at the end of the post event window. This finding is very much in line with Lamb (1995) or Cummins and Lee (2003), who observed similar patterns for specific catastrophes.

- figure 1 about here -

To see how our results differ from existing ones, table 3 compares the daily abnormal market-model returns for a particular event – the September 11 terrorist attacks – as computed along the lines explained in section 2 above, and as computed by Cummins and Lewis (2003) using a different approach. Cummins and Lewis (2003) estimate the market model separately for 43 insurance companies, and then average the 43 individual abnormal returns for each event

day t = 1,..., 31.[6] Despite the differences in approaches, the respective cumulative abnormal returns are in considerable agreement (see fourth and fifth column of Table 3).

- table 3 about here -

Returning to the global picture, figure 1 shows that cumulative unadjusted returns are on average negative throughout the post-event window, and significantly so (see below). This is mainly due to the fact that the European and Japanese markets were in general negative subsequent to most disasters. Also, the post event window for the 1987 European flood catastrophe includes the October 87 stock market crash, with a decline in the total market index within the post event window of 24%. We therefore also computed cumulative abnormal returns separately for the United States, Europe and Japan in order to disentangle the effects of regional resilience and unrelated exogenous effects.

Figures 2 and 3 show the cumulative abnormal returns of the European and Japanese insurance sectors in isolation. It is seen that the overall decline in the unadjusted insurance sector returns is sharper here. But once the parallel large downturns in the general market are accounted for, remaining returns are only slightly negative or even positive, as they were in figure 1.

- figures 2 and 3 about here -

The United States are slightly different. As shown in figure 4, both the total market and the insurance sector recover somewhat faster and show positive returns soon after a disaster. This confirms Chen and Siems (2004), who likewise found a superior resilience of US stock markets to unexpected shocks as compared to several other major stock markets. For instance, while both the total market and the insurance industry declined by about 5% on the day trading

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[6] The authors also use another index to cover the market – the Center for Research in Security Prices (CRSP) equally weighted market index - as compared to the *Thomson Financial Datastream* total market index used here.

resumed in the United States after the September 11 attack (that is, on 17 September 2001), both registered a 1% (market) and 8% (insurance industry only) *increase* over the whole post event window. After hurricane Andrew, the insurance sector declined by 1.1% on day one but increased by 6.8% over the whole post event window (while the rest of the market remained flat).

As is seen in figure 4, the evaluation by investors of both the economy in general (which can be recovered from the figure by adding to the market adjusted returns the difference between the constant expected returns series and the market model series) and the insurance industry in particular do not seem to suffer much from the catastrophes considered here. The point however is that in all regions considered here, whether US or not, the respective insurance sectors do not feature any sizeable abnormal returns quite soon after a disaster.

- figure 4 about here -

This conclusion is also born out by a formal test of statistical significance. Table 4 shows the abnormal returns as computed according to our models, together with estimates of the respective standard deviations and the resulting t-values. It confirms what we have already seen in figures 1 - 4: There is a statistically significant negative abnormal return on event day 1 according to both the market and constant expected returns models, while the null hypothesis that there is no cumulative abnormal return at the end of the post event window cannot be rejected regardless of the model which we use.

- table 4 about here -

The estimate of the standard deviation of the market-model abnormal returns, which enters the denominator of the t-statistic, was obtained by first computing, for each event i, and for each estimation window, the empirical variances S^2_i of the abnormal returns $AR_{it} = R_{it} - \hat{\alpha}_i - \hat{\beta}_i R_{mt}$ (t = -199, .., 0). Under certain regularity conditions (see below), this statistic is a consistent estimator of the true

variance σ^2_i of the abnormal daily returns around catastrophe number i, where the index i runs from i=1 to i=20. Assuming that event day 1 abnormal returns are independent across events (which can be justified from the observation that no two events occur on the same calender day), the variance of the *average* abnormal return

$$(AR_{1,1} + AR_{2,1} + ... + AR_{20,1})/20$$

on day 1 is then

$$(\sigma^2_1 + \sigma^2_2 + ... + \sigma^2_{20})/400 \, ,$$

the square root of which is consistently estimated by

$$(5) \qquad S_i = ((S^2_1 + ... + S^2_{20})/400))^{1/2}.$$

In principle, this expression must be augmented by a term which accounts for the error in estimating the coefficients of the various market models. These terms are however rather small for an estimating window of length 200 used here and can be neglected.

The standard deviations of the average market adjusted and constant expected returns on day 1 are estimated using the same method, that is, the empirical variances of the respective abnormal returns from the estimation window are plugged into formula (5).

If, for each event, post event window abnormal returns are serially uncorrelated (which can safely be assumed), the variance of the respective cumulative abnormal returns (when cumulation is done over event days t=1,...,t=30) is 30 times the expression in formula (5), so an estimate of the standard deviation of the cumulated returns is obtained by multiplying this expression by $30^{1/2}$. This is how the figures for the standard deviations of the cumulative returns in table 4 have been obtained.

This procedure, though standard, is based on the assumption that the true variance of the abnormal returns remains constant in the estimation and post event

windows around each catastrophe, which is hard to justify (Boehmer *et al*. 1991). There is on the contrary ample reason to suppose that variances *increase* in the aftermath of an event. We have checked this hypothesis for our sample and have indeed found a larger empirical variance subsequent to the event in almost all cases, confirming Cummins and Lewis (2003). Therefore, table 5 also shows alternative estimates of the abnormal returns standard deviations by simply taking the empirical standard deviations of the observed post-event returns. These estimates are less precise if there is no event-induced increase in the variance, but they are more reliable if the variance does indeed increase. As is seen in the table, all standard deviations are much larger now. In particular, the day 1 average abnormal returns for the market model and the constant expected returns model, which were statistically significant before, are no longer significant if more realistic estimates of the variance are used.

- table 5 about here -

A minor point concerns the overlap in the post event windows of the 2004 hurricanes. This overlap induces positive correlation among the respective cumulative abnormal returns, which in turn implies that the estimated variance of the average cumulated returns for all three models is biased downwards (see *e.g.* Kiviet and Krämer, 1992). However, as the t-statistics computed from these estimates already do not allow to reject the null hypothesis of no systematic abnormal returns, this null hypothesis cannot be rejected with unbiased variance estimates *a forteriori*.

Some portion of the resilience of the stock prices of local insurance companies to local disasters is certainly due to the fact that some claims are paid by non-local insurance companies. In a follow-up study, we will therefore consider only reinsurance companies, which operate on a global scale, and we will focus on the response of the worldwide insurance industry stock prices to disasters no matter

where they happen. A preliminary look at the data however indicates that the results of the present paper go through here as well.

4. Conclusion

Our empirical findings suggest that large scale disasters do not negatively affect the insurance industry as a whole, at least in the eyes of equity market investors: Stock prices of insurance companies do on average not suffer subsequent to unexpected disasters which were not foreseen when calculating premiums. This implies that investors anticipate that the insurance industry as a whole will be able to make losses back over the foreseeable future, i.e. that the adverse shocks to equity which have resulted from these catastrophes will be compensated by either an outward shift of the demand curve or an ability to raise premiums, or both.

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Table 1: The 20 worst catastrophes from 1974 to 2004 in terms of insured losses

Insured loss[1]	Date	Event	Country/Region
22,274	23.08.1992	Hurricane Andrew	United States
20,716	11.09.2001	Terrorist attacks on WTC, Pentagon and other buildings	United States
18,450	17.01.1994	Northridge earthquake	United States
11,684	02.09.2004	Hurricane Ivan	United States
8,272	11.08.2004	Hurricane Charley	United States
8,097	27.09.199125.01.1990	Typhoon Mireille	Japan Europe
6,864		Winterstorm Daria	
6,802	25.12.1999	Winterstorm Lothar	Europe
6,610	15.09.1989	Hurricane Hugo	United States
5,170	26.08.2004	Hurricane Frances	United States
5,157	16.10.1987	Storm and floods in Europe	Europe
4,770	25.02.1990	Winterstorm Vivian	Europe
4,737	22.09.1999	Typhoon Bart	Japan
4,230	28.09.1998	Hurricane Georges	United States
4,136	13.09.2004	Hurricane Jeanne	United States
3.707	06.09.2004	Typhoon Songda	Japan
3,475	05.06.2001	Tropical storm Allison	United States
3,403	02.05.2003	Thunderstorms, tornadoes, hail	United States
3,304	06.07.1988	Explosion on Piper Alpha drilling platform	United Kingdom
3.169	17.01.1995	Kobe earthquake	Japan

1 In US$ dollar millions, indexed to 2005. Estimates of insured property and business interruption losses. For hurricanes, event dates indicate landfall. Source: Swiss Re (2006).

Table 2: Least Squares estimates of the market model

Event	OLS-estimate for α	OLS-estimate for β	R^2
09/11 terrorist attacks	-0.00031	0.45	0.28
Hurricane Andrew	0.00007	0.78	0.62
Northridge earthquake	-0.00032	0.87	0.41
Hurricane Ivan	0.00027	0.77	0.66
Typhoon Mireille	0.00023	0.94	0.66
Hurricane Charley	0.00030	0.75	0.64
Winterstorm Daria	0.00034	1.04	0.76
Winterstorm Lothar	-0.00090	1.16	0.70
Hurricane Hugo	0.00065	0.85	0.68
Hurricane Frances	0.00034	0.78	0.68
Storms and Floods	-0.00087	0.90	0.45
Winterstorm Vivian	0.00049	1.06	0.79
Typhoon Bart	-0.00172	0.86	0.37
Hurricane Jeanne	0.00026	0.77	0.66
Hurricane George	-0.00005	0.90	0.79
Typhoon Songda	0.00032.	1.31	0.53
Tropical Storm Allison	0.00071	0.49	0.26
Tornados	0.00008	0.94	0.78
Piper alpha	-0.00014	0.95	0.76
Kobe earthquake	-0.00010	1.10	0.58

Table 3: Comparison of estimates of cumulative abnormal returns after September-11 terrorist attacks

Event day[a]	Cummins and Lewis (2003)	Total insurance sector (present paper)	Non-life insurance sector (present paper)
1	-4.74	-2.69	-3.71
2	-4.64	-3.33	-5.56
3	-5.6	-4.19	-6.79
4	-7.66	-3.92	-8.85
5	-9.56	-4.99	-9.63
6	-6.91	-2.02	-5.29
7	-5.4	0.09	-3.13
8	-4.29	2.78	-1.67
9	-1.39	4.49	1.83
10	1.53	5.95	4.15
11	0.8	4.80	2.49
12	1.58	5.81	4.34
13	3.99	8.07	7.34
14	3.32	7.30	7.16
15	4.45	6.25	5.19
16	5.69	4.75	4.22
17	6.33	6.03	6.61
18	6.95	7.07	6.10
19	6.19	7.78	5.10
20	5.41	7.33	5.13
21	6.04	8.41	6.16
22	6.73	8.86	7.45
23	4.77	8.90	6.60
24	3.63	7.35	4.17
25	3.26	5.91	3.02
26	5.63	7.98	5.88
27	3.95	7.24	4.91
28	4.49	7.14	4.53
29	4.25	6.44	3.38
30	4.06	6.36	4.09
31	2.95	5.52	3.64

[a] Cummins and Lewis (2003) number event days differently (day t = 0 is the event day in their notation).

Table 4: Average abnormal returns and standard estimates of standard deviations (percent)

	market model	market adjusted returns	constant expected returns
	a) on event day 1		
average abnormal return	-0.51	-0.34	-0.61
estimated standard deviation	0.16	0.23	0.25
t-value	-3.19**	-1.48	-2.44*
	b) cumulated over days 1,…,30		
average abnormal return	-0.37	-0.44	-1.45
estimated standard deviation	0.88	1.25	1.37
t-value	0.42	-0.35	1.06

*: significant at 5%

**: significant at 1%.

Table 5: Event-window-based estimates of standard deviations

	market model	market adjusted returns	constant expected returns
event day 1	0.91	0.77	1.73
cumulated over days 1,...,30	2.79	4.06	6.14

Figure 1: cumulated abnormal returns
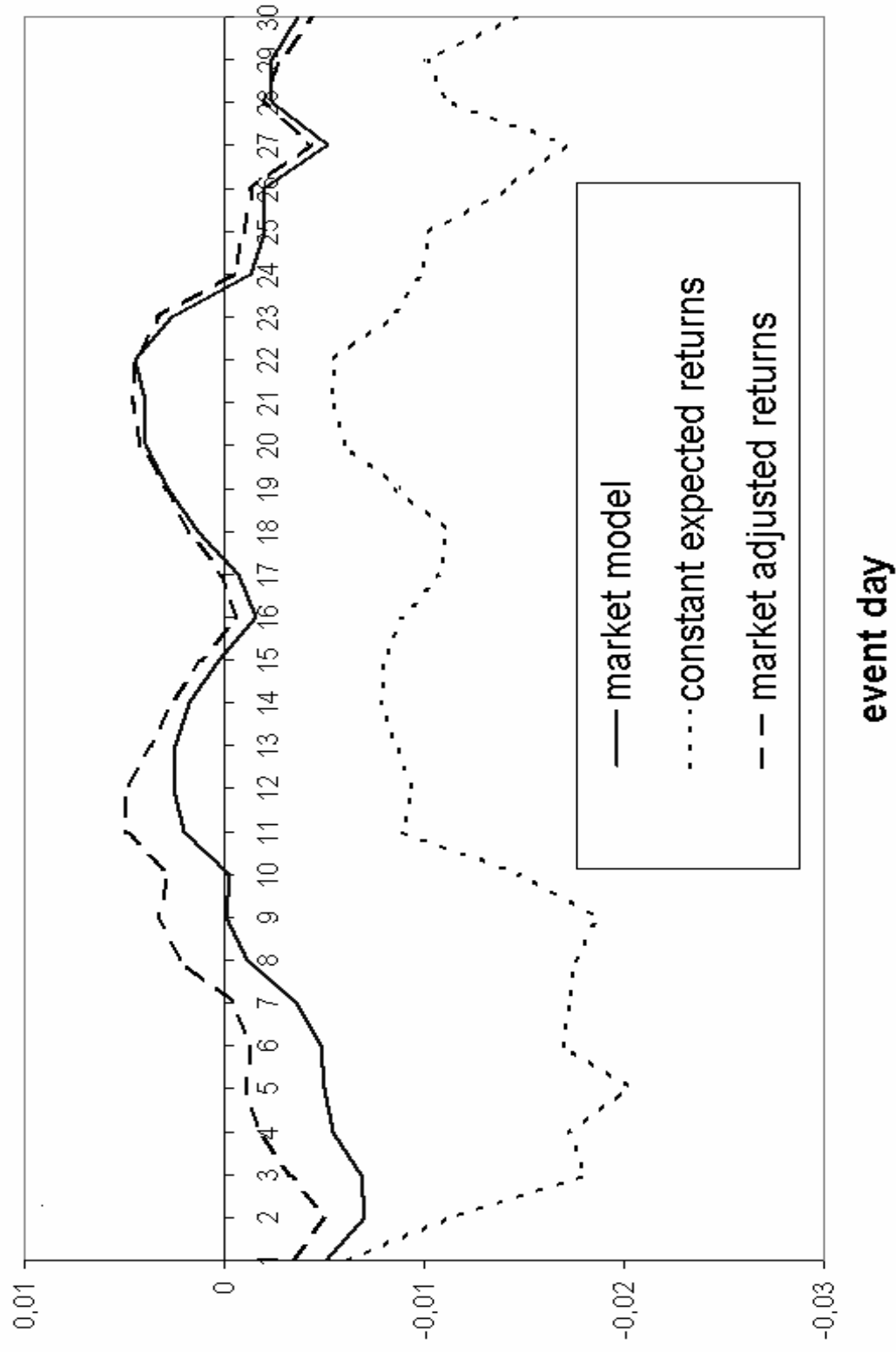
Figure 2: cumulated abnormal returns Europe

event day

— market model
···· constant expected returns
– – market adjusted returns
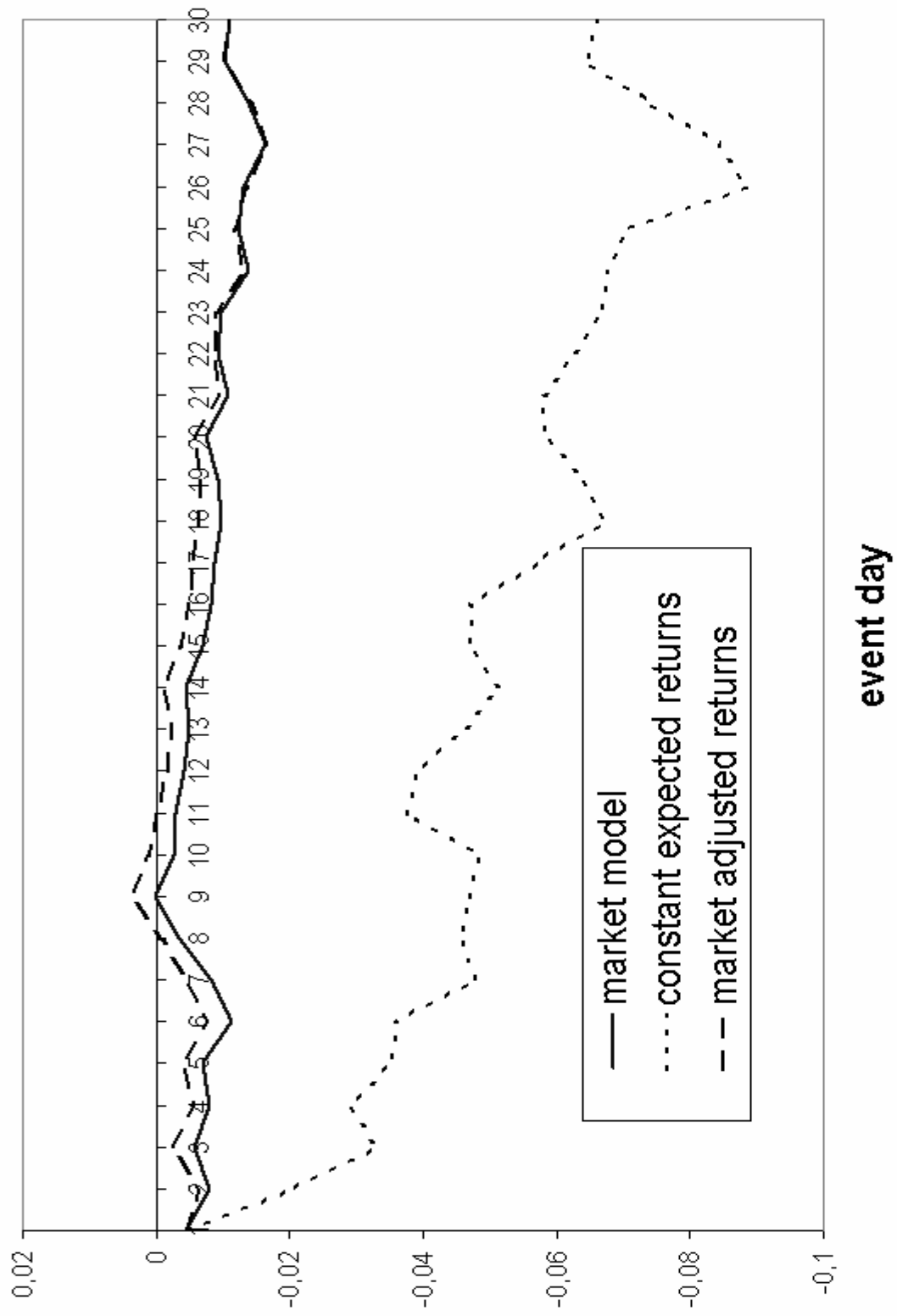
Figure 3: cumulated abnormal returns Japan

event day
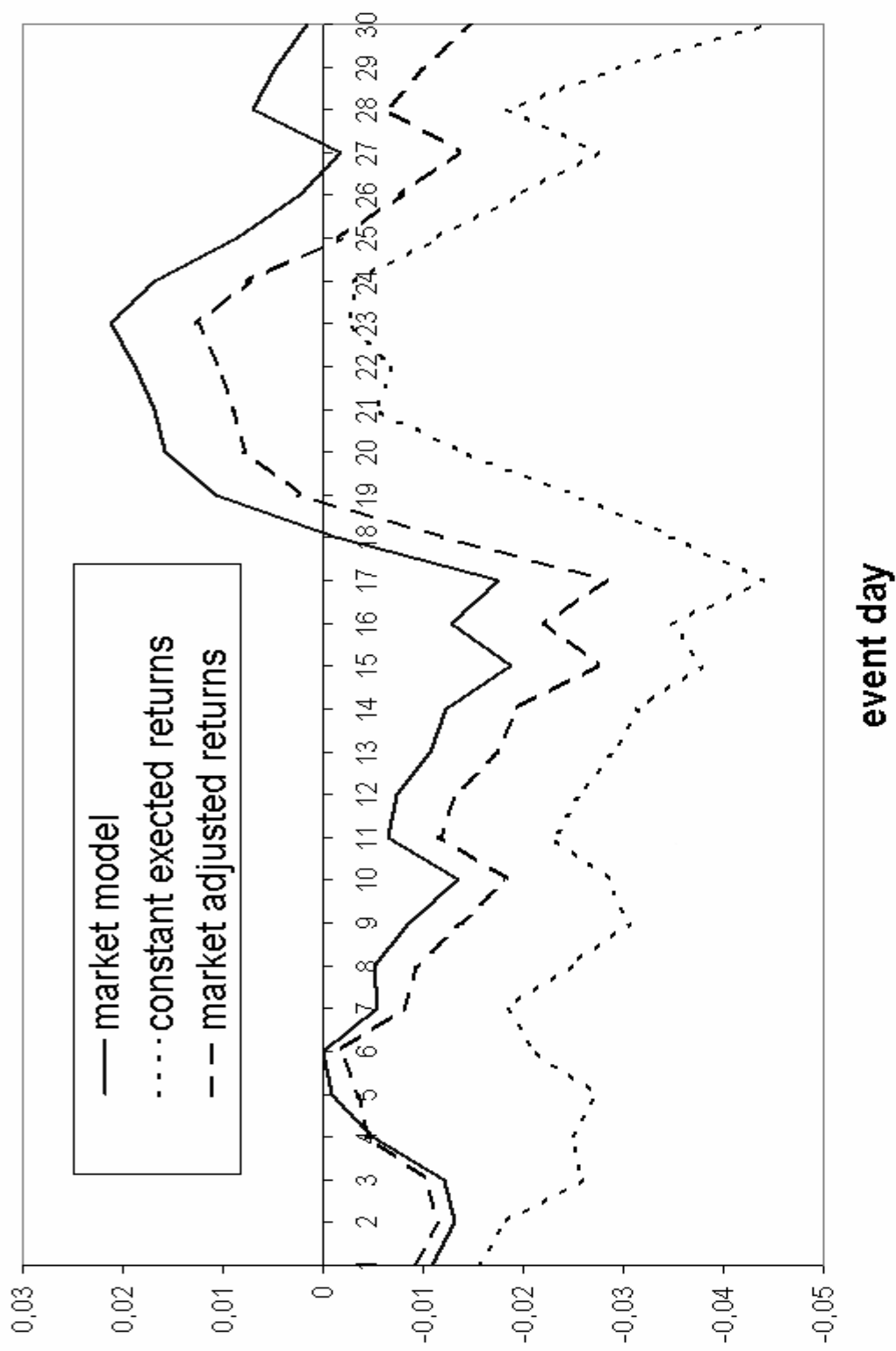
Figure 4: cumulated abnormal returns USA

Legend:
— market model
···· constant expected returns
– – market adjusted returns

event day
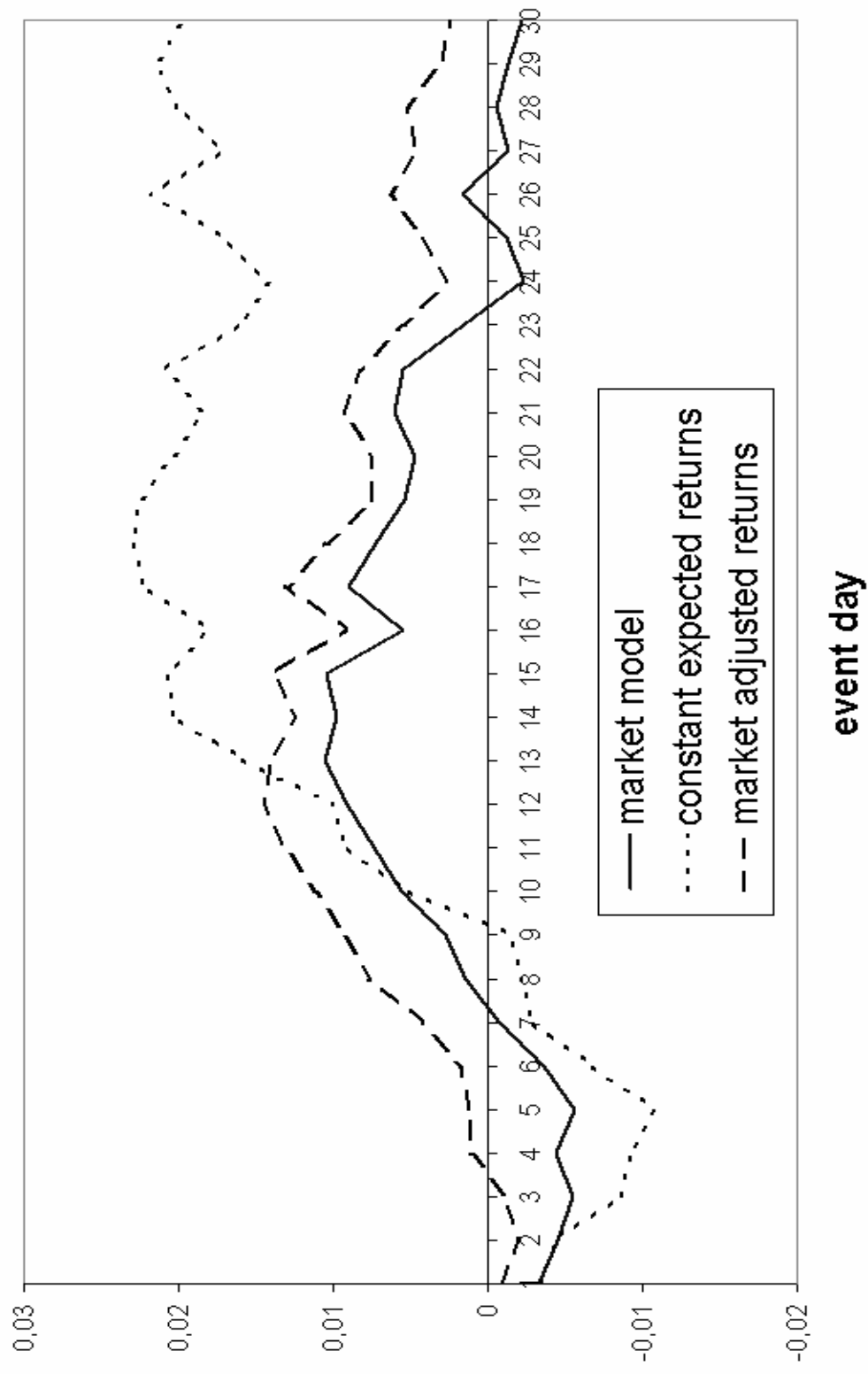
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