Underlying and Consequential Costs of Cyber Security Breaches: Changes in Systematic Risk

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Abstract

Severe security breaches can be costly for publicly listed firms. In order to deploy scarce resources in the most efficient way, decision makers in such firms need to be aware of all cost types associated with security breaches. In addition to obvious direct costs following the discovery of, response to, and mitigation of security breaches, there are also multiple underlying and consequential costs introduced or elevated by security breaches. One cost factor that is prone to be overlooked is systematic risk in the form of cost of equity. We present the results of an analysis of security breach-induced changes in regular, downside, and upside betas that contribute to increases in cost of equity. Analysing a US-centric sample of 202 severe security breaches between 2005 and 2019, we find that severe security breaches are associated with significantly positive increases of systematic risk and systematic downside risk in terms of regular and downside beta, respectively. Given the absence of similar effects for systematic upside risk in terms of upside beta, the analysis also reveals the unsymmetrical nature of the effect of security breaches on systematic risk. The implications of these findings and their relevance for firms' costs of capital are discussed.

1 Introduction

Despite the observation that surveys on data breach costs have a tendency to be subject to particular preconceived policies and agendas, it is generally accepted that security breaches do incur substantial costs for firms and society at large [1, 2]. While recognising that some might question the underlying assumptions and the methodology employed, the Ponemon Institute and IBM estimate the average cost of data breaches to be USD3.92m, with an average cost of USD150 per record breached [3]. It is reasonable to expect that the annual mean and cumulative costs of data breaches will rise further in the future [4].

There are multiple noteworthy studies on the negative economic impacts associated with security breaches (e.g. [1] and [2]). However, many of these contributions focus on obvious or visible costs. Underlying and consequential breach-induced costs imposed on firms and society have had significantly less light shone upon them.

In this paper, we introduce a new taxonomy to support distinguishing between obvious and underlying/consequential costs, and contribute empirical evidence to the less-explored category of underlying and consequential economic impacts. In particular, *cost of equity* — a fundamental aspect at the heart of many firms' corporate finance activities — has not yet been conclusively analysed.

Based upon the capital asset pricing model (CAPM), cost of equity is the rate required by shareholders to compensate for the investment risk incurred. A major component in determining the risk premium is beta, a measure of exposure to non-diversifiable, systematic, or market risk.

A security breach can induce equity investors to alter their risk assessment of a firm's ability to generate future cash flows. For instance, investors might price additional reputational hazard, which can result in lower revenues and greater revenue volatility. Rational economic agents expect to be remunerated accordingly for additional risk and in turn may require greater equity returns, which can be reflected in terms of beta. For instance, Chegg Inc., an education technology company, which suffered from a security breach affecting more than 40 million users in 2018, experienced an increase in regular, downside, and upside beta factors, turning a low-risk stock (with betas <1) into a greater-risk one (with betas >1)[1].

Extant literature features only limited evidence on security breach-induced impacts on financial systematic risk, a measure at the core of firms' cost of equity [5]. As prior literature on security breaches and financial systematic risk (a) is relatively scarce, (b) tends to be industry-specific (and typically not generalisable), and (c) is exclusively focused on symmetric systematic risk, there is ambiguity with regards to whether, and to what extent, security breaches affect organisations' exposure to market risk (i.e., systematic risk).

This paper makes a threefold contribution to the information security economics literature. First, we provide a novel perspective on non-obvious underlying and consequential costs associated with (breaches of) cyber security, thus adding to nascent theories on cyber security investments and management generally. Second, we extend previous work that used small and now-outdated samples [5–7] by presenting more holistic and updated empirical insights into the effect of security breaches on firms' systematic risk. Most importantly, by analysing "a more appropriate measure of portfolio risk" [8], namely dual-beta models, in addition to regular betas, we introduce a new perspective on security breach-induced changes in systematic risk to the information security economics literature. Additionally, we contribute novel insights into firm characteristics mitigating changes in systematic risk.

An improved understanding of changes in systematic risk is of relevance to cyber security economics researchers and practitioners alike. For researchers, an increase in cost of equity following changes in the underlying exposure to financial systematic risk (i.e., beta) might inform frameworks and models on information security investments based on cost–benefit analyses. Increases in systematic risk and cost of equity might also help to explain a multitude of corporate phenomena following security breaches. From a practitioner's perspective, a holistic understanding of potential impacts of security breaches is essential to facilitate economic decision making. Changes in cost of equity resulting from increases in financial systematic risk are also of concern to executives, as the measurement relates to all major corporate finance activities including capital raising, share issues and buybacks, as well as

[1]See Sections 4.2 and 6.2 for further discussions of this exemplifying case study.

shareholder value management. Similarly, for investors, an increase in cost of equity, and consequentially an increase in cost of capital, implies an increase in a firm's risk [9].

The paper is thus motivated by two research questions, which can be stated thus:

- *Do severe security breaches increase firms' cost of equity by elevating systematic risk?*
- *Do severe security breaches affect firms' cost of equity differently in bearish and bullish markets by affecting downside and upside risk differently*[2]*?*

The structure of the remainder of the paper is as follows. First, in Section 2, the theoretical background and related literature are presented. We also introduce financial systematic risk and the two-beta model. The conceptual connection between security breaches and changes in systematic risk is also discussed. We provide an overview of this study's sample characteristics in Section 3 and the methodology used to answer our research questions in Section 4. In Sections 5 and 6 we present and analyse the empirical results stemming from our analysis. We conclude by summarising extant evidence and the contributions of our study, and consider how additional research could further extend the literature on corporate security breach impacts generally and impacts on systematic risk specifically.

2 Background and Motivation

In this section, we give consideration to the background to, and the motivation for, our contribution. We start by considering some related work.

2.1 Related Work

Economic considerations of cyber security are grounded in the seminal work of Anderson and Moore [10–13]. One significant area of research within the economics of information security is cybersecurity investment decision making [14–20]. A key element of consideration for rational stakeholder-value-maximising security executives contemplating cybersecurity investments is the cost-efficient mitigation of negative economic impacts of security breaches [17,21,22]. Executives face multiple difficulties including the justification of security investments, which can be facilitated by conducting holistic cost–benefit analyses. CSOs, CISOs, and similar executives are thus in need of frameworks and models to support such analyses.

In order to conduct thorough cost–benefit analyses, decision makers need to be aware of all potential costs associated with security breaches and investment countermeasures. It is generally accepted that severe cyber security breaches can be costly incidents for targeted firms [1–4]. We contend that negative economic impacts elicited by security breaches can be divided into obvious costs and underlying or consequential costs. Studies considering negative economic impacts of security breaches tend to focus exclusively on obvious costs associated with security breaches (e.g., [3,23]), while not accounting (in any meaningful way) for underlying and consequential ones.

[2] Bearish markets are falling markets characterised by negative index returns; bullish markets are rising markets characterised by positive index returns.

For the purpose of this paper, obvious costs are defined as expenses that are easily observable and can be directly related to line items on a firm's income statement. Such costs are immediate expenses explicitly connected to cyber attacks and their mitigation and remediation. Examples include forensics and audit fees, customer notification costs, legal and regulatory expenditures, and customer acquisition and retention costs [3, 24, 25].

In contrast, underlying and consequential costs are non-obvious. They constitute negative economic impacts to breached firms, their peers, and society at large that cannot be directly attributed to billable items and are of a more collateral, subsidiary, secondary, implicit, or indirect nature. Underlying/consequential costs are less apparent, more derivative, and more wide-ranging.

Negative economic impacts in the underlying and consequential costs category include statistically significant negative market reactions following the announcement of security breaches [26–38] and security investments [39–41]. Breached firms are also associated with increases in audit fees [42], elevated CEO compensation [43], greater corporate social responsibility spending [43], as well as decreases in sales growth, increases in leverage, and worsened financial health [44]. Other examples include the finding that security breaches cause deteriorating product and service quality [45], declines in firm productivity [46], and more frequent senior executive turnover [47]. Security breaches also pose underlying/consequential costs to society as they elicit negative abnormal returns and increases in audit fees for non-breached peer firms, as well as negative equity value implications for cybersecurity insurers [48]. Additionally, breached firms reduce cash outflows in terms of dividend payments and R&D expenses, which affects investors in and suppliers of such firms [43]. Taken together, underlying costs can influence more obvious ones; consequential costs conceptually or temporally follow a security breach, but in a more indirect way. Analysing underlying and consequential costs is of particular academic and professional interest given "the difficulty of precisely quantifying the risks and consequential costs of cybersecurity threats" [49].

We conjecture that changes in cost of equity due to changes in systematic risk can also be considered an item of underlying or consequential cost. Unsystematic and systematic risk are commonly considered to collectively constitute a financial asset's overall risk level [50]. This operationalisation of risk is described by the capital asset pricing model (CAPM), established following the work of Sharpe [51, 52], Lintner [53], Treynor [54], and Mossin [55], based on Markowitz's Modern Portfolio Theory [56]. The CAPM divides a company's risk, i.e., the volatility of its stock returns, into systematic (market, undiversifiable) risk and unsystematic (unique, diversifiable) risk. Systematic market risk — denoted beta — is the sensitivity of a firm's stock returns relative to the returns of a broad market index.

Despite its frequent use by both academics and practitioners [50, 57–63], the CAPM has its limitations. For example, it does not distinguish between bullish and bearish markets, i.e., time periods in which the market return is positive (up) or negative (down). However, risk exposure to general market movements is not necessarily symmetrical in Up and Down Markets. By extending the work of Fabozzi and Francis [64], Kim and Zumwalt [65] were among the first to suggest a model which resolves this issue. They proposed and successfully tested a model that incorporates two different betas: one for periods of time featuring positive market returns and one for negative return periods. This dual-beta model allows for beta coefficients to reveal different figures in Up and Down Markets. The downside beta included in such a dual-beta model is considered to be a more appropriate measure of risk than the CAPM's regular symmetric single beta [8, 65–71]. Thus, we use the dual-beta approach, in addition to the regular CAPM beta, to examine whether changes in systematic risk associated with security breaches behave differently in economic recession or expansion periods.

Generally, beta factors change with the release of firm-specific news as investors adjust their estimates of risk associated with their investment in the respective firm [72–74]. Extant literature features only limited empirical evidence on cyber security breaches and the impact on firms' systematic risk. In their study on five breached consumer electronics firms between 2011 and 2015, Hinz et al. [5] showed that the aggregate change in firms' systematic risk of 0.022 was positive, but insignificantly small. Their findings thereby implied that breached firms' cost of equity, and hence cost of capital, do not increase [5]. Similarly, Nicholas-Donald et al.'s [7] examination of 29 security breaches between 2000 and 2010 revealed an insignificant increase in the risk factor of about 4%. These results are contradicted by a study published in 2012, in which, in a sample of 38 events from 2002 to 2008, it was established that firms' beta factors increased significantly following a security breach announcement [6].

In summary, extant literature presents limited and contradictory evidence as to the increase in systematic risk following security breaches. Additionally, there is no empirical evidence on how security breaches affect firms' systematic downside and upside risks.

2.2 Hypothesis Development

As stated in Section 1, we are motivated by two research questions: Do severe security breaches increase firms' cost of equity by elevating systematic risk?; and Do severe security breaches affect firms' cost of equity differently in bearish and bullish markets by affecting downside and upside risk differently? Based on previous empirical evidence, it is reasonable to assume that rational investors assign greater systematic risk (i.e., higher beta factors) to breached firms' stock and hence expect greater returns on investment to compensate for their risk incurred. Accordingly, we hypothesise as follows.

H1. Severe security breaches in publicly listed companies are associated with increased cost of equity, as indicated by positive changes in systematic risk (i.e., regular beta).

H2. Severe security breaches in publicly listed companies are associated with increased cost of equity in a bull market, as indicated by positive changes in systematic upside risk (i.e., upside beta).

H3. Severe security breaches in publicly listed companies are associated with increased cost of equity in a bear market, as indicated by positive changes in systematic downside risk (i.e., downside beta).

We thereby expected that changes in downside beta exceed those in upside beta, as downside beta is considered to be a more appropriate measure for risk associated with an investment [8] and investors are expected to be more wary and aware of a firm's negative news history during Down Markets relative to Up Markets.

Table 1: An overview of the sampling process

Filtering step	(Sub-)sample size
PRC database (01/2005–05/2019)	8,921 breach events
Filtering out non-public firms' incidents and non-direct subsidiaries	655 firms
Filtering out confounding events, non-severe breaches, and unreported breaches	202 breach events

3 Data Sources and Sample Characteristics

In order to analyse the predicted effects of major security incidents on firms' systematic risk, a representative sample of such security breaches in publicly listed companies had to be created. Generally, obtaining a holistic database on major security breaches in public companies is difficult. Despite the arguable potential to increase stock market transparency, capital market authorities do not provide official lists of cyber security breaches in publicly listed companies. In addition, there is no exhaustive government-sponsored database detailing all security breaches in organisations [75]. Analysing publicly listed companies also gives rise to difficulties related to, for example, companies changing names, tickers, and ownership statuses.

Given the absence of any authoritative source of data, we built a novel dataset based on the Privacy Rights Clearinghouse (PRC) database, which is commonly used in similar studies (e.g., [4, 36, 45, 76]). The PRC database is considered to be the most extensive systematic publicly available database on security incidents and combines security breach data from government and media sources [4, 76].

The PRC database was used as the basis for this study's dataset as US-based companies are commonly subject to extensive data breach notification laws [75], the US stock market is generally considered efficient and highly liquid [77], and public US companies are subject to high equity analyst and media coverage — all of which contributes to a strong information environment [78].

Our final sample (which is summarised in Table 1) was constructed as follows.

First, we downloaded the entire PRC database for entries between January 2005 and May 2019, including information on company names, security breach publication dates, number of records breached, and descriptions of incidents. This initial list featured 8,921 incidents pertaining to 7,608 unique companies that experienced security breaches. In order to establish which of these companies were public when they experienced a security breach, a global list of all companies with publicly traded equity between 2005 and 2019 was downloaded from *S&P Capital IQ*[3]. Two approximate string matching techniques were used to merge the list of public companies to the initial PRC database. All organisations identified as publicly listed were validated manually to delete false positive matches (e.g., public companies with similar names, or companies that at the respective privacy breach announcement date were not already, or no longer, publicly listed). Additionally, to verify the accuracy

[3]`https://www.capitaliq.com/`

of the aforementioned merging approach, unique companies' public ownership statuses were also examined manually for half of the overall set of breached organisations by conducting individual searches on *S&P Capital IQ*. PRC-listed privacy breaches in subsidiaries were excluded from our dataset unless the incident pertained to a direct subsidiary (i.e., companies which can intuitively be identified as subsidiaries of publicly listed companies: national subsidiaries and those with names very similar to the publicly listed parent company/that share a similar name with their respective listed parent company)[4]. Similarly, cases in which publicly listed companies' data was affected, but the security breach itself occurred at an (unnamed) vendor or supplier, were excluded.

The aforementioned steps resulted in a preliminary sample of 655 companies that experienced privacy breaches between January 2005 and May 2019. Subsequently, security breaches that were subject to confounding events (e.g., delistings, mergers and acquisitions) shortly before or after the privacy breach announcement were excluded as such confounding events would skew focal events' potential effects on systematic risk.

The remaining security incidents were classified into severe and non-severe breaches according to the type, volume, and publicity of the respective privacy breach. We followed a rigorous qualitative case-by-case analysis approach that included reading all case descriptions provided by PRC, publicly available online media reports, and court filings (if available). The analysis described in the following included only incidents that financial market participants without sophisticated technological knowledge were likely to identify as severe high-level security breaches of cash flow-affecting severity for the listed entities. To this end, we only included incidents that were the result of intentional coordinated/systematic effort to exploit weaknesses in (non-)physical security systems with malicious intent motivated by gaining personal utility. Hence, we excluded minor cases of negligence (e.g., inappropriate disposal of personal information), deliberate privacy breaches (e.g., companies selling customer data), losses (e.g., documents lost in transit), and casual theft/petty theft (e.g., stolen employee laptops). Small-scale self-contained/isolated/local incidents such as the use of card skimmers or an employee using customer data to set up fake accounts were also excluded.

Crucially, in line with the semi-strong form of the efficient market hypothesis [79], only those incidents which provoked media attention were included in our sample[5].

Corporate and financial information including daily share prices were downloaded using *S&P Capital IQ* and merged with the sample of severe security breaches.

The overall aim of the sampling process delineated above was to mirror the information gathering and decision-making process of equity analysts, investors, and other market participants following security incidents in publicly listed companies. The sample construction

[4]The rationale here is that market participants are unlikely to expect substantial negative cash flow impacts on public companies following privacy breaches in one of their indirect subsidiaries. Moreover, it is fair to assume that (lay) investors are unlikely to be aware of ownership structures if these cannot be deducted from company names. This approach is in line with the logic presented by [36], in which it is argued that "a breach on [a remote/differently-named subsidiary's] products might have less of an effect on the stock of [the parent company]" (pp. 8-9).

[5]The existence of at least one relevant and unambiguous news item was verified using a general web search, as well as specialised websites such as `https://www.breachclarity.com`, which is endorsed by the Identity Theft Resource Center, a resource used by the United States Securities and Exchange Commission (see `https://www.sec.gov/files/speech-jackson-cybersecurity-2018-03-15-data-appendix-updated.pdf`), and hence likely known to stock market participants.

approach was thereby modelled on conversations with professional and retail investors.

Table 1 provides an overview of the sampling process described above. The final sample used for our study consisted of 202 severe security breaches, for which announcement dates[6], breached entity names, parent company names, market capitalisation at breach announcement, country of primary listing, and other financial information were recorded. Out of 202 security breach events, 181 related to firms with a primary listing on a US stock market. The 164 listed companies in our sample had an average market capitalisation of USD52,019.92m at their security breach announcement. Of the 202 incidents, 49, 39, 32, and 28 incidents occurred in the Consumer Discretionary, Information Technology, Financials, and Communication Services industry sectors, respectively. Table 5 (in Appendix A) provides an overview of the security breach events included in our sample.

4 Methodology

In this section, the methodology used to establish post-security breach changes in systematic risk, in terms of regular betas and dual-betas, is described. We first explain how pre- and post-announcement betas as well as dual-betas for our sample of severe security breaches were calculated. Then, we provide one exemplifying case and explain our regression model.

4.1 Analytical Procedure: Betas and Dual-Betas

The aim of the present analysis was to establish differences in systematic risk in terms of beta prior and subsequent to severe high-level security breaches in publicly listed firms. Beta, a measure of correlated relative volatility, indicates the extent to which a listed firm's stock return volatility is correlated with the relevant index volatility, and thereby functions as an indicator of risk exposure to general market movements [52–55]. The dual-beta model extends the regular beta model by introducing downside and upside betas to measure downside and upside risk, respectively [64,65]. Our methodology followed the approach of similar studies (e.g., those of [80], [5] and [39]).

For each security breach in our sample ($n = 202$), we computed six sets of betas: pre-breach regular beta, post-breach regular beta, pre-breach upside beta, post-breach upside beta, pre-breach downside beta, and post-breach downside beta[7].

Each set of betas consisted of 60 daily betas, which were calculated as follows. First, daily returns were established as firm i's share price on day t divided by firm i's share price on day $t-1$.

$$\frac{price_{i,t}}{price_{i,t-1}} - 1 \tag{1}$$

The methodology to obtain regular beta factors is based on the Capital Asset Pricing Model (CAPM) introduced by Lintner [53], Mossin [55], Sharpe [52], and Treynor [54].

[6] In case of conflicting announcement dates or multiple entries for the same security breach, the earlier announcement date was taken into account for this study. Announcement dates were adjusted to the nearest trading day if the actual announcement day fell on a non-trading day.

[7] We thereby assumed that investors assess each security incident individually. Accordingly, events in companies that repeatedly experienced high-level security breaches were analysed independent of previous incidents, as opposed to assuming autocorrelation or evaluating multiple breaches in aggregation.

According to the CAPM, a firm's cost of equity can be defined as

$$R_i = r_f + \beta_i \left(R_m - r_f\right) \tag{2}$$

Here, R_i denotes the expected return in security i, r_f is the risk-free rate, R_m is the market return, and $beta_i$ is the firm-specific indicator of systematic risk (i.e., correlated relative volatility). The difference between R_m and r_f is referred to as the *market risk premium.*

The value of $beta_i$, the stock's sensitivity to index returns, is estimated via ordinary least square regression of stock returns on index returns, and is defined as

$$\beta_i = \frac{cov(R_i, R_m)}{var(R_m)} \tag{3}$$

Here, $cov(R_i, R_m)$ denotes the covariance between an individual stock's returns and the market index and $var(R_m)$ is the variance of index returns. In line with similar studies [5, 39,80–82], we used an estimation period of one year (i.e., 250 trading days) to calculate daily beta factors based on Sharpe's one-factorial market model [51]. The US-oriented sample featured both firms with a primary listing on a US stock exchange as well as firms with a primary listing elsewhere. For our study, only primary listings were considered. Accordingly, for each event, the index used to proxy the market portfolio was the respective country's major multi-industry stock market index[8].

The computation of upside and downside beta factors is similar to the regular beta calculation approach presented above. We followed the Up and Down Markets dual-beta model laid out by Fabozzi and Francis [64] and Kim and Zumwalt [65]. Specifically, Sharpe's [51] single-index model was modified to include upside and downside beta factors to account for days on which a market portfolio's return was ≥ 0 or <0, respectively[9].

$$R_{i,t} = \alpha_i^+ D + \beta_i^+ R_{m,t}^+ D + \alpha_i^- (1 - D) + \beta_i^- R_{m,t}^- (1 - D) + \epsilon_{i,t} \tag{4}$$

Here, $R_{i,t}$, firm i's stock return on day t, is defined as follows. For days t on which the market portfolio return was greater than or equal to zero, α_i^+ is the average stock return idiosyncratic to security i, β_i^+ is the upside beta factor, and $R_{m,t}^+$ is the index return on day t. For days t on which the market portfolio return was negative, the aforementioned logic applies vice versa. D is a binary variable which assumes the value of 1 in Up Markets, that is, when daily market portfolio returns are non-negative, and zero in Down Markets. $\epsilon_{i,t}$ is the residual term with an expected mean of zero.

β_i^+ and β_i^-, the stock's sensitivity to index returns in Up Markets and Down Markets, respectively, are estimated via ordinary least square regression of stock returns on the respective (non-)negative index returns, and are defined as

$$\beta_i^+ = \frac{cov(R_i, R_m^+)}{var(R_m^+)} \tag{5}$$

[8]In line with similar empirical studies (e.g., [28, 39, 81], as well as financial theory based on Sharpe's single-index model conceptualisation of the CAPM [51–56], we proxy market risk in terms of volatility of the respective country's broad major multi-industry stock market index. A list of indices used to proxy country-specific market portfolios can be obtained from the authors upon request.

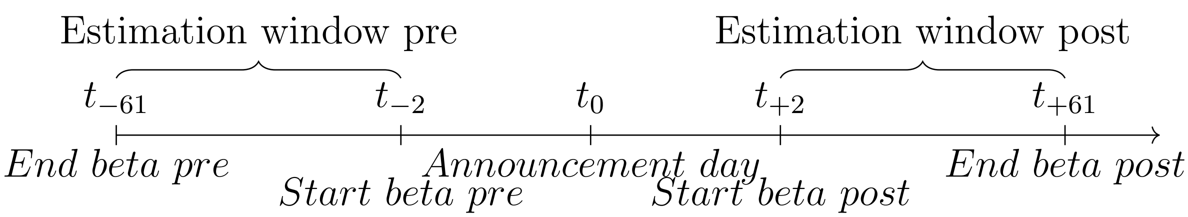
[9]Up Markets could also be defined differently. For instance, as such days on which market portfolio returns exceeded the average market return or the risk-free rate [65].

and

$$\beta_i^- = \frac{cov(R_i, R_m^-)}{var(R_m^-)} \tag{6}$$

Here, $cov(R_i, R_m^+)$ and $cov(R_i, R_m^-)$ denote the covariance between an individual stock's returns and the market index on Up Market days and Down Market days, respectively, and $var(R_m^+)$ and $var(R_m^-)$ are the variances of index returns on Up Market days and Down Market days, respectively. As delineated above, one-year upside and downside betas were calculated using the relevant indices. The number of trading days taken into account to determine dual betas varied contingent upon the number of days in a given year on which market portfolio returns were (non-)negative.

As illustrated below, all three types of daily one-year beta factors (regular, upside, and downside) were computed for periods of 60 trading days prior and subsequent to a security breach announcement, starting two trading days before and after the (potentially adjusted) announcement date, respectively.



As daily beta factors tend to be highly volatile [5], we aggregated daily one-year beta factors over a period of 60 days following graphical and statistical analysis of volatility and outliers of daily one-year betas aggregated between 50 and 90 days[10]. To analyse changes in systematic risk induced by severe security breaches, we averaged each set of 60 daily betas ($\Delta\beta_{i,\bar{t}}, \Delta\beta_{i,\bar{t}}^+, \Delta\beta_{i,\bar{t}}^-$) to yield one value, and established differences between pre- and post-breach betas for each breach announcement in our sample as

$$\begin{aligned}
\Delta\beta_{i,\bar{t}} &= \frac{\sum_{t=t_{+2}}^{t_{+61}} \beta_{i,t}}{60} - \frac{\sum_{t=t_{-2}}^{t_{-61}} \beta_{i,t}}{60} \\
\Delta\beta_{i,\bar{t}}^+ &= \frac{\sum_{t=t_{+2}}^{t_{+61}} \beta_{i,t}^+}{60} - \frac{\sum_{t=t_{-2}}^{t_{-61}} \beta_{i,t}^+}{60} \\
\Delta\beta_{i,\bar{t}}^- &= \frac{\sum_{t=t_{+2}}^{t_{+61}} \beta_{i,t}^-}{60} - \frac{\sum_{t=t_{-2}}^{t_{-61}} \beta_{i,t}^-}{60}
\end{aligned} \tag{7}$$

In order to account for potentially distorting effects of outliers, all three sets of changes in beta were winsorised at the 0.05 level at both tails.

To determine whether changes in regular, upside, and downside beta were of statistical significance, parametric Student t-tests were performed testing the alternative hypothesis that regular and winsorised $\Delta\beta_{i,\bar{t}}$, $\Delta\beta_{i,\bar{t}}^+$, and $\Delta\beta_{i,\bar{t}}^-$ scores are significantly greater than zero in the population of severe security breaches. Given the sample size, near-normal distribution could reasonably be assumed, and Student t-tests appeared justified. Graphic analysis

[10] As discussed in Section 5, the results are qualitatively robust to aggregating over aggregation time periods of 50, 60, 70, 75, 80, and 90 days.

of changes in regular, upside, and downside betas, however, revealed that the distributions present heavy tails. Non-parametric testing, which does not require a particular probability distribution, is thus expedient to confirm t-test results [28, 39, 81, 83]. Conducting both parametric and non-parametric statistical tests is in line with similar empirical studies in information security economics (see [28, 39, 81]). Hence, non-parametric one-sided Wilcoxon signed-rank test scores were calculated additionally[11], testing the alternative hypothesis that the one-sample Hodges-Lehmann-type pseudo-median is greater than zero [84, 85]. All statistical tests were directional, as we expected positive changes across all beta types (as established in Section 2.2).

4.2 Illustration of Beta and Dual-Beta Analysis

In order to illustrate the methodology laid out above, consider the following.

On 01 October 2018, the PRC database recorded a severe security breach in Chegg Inc., an education technology company with a market capitalisation of USD3.1bn at that time. The company suffered from an external attack that affected more than 40 million customers and filed a statement with the Securities and Exchange Commission. The incident was widely reported upon in major news outlets[12].

We excluded the announcement day, as well as the two trading days immediately preceding and following the announcement day to avoid capturing volatility induced by the announcement event, following the logic of the semi-strong efficient market hypothesis [79, 86]. Hence, in order to establish the pre-breach regular beta factor, 60 daily one-year betas were calculated between 27 September 2018 and 05 July 2018, and averaged to yield 0.87. Similarly, 60 daily one-year betas were calculated from 03 October 2018 to 28 December 2018 and averaged to establish a post-breach regular beta of 1.16[13]. This increase in beta by 0.29 (i.e., 33%) suggests that following the announcement of the security breach, Chegg Inc.'s systematic risk increased substantially as its stock became more volatile vis-à-vis general market movements.

Pre- and post-breach upside and downside betas are based on the same period of time. However, only trading days with non-negative — or negative, respectively — market returns were taken into account when regressing Chegg Inc.'s stock returns on the S&P 500. Chegg Inc.'s pre-breach upside and downside betas were 0.57 and 0.61, respectively. Following the severe security breach announcement, these figures increased to 0.94 and 1.00, respectively. These results for Chegg Inc. therefore suggest that in both Up and Down Markets (i.e., during periods of time featuring positive and negative market returns, respectively) Chegg

[11] Other non-parametric tests could have been conducted alternatively. For instance, we considered analysing beta changes using sign tests. However, as expected proportions of positive changes in beta cannot be established unambiguously, we decided not to use this binomial test.

[12] See, for example, `https://www.techcrunch.com/2018/09/26/chegg-resets-40-million-user-passwords-after-data-breach/`, `https://www.cnbc.com/2018/09/26/ed-tech-company-chegg-plunges-after-disclosing-data-breach.html`, and `https://www.zdnet.com/article/chegg-to-reset-passwords-for-40-million-users-after-april-2018-hack/`.

[13] Using 250 trading days to establish daily betas, the first daily pre-breach beta in the set of 60 daily pre-breach betas, for instance, was calculated using returns data between 27 September 2018 and 02 October 2017.

Table 2: Changes in Systematic Risk — Untransformed

Beta Type	n	M	Mdn	t	p_t	$Pseudo$ Mdn	$p_{Wilcoxon}$
$\Delta\beta_{i,\bar{t}}$	202	0.022	0.010	1.682	0.047**	0.015	0.032**
$\Delta\beta^{+}_{i,\bar{t}}$	202	0.004	0.004	0.204	0.419	0.001	0.481
$\Delta\beta^{-}_{i,\bar{t}}$	202	0.031	0.009	1.720	0.043**	0.015	0.089*

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$; n = sample size; M = sample mean; Mdn = sample median; t = test statistics t-test; p_t = p-value t-test; $PseudoMdn$ = pseudo-median Wilcoxon test; $p_{Wilcoxon}$ = p-value Wilcoxon test. Mean and median figures are changes in regular, upside, and downside beta, respectively. t-tests and Wilcoxon signed-rank tests are one-sided, testing the alternative hypothesis that the population mean is greater than zero and that the population pseudo-median is greater than zero, respectively.

Inc.'s upside and downside risks increased due to the security breach, as its stock became more volatile vis-à-vis general market movements during both bull and bear markets.

4.3 Analytical Procedure: Regression Analysis

To further explore our dataset, and to establish firm features that exacerbate the impact of severe security breaches on systematic regular and downside risk, we conducted further baseline regression analyses. Specifically, we examined the following aspects which characterise a firm's information environment and might impact its susceptibility to shocks posed by security breaches: announcement year, industry, firm size, and primary listing country. The announcement year is the calendar year in which a firm announced the focal security breach. Ex-ante, we expected that the impact of security breaches on risk increases over time due to advances in media reporting and data breach notification laws. The industry was defined with respect to the *S&P Capital IQ* industry sector[14]. Differences across industries can stem from divergent regulations, the amount of media coverage an industry is subject to, and investors' assessment of security breaches' relevance for firms in the respective industry.

As noted earlier, our analysis approach attempted to model an 'average' market participant's decision-making process. Accordingly, firms with market capitalisations at breach announcement exceeding USD10bn or USD2bn were defined as large- or medium-sized firms, respectively. Primary listing country is a dummy variable, which takes the value of unity for firms with a primary listing on a US stock exchange and is zero otherwise. Our regression model included all the independent variables mentioned above. The dependent variables were the changes in systematic regular and downside risk.

Table 3: Changes in Systematic Risk — Winsorised

Beta Type	n	M	Mdn	t	p_t	$Pseudo$ Mdn	$p_{Wilcoxon}$
$\Delta\beta_{i,\bar{t}}$	202	0.014	0.010	1.767	0.039^{**}	0.014	0.026^{**}
$\Delta\beta^{+}_{i,\bar{t}}$	202	-0.007	0.004	-0.507	0.694	-0.001	0.535
$\Delta\beta^{-}_{i,\bar{t}}$	202	0.020	0.009	1.504	0.067^{*}	0.016	0.077^{*}

5 Empirical Results

5.1 Overview

The aim of this study was to establish whether severe security breaches are associated with an increase in firms' cost of equity by elevating systematic risk, and whether systematic risk is affected differently in bearish and bullish markets. To this end, we tested three hypotheses, as outlined in Section 2.2.

In this section, relevant results are presented. Based on the methodology of Section 4, we determined changes in systematic risk induced by severe security breaches in publicly listed companies in terms of differences in regular beta, upside beta, and downside beta. We progressed as follows.

First, we examined Student t-test and Wilcoxon signed-rank results for untransformed and winsorised scores of changes in regular beta, upside beta, and downside beta. Tables 2 and 3 indicate, from left to right, the type of beta examined, sample size, mean, median, one-sided Student t-test statistics, and one-sided Wilcoxon signed-rank test statistics. As common, we accepted statistical significance as indicated by p-values less than 0.05, and statistical trends as indicated by p-values less than 0.1, respectively.

Second, we investigated whether time, industry classification, firm size in terms of market capitalisation, or featuring a primary listing on a US stock exchange have a significant impact on changes in systematic risk. As above, we considered the models' independent variables to be statistically significant at p-values of less than 0.05, and discussed statistical trends at p-values less than 0.1, respectively. The regression analysis results are presented in Section 5.5.

Overall, based on Student t-tests and Wilcoxon signed-rank test analyses, we found support in favour of hypotheses **H1** and **H3**. We established that severe security breaches are associated with statistically significant changes in firms' systematic risk and downside risk as measured by differences in regular and downside betas. However, we did not find sufficient evidence to support hypothesis **H2**: upside beta is not statistically significantly affected by severe security breaches in publicly listed firms. Preliminary regression analysis results did not provide additional insights into factors influencing changes in systematic and downside risk.

[14] Communication Services, Consumer Discretionary, Financials, Health Care, Industrials, Information Technology, or Other.

5.2 Regular Beta

We started our analysis by posing the initial research question: Do severe security breaches increase firms' cost of equity by elevating systematic risk? We hypothesised that severe security breaches in publicly listed companies are associated with positive changes in systematic risk (i.e., regular beta).

As noted earlier, regular beta is a measure of systematic risk indicating to what extent aggregate changes in the market affect individual firms' stock returns. Generally, a higher regular beta indicates that the focal asset's volatility is more correlated with index volatility, and hence more exposed to general market risk.

The top rows in Tables 2 and 3 present the analysis results for untransformed changes in regular beta and winsorised changes in regular beta, respectively. Apart from winsorised upside beta scores, all mean and (pseudo-) median figures are of the expected sign. First, consider untransformed differences between pre- and post-breach betas. According to t-test results, the mean change in regular beta of 0.022 can be considered statistically significant ($n = 202, p_t = 0.047$). The non-parametric Wilcoxon signed-rank test provides further evidence in support of this statistical significance ($Mdn = 0.010, p_{Wilcoxon} = 0.032$).

For winsorised differences between pre- and post-breach betas, we find equally strong evidence that severe security breaches in public companies are followed by changes in regular beta. Both statistical tests demonstrate that the population mean and (pseudo-) median are indeed significantly greater than zero ($p_t = 0.039, p_{Wilcoxon} = 0.026$). The winsorised mean ($M = 0.014$) is slightly smaller than the non-winsorised figure ($M = 0.022$), suggesting the presence of some outliers.

Differences between pre- and post-breach regular betas are qualitatively robust to changing the aggregation time period of daily one-year betas. Specifically, across 50, 60, 65, 70, 75, and 80 aggregation days, untransformed and winsorised differences in regular beta always exhibit at least a positive statistical trend ($p < 0.1$) or are statistically significantly positive ($p < 0.05$) as per t-tests and Wilcoxon signed-rank tests.

Overall, we found sufficient evidence in support of hypothesis **H1**. Severe security breaches in publicly listed companies are indeed associated with an increase in systematic risk, as indicated by an increase in regular beta, leading to an increase in cost of equity.

5.3 Upside Beta

At the beginning of our analysis we asked whether severe security breaches affect firms' cost of equity differently in bearish and bullish markets by affecting downside and upside risk. To this end, we hypothesised (**H2** and **H3**): Severe security breaches in publicly listed companies are associated with positive changes in upside risk (i.e., upside beta) and downside risk (i.e., downside beta).

As described above, upside betas signify to what extent aggregate changes in bullish markets (i.e., positive index returns) affect individual firms' stock returns. Generally, a greater upside beta suggests that the focal asset's volatility is more correlated with index volatility, and hence is more exposed to general market risk, during bullish periods of time.

In the middle rows of Tables 2 and 3 we present the analysis results for untransformed changes in upside beta and winsorised changes in upside beta, respectively. According to t-

test results, the mean untransformed difference between pre- and post-breach upside betas of 0.004 cannot be considered meaningfully greater than zero ($n = 202, p_t = 0.419$). Similarly, Wilcoxon signed-rank test results suggest that the population median is not significantly greater than zero ($Mdn = 0.004, p_{Wilcoxon} = 0.481$).

After controlling for the effect of outliers on changes between pre- and post-breach upside betas, we find even stronger evidence that severe security breaches in publicly listed companies are not followed by changes in upside beta. Instead, the winsorised mean change is actually slightly negative at -0.007 ($n = 202, p_t = 0.694$). Additionally, the Wilcoxon signed-rank test results for winsorised differences in upside beta do also confirm that the population median cannot be expected to be greater than zero ($Mdn = 0.004, p_{Wilcoxon} = 0.535$). Considering the difference between the mean change in untransformed upside beta and the mean change in winsorised upside beta of 0.01, outliers do not seem to substantially influence the analysis.

Differences between pre- and post-breach upside betas are qualitatively robust to changing the aggregation time period of daily one-year betas. Specifically, across 50, 60, 65, 70, 75, 80, and 90 aggregation days, untransformed and winsorised differences in upside beta never exhibit positive statistical trends ($p < 0.1$) or statistical significance as per t-tests and Wilcoxon signed-rank tests.

Overall, we do not find evidence to reject the null hypothesis in connection with **H2**. In contrast, our results unanimously suggest that major security breaches in publicly listed companies are not associated with an increase in systematic upside risk, as indicated by no significant increase in upside beta, not leading to an increase in cost of equity.

5.4 Downside Beta

We hypothesised (**H2** and **H3**) that severe security breaches in publicly listed companies are associated with positive changes in upside risk (i.e., upside beta) and downside risk (i.e., downside beta). Additionally, we expected that security breach-induced changes in downside beta exceed those in upside beta.

As noted earlier, downside beta is an indicator for the extent to which general market changes in bearish markets (i.e., negative index returns) affect individual firms' stock returns. Generally, a greater downside beta indicates that the focal asset's volatility is more correlated with index volatility, and hence more exposed to general market risk, during bearish periods of time.

Analysis results for untransformed changes in downside beta and winsorised changes in downside beta, respectively, are presented in the bottom rows of Tables 2 and 3. First, consider untransformed differences between pre- and post-breach downside betas. The untransformed mean change in downside beta of 0.031 can be considered statistically significant ($n = 202, p_t = 0.043$). The median of 0.009 can be considered a statistical trend ($n = 202, p_{Wilcoxon} = 0.089$).

Controlling for outliers in the analysis of downside beta changes also yields results in favour of the hypothesised relationship between security breaches and downside systematic risk. The t-test of winsorised mean changes suggests a positive statistical trend ($M = 0.020, p_t = 0.067$). The non-parametric Wilcoxon signed-rank test corroborates the t-test results. Testing median winsorised differences in downside beta shows a statistical trend indicating that the population median can be expected to be greater than zero ($p_{Wilcoxon} = 0.077$). The minor divergence between untransformed and winsorised mean changes in downside beta of 0.01 suggest the presence of some outliers in the sample.

Differences between pre- and post-breach downside betas are qualitatively robust to changing the aggregation time period of daily one-year betas. Specifically, across 50, 60, 65, 70, 75, and 80 aggregation days, untransformed and winsorised differences in upside beta always exhibit at least positive statistical trends ($p < 0.1$) or are statistically significantly positive as per t-tests and Wilcoxon signed-rank tests.

Overall, we find some evidence in support of hypothesis **H3**. Severe security breaches in publicly listed companies are associated with an increase in systematic downside risk, as evidenced by a significant increase in downside beta, causing an increase in cost of equity.

5.5 Regression Results

Regression analysis results are reported in Table 4. Given the results presented in Sections 5.2–5.4, we only considered security breach-related changes in regular and downside systematic risk. Accordingly, the outcome variables across the analysed regression models 1–4 are the differences between pre- and post-breach betas.

For the two types of beta factors and outlier treatment approaches, the full models including all variables specified above are presented. Specifically, models 1 and 2 examine untransformed changes in regular beta and winsorised changes in regular beta, respectively. Models 3 and 4 consider unadjusted changes in downside beta and winsorised changes in downside beta, respectively. For each model, we report regressors' estimated coefficients as well as standard errors in parentheses. According to the models' F-statistics, none are overall-significant and thus only yield limited insights into firm characteristics affecting the extent to which security breaches induce changes in systematic risk and systematic downside risk, respectively.

Models 1 and 2 suggest the presence of a weak negative statistical association that exists between security breach-related changes in regular beta and Industrial companies ($\beta_{Industrials,\, untransformed} = -0.110$, $se_{Industrials,\, untransformed} = 0.062$; $\beta_{Industrials,\, winsorised} = -0.066$, $se_{Industrials,\, winsorised} = 0.037$). Surprisingly, no other industry-based differences are observable.

Considering skewness-reduced regular beta differences in model 2 also reveals a statistically significant and negative association between winsorised changes in regular beta and primary listings on US stock exchanges ($\beta_{Primary\, Listing\, US,\, winsorised} = -0.053$, $se_{Primary\, Listing\, US,\, winsorised} = 0.026$).

Analysing the effect of firm characteristics on security breach-associated changes in systematic downside risk, models 3 and 4 suggest firm size effects. Specifically, both models indicate the presence of weak negative statistical associations between firms of high market capitalisations and shifts in systematic downside risk ($\beta_{Large\, firms,\, untransformed} = -0.085$, $se_{Large\, firms,\, untransformed} = 0.049$; $\beta_{Large\, firms,\, winsorised} = -0.070$, $se_{Large\, firms,\, winsorised} = 0.035$). In addition, both models indicate the existence of a similar trend for medium-sized firms ($\beta_{Medium\, firms,\, untransformed} = -0.088$, $se_{Medium\, firms,\, untransformed} = 0.053$, $\beta_{Medium\, firms,\, winsorised} = -0.065$, $se_{Medium\, firms,\, winsorised} = 0.038$).

Table 4: Regression Results

	Dependent variable:			
	$\Delta\beta_{i,\bar{t}}$	$\Delta\beta_{i,\bar{t}}, winsorised$	$\Delta\beta^{-}_{i,\bar{t}}$	$\Delta\beta^{-}_{i,\bar{t}}, winsorised$
	(1)	(2)	(3)	(4)
Year	−0.002	−0.001	−0.008	−0.004
	(0.004)	(0.002)	(0.006)	(0.004)
Communication Services	−0.044	0.008	−0.058	−0.045
	(0.062)	(0.036)	(0.086)	(0.061)
Consumer Discretionary	−0.047	−0.006	−0.031	−0.041
	(0.057)	(0.034)	(0.079)	(0.057)
Financials	0.002	0.002	−0.004	−0.034
	(0.061)	(0.036)	(0.085)	(0.061)
Health Care	0.006	0.025	0.082	0.053
	(0.069)	(0.041)	(0.097)	(0.069)
Industrials	−0.110*	−0.066*	−0.085	−0.081
	(0.062)	(0.037)	(0.087)	(0.062)
Information Technology	−0.048	−0.004	−0.031	−0.022
	(0.058)	(0.034)	(0.081)	(0.058)
Firm Size: Large	−0.026	−0.017	−0.085*	−0.070*
	(0.036)	(0.021)	(0.049)	(0.035)
Firm Size: Medium	−0.025	−0.024	−0.088*	−0.065*
	(0.038)	(0.023)	(0.053)	(0.038)
Primary Listing US	−0.047	−0.053**	−0.004	−0.015
	(0.044)	(0.026)	(0.061)	(0.044)
Constant	4.959	2.644	15.932	8.684
	(8.383)	(4.940)	(11.658)	(8.356)
Observations	202	202	202	202
R^2	0.041	0.066	0.046	0.049
Adjusted R^2	-0.009	0.017	-0.004	-0.0003
Residual Std. Error	0.186 (df = 191)	0.109 (df = 191)	0.258 (df = 191)	0.185 (df = 191)
F Statistic	0.818 (df = 10; 191)	1.350 (df = 10; 191)	0.916 (df = 10; 191)	0.994 (df = 10; 191)
Note:				*p<0.1; **p<0.05; ***p<0.01

5.6 Summary

Overall, we find substantial evidence in support of the predicted empirical relationships. Severe security breaches in publicly listed firms are associated with changes in systematic risk as indicated by beta factors. However, there are differences across the three types of beta assessed.

For regular betas, untransformed scores are associated with statistically significant positive changes. These results are supported by tests on winsorised figures which also indicate that changes in regular beta are statistically significantly greater than zero. This leads us to accept hypothesis **H1**. Severe security breaches in publicly listed companies are indeed associated with significant positive changes in systematic risk as indicated by positive post-breach differences in regular beta.

Considering upside betas, all statistical tests unambiguously suggest that security breach-induced changes in upside beta are not statistically significantly greater than zero. We can hence not accept hypothesis **H2**. Severe security breaches in publicly listed companies are not associated with significant increases in systematic positive risk as indicated by an absence of significantly positive post-breach differences in upside beta.

Results for downside betas are less unequivocal. Nevertheless, evidence in support of hypothesis **H3** outweighs antithetical evidence. All four statistical tests demonstrate that there is at least a strong statistical trend towards an increase in downside betas following security breaches. The t-tests of untransformed differences in downside beta reveal the presence of a statistically significant change. Accordingly, we accept hypothesis **H3**. Severe security breaches in publicly listed companies are associated with significant increases in systematic negative risk as indicated by significantly positive post-breach differences in downside beta.

The initial regression analysis does not yield substantial insights into firm characteristics aggravating or alleviating the impact of severe security breaches on systematic regular and negative risk. We found statistical trends indicating that industrial firms and those with a primary listing on a US stock exchange are less prone to increases in systematic risk following security breaches. Similarly, we found statistical trends suggesting a negative association between large to medium-sized firms and increases in systematic downside risk.

6 Discussion

The research described in this paper was motivated by the absence of comprehensive large-sample contemporary analyses on costs of equity implications of security breaches. Moreover, as downside beta is a more appropriate measure for financial risk [8], and investors are likely to be more wary and aware of a firm's negative news history when markets yield negative returns, we also considered the effect of security breaches on cost of equity in Up and Down Markets.

6.1 Changes in Regular, Downside, and Upside Beta

Beta is a measure of systematic risk indicating to what extent aggregate changes in the market affect individual firms' stock returns. Generally, a higher beta indicates that the focal asset's volatility is more correlated with index volatility, and hence more exposed to general market risk. It is thereby necessary to distinguish between regular beta calculated irrespective of market returns' directions, upside beta taking into account firms' returns during Up Markets, and downside beta, the most appropriate measure of financial risk [64, 65], focusing on firms' risk exposure when markets yield negative returns.

First, we posed the question *Do severe security breaches increase firms' cost of equity by elevating systematic risk?* We found strong evidence in support of hypothesis **H1**. Severe security breaches in publicly listed companies are associated with increased cost of equity as indicated by positive changes systematic risk. Second, we explored whether severe security breaches affect firms' cost of equity differently in bearish and bullish markets by affecting downside and upside risk differently. We did not find evidence in support of hypothesis **H2**. Severe security breaches in publicly listed companies are not systematically associated with increased cost of equity in a bull market as indicated by positive changes in systematic upside risk. However, there was sufficient evidence supporting hypothesis **H3**, conjecturing that severe security breaches in publicly listed companies are associated with increased cost of equity in a bear market as indicated by positive changes in systematic downside risk.

Accordingly, we conjecture that severe security breaches induce increases in firms' cost of equity by elevating systematic risk. However, the effect on systematic risk is not of a symmetrical nature. Firms' cost of equity are more severely affected when stock market indices yield negative returns.

Our finding that severe security breaches are associated with significant increases in regular beta is difficult to compare with prior small-scale studies. We established an average increase in regular beta of 0.022, which corresponds to an average percentage increase of 2.07%. Analysing security breaches in US companies, Nicholas-Donald et al. [7] reported a mean increase in regular beta of 0.034. However, the study only made use of a small sample of 29 events, and did not aggregate beta factors over multiple days, which, given high daily volatility [5], poses methodological issues and hinders comparison. Hinz et al. [5] correctly accounted for daily beta volatility. In their small-sample ($n = 6$) study, the authors established an unadjusted average beta increase of 0.022, which corresponds to the increase in regular beta present in our sample.

The effect size of severe security breaches-induced change in regular beta of 0.022 is broadly in conformity with similar studies on different types of events. Analysing the effect of firm-specific earnings announcements, which have an immediate impact on investors' firm valuation processes and hence share prices, Patton and Verardo [72] showed that regular betas increase by 0.16 on average, whereas Ball and Kothari [73] demonstrated that beta increases by an average of 0.04 in the 10 days after earnings announcements relative to the 10 days before the announcements. Grammatikos and Vermeulen [74], who analysed changes in systematic risk following the 2007–2009 financial crisis, established changes in beta factors between -1.20 and 0.97, averaging at -0.14. Using daily measures, Chatterjee and Lubatkin found that unrelated corporate mergers reduce acquiring firms' beta by 0.058 [87]. In summary, breach-induced changes in regular beta are of smaller magnitude than changes in systematic risk elicited by other types of firm- or market-related events. Given the long-lasting fundamental changes associated with the aforementioned types of events, it is not surprising that beta changes caused by security breach are statistically and economically significant, but overall of lower magnitude.

The average increase in downside beta of 0.031 (i.e., 2.92%) constitutes a strong statistical trend, whereas the small average increase in upside beta of 0.004 (i.e., 0.38%) is not statistically meaningful at conventional levels. The observation that breach-induced changes in downside beta are more severe than changes in upside beta is in line with intuition. Downside beta is considered to be a more appropriate measure of risk than the CAPM's regular symmetric single beta [8, 65–71], and investors are more wary and aware of a firm's negative news history during Down Markets. It is fair to assume that changes in regular beta hence mainly stem from greater exposure to market fluctuations in bearish markets.

Generally, the positive change in regular and downside beta suggests that market participants alter their estimate of breached firms' operational risk. The announcement of a severe security breach appears to remind investors of the negative economic repercussions associated with such events. Moreover, the short- and long-term direct costs of recovering from security breaches (e.g., forensics and audit fees, legal and regulatory expenditures, revenue losses, and customer re-acquisition and retention costs) reduce breached firms' ability to react flexibly to changing market conditions and consumer demand.

The finding that systematic risk in terms of beta and downside beta increases following a security breaches carries multiple material implications for breached firms. As laid out in Equation 2, according to the CAPM [52–55], beta is the focal element of a firm's cost of equity. Shifts in beta imply variations in a stock's sensitivity to market risk and indicate changes in investors' assessment of a firm's systematic risk (i.e., the proportion of overall investment risk that is specific to the focal firm and cannot be eliminated by portfolio diversification).

Market cyclicality affects high-beta firms' stock more strongly than it does low-beta firms [88, 89]. With increased exposure to aggregate market risk ($beta_i$), investors expect a greater proportion of risk premium ($R_m - r_f$). Put differently, investors expect to be compensated for taking on greater individual risk incurred by investing in a firm subject to greater market risk. Accordingly, a firm's cost of equity increases.

A firm's weighted average cost of capital (WACC) consists of its proportionately weighted cost of equity and debt factors. Accordingly, all other things being equal, with increases in beta, a firm's cost of equity increases, which in turn results in an increase in WACC. An increase in beta, cost of equity, and consequentially cost of capital, leads to an increase in risk factors[15], heightened cost of funding a firm's operations, elevated discount factors applied in valuation scenarios, and reduced share prices [9, 88, 90, 91].

Following a value-based planning (or shareholder value) approach, value creation on project-level is commonly defined in financial terms, as the project's net present value (NPV) [88], which decreases with greater discount factors [92]. In the context of cyber security investments, an NPV calculation is intended to summarise the net benefit gained from investments in security controls into one single value [93]. The discount factor applied in NPV-based project valuations is typically based on WACC. Discounted future economic benefits thereby decrease with greater WACCs, resulting in lower NPVs. A low NPV might render an otherwise sound project economically unviable. Accordingly, greater systematic risk (β_i and β_i^-) factors following security breaches, causing greater WACCs and discount factors, can induce executives to shy away from pursuing investments in information security.

Moreover, on firm-level, discounted cash flow-based company valuations also decrease with greater discount factors (i.e., WACC) [91]. As discounted cash flows are highly correlated with stock prices [90], greater WACC coefficients cause lower market values. In the context of security breaches, this implies that one of the factors influencing share price drops following security breaches (see [26–38]) can be due to investors expecting increases in

[15] Investors tend to use the terms risk factor and discount factor synonymously.

systematic risk, and hence applying greater discount factors to future cash flows.

From a broader perspective, security breaches also introduce additional costs to society at large. Greater cost of capital (i.e., greater cash outflows) might increase prices for consumers if firms try to offset increasing costs by generating additional revenue. Alternatively, breached firms might reduce capital expenditures and delay investments, which would elicit negative repercussions even in intrinsically unrelated industries. Additionally, capital markets become less efficient given that investors' fair price discovery process is impeded by security breaches inducing changes to firms' cost of capital structure.

In summary, financial valuations of projects, investments, and firms are based on the time value of money concept, which incorporates a discount factor reflecting risk. In corporate scenarios, this discount factor is usually based on the weighted average cost of capital (WACC) principle, which partially depends on a firm's systematic risk, measured as the firm-and-time-specific beta. All other things being equal, a firm with a relatively low beta features lower cost of capital, and thus the ability to invest in lower-return projects and to command higher company valuations [60, 90, 92]. Following this line of argumentation, a security breach causing increases in regular and downside beta can render investments economically unfavourable and depress stock prices.

6.2 Illustration of Changes in Cost of Equity

In order to demonstrate the relevance of beta for a breached firm's cost of equity, consider the following, which builds upon the example of Section 4.2.

Chegg's pre- and post-breach betas were in line with the industry. In 2018, US Business & Consumer Services and Retail companies typically featured a beta of around 1.17 and 1.05, respectively[16]. To illustrate breach-induced changes in cost of equity, we apply Equation 2 using a risk-free rate (r_f), as proxied by US Treasury Bonds, of 2.68%, and an implied equity risk premium ($R_m - r_f$) of 5.96% [94].

Chegg's regression-based averaged pre-breach regular, upside, and downside betas were 0.87, 0.57, and 0.61, respectively. Following the security breach, these figures increased to 1.16, 0.94, and 1.00. Considering regular beta, Chegg's cost of equity hence increased by 1.73 percent points from 7.87% to 9.59%. The increase in downside cost of equity is even more pronounced with an increase of 2.32 percentage points from 6.36% to 8.64%. Chegg's cost of equity have thereby increased beyond industry average figures[17].

According to Chegg's Q4-2018 annual report, common equity made up 59.14% of its total capital. Hence, an increase in cost of equity by 1.73 or 2.32 percentage points would ceteris paribus result in a positive cost of capital change by 1.02 or 1.37 percentage points, respectively, which is economically significant.

[16] https://web.archive.org/web/20181020131527/http://people.stern.nyu.edu/adamodar/New_Home_Page/datafile/wacc.htm

[17] https://web.archive.org/web/20181020131527/http://people.stern.nyu.edu/adamodar/New_Home_Page/datafile/wacc.htm

6.3 Factors Influencing Changes in Beta

The regression models presented above indicate a weak negative statistical association between security breach-related changes in regular beta and Industrial companies. This finding suggests that firms operating in said sector are less susceptible to changes in systematic beta than firms in other industries.

Generally, differences between industries are not distinctively pronounced, which might be due to small sub-sample sizes. Interestingly, obvious direct costs and increases in underlying/consequential cost of equity are not necessarily interlinked. Direct costs of security breaches tend to be the highest in Healthcare [3]. However, Healthcare companies are not associated with significantly greater changes in beta or downside beta than companies in other industries.

The impact of security breach announcements on regular beta is more severe in firms that do not feature a primary listing on a US stock exchange. This might be due to the more advanced information environment and higher market liquidity present in the US.

We also established a firm size effect with regards to the impact of security breaches on downside beta. A statistical trend indicates that breached medium- and large-sized firms are less prone to suffer from increases in downside beta. Firm size is generally negatively associated with information asymmetries [95, 96], as larger firms attract greater analyst and media coverage. Hence, it is likely that small firms' security breach announcements carry greater relative informational value to investors whose changes in breached firms' risk assessments are hence more pronounced.

6.4 Limitations

There are some limitations to our study's design and results.

First, the strategy chosen to construct the final sample for our analysis was based on an attempt to model an average investor who has an understanding of capital markets, actively follows equity analyst and media reports, and has a limited technical understanding of cyber security risks and breaches. Such a lay person is assumed to only consider highly severe security breaches in parent companies and direct subsidiaries in the investment decision-making processes. However, in reality, there is a broad range of stock market participants with diverse sets of financial and technological resources and capabilities. Accordingly, they might consider different factors in their assessments of security breaches, which might in turn result in breach severity assessments divergent from our classification scheme.

Relatedly, as mentioned above, Up and Down Markets can be defined in various ways [65]. It is hence debatable whether average market participants define upside and downside risk as presented here (i.e., on a daily basis, benchmarking actual returns against zero).

As common in related studies, we proxied market risk in terms of volatility of the respective country's broad major multi-industry stock market index. To verify robustness of our results, the analysis could be repeated using industry-based indices instead of country-based ones. For instance, for the example used in Sections 4.2 and 6.2, the relevant stock market could be proxied by using Business & Consumer Services or Retail indices.

The difference between untransformed and winsorised changes in beta suggest the presence of outliers in our sample. Such outliers may be due to small samples of daily downside betas, as daily beta factors are highly volatile [5]. Small daily downside beta samples are due to markets yielding predominantly non-negative returns around a particular security breach.

As none of the regression models' F-statistics indicated overall-significance, insights into firm characteristics affecting the extent to which security breaches induce changes in systematic risk and systematic downside risk were rather limited. Accordingly, the variables chosen to explain changes in beta need to be reconsidered.

7 Conclusions and Future Research

Cyber security investments are motivated by the mitigation of potentially costly corporate incidents. To make fully-informed decisions, corporate security executives have to be aware of all costs induced by security breaches. Previous literature has typically focused on (direct) obvious costs such as forensics and audit fees, customer notification costs, legal and regulatory expenditures, and customer acquisition and retention costs [3, 24, 25]. However, less obvious underlying/consequential costs such as increases in cost of equity following security breaches have been given less attention in the information security economics literature.

Analysing 202 security breaches between 2005 and 2019, we find that severe security breaches are associated with statistically and economically significant positive increases of systematic risk and systematic downside risk in terms of regular and downside beta. On average, breached firms experience a rise in regular and downside beta of 0.022 and 0.031, respectively. Security breaches do not appear to be systematically linked to increases in systematic upside risk in terms of upside beta.

As cost of equity are a reflection of how risky investors deem an investment in a company to be, our findings imply that market participants consider breached firms a greater investment risk. Consequently, investors' return expectations increase, resulting in elevated costs of equity and by implication cost of capital. In summary, security breaches hence raise cost of capital.

This paper contributes novel insights to the literature on underlying/consequential economic effects of security breaches generally and changes in financial systematic risk exposure specifically. To the best of our knowledge, it is the first study in this area to consider firm characteristics mitigating changes in systematic risk as well as post-breach changes in both upside and downside risk.

Focusing exclusively on obvious costs neglects an entire subset of relevant economic considerations. To this end, our study represents an important step towards a more holistic concept of security breaches' economic impact and can thus aid corporate information security investment and policy makers.

Rational information security decision makers in the market for cyber security investments need to deploy scarce economic resources in the most efficient way to maximise shareholder value [21, 22]. In order to do so, they require frameworks and models to conduct sophisticated cost–benefit analyses. In the course of this process, underlying and consequential costs to firms and society stemming from security breaches can easily be overlooked. The results of this present study can help demonstrate the benefits of investments in security controls, as deploying capital in this way cannot only decrease obvious direct costs, but may also reduce underlying/consequential costs such as increases in cost of equity.

Relatedly, the results of our study imply that corporate decision makers in breached firms need to pay particular attention to their cost of capital to mitigate potential increases. As costs of capital are systematically associated with a firm's leverage [97], breached firms are likely to adjust their capital structure following a breach.

Policy makers are interested in reducing negative externalities of security breaches imposed on society. First, capital market participants are exposed to market inefficiencies as share prices can take a (temporary) hit following security breaches [26–38]. Second, corporate information security incentives are often misaligned as firms can externalise costs to society and invest more in damage control than in attack deterrence [18]. Policy makers might find the results of our study conducive to promote investments in information security to for-profit firms. By making underlying and consequential costs more salient to executives, corporate decision makers might be more inclined to undertake appropriate investments in security controls, improve processes, and train staff.

In future studies, we aim to extend and improve our initial study by broadening our sample and advancing the process of filtering out security breach events that are considered non-severe by stock market participants. Research on security breaches is inherently subject to issues of data availability and quality. Future iterations will include a larger number of severe security breaches. Specifically, we aim to include security incidents in European companies to strengthen the robustness and generalisability of our findings. Relatedly, our sampling process aiming to mirror investors' perception of security breaches' severity was based on limited initial explorative conversations with professional and retail investors. To strengthen the validity and reproducibility of our sampling approach, future use of the database of severe security breaches will be proceeded by presenting and explaining the established criteria of severe security breaches to a second coder for categorising (a subset of) all breaches in publicly listed companies into severe and non-severe breaches. Then, intercoder reliability will be measured to verify reliability of the qualitative process laid out in Section 3. Relatedly, future work could establish investors' decision-making processes in a more formal way, for instance, by conducting (semi-)structured interviews or even behavioural experiments with investors to establish how market participants define security breach severity.

Moreover, we will conduct analyses taking into account unlevered betas [5] as well as multiple time frames to establish whether post-breach changes in costs of equity are influenced by financial risk and whether cost of capital changes persist over time. We will also demonstrate the effect of security breaches on cost of equity in monetary terms as well as relative to the respective risk-free rates and industry averages, in order to convey the relevance of this underlying/consequential cost to practitioners more effectively.

Relatedly, preliminary regression analysis results did not provide additional insights into factors influencing changes in systematic and downside risk. In further research, we aim to extend our results by including additional factors that might help explaining why particular firms are more susceptible to breach-induced changes in systematic risk. Specifically, we will include further factors related to firms' capital structures [97], including leverage (debt/equity and debt-service-coverage ratios), working capital management (changes over time, amount relative to industry competitors), as well as shareholder compensation (buybacks and dividends). Future versions of our analysis could also include factors intended to measure firms' operational resources and capabilities, such as operating profits, cash flows, marketing expenses, and patenting activities[18].

From strategic management and investment perspectives, it is generally accepted that systematic risk results from two main components: operating risk and financial risk (i.e., leverage) [89, 100–102]. Further research could examine whether security breaches affect one or both components of systematic risk in the long term. A related research question worth exploring would be *What cost of capital-related measures do companies take after a security breach, and is there a shift in capital structures?*

More generally, the research described in this paper can be considered part of the wider endeavour to establish an improved understanding of underlying and consequential cyber security costs and benefits in order to advance cyber-risk quantification and inform information security investment decisions. Having presented the results of an analysis on changes in cost of equity following a security breach, in future work we plan to focus on the other component of cost of capital: cost of debt. We are currently exploring the extent to which security breaches effect firms' cost of debt (i.e., cost of raising capital from debt markets). Moreover, given the scarcity of research on breach-induced underlying and consequential costs imposed on firms and society, more empirical evidence on additional types of such costs is needed.

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A Severe Security Breaches Sample

Date (Adj.) is the PRC breach announcement date, potentially adjusted as described in Section 4. MCap ($m) is the market capitalisation at the (adjusted) breach announcement date. Consumer Disc = Consumer Discretionary; Communication = Communication Services; IT = Information Technology.

Event	Date (Adj.)	Company	MCap ($m)	Industry Sector	Country
1	09/02/2006	OfficeMax	1,975.29	Consumer Disc	USA
2	01/08/2006	Dollar Tree	2,734.14	Consumer Disc	USA
3	28/08/2006	Copart	2,485.42	Industrials	USA
4	22/09/2006	North Fork Bank	13,145.98	Financials	USA
5	20/12/2006	Deb Shops	373.96	Consumer Disc	USA
6	12/01/2007	MoneyGram International	2,450.91	IT	USA
7	17/01/2007	TJ stores (TJX)	13,484.58	Consumer Disc	USA
8	16/02/2007	Brunswick Corp.	3,070.05	Consumer Disc	USA
9	21/02/2007	Fidelity National Information Services	8,945.43	IT	USA
10	23/07/2007	Fox News	73,140.71	Communication	USA
11	23/08/2007	Monster.com	4,412.59	Communication	USA
12	12/09/2007	Hartford Life Insurance	27,771.67	Financials	USA
13	14/09/2007	TD Ameritrade Holding	10,714.96	Financials	USA
14	10/10/2007	Commerce Bank	3,258.36	Financials	USA
15	31/03/2008	Advance Auto Parts	3,372.99	Consumer Disc	USA
16	10/06/2008	1st Source Bank	460.16	Financials	USA
17	19/06/2008	Citibank	113,728.31	Financials	USA
18	12/08/2008	Wells Fargo	34,541.68	Financials	USA
19	10/09/2008	Franklin Savings and Loan	13.55	Financials	USA
20	06/11/2008	Express Scripts	14,335.30	Health Care	USA
21	20/01/2009	Heartland Payment Systems	533.65	IT	USA
22	23/01/2009	Monster.com	1,149.05	Communication	USA
23	03/02/2009	SRA International	913.76	IT	USA
24	11/03/2009	Sprint	9,849.17	Communication	USA
25	16/03/2009	Comcast	45,130.05	Communication	USA
26	28/05/2009	Aetna	11,976.92	Health Care	USA
27	23/11/2009	Hancock Fabrics	25.95	Consumer Disc	USA
28	09/04/2010	Charles Schwab	22,943.69	Financials	USA
29	04/06/2010	Digital River	1,033.75	IT	USA
30	09/06/2010	Apple, AT&T	147,134.10	Communication	USA
31	23/06/2010	Anthem Blue Cross, WellPoint	22,653.73	Health Care	USA
32	09/07/2010	Cisco Live 2010	129,643.13	IT	USA
33	02/09/2010	Sprint	12,800.94	Communication	USA

Table 5 continued from previous page

Event	Date (Adj.)	Company	MCap ($m)	Industry Sector	Country
34	10/12/2010	Genesco	882.10	Consumer Disc	USA
35	10/12/2010	Walgreens	33,725.58	Consumer Staples	USA
36	01/04/2011	iTunes (Apple)	317,435.55	IT	USA
37	06/04/2011	Hartford Life Insurance Company	12,439.21	Financials	USA
38	10/05/2011	Fox.com	47,443.97	Communication	USA
39	25/05/2011	Bank of America	115,313.12	Financials	USA
40	27/05/2011	Lockheed Martin	27,004.14	Industrials	USA
41	09/06/2011	Citibank	110,379.11	Financials	USA
42	08/07/2011	Capital Grille	7,260.81	Consumer Disc	USA
43	26/08/2011	Fidelity National Information Services	8,375.17	IT	USA
44	23/09/2011	Hewlett-Packard Enterprise Services	44,349.11	IT	USA
45	02/02/2012	VeriSign	5,871.51	IT	USA
46	10/02/2012	Intel	135,930.94	IT	USA
47	22/02/2012	DHI Mortgage Company	4,413.94	Consumer Disc	USA
48	30/03/2012	Global Payments	3,722.11	IT	USA
49	25/04/2012	Cryptic Studios, Perfect World	595.98	Communication	USA
50	04/05/2012	Ford-Motor Websites	40,720.64	Consumer Disc	USA
51	18/05/2012	Comcast	92,220.86	Communication	USA
52	06/06/2012	LinkedIn.com	9,615.30	Communication	USA
53	13/07/2012	Nvidia	7,769.08	IT	USA
54	09/08/2012	Blizzard Entertainment	12,944.15	Communication	USA
55	04/09/2012	Apple	632,720.92	IT	USA
56	10/10/2012	Equifax	5,850.56	Industrials	USA
57	12/10/2012	Korn/Ferry International	672.52	Industrials	USA
58	24/10/2012	Barnes & Noble	911.93	Consumer Disc	USA
59	14/11/2012	Adobe	15,958.09	IT	USA
60	11/01/2013	Advanced Micro Devices, Nvidia	1,900.90	IT	USA
61	30/01/2013	The New York Times	1,287.46	Communication	USA
62	19/02/2013	Apple	431,957.29	IT	USA
63	19/02/2013	Express Scripts, Ernst & Young	45,461.82	Health Care	USA
64	22/02/2013	Microsoft	232,524.56	IT	USA
65	27/02/2013	Information Handling Services	6,981.78	Industrials	USA
66	28/03/2013	American Express	74,339.99	Financials	USA
67	28/03/2013	JPMorgan Chase	180,537.84	Financials	USA
68	12/06/2013	comScore	765.78	Communication	USA
69	22/07/2013	Apple	400,329.81	IT	USA
70	26/07/2013	NASDAQ OMX	5,457.94	Financials	USA
71	08/08/2013	US Airways	3,644.48	Industrials	USA
72	09/08/2013	Northrop Grunman	21,978.46	Industrials	USA
73	04/10/2013	Adobe	25,779.19	IT	USA

Table 5 continued from previous page

Event	Date (Adj.)	Company	MCap ($m)	Industry Sector	Country
74	22/10/2013	Aaron's	2,203.58	Consumer Disc	USA
75	28/10/2013	Dun & Bradstreet	4,232.36	Industrials	USA
76	07/11/2013	CME Group, CME ClearPort	24,958.60	Financials	USA
77	25/11/2013	Crown Castle International Corp	24,278.99	Real Estate	USA
78	05/12/2013	JPMorgan Chase	209,599.53	Financials	USA
79	06/12/2013	B&G Foods North America, Maple Grove Farms	1,804.87	Consumer Staples	USA
80	13/12/2013	Target Corp	39,416.99	Consumer Disc	USA
81	27/12/2013	American Express Company	95,546.64	Financials	USA
82	07/02/2014	Boston Scientific	17,491.40	Health Care	USA
83	07/02/2014	Medtronic	55,498.29	Health Care	USA
84	12/02/2014	Las Vegas Sands Hotels and Casinos	64,389.40	Consumer Disc	USA
85	20/02/2014	Alaska Communications	106.87	Communication	USA
86	26/02/2014	Apple	461,470.50	IT	USA
87	27/02/2014	J.M. Smucker Company	10,331.57	Consumer Staples	USA
88	04/03/2014	Capital One	42,199.12	Financials	USA
89	25/04/2014	Federal Home Loan Mortgage Corporation (Freddie Mac)	12,562.82	Financials	USA
90	28/04/2014	AOL	3,334.73	Communication	USA
91	21/05/2014	Ebay	65,749.74	Consumer Disc	USA
92	12/06/2014	Fidelity National Financial	9,021.45	Financials	USA
93	08/07/2014	Aecom	3,164.09	Industrials	USA
94	11/07/2014	Boeing	93,406.37	Industrials	USA
95	11/07/2014	Lockheed Martin	50,590.16	Industrials	USA
96	21/07/2014	Dominion Resources	40,724.19	Utilities	USA
97	15/08/2014	Supervalue	2,427.82	Consumer Staples	USA
98	18/08/2014	Community Health Systems	5,967.57	Health Care	USA
99	18/08/2014	MeetMe	104.65	Communication	USA
100	28/08/2014	J.P Morgan Chase	222,489.40	Financials	USA
101	02/09/2014	Apple	613,756.37	IT	USA
102	02/09/2014	The Home Depot	122,680.79	Consumer Disc	USA
103	06/10/2014	AT&T	184,051.14	Communication	USA
104	10/10/2014	Sears Holding Company / K-Mart	2,638.38	Consumer Disc	USA
105	20/10/2014	Staples	7,923.67	Consumer Disc	USA
106	03/11/2014	Fidelity National Financial	8,268.75	Financials	USA
107	04/11/2014	Hilton/Hilton Honors Program	24,221.58	Consumer Disc	USA
108	26/11/2014	Shutterfly/Tiny Prints/ Treats/Wedding Divas	1,685.19	Consumer Disc	USA
109	26/12/2014	Microsoft xBox	394,667.79	IT	USA
110	02/01/2015	United Airlines	24,687.14	Industrials	USA
111	05/01/2015	Morgan Stanley	73,402.62	Financials	USA

Table 5 continued from previous page

Event	Date (Adj.)	Company	MCap ($m)	Industry Sector	Country
112	06/01/2015	NVIDIA Corporation	10,430.48	IT	USA
113	05/02/2015	Anthem	37,044.00	Health Care	USA
114	02/03/2015	Natural Grocers	664.06	Consumer Staples	USA
115	02/04/2015	Microsoft/Xbox One	330,530.50	IT	USA
116	08/04/2015	AT&T	169,458.99	Communication	USA
117	12/05/2015	Starbucks	74,545.12	Consumer Disc	USA
118	12/06/2015	Fred's	724.26	Consumer Disc	USA
119	29/07/2015	United Airlines	21,611.78	Industrials	USA
120	07/08/2015	Ubiquiti Networks	2,784.36	IT	USA
121	19/08/2015	Web.com	1,102.07	IT	USA
122	25/09/2015	Hilton Hotels	22,800.24	Consumer Disc	USA
123	09/10/2015	E-Trade	7,589.87	Financials	USA
124	12/10/2015	Dow Jones & Company	8,126.08	Communication	USA
125	09/11/2015	Comcast	171,805.69	Communication	USA
126	20/11/2015	Starwood Hotels	12,333.58	Consumer Disc	USA
127	21/12/2015	Juniper Network	10,514.47	IT	USA
128	11/01/2016	Blucora (TaxAct)	369.34	Financials	USA
129	15/01/2016	Hyatt Hotels	5,135.17	Consumer Disc	USA
130	27/01/2016	Wendy's	2,630.87	Consumer Disc	USA
131	01/03/2016	Central Concrete Supply Company	778.46	Materials	USA
132	04/03/2016	Seagate	10,235.45	IT	USA
133	08/03/2016	1-800-Flowers	512.47	Consumer Disc	USA
134	28/03/2016	Sprouts Farmers Market	4,345.30	Consumer Staples	USA
135	03/05/2016	Charles Schwab	36,999.20	Financials	USA
136	05/05/2016	ADP	39,380.98	IT	USA
137	16/05/2016	Noodles and Company	281.77	Consumer Disc	USA
138	13/06/2016	Twitter	10,135.05	Communication	USA
139	16/06/2016	Advanced Auto Parts	11,323.83	Consumer Disc	USA
140	29/07/2016	Disney Consumer Products and Interactive Media	155,673.12	Communication	USA
141	23/09/2016	Jive Software/Producteev	333.37	IT	USA
142	12/10/2016	Vera Bradley	527.93	Consumer Disc	USA
143	22/11/2016	The Madison Square Garden Company	4,143.55	Communication	USA
144	23/11/2016	Hewlett Packard Enterprise Services	39,234.30	IT	USA
145	30/11/2016	Google Android	528,611.61	Communication	USA
146	12/12/2016	Quest Diagnostics	12,714.67	Health Care	USA
147	27/01/2017	eHealth Insurance	227.25	Financials	USA
148	27/01/2017	WellCare Health Plans	6,436.22	Health Care	USA
149	02/02/2017	Sunrun	572.03	Industrials	USA
150	06/02/2017	Capital One	42,075.12	Financials	USA
151	07/03/2017	Verifone	2,242.76	IT	USA
152	15/03/2017	Dunn and Bradstreet	3,986.97	Industrials	USA
153	26/04/2017	Chipotle Mexican Grill	13,843.96	Consumer Disc	USA

Table 5 continued from previous page

Event	Date (Adj.)	Company	MCap ($m)	Industry Sector	Country
154	02/05/2017	Sabre Corporation	6,860.51	IT	USA
155	04/05/2017	Gannett Co	954.54	Communication	USA
156	17/05/2017	Rite Aid	3,849.21	Consumer Staples	USA
157	02/06/2017	Game Stop	2,295.56	Consumer Disc	USA
158	19/06/2017	Bed Bath & Beyond	5,065.82	Consumer Disc	USA
159	20/06/2017	The Buckle	819.71	Consumer Disc	USA
160	31/07/2017	Anthem	48,895.89	Health Care	USA
161	30/08/2017	Instagram	493,481.08	Communication	USA
162	07/09/2017	Equifax Corporation	17,179.56	Industrials	USA
163	29/09/2017	Briggs & Stratton Corp.	1,004.76	Industrials	USA
164	14/11/2017	ABM Industries	2,613.25	Industrials	USA
165	16/11/2017	Hyatt Hotels	8,322.74	Consumer Disc	USA
166	22/01/2018	The Coca-Cola Company	201,870.42	Consumer Staples	USA
167	16/02/2018	Marriott International	49,505.06	Consumer Disc	USA
168	29/03/2018	Under Armour	6,790.71	Consumer Disc	USA
169	06/04/2018	Delta Air Lines	37,363.67	Industrials	USA
170	17/04/2018	Inogen	3,040.36	Health Care	USA
171	20/04/2018	SunTrust Banks	31,301.17	Financials	USA
172	12/06/2018	HealthEquity	4,962.44	Health Care	USA
173	12/06/2018	Nuance Communications	4,171.50	IT	USA
174	06/07/2018	Coty	10,627.61	Consumer Staples	USA
175	28/09/2018	Facebook	474,831.98	Communication	USA
176	01/10/2018	Chegg	3,124.79	Consumer Disc	USA
177	05/10/2018	Five below	6,552.92	Consumer Disc	USA
178	09/10/2018	Roadrunner Transportation Systems	29.23	Industrials	USA
179	25/10/2018	CNO Financial Group	3,092.20	Financials	USA
180	05/11/2018	Nordstrom	11,352.88	Consumer Disc	USA
181	16/11/2018	HealthEquity	5,310.88	Health Care	USA
182	01/03/2017	Autoneum North America	1,255.56	Consumer Disc	CHE
183	11/09/2017	ABB	51,723.53	Industrials	CHE
184	09/10/2018	Givaudan Flavors Corp.	21,918.17	Materials	CHE
185	14/06/2016	Acer Service Corp.	1,467.36	IT	TWN
186	28/06/2018	Adidas	43,246.28	Consumer Disc	DEU
187	12/03/2007	Dai Nippon	10,456.02	Industrials	JAP
188	04/09/2009	Mitsubishi	32,628.55	Industrials	JAP
189	27/12/2010	American Honda Motor	71,622.71	Consumer Disc	JAP
190	17/06/2011	Sega	4,900.28	Consumer Disc	JAP
191	02/03/2012	Epson America	2,449.03	IT	JAP
192	02/05/2012	Emerson (Funai Corp.)	629.12	Consumer Disc	JAP
193	03/06/2009	Aviva	15,023.03	Financials	GBR
194	26/09/2013	LexisNexis	30,041.68	Industrials	GBR
195	01/10/2015	Experian	15,581.94	Industrials	GBR
196	26/07/2016	Kimpton Hotels	7,787.42	Consumer Disc	GBR
197	28/12/2016	InterContinental Hotels Group	8,548.59	Consumer Disc	GBR

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Event	Date (Adj.)	Company	MCap ($m)	Industry Sector	Country
198	16/04/2013	Iberdola USA, Central Maine Power	30,454.70	Utilities	ESP
199	04/03/2015	Mandarin Oriental Hotel Group	1,766.55	Consumer Disc	SGP
200	28/12/2017	Miracle-Ear and Amplifon (USA)	3,437.16	Health Care	ITA
201	30/11/2015	VTech	2,814.59	IT	HKG
202	22/10/2015	Xero	1,452.39	IT	AUS
		Mean	52,019.92		

B Descriptive Statistics: Regular Beta per Event

All descriptive statistics presented in the appendix are based on 60 daily one-year betas. For each event, across 60 daily betas, Min and Max demonstrate the lowest and greatest value, respectively. Mean (M), Median (Mdn), and Standard Deviation (SD) are based on each event's respective 60 daily values.

	Regular Pre-Breach					Regular Post-Breach				
Event	Min	Max	M	Mdn	SD	Min	Max	M	Mdn	SD
1	0.756	0.919	0.835	0.802	0.063	0.877	1.092	0.997	0.997	0.054
2	0.713	0.828	0.770	0.773	0.027	0.786	0.954	0.843	0.842	0.044
3	1.012	1.129	1.071	1.070	0.031	0.800	0.988	0.890	0.879	0.068
4	0.814	0.873	0.844	0.844	0.015	0.789	0.836	0.812	0.813	0.013
5	0.917	1.161	1.042	1.059	0.066	1.187	1.438	1.359	1.376	0.060
6	1.485	1.832	1.720	1.727	0.067	1.522	1.805	1.651	1.623	0.099
7	0.962	1.111	1.031	1.023	0.042	1.046	1.133	1.086	1.080	0.027
8	1.051	1.184	1.104	1.098	0.041	1.151	1.218	1.182	1.181	0.018
9	1.097	1.170	1.129	1.125	0.017	1.094	1.175	1.147	1.149	0.017
10	0.929	1.054	0.989	0.993	0.031	0.938	1.064	1.022	1.027	0.031
11	1.302	2.085	1.715	1.737	0.221	1.163	1.248	1.202	1.198	0.025
12	1.073	1.255	1.161	1.145	0.059	1.199	1.260	1.220	1.217	0.017
13	1.290	1.584	1.394	1.385	0.070	1.150	1.310	1.238	1.258	0.053
14	0.719	0.825	0.781	0.783	0.030	0.780	0.914	0.844	0.836	0.042
15	0.890	1.021	0.965	0.964	0.034	0.972	1.022	0.992	0.991	0.014
16	2.068	2.140	2.101	2.106	0.017	2.087	2.278	2.195	2.221	0.064
17	1.670	1.802	1.757	1.756	0.031	1.797	2.181	1.985	2.006	0.124
18	1.660	2.264	1.814	1.686	0.212	2.326	4.651	3.077	2.934	0.685
19	-0.527	-0.320	-0.409	-0.404	0.076	-0.583	1.434	0.253	0.411	0.604
20	0.702	1.000	0.827	0.757	0.108	0.946	0.976	0.957	0.957	0.006
21	0.806	0.956	0.897	0.913	0.048	0.895	0.992	0.954	0.966	0.030
22	1.058	1.113	1.086	1.085	0.014	1.096	1.180	1.129	1.115	0.027
23	0.617	0.762	0.731	0.737	0.024	0.676	0.739	0.698	0.701	0.012
24	1.734	1.809	1.784	1.793	0.021	1.740	1.791	1.759	1.757	0.009

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	Regular Pre-Breach					Regular Post-Breach				
25	1.158	1.203	1.180	1.184	0.013	1.203	1.224	1.215	1.217	0.006
26	1.024	1.121	1.086	1.087	0.026	1.037	1.071	1.057	1.057	0.007
27	0.926	1.217	1.103	1.104	0.064	0.456	1.486	1.066	1.140	0.280
28	1.369	1.586	1.487	1.495	0.061	1.107	1.286	1.176	1.147	0.059
29	0.969	1.076	1.026	1.023	0.028	0.976	1.059	1.019	1.021	0.022
30	0.525	0.631	0.570	0.571	0.024	0.549	0.609	0.577	0.573	0.016
31	0.625	0.750	0.690	0.693	0.026	0.671	0.834	0.763	0.742	0.053
32	0.979	1.124	1.054	1.049	0.041	1.063	1.100	1.085	1.086	0.010
33	1.283	1.403	1.354	1.358	0.027	1.232	1.441	1.325	1.334	0.054
34	1.226	1.271	1.253	1.253	0.009	1.210	1.314	1.261	1.251	0.032
35	0.777	0.890	0.852	0.862	0.033	0.880	0.912	0.893	0.892	0.007
36	0.992	1.058	1.013	1.006	0.019	0.886	1.023	0.957	0.950	0.043
37	1.805	1.874	1.851	1.866	0.025	1.866	1.999	1.926	1.933	0.035
38	1.478	1.514	1.494	1.492	0.008	1.431	1.555	1.503	1.512	0.038
39	1.489	1.593	1.550	1.562	0.030	1.412	1.945	1.561	1.515	0.168
40	0.620	0.696	0.677	0.685	0.020	0.589	0.704	0.636	0.629	0.034
41	1.277	1.420	1.334	1.325	0.044	1.296	1.708	1.453	1.351	0.170
42	0.848	0.918	0.886	0.884	0.019	0.803	0.897	0.856	0.849	0.026
43	0.817	1.018	0.912	0.920	0.063	0.949	1.060	1.012	1.009	0.028
44	0.768	1.003	0.857	0.815	0.083	0.944	1.123	1.059	1.072	0.056
45	0.976	1.007	0.988	0.988	0.008	0.969	0.992	0.983	0.985	0.007
46	0.769	0.858	0.832	0.843	0.027	0.833	0.859	0.849	0.851	0.007
47	1.228	1.276	1.256	1.258	0.013	1.240	1.309	1.279	1.277	0.018
48	1.029	1.044	1.037	1.037	0.004	1.021	1.045	1.033	1.034	0.006
49	1.155	1.252	1.189	1.178	0.027	1.246	1.307	1.275	1.280	0.019
50	1.341	1.358	1.350	1.350	0.004	1.282	1.361	1.336	1.353	0.026
51	0.970	1.002	0.981	0.977	0.009	0.929	0.970	0.957	0.957	0.007
52	1.289	1.339	1.317	1.319	0.014	1.151	1.346	1.282	1.298	0.046
53	1.466	1.508	1.488	1.488	0.015	1.378	1.501	1.453	1.453	0.031
54	0.619	0.677	0.645	0.640	0.016	0.639	0.775	0.675	0.663	0.035
55	0.750	0.806	0.787	0.796	0.017	0.769	1.145	0.921	0.877	0.113
56	1.056	1.100	1.081	1.082	0.013	0.891	1.050	0.957	0.940	0.055
57	1.930	2.219	2.068	2.063	0.097	1.399	1.992	1.641	1.549	0.197
58	0.601	1.099	0.822	0.813	0.124	0.491	0.937	0.684	0.678	0.096
59	1.145	1.309	1.215	1.221	0.045	1.162	1.277	1.205	1.188	0.041
60	2.147	2.338	2.241	2.235	0.057	2.124	2.258	2.185	2.190	0.036
61	1.452	1.661	1.535	1.511	0.063	1.400	1.537	1.453	1.443	0.034
62	1.084	1.276	1.221	1.245	0.062	1.182	1.278	1.237	1.237	0.020
63	0.911	0.977	0.939	0.938	0.017	0.863	0.953	0.907	0.911	0.017
64	1.000	1.132	1.094	1.107	0.036	1.038	1.096	1.077	1.080	0.016
65	0.790	0.866	0.832	0.830	0.019	0.755	0.821	0.796	0.796	0.017
66	1.067	1.156	1.104	1.112	0.024	1.014	1.089	1.055	1.060	0.021
67	1.338	1.498	1.401	1.405	0.031	1.248	1.349	1.304	1.305	0.030

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	Regular Pre-Breach					Regular Post-Breach				
68	0.653	0.899	0.763	0.707	0.088	0.738	1.160	0.939	0.849	0.167
69	1.083	1.268	1.136	1.109	0.054	0.982	1.133	1.073	1.084	0.041
70	0.992	1.086	1.028	1.027	0.026	0.988	1.055	1.024	1.028	0.019
71	0.714	0.956	0.830	0.834	0.059	0.855	1.101	1.007	1.038	0.074
72	0.835	0.888	0.860	0.863	0.016	0.815	0.898	0.854	0.856	0.027
73	0.867	0.974	0.915	0.907	0.037	0.976	1.171	1.060	1.067	0.058
74	0.780	0.861	0.819	0.821	0.016	0.730	0.846	0.780	0.783	0.028
75	0.779	0.923	0.852	0.866	0.039	0.936	1.085	0.986	0.957	0.055
76	0.719	0.785	0.759	0.761	0.019	0.799	0.889	0.848	0.849	0.023
77	0.728	0.819	0.777	0.776	0.019	0.716	0.830	0.769	0.774	0.027
78	1.191	1.260	1.229	1.229	0.017	1.190	1.261	1.222	1.217	0.020
79	0.987	1.068	1.029	1.034	0.021	0.877	1.050	0.969	0.990	0.056
80	0.536	0.599	0.562	0.561	0.017	0.554	0.660	0.631	0.636	0.022
81	1.045	1.101	1.079	1.080	0.013	1.128	1.208	1.165	1.158	0.026
82	1.088	1.155	1.124	1.132	0.020	1.113	1.263	1.165	1.133	0.054
83	0.903	0.947	0.919	0.920	0.011	0.883	0.938	0.920	0.927	0.016
84	1.258	1.429	1.330	1.330	0.046	1.419	1.577	1.507	1.501	0.039
85	1.146	1.382	1.255	1.236	0.069	1.344	1.592	1.464	1.457	0.083
86	0.491	0.767	0.618	0.606	0.084	0.390	0.523	0.468	0.488	0.048
87	0.831	0.895	0.859	0.856	0.017	0.790	0.843	0.814	0.816	0.017
88	1.075	1.173	1.138	1.148	0.030	1.127	1.188	1.164	1.164	0.015
89	0.810	1.392	1.122	1.188	0.165	0.374	1.144	0.800	0.766	0.193
90	0.964	1.203	1.054	1.039	0.072	1.102	1.199	1.142	1.138	0.022
91	1.027	1.078	1.052	1.052	0.010	0.968	1.046	1.016	1.019	0.018
92	0.897	0.972	0.943	0.945	0.022	0.615	0.949	0.735	0.764	0.094
93	1.415	1.561	1.460	1.454	0.033	1.370	1.573	1.430	1.397	0.064
94	1.130	1.167	1.148	1.149	0.009	1.031	1.146	1.080	1.081	0.035
95	0.960	1.012	0.981	0.975	0.017	0.983	1.055	1.013	1.015	0.014
96	0.546	0.717	0.645	0.656	0.052	0.549	0.612	0.576	0.577	0.015
97	1.249	1.441	1.335	1.304	0.057	1.182	1.364	1.277	1.276	0.057
98	0.857	1.050	0.933	0.906	0.058	0.977	1.191	1.067	1.043	0.075
99	1.999	2.688	2.251	2.122	0.225	2.103	2.278	2.185	2.183	0.042
100	1.171	1.216	1.193	1.192	0.011	1.097	1.171	1.146	1.142	0.017
101	0.432	0.584	0.502	0.494	0.043	0.537	0.707	0.642	0.631	0.048
102	0.741	0.790	0.770	0.771	0.010	0.773	0.873	0.819	0.814	0.036
103	0.637	0.669	0.655	0.656	0.008	0.523	0.616	0.564	0.559	0.025
104	1.234	1.567	1.404	1.381	0.075	1.146	1.474	1.276	1.266	0.081
105	0.915	1.302	1.120	1.105	0.092	0.618	0.895	0.771	0.820	0.098
106	0.585	0.687	0.640	0.636	0.029	0.565	0.678	0.615	0.598	0.039
107	0.830	1.014	0.882	0.853	0.057	1.005	1.168	1.068	1.074	0.054
108	1.215	1.504	1.354	1.335	0.098	1.012	1.274	1.146	1.149	0.068
109	0.900	0.985	0.947	0.954	0.024	0.930	1.188	1.097	1.150	0.098
110	1.473	1.634	1.561	1.567	0.042	1.285	1.462	1.390	1.402	0.047

Table 6 continued from previous page

	Regular Pre-Breach					Regular Post-Breach				
111	1.293	1.408	1.329	1.325	0.025	1.326	1.408	1.371	1.376	0.023
112	1.153	1.289	1.208	1.207	0.034	1.221	1.381	1.299	1.302	0.049
113	0.936	1.048	0.973	0.969	0.023	1.053	1.127	1.086	1.082	0.026
114	0.696	1.222	0.946	0.949	0.193	0.358	0.700	0.532	0.511	0.106
115	0.930	1.188	1.106	1.150	0.093	1.102	1.173	1.145	1.152	0.020
116	0.488	0.566	0.526	0.533	0.021	0.592	0.633	0.619	0.622	0.011
117	0.773	0.845	0.815	0.818	0.019	0.796	0.845	0.822	0.821	0.013
118	0.683	0.798	0.720	0.706	0.032	0.633	0.845	0.727	0.734	0.043
119	1.090	1.190	1.139	1.137	0.025	0.861	1.153	0.992	0.951	0.087
120	1.123	1.258	1.181	1.176	0.032	0.705	1.129	0.847	0.786	0.129
121	1.276	1.478	1.362	1.324	0.078	1.017	1.211	1.060	1.054	0.032
122	1.043	1.201	1.144	1.169	0.050	1.021	1.143	1.069	1.057	0.036
123	1.349	1.444	1.394	1.388	0.029	1.416	1.479	1.440	1.432	0.018
124	1.046	1.160	1.113	1.117	0.029	1.117	1.206	1.162	1.158	0.025
125	0.930	0.996	0.964	0.963	0.017	0.929	0.999	0.968	0.973	0.018
126	1.039	1.121	1.093	1.098	0.021	1.030	1.090	1.057	1.053	0.018
127	0.925	1.009	0.975	0.981	0.022	0.944	1.001	0.977	0.976	0.014
128	0.758	0.884	0.844	0.844	0.030	0.833	1.003	0.899	0.900	0.045
129	0.963	1.015	0.978	0.976	0.013	0.965	1.030	1.007	1.009	0.015
130	0.694	0.741	0.721	0.720	0.011	0.694	0.769	0.721	0.719	0.015
131	0.890	1.199	1.045	1.032	0.096	1.147	1.240	1.184	1.176	0.026
132	1.088	1.321	1.182	1.150	0.078	1.294	1.358	1.323	1.324	0.013
133	0.749	0.897	0.822	0.821	0.037	0.792	0.876	0.833	0.832	0.020
134	0.581	0.755	0.672	0.663	0.048	0.765	0.866	0.821	0.840	0.034
135	1.379	1.541	1.458	1.477	0.056	1.560	1.716	1.634	1.598	0.063
136	1.020	1.047	1.033	1.033	0.009	1.012	1.032	1.023	1.023	0.005
137	0.576	0.678	0.643	0.653	0.027	0.632	0.725	0.683	0.685	0.026
138	1.109	1.172	1.146	1.148	0.017	1.158	1.392	1.227	1.208	0.053
139	0.862	0.916	0.887	0.877	0.018	0.858	1.009	0.899	0.871	0.049
140	0.928	0.960	0.943	0.944	0.010	0.899	0.945	0.919	0.915	0.013
141	0.820	1.185	0.935	0.836	0.140	1.198	1.295	1.259	1.269	0.029
142	0.768	0.987	0.890	0.921	0.059	0.687	0.943	0.819	0.819	0.069
143	0.551	0.663	0.601	0.587	0.037	0.528	0.673	0.609	0.610	0.028
144	1.615	1.700	1.652	1.649	0.022	1.484	1.630	1.569	1.578	0.031
145	0.930	0.977	0.952	0.952	0.011	0.915	1.033	0.972	0.967	0.031
146	0.841	0.934	0.885	0.886	0.022	0.850	0.937	0.903	0.900	0.019
147	1.111	1.345	1.239	1.233	0.058	1.174	1.381	1.289	1.305	0.058
148	0.780	0.966	0.873	0.887	0.046	0.588	0.845	0.691	0.694	0.069
149	0.633	1.256	0.902	0.884	0.181	1.039	1.679	1.467	1.562	0.194
150	1.425	1.577	1.465	1.451	0.036	1.522	1.620	1.568	1.555	0.030
151	1.251	1.397	1.322	1.323	0.045	1.130	1.231	1.168	1.157	0.030
152	1.031	1.292	1.174	1.191	0.072	0.997	1.082	1.043	1.053	0.028
153	0.448	0.623	0.551	0.550	0.049	0.544	0.746	0.653	0.660	0.058

Table 6 continued from previous page

	Regular Pre-Breach					Regular Post-Breach				
154	0.908	1.026	0.950	0.944	0.031	1.013	1.091	1.057	1.058	0.017
155	1.099	1.391	1.300	1.327	0.076	1.327	1.651	1.480	1.417	0.105
156	0.293	0.554	0.429	0.440	0.080	0.582	2.050	1.384	1.680	0.566
157	1.349	1.449	1.397	1.394	0.026	1.368	1.624	1.462	1.439	0.064
158	1.195	1.351	1.274	1.274	0.051	1.111	1.391	1.246	1.248	0.057
159	1.021	1.191	1.114	1.123	0.045	1.082	1.416	1.195	1.178	0.069
160	0.997	1.214	1.099	1.070	0.073	0.949	1.193	1.102	1.112	0.045
161	1.005	1.145	1.085	1.100	0.046	1.140	1.391	1.272	1.279	0.064
162	0.954	1.066	1.003	0.996	0.026	0.728	0.897	0.814	0.820	0.042
163	1.360	1.794	1.579	1.457	0.156	1.725	1.938	1.858	1.862	0.054
164	1.203	1.325	1.274	1.286	0.032	0.953	1.329	1.224	1.261	0.095
165	0.911	1.085	0.972	0.959	0.051	0.840	1.002	0.922	0.924	0.035
166	0.127	0.360	0.248	0.275	0.085	0.114	0.542	0.460	0.508	0.121
167	1.151	1.244	1.192	1.191	0.025	1.031	1.121	1.058	1.052	0.022
168	1.166	1.631	1.440	1.428	0.103	1.216	1.344	1.268	1.265	0.031
169	1.141	1.885	1.431	1.310	0.261	1.056	1.179	1.102	1.089	0.039
170	0.997	1.625	1.157	1.068	0.207	0.991	1.134	1.067	1.063	0.034
171	1.261	1.622	1.360	1.309	0.103	1.132	1.206	1.168	1.164	0.020
172	0.748	0.879	0.808	0.809	0.024	0.763	0.846	0.802	0.801	0.022
173	0.903	1.126	1.030	1.057	0.073	0.878	0.946	0.913	0.909	0.017
174	0.316	0.381	0.350	0.351	0.016	0.342	0.432	0.387	0.392	0.027
175	1.272	1.351	1.320	1.331	0.025	1.228	1.324	1.280	1.282	0.028
176	0.828	0.927	0.872	0.875	0.028	0.892	1.271	1.162	1.230	0.120
177	0.672	0.719	0.694	0.691	0.011	0.693	1.066	0.897	0.868	0.099
178	1.341	1.538	1.442	1.453	0.052	0.680	1.448	1.034	0.993	0.200
179	0.892	0.937	0.921	0.922	0.010	0.902	1.020	0.965	0.955	0.039
180	0.825	0.914	0.873	0.871	0.021	0.796	0.873	0.829	0.827	0.021
181	0.751	1.062	0.837	0.782	0.093	1.101	1.577	1.343	1.353	0.132
182	0.991	1.057	1.029	1.036	0.018	0.967	1.080	1.024	1.030	0.027
183	0.665	0.808	0.718	0.719	0.029	0.652	0.737	0.684	0.678	0.025
184	0.811	0.849	0.830	0.830	0.010	0.776	0.822	0.797	0.797	0.010
185	1.584	1.672	1.610	1.601	0.021	1.507	1.705	1.661	1.675	0.042
186	0.784	0.858	0.817	0.813	0.018	0.862	0.945	0.904	0.905	0.030
187	0.725	0.817	0.779	0.777	0.024	0.713	0.763	0.739	0.741	0.012
188	1.055	1.080	1.067	1.066	0.008	1.041	1.225	1.122	1.131	0.061
189	0.867	0.899	0.883	0.885	0.008	0.699	0.884	0.829	0.838	0.055
190	0.835	0.934	0.883	0.869	0.024	0.935	1.066	1.009	1.025	0.038
191	0.861	0.902	0.887	0.889	0.008	0.877	1.119	1.037	1.057	0.074
192	0.743	0.923	0.819	0.762	0.073	0.894	1.001	0.958	0.962	0.025
193	1.808	1.998	1.922	1.914	0.047	2.002	2.049	2.029	2.030	0.012
194	0.757	0.956	0.821	0.814	0.053	0.738	0.802	0.768	0.762	0.016
195	0.883	0.983	0.947	0.947	0.022	0.973	1.055	1.014	1.012	0.018
196	1.070	1.198	1.121	1.085	0.051	1.167	1.227	1.202	1.205	0.019

Table 6 continued from previous page

	Regular Pre-Breach					Regular Post-Breach				
197	1.184	1.248	1.213	1.220	0.018	1.231	1.336	1.277	1.276	0.028
198	1.349	1.390	1.364	1.368	0.013	1.311	1.386	1.357	1.362	0.023
199	0.391	0.523	0.467	0.467	0.033	0.434	0.509	0.480	0.483	0.017
200	0.204	0.380	0.259	0.238	0.048	0.348	0.524	0.451	0.461	0.046
201	0.278	0.319	0.300	0.300	0.009	0.294	0.376	0.329	0.334	0.022
202	0.338	0.611	0.501	0.527	0.087	0.525	0.808	0.630	0.618	0.083
Mean	0.980	1.137	1.055	1.050	0.045	0.986	1.173	1.077	1.077	0.054

C Descriptive Statistics: Upside Beta per Event

	Upside Pre-Breach					Upside Post-Breach				
Event	Min	Max	M	Mdn	SD	Min	Max	M	Mdn	SD
1	0.704	1.148	0.962	1.070	0.164	0.555	0.783	0.695	0.732	0.072
2	0.389	0.849	0.634	0.661	0.133	0.413	0.713	0.480	0.465	0.057
3	0.862	1.012	0.969	0.976	0.037	0.525	0.908	0.689	0.620	0.149
4	0.500	0.595	0.555	0.562	0.032	0.464	0.590	0.523	0.521	0.024
5	1.671	1.864	1.767	1.767	0.043	1.673	2.001	1.867	1.869	0.064
6	0.752	1.306	0.915	0.871	0.141	1.145	1.288	1.194	1.191	0.032
7	0.899	1.228	1.025	1.002	0.092	1.013	1.203	1.126	1.147	0.065
8	0.698	1.011	0.827	0.786	0.112	0.943	1.091	1.014	1.013	0.033
9	1.115	1.280	1.213	1.211	0.037	0.936	1.220	1.078	1.088	0.083
10	0.939	1.114	1.039	1.058	0.059	0.892	1.108	1.043	1.054	0.057
11	0.822	2.462	1.785	1.918	0.508	0.715	0.907	0.783	0.779	0.045
12	1.075	1.215	1.108	1.099	0.032	1.076	1.390	1.194	1.165	0.106
13	1.206	1.706	1.400	1.386	0.135	0.882	1.225	1.076	1.066	0.109
14	0.870	1.098	0.969	0.981	0.062	0.996	1.241	1.135	1.149	0.079
15	0.771	1.030	0.915	0.920	0.077	0.742	0.943	0.865	0.889	0.066
16	2.637	2.954	2.736	2.724	0.068	2.672	3.296	3.024	3.117	0.223
17	2.396	2.535	2.466	2.470	0.037	2.432	2.778	2.590	2.587	0.095
18	2.337	3.270	2.588	2.412	0.304	3.288	7.744	4.514	3.644	1.543
19	-0.300	0.019	-0.072	-0.043	0.070	-0.006	2.785	1.235	1.652	0.972
20	0.578	1.107	0.822	0.766	0.154	0.960	1.004	0.978	0.978	0.010
21	0.678	0.893	0.807	0.823	0.055	0.646	0.824	0.743	0.722	0.061
22	1.010	1.122	1.071	1.072	0.033	1.083	1.251	1.154	1.134	0.052
23	0.478	0.610	0.565	0.577	0.038	0.511	0.587	0.559	0.570	0.025
24	1.853	1.944	1.885	1.884	0.016	1.868	1.959	1.928	1.931	0.021
25	1.278	1.367	1.308	1.304	0.024	1.379	1.424	1.405	1.406	0.009
26	0.828	1.013	0.979	0.994	0.047	0.969	1.048	1.016	1.026	0.024
27	-0.866	0.070	-0.318	-0.266	0.373	-0.539	-0.043	-0.251	-0.161	0.176
28	1.610	1.915	1.767	1.761	0.083	1.027	1.499	1.239	1.195	0.149
29	1.290	1.619	1.461	1.476	0.082	1.165	1.367	1.260	1.263	0.050

Table 7 continued from previous page

	Upside Pre-Breach					Upside Post-Breach				
30	0.486	0.720	0.580	0.562	0.064	0.605	0.732	0.664	0.658	0.034
31	0.631	0.894	0.742	0.705	0.096	0.572	0.687	0.611	0.604	0.025
32	0.968	1.294	1.125	1.068	0.104	0.966	1.104	1.041	1.047	0.044
33	0.979	1.215	1.074	1.057	0.080	0.981	1.398	1.146	1.163	0.099
34	1.007	1.082	1.048	1.048	0.020	1.058	1.255	1.167	1.158	0.056
35	0.689	0.745	0.724	0.727	0.015	0.687	0.750	0.720	0.724	0.021
36	1.107	1.195	1.151	1.150	0.021	1.046	1.243	1.158	1.177	0.065
37	1.578	1.718	1.654	1.655	0.048	1.670	1.836	1.715	1.717	0.032
38	1.520	1.611	1.556	1.547	0.025	1.290	1.570	1.463	1.517	0.097
39	1.592	1.649	1.619	1.618	0.014	1.642	2.335	1.787	1.690	0.223
40	0.535	0.605	0.574	0.574	0.018	0.557	0.672	0.608	0.604	0.035
41	1.091	1.230	1.153	1.155	0.030	1.154	1.804	1.403	1.230	0.263
42	0.916	1.147	0.964	0.947	0.049	0.874	1.116	0.989	1.032	0.081
43	0.802	1.073	0.927	0.923	0.087	0.921	1.023	0.983	0.994	0.030
44	0.685	0.960	0.831	0.791	0.076	0.760	1.033	0.945	0.971	0.069
45	1.118	1.281	1.192	1.187	0.063	1.132	1.166	1.150	1.152	0.009
46	0.806	0.885	0.833	0.827	0.023	0.764	0.823	0.803	0.809	0.017
47	1.053	1.165	1.118	1.121	0.027	1.005	1.174	1.099	1.121	0.055
48	1.141	1.168	1.159	1.160	0.006	1.203	1.228	1.217	1.217	0.005
49	1.126	1.480	1.294	1.345	0.116	1.135	1.280	1.211	1.219	0.039
50	1.432	1.518	1.477	1.486	0.027	1.344	1.515	1.439	1.458	0.060
51	0.835	0.871	0.856	0.857	0.008	0.811	0.921	0.837	0.829	0.030
52	1.451	1.573	1.519	1.508	0.031	1.301	1.488	1.380	1.370	0.057
53	1.796	1.903	1.852	1.850	0.026	1.412	1.833	1.621	1.592	0.141
54	0.564	0.629	0.600	0.608	0.018	0.555	0.698	0.632	0.636	0.041
55	0.631	0.791	0.733	0.747	0.044	0.651	1.179	0.812	0.769	0.141
56	0.949	1.119	1.058	1.070	0.058	0.628	1.039	0.830	0.843	0.130
57	1.892	2.489	2.223	2.294	0.193	1.380	2.170	1.704	1.564	0.270
58	0.791	1.127	1.000	1.028	0.091	0.403	0.952	0.669	0.733	0.156
59	1.100	1.259	1.166	1.163	0.045	1.126	1.262	1.183	1.180	0.042
60	1.667	1.927	1.802	1.802	0.061	1.633	1.922	1.735	1.737	0.058
61	1.485	1.890	1.678	1.649	0.132	1.276	1.462	1.345	1.332	0.041
62	1.006	1.671	1.372	1.408	0.185	1.469	1.803	1.680	1.734	0.106
63	0.816	1.028	0.897	0.876	0.054	0.800	0.930	0.867	0.868	0.037
64	0.927	1.202	1.108	1.111	0.072	1.132	1.241	1.170	1.169	0.020
65	0.890	0.997	0.935	0.940	0.027	0.846	0.939	0.903	0.899	0.023
66	1.119	1.197	1.157	1.158	0.018	1.081	1.151	1.118	1.116	0.014
67	1.095	1.408	1.216	1.226	0.061	1.023	1.207	1.102	1.095	0.049
68	-0.133	0.160	-0.010	-0.078	0.111	0.027	1.158	0.552	0.247	0.492
69	1.368	1.678	1.451	1.447	0.057	1.476	1.790	1.640	1.604	0.104
70	1.069	1.242	1.178	1.180	0.058	1.341	1.479	1.402	1.390	0.036
71	0.604	0.853	0.744	0.724	0.065	0.705	1.376	1.123	1.213	0.214
72	0.530	0.778	0.663	0.713	0.094	0.502	0.728	0.598	0.569	0.077

Table 7 continued from previous page

	Upside Pre-Breach					Upside Post-Breach				
73	0.905	1.238	1.032	1.013	0.107	1.186	1.566	1.289	1.269	0.092
74	1.020	1.225	1.109	1.114	0.047	0.781	1.049	0.921	0.940	0.068
75	0.819	1.150	0.979	0.996	0.088	1.063	1.425	1.188	1.120	0.138
76	0.765	0.925	0.822	0.793	0.052	0.981	1.379	1.188	1.113	0.133
77	0.919	1.077	1.007	1.006	0.045	0.788	1.031	0.894	0.886	0.074
78	0.975	1.185	1.071	1.079	0.066	1.169	1.396	1.308	1.329	0.074
79	0.966	1.125	1.060	1.075	0.036	0.800	1.094	0.992	1.036	0.086
80	0.306	0.408	0.360	0.363	0.027	0.261	0.566	0.445	0.487	0.083
81	1.115	1.293	1.206	1.196	0.049	1.281	1.428	1.336	1.321	0.040
82	0.564	0.747	0.641	0.637	0.045	0.501	0.857	0.654	0.599	0.127
83	0.732	0.931	0.827	0.812	0.071	0.856	0.950	0.896	0.892	0.023
84	0.882	1.279	1.081	1.128	0.146	1.049	1.313	1.158	1.146	0.066
85	-0.288	0.201	-0.101	-0.103	0.105	-0.511	0.151	-0.039	-0.058	0.140
86	0.284	1.289	0.692	0.653	0.326	-0.043	0.305	0.159	0.200	0.121
87	0.804	1.047	0.937	0.924	0.062	0.612	0.828	0.707	0.715	0.068
88	1.114	1.414	1.237	1.190	0.104	1.204	1.312	1.251	1.247	0.024
89	0.286	1.361	0.771	0.630	0.358	-0.475	0.635	0.151	0.182	0.392
90	1.237	1.617	1.411	1.409	0.077	1.391	1.617	1.526	1.541	0.061
91	0.699	0.995	0.798	0.777	0.064	0.608	0.781	0.689	0.692	0.059
92	0.425	0.656	0.537	0.526	0.062	0.426	0.711	0.519	0.496	0.079
93	0.924	1.006	0.969	0.971	0.021	0.942	1.027	0.984	0.987	0.021
94	1.001	1.113	1.051	1.044	0.029	1.073	1.261	1.192	1.205	0.051
95	1.059	1.171	1.113	1.113	0.029	1.113	1.341	1.217	1.217	0.059
96	0.639	0.752	0.688	0.689	0.028	0.692	0.924	0.833	0.844	0.056
97	1.716	2.037	1.888	1.866	0.087	1.624	1.996	1.759	1.760	0.066
98	0.252	1.006	0.615	0.596	0.241	0.204	0.673	0.430	0.354	0.161
99	1.528	3.473	2.266	2.114	0.557	1.670	2.036	1.869	1.862	0.104
100	1.332	1.515	1.442	1.462	0.056	1.213	1.420	1.319	1.329	0.054
101	0.025	0.159	0.079	0.079	0.032	-0.113	0.388	0.136	0.059	0.198
102	0.580	0.691	0.634	0.627	0.025	0.494	0.722	0.605	0.575	0.088
103	0.587	0.707	0.647	0.668	0.041	0.460	0.610	0.536	0.519	0.041
104	-1.155	-0.337	-0.670	-0.627	0.201	-1.598	-0.176	-1.002	-1.094	0.356
105	0.837	1.160	1.032	1.046	0.063	0.526	0.846	0.718	0.774	0.106
106	0.410	0.697	0.500	0.472	0.078	0.596	0.746	0.690	0.700	0.035
107	0.619	1.013	0.742	0.708	0.110	0.926	1.151	1.018	1.028	0.065
108	0.307	1.017	0.700	0.600	0.265	0.112	0.705	0.447	0.402	0.134
109	0.970	1.269	1.136	1.146	0.072	1.247	1.393	1.326	1.320	0.049
110	1.092	1.498	1.319	1.334	0.069	1.119	1.566	1.376	1.374	0.112
111	1.123	1.390	1.224	1.211	0.040	1.148	1.303	1.218	1.223	0.032
112	1.556	1.833	1.691	1.697	0.076	1.396	1.653	1.524	1.509	0.076
113	1.012	1.246	1.137	1.109	0.063	1.282	1.362	1.312	1.310	0.019
114	0.122	0.613	0.308	0.308	0.141	-0.215	0.190	-0.036	-0.036	0.086
115	1.229	1.393	1.324	1.320	0.051	1.095	1.260	1.189	1.181	0.049

Table 7 continued from previous page

	Upside Pre-Breach					Upside Post-Breach				
116	0.489	0.623	0.563	0.562	0.038	0.496	0.664	0.571	0.561	0.048
117	0.411	0.548	0.491	0.491	0.040	0.438	0.534	0.492	0.501	0.028
118	0.767	1.101	0.965	1.011	0.101	0.215	0.801	0.612	0.686	0.173
119	0.720	1.007	0.855	0.871	0.080	0.504	0.899	0.664	0.597	0.142
120	1.199	1.545	1.376	1.403	0.099	1.012	1.449	1.141	1.092	0.125
121	1.508	1.653	1.577	1.578	0.036	1.008	1.547	1.172	1.138	0.104
122	1.019	1.252	1.147	1.163	0.074	0.923	1.098	0.999	0.998	0.053
123	1.023	1.425	1.211	1.143	0.135	1.441	1.592	1.547	1.548	0.026
124	0.824	0.977	0.908	0.900	0.035	0.902	1.146	0.993	0.970	0.061
125	0.871	1.071	0.962	0.964	0.052	0.841	0.952	0.901	0.914	0.030
126	0.780	0.966	0.842	0.810	0.064	0.847	1.009	0.929	0.927	0.039
127	0.684	0.903	0.810	0.798	0.062	0.769	1.045	0.918	0.974	0.102
128	0.798	1.118	0.946	0.953	0.098	0.251	0.811	0.495	0.401	0.216
129	0.981	1.077	1.029	1.025	0.026	0.886	1.017	0.965	0.966	0.034
130	0.577	0.719	0.688	0.700	0.033	0.598	0.746	0.667	0.664	0.028
131	0.839	1.613	1.183	1.115	0.274	1.322	1.487	1.413	1.401	0.051
132	1.414	1.703	1.535	1.518	0.097	1.583	1.860	1.733	1.802	0.110
133	0.062	0.490	0.268	0.293	0.139	0.409	0.544	0.464	0.459	0.036
134	0.518	0.929	0.741	0.708	0.146	0.889	0.997	0.934	0.934	0.020
135	1.209	1.475	1.384	1.417	0.084	1.388	1.479	1.437	1.451	0.029
136	1.029	1.090	1.064	1.069	0.016	1.018	1.093	1.061	1.060	0.010
137	0.686	0.907	0.806	0.824	0.053	0.707	1.136	0.842	0.781	0.134
138	1.277	1.520	1.473	1.476	0.039	1.226	1.614	1.465	1.500	0.125
139	0.777	0.875	0.819	0.815	0.027	0.829	1.062	0.910	0.878	0.080
140	0.997	1.062	1.022	1.022	0.016	0.930	0.999	0.971	0.972	0.017
141	0.185	0.506	0.335	0.311	0.103	0.260	0.679	0.436	0.397	0.128
142	0.564	1.152	0.957	1.062	0.167	0.350	0.720	0.560	0.651	0.142
143	0.391	0.602	0.479	0.487	0.069	0.415	0.793	0.532	0.502	0.090
144	0.914	1.153	1.007	0.988	0.067	0.708	1.102	0.958	1.027	0.124
145	0.972	1.069	1.018	1.018	0.029	1.019	1.189	1.082	1.059	0.053
146	0.741	0.982	0.857	0.847	0.053	0.540	0.808	0.750	0.766	0.058
147	1.695	2.071	1.911	1.912	0.096	1.755	2.435	2.169	2.257	0.218
148	0.804	1.003	0.890	0.890	0.039	0.489	0.924	0.613	0.582	0.109
149	-0.861	-0.219	-0.567	-0.575	0.211	-0.804	0.654	0.092	0.386	0.495
150	1.410	1.559	1.455	1.441	0.039	1.494	1.727	1.571	1.543	0.069
151	1.355	1.786	1.659	1.721	0.119	1.137	1.361	1.228	1.227	0.055
152	1.002	1.253	1.172	1.179	0.056	0.749	1.036	0.918	0.975	0.097
153	0.447	0.947	0.690	0.677	0.138	0.548	0.857	0.732	0.730	0.090
154	0.907	1.254	1.032	1.023	0.089	0.924	1.050	0.986	0.981	0.038
155	0.850	1.481	1.283	1.293	0.147	1.338	1.746	1.566	1.553	0.128
156	0.087	0.267	0.187	0.184	0.048	-0.216	0.449	0.237	0.226	0.138
157	0.955	1.257	1.068	1.065	0.061	1.259	1.670	1.421	1.434	0.081
158	1.128	1.279	1.212	1.226	0.047	1.074	1.509	1.321	1.309	0.113

Table 7 continued from previous page

	Upside Pre-Breach					Upside Post-Breach				
159	1.067	1.377	1.214	1.212	0.084	0.624	1.557	1.211	1.249	0.272
160	0.809	1.183	1.024	1.024	0.119	1.038	1.191	1.135	1.143	0.039
161	0.647	0.785	0.745	0.744	0.024	0.798	1.391	1.007	0.922	0.190
162	0.875	1.216	0.982	0.948	0.102	0.492	0.843	0.632	0.602	0.080
163	1.580	1.940	1.770	1.796	0.112	1.416	1.798	1.663	1.674	0.093
164	1.072	1.280	1.167	1.163	0.055	0.696	1.403	1.183	1.260	0.194
165	0.720	0.936	0.876	0.898	0.051	0.475	0.798	0.611	0.615	0.083
166	0.115	0.521	0.300	0.295	0.146	0.118	0.378	0.270	0.285	0.072
167	0.940	1.219	1.045	1.037	0.073	0.719	1.007	0.837	0.825	0.064
168	1.896	2.519	2.212	2.209	0.173	2.142	2.344	2.213	2.204	0.056
169	1.056	1.798	1.375	1.221	0.257	0.850	1.007	0.896	0.882	0.041
170	0.871	1.828	1.205	0.961	0.354	0.825	0.977	0.914	0.917	0.034
171	1.259	1.603	1.426	1.384	0.089	1.134	1.302	1.209	1.208	0.054
172	0.852	1.223	0.929	0.905	0.087	0.737	0.981	0.856	0.850	0.073
173	0.578	0.815	0.707	0.717	0.067	0.444	0.586	0.533	0.541	0.041
174	0.234	0.483	0.322	0.337	0.050	0.193	0.470	0.333	0.375	0.110
175	1.230	1.328	1.292	1.298	0.020	1.154	1.335	1.260	1.260	0.047
176	0.462	0.690	0.568	0.551	0.073	0.553	1.307	0.943	1.028	0.226
177	0.571	0.698	0.652	0.669	0.038	0.678	1.235	0.971	0.973	0.138
178	0.018	0.862	0.332	0.197	0.275	-0.255	0.856	0.228	0.329	0.296
179	0.719	0.849	0.800	0.805	0.033	0.624	1.044	0.811	0.734	0.154
180	0.775	1.084	0.886	0.876	0.064	0.720	0.948	0.834	0.839	0.052
181	0.737	1.353	0.951	0.909	0.178	1.318	1.516	1.425	1.422	0.040
182	0.913	1.029	0.972	0.971	0.023	0.767	0.968	0.860	0.863	0.049
183	0.755	1.075	0.971	0.995	0.087	0.813	0.916	0.854	0.844	0.028
184	0.675	0.765	0.716	0.712	0.022	0.695	0.876	0.800	0.791	0.046
185	1.633	1.749	1.681	1.673	0.033	1.143	1.611	1.504	1.505	0.099
186	0.796	0.970	0.884	0.881	0.057	0.591	0.904	0.732	0.680	0.090
187	0.737	0.869	0.787	0.778	0.034	0.775	0.836	0.806	0.805	0.015
188	0.983	1.004	0.996	0.999	0.006	0.783	1.023	0.962	0.960	0.048
189	0.877	0.988	0.949	0.961	0.032	0.673	0.970	0.842	0.838	0.091
190	0.434	0.683	0.551	0.544	0.045	0.694	0.932	0.818	0.791	0.085
191	0.838	0.997	0.920	0.902	0.050	0.905	1.223	1.126	1.141	0.092
192	0.225	0.670	0.594	0.629	0.096	0.633	0.974	0.869	0.886	0.079
193	1.703	1.862	1.762	1.758	0.038	1.633	1.698	1.660	1.661	0.019
194	0.702	1.099	0.815	0.797	0.099	0.733	0.852	0.793	0.802	0.035
195	0.938	1.082	1.022	1.041	0.043	0.929	1.077	1.010	1.021	0.038
196	1.139	1.343	1.219	1.195	0.056	1.185	1.275	1.223	1.215	0.027
197	1.192	1.275	1.241	1.250	0.023	1.158	1.392	1.257	1.244	0.058
198	1.263	1.307	1.282	1.280	0.011	1.233	1.296	1.267	1.267	0.017
199	0.546	0.800	0.659	0.629	0.063	0.748	0.919	0.813	0.807	0.041
200	0.184	0.538	0.294	0.243	0.107	0.356	0.518	0.446	0.457	0.044
201	0.219	0.402	0.359	0.370	0.044	0.348	0.438	0.400	0.404	0.025

Table 7 continued from previous page

	Upside Pre-Breach					Upside Post-Breach				
202	-0.595	-0.068	-0.346	-0.338	0.178	-0.300	0.103	-0.099	-0.077	0.113
Mean	0.868	1.161	1.009	1.004	0.084	0.855	1.182	1.013	1.010	0.097

D Descriptive Statistics: Downside Beta per Event

	Downside Pre-Breach					Downside Post-Breach				
Event	Min	Max	M	Mdn	SD	Min	Max	M	Mdn	SD
1	0.627	1.145	0.908	0.876	0.161	1.003	1.157	1.096	1.100	0.031
2	0.488	0.819	0.646	0.653	0.102	0.461	0.709	0.601	0.627	0.069
3	0.465	0.790	0.645	0.657	0.085	0.494	0.658	0.554	0.559	0.049
4	0.431	0.585	0.514	0.508	0.047	0.372	0.634	0.524	0.558	0.081
5	-0.362	0.243	-0.020	0.032	0.179	-0.078	0.717	0.289	0.280	0.268
6	1.278	2.141	1.995	2.045	0.176	1.672	2.204	1.897	1.708	0.229
7	0.967	1.135	1.069	1.070	0.042	0.981	1.153	1.069	1.065	0.050
8	1.203	1.516	1.403	1.452	0.108	1.276	1.516	1.380	1.368	0.061
9	1.022	1.225	1.168	1.178	0.052	1.148	1.320	1.217	1.204	0.038
10	0.864	1.150	1.003	1.008	0.070	0.944	1.104	1.037	1.034	0.034
11	1.071	1.512	1.209	1.161	0.123	1.044	1.383	1.166	1.110	0.100
12	1.065	1.378	1.223	1.199	0.102	1.308	1.385	1.345	1.335	0.023
13	1.018	1.321	1.148	1.135	0.080	1.059	1.244	1.133	1.122	0.052
14	0.642	0.781	0.700	0.698	0.025	0.655	0.863	0.755	0.763	0.060
15	1.256	1.425	1.366	1.367	0.038	1.262	1.330	1.292	1.289	0.019
16	1.536	1.623	1.561	1.553	0.023	1.477	1.808	1.583	1.573	0.077
17	1.397	1.530	1.458	1.459	0.039	1.493	2.112	1.711	1.749	0.157
18	1.035	1.553	1.209	1.177	0.145	1.509	5.363	2.980	2.988	1.196
19	0.047	0.893	0.538	0.650	0.224	0.209	2.151	1.009	1.029	0.494
20	0.822	1.180	0.983	0.916	0.118	1.052	1.091	1.065	1.062	0.011
21	0.724	0.857	0.808	0.835	0.043	0.777	0.917	0.857	0.874	0.042
22	0.922	1.022	0.951	0.955	0.015	0.931	0.974	0.952	0.952	0.009
23	0.561	0.868	0.722	0.704	0.059	0.640	0.728	0.688	0.692	0.022
24	2.105	2.274	2.191	2.210	0.055	2.220	2.291	2.253	2.252	0.020
25	1.119	1.162	1.142	1.146	0.013	1.064	1.121	1.101	1.105	0.016
26	1.299	1.392	1.340	1.336	0.025	1.340	1.425	1.379	1.377	0.021
27	1.309	2.270	1.745	1.634	0.341	1.245	3.127	2.678	2.858	0.467
28	1.161	1.359	1.284	1.287	0.048	1.051	1.245	1.143	1.127	0.059
29	0.907	1.110	1.040	1.058	0.046	1.137	1.228	1.191	1.198	0.022
30	0.545	0.740	0.621	0.599	0.062	0.550	0.653	0.617	0.618	0.025
31	0.427	0.700	0.578	0.553	0.086	0.563	0.908	0.752	0.681	0.124
32	0.952	1.045	0.992	0.986	0.027	1.010	1.109	1.052	1.040	0.032
33	1.038	1.261	1.204	1.217	0.048	1.055	1.268	1.164	1.164	0.057
34	0.989	1.113	1.032	1.026	0.029	1.064	1.201	1.144	1.159	0.042
35	0.757	0.981	0.883	0.875	0.052	0.969	1.079	1.028	1.050	0.039

Table 8 continued from previous page

	Downside Pre-Breach					Downside Post-Breach				
36	1.116	1.231	1.163	1.150	0.038	0.993	1.186	1.081	1.078	0.055
37	1.615	1.740	1.670	1.646	0.045	1.598	1.706	1.650	1.661	0.031
38	1.354	1.439	1.392	1.386	0.023	1.397	1.582	1.483	1.488	0.049
39	1.399	1.496	1.454	1.448	0.025	1.297	2.167	1.587	1.545	0.270
40	0.885	0.945	0.914	0.914	0.012	0.734	0.923	0.816	0.818	0.051
41	1.417	1.631	1.517	1.514	0.048	1.370	1.959	1.599	1.515	0.226
42	0.859	1.042	0.982	1.008	0.051	0.863	1.033	0.933	0.942	0.039
43	0.726	0.978	0.850	0.838	0.085	0.941	1.066	1.012	1.006	0.035
44	0.751	1.121	0.921	0.877	0.136	0.930	1.060	0.999	1.004	0.047
45	0.865	0.927	0.886	0.883	0.016	0.880	0.918	0.896	0.896	0.010
46	0.784	0.814	0.796	0.795	0.010	0.757	0.800	0.778	0.779	0.011
47	1.191	1.259	1.228	1.228	0.013	1.186	1.256	1.214	1.217	0.017
48	1.015	1.066	1.043	1.045	0.014	0.965	1.014	0.980	0.980	0.010
49	1.067	1.299	1.206	1.228	0.069	0.938	1.071	0.987	0.972	0.038
50	1.297	1.363	1.331	1.335	0.021	1.308	1.351	1.338	1.339	0.007
51	1.085	1.111	1.099	1.098	0.007	1.050	1.116	1.080	1.073	0.017
52	1.316	1.501	1.432	1.437	0.050	0.810	1.424	1.270	1.382	0.178
53	1.354	1.441	1.397	1.398	0.024	1.350	1.582	1.474	1.490	0.045
54	0.742	0.823	0.777	0.779	0.019	0.742	1.048	0.848	0.781	0.101
55	0.767	0.883	0.826	0.823	0.037	0.816	1.218	0.977	0.911	0.143
56	1.044	1.109	1.075	1.072	0.020	0.993	1.116	1.057	1.063	0.042
57	1.996	2.432	2.204	2.197	0.131	1.488	2.223	1.788	1.800	0.238
58	0.412	1.206	0.722	0.675	0.227	0.281	2.023	1.450	1.530	0.433
59	0.852	1.325	1.061	1.116	0.143	1.115	1.303	1.209	1.213	0.051
60	1.645	2.051	1.897	1.891	0.115	1.894	2.064	1.966	1.973	0.042
61	1.233	1.602	1.392	1.345	0.114	1.324	1.751	1.487	1.443	0.114
62	1.175	1.354	1.284	1.301	0.055	1.178	1.384	1.297	1.297	0.054
63	1.097	1.228	1.166	1.184	0.047	0.950	1.105	1.059	1.075	0.046
64	0.880	1.044	0.979	0.995	0.047	0.856	1.063	0.970	1.009	0.077
65	0.227	0.402	0.306	0.300	0.038	0.276	0.399	0.337	0.325	0.035
66	1.033	1.175	1.120	1.132	0.042	0.814	1.081	0.954	0.985	0.079
67	1.323	1.431	1.394	1.399	0.032	1.133	1.375	1.290	1.306	0.056
68	0.993	1.172	1.072	1.071	0.046	0.728	1.074	0.857	0.837	0.082
69	1.292	1.448	1.389	1.389	0.037	1.456	1.576	1.511	1.508	0.035
70	0.913	1.289	1.128	1.208	0.130	0.814	0.910	0.862	0.861	0.031
71	1.006	1.416	1.234	1.247	0.114	1.300	1.541	1.459	1.474	0.061
72	0.867	0.990	0.936	0.930	0.022	0.874	1.037	0.985	0.989	0.026
73	0.434	0.578	0.524	0.525	0.036	0.349	0.657	0.481	0.474	0.094
74	0.819	0.941	0.898	0.908	0.029	0.731	1.002	0.818	0.791	0.074
75	0.672	0.840	0.755	0.758	0.040	0.759	0.988	0.912	0.929	0.065
76	0.603	0.699	0.657	0.660	0.030	0.556	0.660	0.617	0.623	0.022
77	0.191	0.335	0.286	0.298	0.041	0.305	0.574	0.433	0.407	0.091
78	1.048	1.248	1.167	1.195	0.068	1.101	1.158	1.126	1.125	0.016

Table 8 continued from previous page

	Downside Pre-Breach					Downside Post-Breach				
79	0.712	0.836	0.766	0.761	0.025	0.721	1.020	0.869	0.824	0.093
80	0.474	0.562	0.517	0.520	0.020	0.413	0.651	0.514	0.500	0.078
81	0.836	0.960	0.892	0.888	0.026	0.979	1.146	1.073	1.076	0.057
82	1.409	1.552	1.476	1.482	0.038	1.435	1.650	1.520	1.496	0.069
83	0.824	1.020	0.889	0.885	0.033	0.966	1.085	1.012	0.999	0.035
84	1.590	1.833	1.700	1.696	0.053	1.684	1.833	1.751	1.760	0.035
85	0.857	1.644	1.332	1.439	0.249	1.621	1.840	1.735	1.726	0.056
86	0.973	1.393	1.231	1.270	0.135	0.781	1.058	0.910	0.952	0.092
87	0.506	0.689	0.593	0.585	0.040	0.506	0.596	0.560	0.561	0.018
88	0.884	1.047	0.968	0.967	0.044	1.042	1.189	1.120	1.133	0.044
89	1.577	2.850	2.335	2.409	0.329	1.587	2.724	2.086	2.100	0.410
90	1.114	1.737	1.250	1.228	0.133	1.189	1.455	1.336	1.330	0.086
91	0.972	1.079	1.033	1.033	0.027	0.697	1.066	0.859	0.865	0.092
92	1.189	1.515	1.372	1.365	0.080	0.793	1.184	0.951	1.043	0.119
93	1.258	1.607	1.375	1.311	0.107	1.326	1.589	1.414	1.382	0.077
94	1.110	1.165	1.137	1.139	0.014	0.996	1.176	1.083	1.071	0.054
95	0.846	0.889	0.870	0.870	0.012	0.779	0.907	0.828	0.827	0.024
96	0.274	0.573	0.445	0.487	0.095	0.368	0.533	0.461	0.477	0.042
97	1.614	1.979	1.797	1.766	0.091	1.271	1.511	1.421	1.444	0.064
98	0.997	1.201	1.140	1.149	0.046	1.091	1.323	1.186	1.176	0.060
99	1.821	2.791	2.168	2.103	0.243	1.474	2.045	1.778	1.832	0.184
100	1.232	1.410	1.347	1.360	0.053	1.228	1.376	1.299	1.282	0.046
101	0.713	0.832	0.768	0.749	0.039	0.594	0.752	0.652	0.639	0.038
102	0.920	1.146	1.068	1.098	0.075	0.760	0.874	0.813	0.806	0.031
103	0.597	0.710	0.667	0.677	0.034	0.629	0.691	0.663	0.662	0.013
104	1.754	2.272	2.039	2.030	0.099	1.643	1.991	1.760	1.754	0.068
105	0.772	1.426	1.056	1.065	0.147	0.500	0.905	0.719	0.751	0.130
106	0.719	0.850	0.804	0.810	0.034	0.696	0.895	0.812	0.833	0.058
107	1.193	1.325	1.284	1.301	0.039	1.157	1.338	1.269	1.288	0.051
108	0.662	1.198	1.012	1.030	0.121	0.587	1.004	0.787	0.791	0.092
109	0.645	0.757	0.724	0.740	0.033	0.747	1.344	1.140	1.269	0.220
110	2.163	2.559	2.371	2.372	0.095	1.832	2.085	1.967	1.983	0.077
111	1.391	1.557	1.472	1.470	0.027	1.358	1.551	1.458	1.454	0.052
112	1.347	1.462	1.389	1.389	0.019	1.254	1.572	1.411	1.394	0.092
113	0.661	0.948	0.758	0.769	0.065	0.939	1.140	1.057	1.043	0.046
114	-0.448	0.764	0.141	0.202	0.448	-0.769	-0.094	-0.385	-0.347	0.197
115	0.768	1.344	1.169	1.272	0.206	1.329	1.381	1.351	1.350	0.013
116	0.515	0.718	0.594	0.582	0.068	0.695	0.779	0.730	0.729	0.024
117	0.828	0.963	0.904	0.910	0.040	0.899	0.995	0.943	0.939	0.030
118	-0.028	0.336	0.096	0.052	0.094	0.160	0.888	0.455	0.394	0.232
119	1.379	1.768	1.492	1.440	0.130	1.051	1.471	1.223	1.143	0.153
120	1.056	1.402	1.260	1.287	0.094	0.348	1.113	0.638	0.611	0.203
121	1.137	1.558	1.275	1.216	0.138	0.929	1.108	0.971	0.961	0.029

Table 8 continued from previous page

	Downside Pre-Breach					Downside Post-Breach				
122	0.999	1.317	1.191	1.269	0.121	1.092	1.172	1.138	1.140	0.021
123	1.534	1.726	1.617	1.598	0.061	1.478	1.625	1.559	1.576	0.043
124	1.302	1.614	1.458	1.502	0.079	1.452	1.536	1.503	1.497	0.019
125	0.998	1.097	1.027	1.016	0.027	0.883	1.033	0.984	0.977	0.030
126	1.260	1.357	1.314	1.314	0.030	1.302	1.494	1.386	1.380	0.050
127	0.899	1.065	0.955	0.939	0.042	0.891	1.071	0.983	0.991	0.057
128	0.454	0.775	0.584	0.563	0.078	0.846	1.052	0.929	0.925	0.048
129	0.982	1.107	1.057	1.066	0.031	1.093	1.208	1.154	1.153	0.030
130	0.535	0.637	0.579	0.578	0.026	0.515	0.647	0.554	0.545	0.032
131	1.171	1.417	1.312	1.312	0.057	1.381	1.469	1.431	1.437	0.022
132	0.741	0.952	0.837	0.808	0.073	0.828	0.917	0.868	0.868	0.025
133	0.499	0.749	0.650	0.652	0.050	0.569	0.775	0.706	0.710	0.046
134	0.500	0.702	0.612	0.621	0.055	0.531	0.706	0.612	0.573	0.062
135	1.663	1.823	1.770	1.792	0.051	1.709	2.057	1.873	1.813	0.132
136	1.090	1.120	1.107	1.109	0.008	1.034	1.090	1.070	1.075	0.016
137	0.465	0.607	0.528	0.522	0.040	0.332	0.620	0.470	0.468	0.082
138	1.136	1.260	1.193	1.194	0.034	1.099	1.516	1.242	1.212	0.106
139	1.102	1.197	1.152	1.166	0.027	0.775	1.148	0.930	0.940	0.077
140	1.012	1.060	1.036	1.037	0.013	0.922	1.058	1.026	1.036	0.028
141	0.524	1.254	0.772	0.572	0.286	1.326	1.550	1.419	1.383	0.084
142	0.660	1.038	0.832	0.792	0.135	0.861	1.127	1.006	1.007	0.058
143	0.580	0.676	0.634	0.633	0.025	0.375	0.708	0.610	0.634	0.078
144	1.977	2.153	2.048	2.021	0.050	1.931	2.217	2.056	2.043	0.064
145	0.923	1.046	0.996	1.013	0.038	0.758	0.933	0.869	0.869	0.047
146	0.831	0.966	0.887	0.875	0.040	0.922	1.100	0.999	1.007	0.053
147	0.889	1.268	1.014	0.983	0.105	0.791	1.094	0.924	0.937	0.063
148	0.786	1.027	0.911	0.902	0.072	0.583	0.755	0.649	0.654	0.039
149	0.242	1.641	1.000	1.255	0.462	1.353	1.833	1.611	1.583	0.140
150	1.416	1.645	1.515	1.527	0.041	1.420	1.553	1.497	1.498	0.028
151	1.541	1.848	1.709	1.711	0.075	1.723	1.916	1.810	1.791	0.057
152	1.104	1.431	1.232	1.211	0.103	1.163	1.348	1.262	1.246	0.049
153	0.692	0.886	0.801	0.842	0.071	0.752	1.144	0.907	0.917	0.091
154	1.023	1.301	1.109	1.103	0.054	1.141	1.406	1.313	1.307	0.045
155	0.975	1.231	1.110	1.114	0.070	1.088	1.877	1.489	1.400	0.247
156	0.584	0.759	0.687	0.695	0.045	0.524	2.042	1.311	1.805	0.636
157	0.970	1.334	1.102	1.060	0.120	0.931	1.239	1.085	1.103	0.080
158	0.838	1.075	0.964	0.971	0.080	0.943	1.429	1.226	1.233	0.084
159	0.655	1.099	0.793	0.758	0.117	0.638	1.124	0.837	0.824	0.119
160	0.682	1.121	0.889	0.788	0.158	0.962	1.356	1.136	1.143	0.077
161	1.010	1.270	1.192	1.230	0.087	1.225	1.439	1.370	1.370	0.051
162	0.965	1.074	1.032	1.043	0.033	0.565	0.806	0.685	0.688	0.073
163	1.250	2.340	1.753	1.443	0.399	2.296	2.475	2.394	2.393	0.049
164	1.006	1.410	1.221	1.196	0.102	0.861	1.233	1.047	1.038	0.092

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	Downside Pre-Breach					Downside Post-Breach				
165	1.091	1.393	1.220	1.196	0.082	0.864	1.207	1.119	1.168	0.100
166	0.184	0.284	0.230	0.219	0.031	0.228	0.805	0.688	0.735	0.160
167	1.151	1.493	1.343	1.365	0.081	1.096	1.167	1.136	1.135	0.018
168	0.938	2.021	1.333	1.208	0.261	0.805	0.955	0.885	0.889	0.045
169	1.020	1.968	1.352	1.178	0.343	1.017	1.094	1.066	1.070	0.021
170	0.775	1.390	0.957	0.936	0.177	0.828	0.916	0.879	0.883	0.021
171	1.298	2.227	1.505	1.395	0.274	1.262	1.357	1.315	1.320	0.028
172	-0.145	0.053	-0.003	0.005	0.033	0.002	0.132	0.064	0.075	0.029
173	1.050	1.127	1.086	1.085	0.018	1.082	1.211	1.128	1.106	0.045
174	-0.082	-0.016	-0.050	-0.053	0.019	-0.223	-0.040	-0.138	-0.161	0.050
175	1.160	1.316	1.216	1.190	0.056	1.069	1.219	1.145	1.157	0.038
176	0.560	0.668	0.615	0.616	0.025	0.679	1.172	1.000	1.047	0.127
177	0.580	0.764	0.658	0.648	0.061	0.711	1.197	1.003	0.989	0.111
178	1.242	1.678	1.468	1.481	0.130	0.504	1.291	0.840	0.794	0.209
179	1.037	1.170	1.127	1.125	0.025	1.116	1.204	1.157	1.158	0.022
180	0.736	0.890	0.820	0.818	0.050	0.570	0.748	0.657	0.643	0.045
181	0.079	0.633	0.265	0.156	0.179	0.735	1.622	1.091	1.064	0.245
182	1.279	1.477	1.373	1.360	0.055	1.258	1.333	1.298	1.298	0.019
183	0.588	1.158	0.695	0.659	0.137	0.505	0.626	0.559	0.554	0.034
184	0.740	0.871	0.780	0.781	0.025	0.759	0.863	0.800	0.798	0.029
185	1.395	1.489	1.450	1.449	0.024	1.430	2.074	1.671	1.635	0.168
186	0.976	1.069	1.028	1.031	0.024	0.837	1.004	0.920	0.923	0.043
187	0.610	0.735	0.666	0.657	0.037	0.580	0.645	0.614	0.612	0.013
188	0.885	0.927	0.909	0.908	0.012	0.898	1.401	1.126	1.150	0.194
189	0.749	0.899	0.834	0.848	0.042	0.529	0.788	0.702	0.733	0.083
190	1.156	1.241	1.181	1.177	0.019	1.224	1.337	1.291	1.297	0.034
191	0.725	0.788	0.750	0.743	0.017	0.744	1.212	1.059	1.093	0.139
192	0.377	0.545	0.492	0.515	0.045	0.397	0.568	0.469	0.463	0.043
193	1.411	1.534	1.499	1.493	0.021	1.457	1.491	1.475	1.474	0.008
194	0.877	0.995	0.919	0.908	0.037	0.848	0.954	0.901	0.906	0.030
195	0.707	0.928	0.797	0.758	0.079	0.923	1.064	0.984	0.974	0.047
196	1.034	1.261	1.132	1.060	0.093	1.289	1.551	1.458	1.495	0.086
197	1.298	1.551	1.392	1.376	0.078	1.335	1.576	1.460	1.460	0.071
198	1.322	1.452	1.357	1.353	0.035	1.389	1.442	1.422	1.423	0.013
199	0.470	0.855	0.707	0.704	0.087	0.602	0.734	0.680	0.680	0.027
200	0.248	0.554	0.445	0.482	0.096	0.333	0.796	0.538	0.520	0.142
201	0.426	0.501	0.470	0.474	0.022	0.294	0.429	0.357	0.360	0.039
202	1.091	1.666	1.348	1.318	0.178	0.901	1.182	1.017	1.025	0.073
Mean	0.932	1.207	1.066	1.062	0.078	0.951	1.246	1.097	1.099	0.084

E Descriptive Statistics: Changes in Regular, Upside, and Downside Beta per Event

All changes in beta per event presented are based on 60 daily one-year betas. The differences between aggregated (i.e., mean) pre- and post-breach betas are shown in absolute (Abs) and percentage (%) terms.

	Regular			Upside			Downside		
Event	Pre	Abs	%	Pre	Abs	%	Pre	Abs	%
1	0.835	0.163	19.47	0.962	-0.267	-27.74	0.908	0.189	20.78
2	0.770	0.073	9.50	0.634	-0.154	-24.35	0.646	-0.045	-7.00
3	1.071	-0.181	-16.88	0.969	-0.280	-28.88	0.645	-0.092	-14.24
4	0.844	-0.032	-3.80	0.555	-0.032	-5.73	0.514	0.010	1.94
5	1.042	0.317	30.38	1.767	0.100	5.68	-0.020	0.309	n.m.
6	1.720	-0.069	-4.02	0.915	0.278	30.42	1.995	-0.099	-4.94
7	1.031	0.055	5.32	1.025	0.100	9.80	1.069	0.000	-0.04
8	1.104	0.078	7.04	0.827	0.187	22.56	1.403	-0.023	-1.63
9	1.129	0.018	1.57	1.213	-0.135	-11.13	1.168	0.049	4.22
10	0.989	0.032	3.28	1.039	0.004	0.39	1.003	0.035	3.47
11	1.715	-0.513	-29.93	1.785	-1.002	-56.13	1.209	-0.044	-3.61
12	1.161	0.060	5.13	1.108	0.085	7.70	1.223	0.122	10.00
13	1.394	-0.156	-11.19	1.400	-0.324	-23.12	1.148	-0.015	-1.28
14	0.781	0.063	8.12	0.969	0.166	17.08	0.700	0.055	7.84
15	0.965	0.027	2.79	0.915	-0.050	-5.49	1.366	-0.074	-5.38
16	2.101	0.094	4.48	2.736	0.288	10.53	1.561	0.022	1.39
17	1.757	0.228	13.00	2.466	0.124	5.01	1.458	0.253	17.35
18	1.814	1.262	69.57	2.588	1.926	74.39	1.209	1.772	146.56
19	-0.409	0.662	n.m.	-0.072	1.306	n.m.	0.538	0.471	87.49
20	0.827	0.130	15.78	0.822	0.156	18.97	0.983	0.082	8.33
21	0.897	0.057	6.40	0.807	-0.064	-7.94	0.808	0.049	6.11
22	1.086	0.043	3.95	1.071	0.083	7.76	0.951	0.000	0.04
23	0.731	-0.033	-4.45	0.565	-0.005	-0.93	0.722	-0.034	-4.68
24	1.784	-0.025	-1.42	1.885	0.043	2.30	2.191	0.062	2.84
25	1.180	0.036	3.01	1.308	0.097	7.41	1.142	-0.041	-3.56
26	1.086	-0.029	-2.68	0.979	0.037	3.80	1.340	0.039	2.94
27	1.103	-0.038	-3.41	-0.318	0.067	21.14	1.745	0.933	53.47
28	1.487	-0.312	-20.96	1.767	-0.528	-29.87	1.284	-0.141	-10.97
29	1.026	-0.008	-0.77	1.461	-0.201	-13.74	1.040	0.151	14.51
30	0.570	0.007	1.23	0.580	0.084	14.56	0.621	-0.004	-0.67
31	0.690	0.073	10.61	0.742	-0.131	-17.68	0.578	0.175	30.23
32	1.054	0.031	2.97	1.125	-0.084	-7.47	0.992	0.059	5.99
33	1.354	-0.030	-2.19	1.074	0.072	6.74	1.204	-0.040	-3.30
34	1.253	0.009	0.69	1.048	0.119	11.35	1.032	0.112	10.85
35	0.852	0.040	4.72	0.724	-0.004	-0.50	0.883	0.145	16.44
36	1.013	-0.056	-5.48	1.151	0.007	0.59	1.163	-0.082	-7.07

Table 9 continued from previous page

	Regular			Upside			Downside		
37	1.851	0.075	4.07	1.654	0.061	3.67	1.670	-0.019	-1.16
38	1.494	0.009	0.63	1.556	-0.093	-5.96	1.392	0.091	6.55
39	1.550	0.011	0.70	1.619	0.168	10.38	1.454	0.133	9.16
40	0.677	-0.040	-5.98	0.574	0.034	5.96	0.914	-0.098	-10.69
41	1.334	0.119	8.93	1.153	0.250	21.65	1.517	0.083	5.44
42	0.886	-0.030	-3.37	0.964	0.026	2.65	0.982	-0.049	-4.95
43	0.912	0.100	10.92	0.927	0.057	6.10	0.850	0.162	19.03
44	0.857	0.202	23.58	0.831	0.114	13.72	0.921	0.077	8.39
45	0.988	-0.005	-0.54	1.192	-0.043	-3.57	0.886	0.009	1.05
46	0.832	0.017	2.05	0.833	-0.030	-3.62	0.796	-0.018	-2.29
47	1.256	0.023	1.84	1.118	-0.019	-1.73	1.228	-0.014	-1.13
48	1.037	-0.004	-0.40	1.159	0.059	5.05	1.043	-0.063	-6.00
49	1.189	0.086	7.20	1.294	-0.083	-6.39	1.206	-0.219	-18.15
50	1.350	-0.013	-1.00	1.477	-0.038	-2.59	1.331	0.007	0.51
51	0.981	-0.024	-2.40	0.856	-0.019	-2.20	1.099	-0.018	-1.66
52	1.317	-0.035	-2.65	1.519	-0.139	-9.18	1.432	-0.162	-11.33
53	1.488	-0.035	-2.36	1.852	-0.231	-12.49	1.397	0.077	5.49
54	0.645	0.030	4.68	0.600	0.031	5.24	0.777	0.071	9.17
55	0.787	0.134	17.00	0.733	0.079	10.75	0.826	0.151	18.28
56	1.081	-0.124	-11.50	1.058	-0.228	-21.57	1.075	-0.018	-1.66
57	2.068	-0.427	-20.63	2.223	-0.519	-23.34	2.204	-0.416	-18.89
58	0.822	-0.138	-16.76	1.000	-0.331	-33.09	0.722	0.727	100.72
59	1.215	-0.011	-0.90	1.166	0.017	1.43	1.061	0.149	14.03
60	2.241	-0.056	-2.48	1.802	-0.067	-3.72	1.897	0.069	3.63
61	1.535	-0.083	-5.38	1.678	-0.333	-19.85	1.392	0.095	6.84
62	1.221	0.016	1.29	1.372	0.308	22.41	1.284	0.013	1.02
63	0.939	-0.033	-3.46	0.897	-0.030	-3.35	1.166	-0.106	-9.12
64	1.094	-0.017	-1.56	1.108	0.061	5.55	0.979	-0.009	-0.92
65	0.832	-0.036	-4.35	0.935	-0.032	-3.44	0.306	0.031	10.01
66	1.104	-0.049	-4.47	1.157	-0.039	-3.38	1.120	-0.166	-14.82
67	1.401	-0.097	-6.91	1.216	-0.115	-9.42	1.394	-0.105	-7.51
68	0.763	0.176	23.02	-0.010	0.562	n.m.	1.072	-0.215	-20.06
69	1.136	-0.063	-5.54	1.451	0.190	13.07	1.389	0.122	8.77
70	1.028	-0.004	-0.43	1.178	0.224	19.05	1.128	-0.266	-23.55
71	0.830	0.176	21.26	0.744	0.379	50.92	1.234	0.225	18.27
72	0.860	-0.006	-0.70	0.663	-0.066	-9.89	0.936	0.049	5.28
73	0.915	0.144	15.76	1.032	0.258	24.96	0.524	-0.043	-8.18
74	0.819	-0.039	-4.74	1.109	-0.188	-16.92	0.898	-0.080	-8.96
75	0.852	0.135	15.79	0.979	0.210	21.42	0.755	0.157	20.73
76	0.759	0.088	11.65	0.822	0.366	44.50	0.657	-0.039	-5.96
77	0.777	-0.008	-1.00	1.007	-0.113	-11.27	0.286	0.148	51.71
78	1.229	-0.007	-0.61	1.071	0.238	22.18	1.167	-0.042	-3.57
79	1.029	-0.060	-5.79	1.060	-0.068	-6.42	0.766	0.103	13.51

Table 9 continued from previous page

	Regular			Upside			Downside		
80	0.562	0.069	12.34	0.360	0.086	23.76	0.517	-0.003	-0.54
81	1.079	0.086	7.96	1.206	0.130	10.75	0.892	0.181	20.33
82	1.124	0.041	3.64	0.641	0.014	2.15	1.476	0.044	3.00
83	0.919	0.001	0.08	0.827	0.069	8.29	0.889	0.123	13.85
84	1.330	0.177	13.32	1.081	0.077	7.08	1.700	0.052	3.04
85	1.255	0.209	16.65	-0.101	0.062	61.76	1.332	0.403	30.24
86	0.618	-0.150	-24.29	0.692	-0.533	-77.00	1.231	-0.321	-26.07
87	0.859	-0.045	-5.24	0.937	-0.230	-24.51	0.593	-0.033	-5.52
88	1.138	0.026	2.33	1.237	0.013	1.06	0.968	0.152	15.71
89	1.122	-0.322	-28.73	0.771	-0.620	-80.43	2.335	-0.249	-10.66
90	1.054	0.088	8.37	1.411	0.114	8.11	1.250	0.086	6.89
91	1.052	-0.037	-3.47	0.798	-0.109	-13.63	1.033	-0.175	-16.91
92	0.943	-0.208	-22.07	0.537	-0.018	-3.43	1.372	-0.421	-30.67
93	1.460	-0.029	-2.00	0.969	0.015	1.52	1.375	0.040	2.87
94	1.148	-0.068	-5.89	1.051	0.141	13.43	1.137	-0.054	-4.72
95	0.981	0.032	3.25	1.113	0.104	9.33	0.870	-0.042	-4.78
96	0.645	-0.068	-10.62	0.688	0.145	21.07	0.445	0.015	3.43
97	1.335	-0.058	-4.31	1.888	-0.128	-6.81	1.797	-0.376	-20.91
98	0.933	0.134	14.35	0.615	-0.185	-30.06	1.140	0.046	4.00
99	2.251	-0.066	-2.91	2.266	-0.397	-17.52	2.168	-0.390	-17.98
100	1.193	-0.047	-3.92	1.442	-0.124	-8.56	1.347	-0.048	-3.55
101	0.502	0.140	27.78	0.079	0.057	71.51	0.768	-0.116	-15.09
102	0.770	0.050	6.48	0.634	-0.029	-4.52	1.068	-0.254	-23.83
103	0.655	-0.090	-13.81	0.647	-0.111	-17.16	0.667	-0.004	-0.55
104	1.404	-0.128	-9.10	-0.670	-0.332	-49.49	2.039	-0.278	-13.65
105	1.120	-0.349	-31.18	1.032	-0.314	-30.45	1.056	-0.337	-31.88
106	0.640	-0.025	-3.83	0.500	0.190	37.91	0.804	0.008	1.03
107	0.882	0.186	21.06	0.742	0.275	37.07	1.284	-0.016	-1.21
108	1.354	-0.209	-15.41	0.700	-0.252	-36.03	1.012	-0.225	-22.25
109	0.947	0.150	15.88	1.136	0.190	16.72	0.724	0.416	57.43
110	1.561	-0.170	-10.92	1.319	0.056	4.28	2.371	-0.403	-17.02
111	1.329	0.042	3.15	1.224	-0.006	-0.47	1.472	-0.014	-0.92
112	1.208	0.091	7.55	1.691	-0.167	-9.88	1.389	0.022	1.59
113	0.973	0.114	11.70	1.137	0.174	15.33	0.758	0.300	39.57
114	0.946	-0.414	-43.80	0.308	-0.344	n.m.	0.141	-0.526	n.m.
115	1.106	0.040	3.60	1.324	-0.134	-10.16	1.169	0.183	15.63
116	0.526	0.092	17.53	0.563	0.008	1.40	0.594	0.136	22.90
117	0.815	0.006	0.77	0.491	0.001	0.29	0.904	0.039	4.30
118	0.720	0.007	1.03	0.965	-0.353	-36.55	0.096	0.359	374.65
119	1.139	-0.148	-12.95	0.855	-0.192	-22.39	1.492	-0.269	-18.04
120	1.181	-0.335	-28.33	1.376	-0.235	-17.07	1.260	-0.622	-49.38
121	1.362	-0.302	-22.17	1.577	-0.404	-25.66	1.275	-0.304	-23.82
122	1.144	-0.075	-6.58	1.147	-0.148	-12.88	1.191	-0.053	-4.46

Table 9 continued from previous page

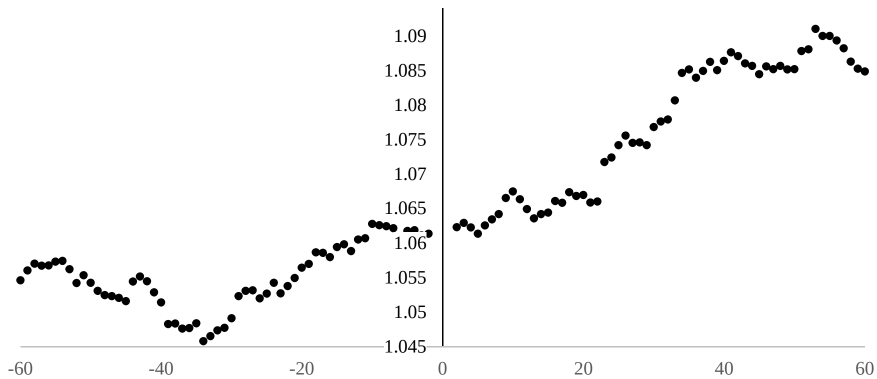
	Regular			Upside			Downside		
123	1.394	0.047	3.35	1.211	0.336	27.71	1.617	-0.057	-3.55
124	1.113	0.050	4.47	0.908	0.086	9.44	1.458	0.045	3.10
125	0.964	0.004	0.45	0.962	-0.062	-6.43	1.027	-0.042	-4.13
126	1.093	-0.036	-3.27	0.842	0.087	10.35	1.314	0.072	5.51
127	0.975	0.002	0.21	0.810	0.108	13.39	0.955	0.028	2.95
128	0.844	0.055	6.55	0.946	-0.451	-47.71	0.584	0.344	58.93
129	0.978	0.029	2.93	1.029	-0.064	-6.21	1.057	0.097	9.20
130	0.721	0.000	0.01	0.688	-0.021	-3.10	0.579	-0.026	-4.42
131	1.045	0.138	13.25	1.183	0.230	19.41	1.312	0.118	9.02
132	1.182	0.141	11.93	1.535	0.198	12.91	0.837	0.031	3.76
133	0.822	0.011	1.34	0.268	0.196	73.07	0.650	0.056	8.64
134	0.672	0.150	22.31	0.741	0.193	26.09	0.612	0.001	0.13
135	1.458	0.176	12.08	1.384	0.053	3.86	1.770	0.103	5.82
136	1.033	-0.010	-1.01	1.064	-0.003	-0.25	1.107	-0.037	-3.33
137	0.643	0.040	6.16	0.806	0.037	4.55	0.528	-0.057	-10.88
138	1.146	0.081	7.08	1.473	-0.008	-0.56	1.193	0.049	4.10
139	0.887	0.012	1.36	0.819	0.091	11.11	1.152	-0.222	-19.30
140	0.943	-0.024	-2.50	1.022	-0.051	-5.01	1.036	-0.010	-0.93
141	0.935	0.324	34.66	0.335	0.101	30.18	0.772	0.647	83.84
142	0.890	-0.071	-7.97	0.957	-0.397	-41.46	0.832	0.174	20.88
143	0.601	0.008	1.26	0.479	0.053	11.10	0.634	-0.024	-3.77
144	1.652	-0.083	-5.01	1.007	-0.049	-4.83	2.048	0.008	0.37
145	0.952	0.020	2.08	1.018	0.065	6.35	0.996	-0.127	-12.78
146	0.885	0.018	2.01	0.857	-0.106	-12.41	0.887	0.112	12.58
147	1.239	0.050	4.01	1.911	0.258	13.47	1.014	-0.090	-8.88
148	0.873	-0.182	-20.81	0.890	-0.278	-31.20	0.911	-0.262	-28.74
149	0.902	0.565	62.68	-0.567	0.659	n.m.	1.000	0.611	61.06
150	1.465	0.102	6.98	1.455	0.116	7.95	1.515	-0.019	-1.23
151	1.322	-0.154	-11.66	1.659	-0.431	-25.97	1.709	0.101	5.91
152	1.174	-0.131	-11.15	1.172	-0.254	-21.64	1.232	0.029	2.39
153	0.551	0.102	18.46	0.690	0.042	6.08	0.801	0.106	13.29
154	0.950	0.108	11.33	1.032	-0.046	-4.43	1.109	0.204	18.44
155	1.300	0.181	13.91	1.283	0.283	22.02	1.110	0.379	34.13
156	0.429	0.955	222.48	0.187	0.050	26.99	0.687	0.624	90.80
157	1.397	0.065	4.68	1.068	0.353	33.02	1.102	-0.017	-1.55
158	1.274	-0.027	-2.15	1.212	0.109	8.96	0.964	0.262	27.19
159	1.114	0.081	7.24	1.214	-0.003	-0.26	0.793	0.044	5.60
160	1.099	0.003	0.26	1.024	0.111	10.88	0.889	0.247	27.73
161	1.085	0.187	17.28	0.745	0.262	35.19	1.192	0.179	14.98
162	1.003	-0.189	-18.85	0.982	-0.350	-35.66	1.032	-0.347	-33.65
163	1.579	0.279	17.63	1.770	-0.106	-6.01	1.753	0.640	36.52
164	1.274	-0.050	-3.96	1.167	0.016	1.33	1.221	-0.174	-14.27
165	0.972	-0.050	-5.17	0.876	-0.265	-30.26	1.220	-0.101	-8.27

Table 9 continued from previous page

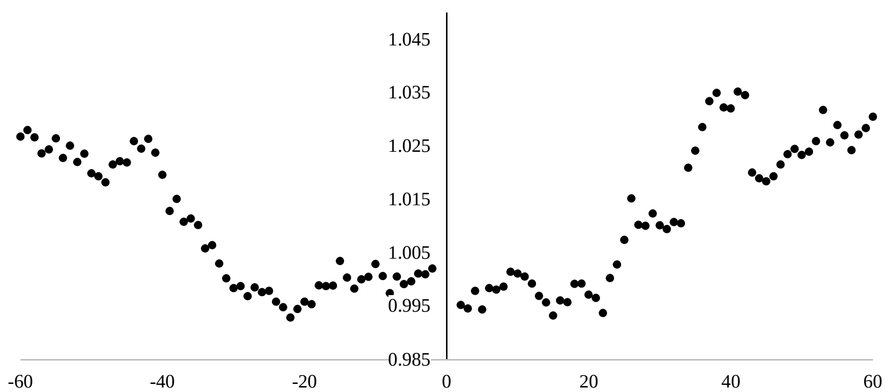
	Regular			Upside			Downside		
166	0.248	0.212	85.61	0.300	-0.029	-9.75	0.230	0.458	198.62
167	1.192	-0.134	-11.25	1.045	-0.208	-19.87	1.343	-0.207	-15.44
168	1.440	-0.172	-11.93	2.212	0.002	0.09	1.333	-0.448	-33.63
169	1.431	-0.329	-23.02	1.375	-0.479	-34.86	1.352	-0.286	-21.17
170	1.157	-0.090	-7.78	1.205	-0.291	-24.15	0.957	-0.078	-8.11
171	1.360	-0.193	-14.16	1.426	-0.217	-15.23	1.505	-0.189	-12.59
172	0.808	-0.005	-0.63	0.929	-0.073	-7.85	-0.003	0.067	n.m.
173	1.030	-0.116	-11.29	0.707	-0.174	-24.60	1.086	0.042	3.83
174	0.350	0.037	10.70	0.322	0.011	3.44	-0.050	-0.089	-179.00
175	1.320	-0.040	-3.02	1.292	-0.031	-2.44	1.216	-0.071	-5.83
176	0.872	0.291	33.34	0.568	0.375	66.03	0.615	0.385	62.60
177	0.694	0.202	29.14	0.652	0.319	48.88	0.658	0.344	52.32
178	1.442	-0.408	-28.30	0.332	-0.104	-31.22	1.468	-0.628	-42.76
179	0.921	0.043	4.72	0.800	0.010	1.29	1.127	0.030	2.65
180	0.873	-0.044	-5.09	0.886	-0.053	-5.94	0.820	-0.164	-19.97
181	0.837	0.506	60.45	0.951	0.475	49.94	0.265	0.826	311.31
182	1.029	-0.004	-0.42	0.972	-0.112	-11.50	1.373	-0.075	-5.46
183	0.718	-0.034	-4.76	0.971	-0.118	-12.10	0.695	-0.135	-19.50
184	0.830	-0.033	-3.94	0.716	0.084	11.76	0.780	0.020	2.62
185	1.610	0.051	3.20	1.681	-0.177	-10.56	1.450	0.221	15.26
186	0.817	0.088	10.75	0.884	-0.152	-17.23	1.028	-0.108	-10.47
187	0.779	-0.040	-5.17	0.787	0.019	2.36	0.666	-0.052	-7.77
188	1.067	0.056	5.24	0.996	-0.034	-3.45	0.909	0.218	23.96
189	0.883	-0.055	-6.19	0.949	-0.107	-11.28	0.834	-0.131	-15.73
190	0.883	0.126	14.24	0.551	0.267	48.51	1.181	0.110	9.35
191	0.887	0.150	16.92	0.920	0.206	22.37	0.750	0.309	41.14
192	0.819	0.139	17.00	0.594	0.275	46.28	0.492	-0.023	-4.59
193	1.922	0.107	5.58	1.762	-0.102	-5.80	1.499	-0.024	-1.61
194	0.821	-0.054	-6.54	0.815	-0.022	-2.68	0.919	-0.018	-1.96
195	0.947	0.067	7.07	1.022	-0.012	-1.19	0.797	0.187	23.50
196	1.121	0.081	7.26	1.219	0.004	0.34	1.132	0.326	28.78
197	1.213	0.064	5.31	1.241	0.016	1.30	1.392	0.068	4.90
198	1.364	-0.007	-0.51	1.282	-0.015	-1.14	1.357	0.065	4.76
199	0.467	0.013	2.80	0.659	0.154	23.45	0.707	-0.026	-3.72
200	0.259	0.192	73.98	0.294	0.152	51.72	0.445	0.093	20.92
201	0.300	0.029	9.70	0.359	0.041	11.32	0.470	-0.113	-24.06
202	0.501	0.129	25.69	-0.346	0.247	71.31	1.348	-0.331	-24.53
Mean	1.055	0.022	2.07	1.009	0.004	0.38	1.066	0.031	2.92

F Descriptive Statistics: Daily Pre- and Post-Breach Betas Averaged Across Events

Graph 1: Daily Mean Regular Beta



Graph 2: Daily Mean Upside Beta



Graph 3: Daily Mean Downside Beta