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MARKET VALUE OF VOLUNTARY DISCLOSURES CONCERNING INFORMATION SECURITY[1]

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Abstract

Information security is a fundamental concern for corporations operating in today's digital economy. The number of firms disclosing items concerning their information security on reports filed with the U.S. Securities and Exchange Commission (SEC) has increased in recent years. A question then arises as to whether or not there is value to the voluntary disclosures concerning information security. Thus, the primary objective of this paper is to assess empirically the market value of voluntary disclosures of items pertaining to information security. Based on a sample of 1,641 disclosing and 19,266 non-disclosing firm-years in a cross-sectional pooled model, our primary findings provide strong evidence that voluntarily disclosing items concerning information security is associated positively with the market value of a firm. These findings are based on the use of a market-value relevance model, as well as a bid-ask spread analysis. The study's findings are robust to alternative statistical analyses. The findings also provide support for the signaling argument, which states that managers disclose information in a manner consistent with increased firm value. Finally, the study findings provide some insight into the strategic choice that firms make regarding voluntary disclosures about information security.

Keywords: Information security, market value, voluntary disclosures, selection-bias, bid–ask spread

Introduction

Due in part to the rise of the Internet and the corresponding growth in e-commerce, a firm's information related assets are now among its most valuable assets. Unfortunately, these assets are vulnerable to theft, alteration, and denial of timely access. Indeed, information security breaches are capable of having a significant negative effect on the value of a corporation (see Campbell et al. 2003; Cavusoglu et al. 2004; Ishiguro et al. 2006). Thus, it is not surprising to find corporations spending large sums of money on information

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security related activities designed to prevent, detect, and correct information security breaches (see Berinato 2007; Latimer-Livingston and Tracy 2008; Tam and Lawton 2007). In fact, information security has become a fundamental concern for modern corporations (e.g., Cangemi 2001; Gordon and Loeb 2002; Park et al. 2006; Pavlou et al. 2007; Straub and Welke 1998).[2] Furthermore, evidence exists that firms have increased their voluntary disclosures regarding information security (Gordon et al. 2006). A question then arises as to whether or not there is value to these voluntary disclosures concerning information security.

The primary objective of this paper is to assess empirically the market value to stockholders of voluntary disclosures (i.e., disclosures beyond what is required by regulation) concerning information security. To our knowledge, this is the first paper that comprehensively investigates this issue. For the purpose of this paper, voluntary disclosures concerning information security are based on the disclosure terms shown in Table 1. Using a sample of 1,641 disclosing and 19,266 non-disclosing firm-years in a cross-sectional pooled model, our findings provide statistically significant evidence that voluntary disclosures about information security have a positive effect on the market value of a firm. In addition, we find that this positive effect is especially pronounced among firms in industries that rely heavily on e-commerce. We also find that the voluntary disclosure regarding proactive security activities results in a pronounced positive effect on market value. Moreover, our findings provide support for the signaling argument, which states that managers disclose information to revise investors' beliefs in a manner consistent with increasing firm value. These findings should be of particular interest to those responsible for strategic choices regarding voluntary disclosure decisions, as well as those responsible for securing corporate funds for information security activities.

The fundamental methodology used in our analysis is based on the value-relevance design. However, we also conducted a bid-ask spread analysis to check the impact of voluntary disclosures concerning information security. The results related to the bid-ask spread are consistent with those found under the value-relevance analysis. In addition, the results are robust to various models (e.g., matched-pairs, returns analysis, and selection-bias) and additional statistical tests designed to check the assumptions underlying these models.

The remainder of the paper is organized as follows. In the next section, we develop the basic argument relating the market value to voluntary disclosures concerning information security in the annual reports filed with the Securities and Exchange Commission (SEC). In the third section of this paper, the empirical study designed to test the basic argument developed in the second section is described. In the fourth section, the findings from the primary empirical study are presented. The fifth section is where additional analyses are provided, as well as checks of the robustness of the findings presented in the fourth section. The additional analyses section also includes an exploratory study of the types of information security disclosures and industry analyses. A discussion of the study's overall results is presented in the sixth section. Limitations of our study and directions for future research are suggested, along with concluding comments, in the seventh and final section.

Basic Argument

Voluntary disclosures in the annual report concerning information security allow a corporation to provide signals to the marketplace that the firm is actively engaged in preventing, detecting, and correcting security breaches. These signals should increase a firm's net present value (NPV) and, in turn, its stock market value in a number of ways.[3] For example, these signals should increase consumers' trust to engage in e-commerce by lowering the uncertainty of doing business online that is associated with information security concerns (Pavlou et al. 2007).[4] An increase in consumers' trust to engage in e-commerce with a particular firm should increase the firm's expected net cash flows and, in turn, the firm's NPV and its market value.

Voluntary disclosures pertaining to information security also could serve to mitigate potential litigation costs due to the reduction in liability resulting from the increased transparency associated with disclosures (e.g., Kasznik and Lev 1995; Skinner 1997). Additionally, economically rational computer hackers seeking bounty might shy away from devoting resources to attack systems in which the probability of a successful attack has been lowered and the cost of a successful attack has been raised (see Schecter and Smith 2003). Either of these two situations should result in a firm being able to hold on to more of its cash flows and, in turn, increase the firm's NPV and its market value.

[2]The term *information security* as used in this paper relates to activities that are designed to protect the confidentiality of private information, ensure the availability of information to authorized users, and protect the integrity of information (see Gordon and Loeb 2002, p. 439; Pfleeger and Pfleeger 2006).

[3]The stock market value of a firm is directly related to the NPV of the firm's discounted expected future cash flow (e.g., Barth 2000).

[4]Casey (2004) writes about trust building with specific reference to disclosing information security breaches.

Table 1. List of Keywords Used in Annual Filings Search

Keyword	Number of Instances
Security Measure*	2,211
Authentication	1,823
Encryption	1,411
Computer Virus*	1,277
Security Breach*	1,209
Disaster Recovery	1,182
Information Security	937
(Network or Computer) Join(1) Security	906
Access Control	595
Intrusion	573
Business Continuity	406
Security Management	224
Hacker	204
Security Monitoring	188
Denial of Service	158
Cyber Security	26
Cyber Attack*	19
Security Incident	16
Infosec	7
Security Expenditure*	7
Computer System Security	3
Cybersecurity	3
Computer Breach*	2
Computer Intrusion*	1

*Represent wild-card searches (e.g., both "security measure" and "security measures" were used).

Finally, voluntary disclosures regarding a firm's information security could lower the firm's cost of capital by reducing the information asymmetry between a firm's management and its investors, as well as among the investors (see Botosan 1997; Healy and Palepu 2001; Sengupta 1998; Verrecchia 1983, 2001). Under this lower cost of capital scenario, a firm's NPV and, in turn, its market value will increase because the rate used to discount expected future cash flows will be lower (i.e., the discount rate is based on the firm's cost of capital). If firms with opportunities to generate high returns could not distinguish themselves from corporations that only have opportunities to generate low returns, investors would fund both types of firms at the same level, which is the level associated with low returns.[5] Thus, firms with opportunities to generate high returns due to their voluntary disclosures concerning information security will do so in order to signal their high return potential to the market.[6] Of course, if one firm could benefit from voluntary disclosures concerning information security, other firms presumably could do the same. In other words, the "unraveling" principle suggests full disclosure in equilibrium by all firms (e.g., see Milgrom 1981; Grossman 1981).[7] However, Suijs (2007, p. 392) provides a

[5]This result is similar to the lemon's problem discussed by Akerlof (1970).

[6]Legislation on information security is restricted currently to selected industries and events. For example, the Health Insurance Portability and Accountability Act (HIPAA) requires healthcare firms to ensure that a patient's information is protected, while the Gramm-Leach-Bliley Act (GLB) mandates that financial and banking industry firms employ controls to safeguard each customer's information. Implementation of these controls is not, however, part of the public reporting (i.e., disclosure) requirements that firms need to follow in their filings with the SEC.

[7]Milgrom (1981) and Grossman (1981) have shown conditions under which each firm, fearing that nondisclosure will be interpreted as hiding the worst possible news, will rationally choose to disclose information voluntarily. In this sense, each firm's choice on whether or not to disclose information is said to "unravel."

cogent argument that "full disclosure need not apply if firms are uncertain about investor response to the disclosed information."[8] Thus, voluntary disclosure of items relating to information security likely would take place for some, but not all, firms.

In essence, managers need to make a strategic choice as to whether or not voluntary disclosures concerning information security will provide net benefits (in terms of market value) to their firms.[9] The clear trend toward more voluntary disclosures of items regarding information security (e.g., Gordon et al. 2006) suggests that managers recognize this choice. To date, however, no one has assessed empirically whether or not decisions regarding voluntary disclosures result in the desired outcome of increased firm value. In order to fill this void, we test empirically the value-relevance of voluntary disclosures concerning information security. Specifically, we conducted an exploratory empirical study to test the basic argument below:

> **Voluntary disclosures concerning information security, in the annual reports filed with the SEC, will be associated positively with increases in the stock market value of those firms making such disclosures.**

Empirical Study

Sample

The annual reports (i.e., 10-Ks, 10-KSBs, and 20-Fs), filed with the SEC, were analyzed for voluntary disclosures pertaining to information security.[10] This type of analysis has been widely used in other voluntary disclosure studies (e.g., Bhojraj et al. 2004; Botosan 1997; Bryan 1997). We examined all publicly traded firms that filed an annual report with the SEC between the years 2000 and 2004. The initial year of data considered was 2000 for the following two reasons. First, by the end of 2000, computer and information security issues were a major concern for most organizations, due to extensive media coverage of security breaches (Genusa 2001). Second, by selecting the year 2000 as the lower cut-off, we avoid potential confounding of results related to Y2K activities.

To collect the sample of firms that made voluntary disclosures concerning information security, the 24 keywords (e.g., security measure, authentication, computer virus, and security breach) detailed in Table 1 were used in a meta-search engine. The number of occurrences for each of the keywords is also shown in Table 1.[11] All the annual reports filed with the SEC during the period 2000–2004 were searched.[12]

A firm was included for further examination if its SEC filing contained one or more of these keywords. Additionally, 200 words surrounding the mention of a keyword were recorded

[8] Suijs (2007) provides an excellent discussion and proof of this argument as well as a comprehensive discussion of many related papers (see Dutta and Trueman 2002; Dye 2001).

[9] In other words, potential costs are associated with voluntary disclosure. For example, the voluntary disclosure related to a firm's information security could be interpreted as signaling to the marketplace that the firm is concerned with vulnerabilities posed by the firm's actual and/or potential deficiencies in information security (Genusa 2001). Voluntary disclosure also creates potential proprietary and information gathering costs for firms, as well as the possibility of competition exploiting the information. These costs could result in a decrease in a firm's NPV and, in turn, its market value. Thus, it is important for firms to consider the cost–benefit aspects of voluntary disclosure (see Benston 1969).

To the extent that all firms are subject to information security risks, a firm's disclosure provides market participants with a signal about the firm's commitment to addressing those risks.

[10] A major advantage of using SEC filings is that the data is publicly available, thereby permitting replication of this study. Outside of these SEC filings, there is little publicly available information regarding information security of a firm. We confirmed this by searching press releases and trade publications (using the ABI/INFORM, LexisNexus, and Factiva databases), as well as the reports that are sent annually to a firm's shareholders.

[11] "Security investments" was also used as a keyword. However, due to the fact that "stock investments" also are referred to as security investments, this keyword identified a host of annual filings that were not related to information security. Hence, this keyword phrase was dropped. Additionally, keyword phrases (e.g., "intrusion detection") are picked up by the use of single keywords (e.g., "intrusion").

We also did a keyword search of the phrase "information assurance" for the years 2000–2004 and found 65 hits. Of the 65 occurrences, 50 relate to firms that are offering services or products related to information assurance. The 15 other occurrences relate to subsidiaries, clients, or potential market opportunities. Thus, none of the "information assurance" disclosures is about the firm's information security.

[12] 10-K is the official annual financial document that companies file with the U.S. SEC. It contains detailed financial statements and financial footnotes. 10-KSB is a modified 10-K annual report, which is filed by companies whose revenues are less than (US) $ 25 million, that are a U.S. or Canadian issuer, that are not an investment firm and, if they are a majority owned subsidiary, then the parent is also a small business issuer. Finally, 20-F is the annual form that is required to be submitted by foreign private holders issuing equity in the United States pursuant to Section 13 or 15(d) of the Securities Exchange Act 1934 (http://www.sec.gov/about/laws/sea34.pdf).

and downloaded into a database. Based on the keywords, we found 11,160 firm-year reports that were reduced to 6,485 firm-year reports after eliminating the firms with missing ticker symbols and those whose fiscal year did not coincide with the calendar year (Table 2, Panel A).

All 6,485 firm-year filings were read to determine whether or not the disclosures were actually related to information security. In other words, the mere mention of one of the key terms shown in Table 1 does not necessarily imply that the disclosures are about information security. For example, some firms mentioned the term "security measure," which referred to the security related to protecting their physical inventory. Our definition of "voluntary disclosures concerning information security" is based on disclosure of one or more of the terms mentioned in Table 1, provided the term(s) relate specifically to information security. The sample of firms that provide at least one information security related disclosure is 2,479 firm-years (Table 2, Panel A). A firm (both disclosing and non-disclosing) was included in the final sample for analysis if all of its financial information was available, if the firm had a positive book value (e.g., Collins et al. 1999; Hayn 1995), if the firm industry classification was not missing, and if the firm was not an outlier (e.g., Collins et al. 1997; Kothari and Shanken 2003, p. 76).[13]

The final sample of firms consisted of 1,641 disclosing firm-years and 19,266 non-disclosing firm-years (see Table 2, Panel B). This sample consists of 35 unique industries, including a group of firms that are not classified (Table 11 lists the complete breakdown of the industries). The industry membership mapping is based on the two digit SIC code used by Fama and French (1997) and the industry classification as provided by Bhojraj et al. (2003).

Table 2, Panel C, shows that overall there are 5,766 unique firms in the sample, of which 4,970 (86.19 percent) do not have disclosures related to information security. Of the 796 disclosing firms, 412 firms (51.76 percent) provided disclosures concerning information security more than once (see Table 2, Panel D).

Research Design

Our basic research design is the value relevance methodology, a well-established research methodology for investigating various factors associated with firm value. The basic premise in this type of research is that the primary users of a firm's annual report are investors who are interested in information that can help assess the market value of the firm's equity. Consequently, valuation is a key input to, and output of, investors' decisions (Barth 2000). Thus, the focus of this type of research is on exploring the association between reported items (financial and/or nonfinancial) and the firm's equity value (Barth et al. 2001).

In the value-relevance paradigm, studies are concerned with whether or not information of interest is useful in explaining a firm's market value or return over a long period of time (e.g., a year). Given the long time period aspect of value-relevance studies, they are often called "incremental" association studies. The information of interest is deemed to be value-relevant if its estimated regression coefficient, in a valuation model, is significantly different from zero (Holthausen and Watts 2001). Examples of the value-relevance methodology include the paper by Aboody and Lev (1998), which shows that information concerning capitalization of software development costs has an impact on the market value of firms. This methodology also has been used in a variety of other studies (e.g., Amir and Lev 1996; Barth and Beaver 1998).

Value-relevance studies focusing on incremental association over a long time period (often called "long window") differ from studies focusing on "marginal" information content. Studies focusing on marginal information content are commonly referred to as event (or announcement) studies. Although both types of studies are concerned with the impact of information on the market value of firms, the main question of interest in an event study is whether or not the event (e.g., earnings announcement) provides new information to the market place in a timely fashion. That is, the main issue being addressed in an event study is whether or not the specific event conveys new information to the market place within a short period (i.e., short "window") of time around the event.[14] Hence, in an event study design, a key requirement is the ability to isolate an event from other factors surrounding the event. Event studies have been popular for some time in the accounting and finance literature. More recently they have been used in the information technology and computer security literature (see Agrawal et al. 2006; Campbell et al. 2003; Dos Santos et al. 1993; Gordon et al. 2010; Raghu et al. 2008; Song et al. 2007).

[13] Book value is a proxy for a firm abandonment option or expected future normal earnings, as such negative book values might be an indication of going-concern issues. Data in the top or bottom 1 percentile range for each of our financial variables are considered as influential or outlier observations.

[14] Event studies assume that markets are efficient (at least in the semi-strong form), which means public information is disseminated quickly into the market place. However, as pointed out in the literature, event studies are confounding tests of market efficiency with tests of market value. In addition, there is a large body of literature which points out that financial markets are not nearly as efficient as was once believed (e.g., Shleifer 2000).

Table 2. Summary of Sample Selection Process

Panel A:

	No. of observations (hits) based on all the keywords for 2000-04
Total firm-years	11,160
Missing tickers or non-December fiscal year	**(4,675)**
Valid observations, firm-years	6,485
Non-security related observations	**(4,006)**
Disclosing sample	2,479

Panel B:

	No. of disclosing firms-years	Percent	No. of non-disclosing firm-years	Percent
Total firm-years	2,479	100.00%	25,088	100.00%
Missing Permno	**(563)**	**(22.71%)**		**0.00%**
Firms identified	1,916	77.29%	25,088	100.00%
Missing financial + outliers	(274)	(11.05%)	(5,557)	(22.15%)
Missing industry classification	(5)	(0.20%)	(265)	(1.06%)
Total firm-year sample	**1,641**	**66.04%**	**19,266**	**76.79%**
Sample size				
Disclosers (firm-years)	1,641	7.85%		
Non-disclosers (firm-years)	19,266	92.15%		
Total Sample (firm-years)	20,907	100.00%		

Panel C: Breakdown of Sample by Unique Firms

Disclosures	Unique Firms	Percent of Total
No	4,970	86.19%
Yes	796	13.81%
Total unique firms	5,766	100%

Panel D: Breakdown of Unique Firms Providing Security Disclosures

Number of Disclosures	Unique Firms	Percent of Total
1	384	48.245
2	157	19.72%
3	134	16.83%
4	64	8.04%
5	57	7.16%
Unique firms	796	100%

The value-relevance methodology, as opposed to the event study methodology, is best suited for our study. This is because disclosures related to information security are part of a bundle of that includes many other disclosures released in the annual reports filed with the SEC.

In value-relevance research, both price-levels and returns models are employed. The selection of the most appropriate model (i.e., levels versus returns) depends on the hypothesis of interest and on econometric concerns (Landsman and Magliolo 1988). The main difference between the two types of analyses is that the price-levels model concentrates on determining what is associated with the firm value, while the returns model is concerned with addressing changes in value over a given period of time (Barth et al. 2001) and takes into consideration first-differences (i.e., returns are derived from the difference in stock prices over a given time period—usually a year).[15] The primary question of interest in this study is the *association* of voluntary disclosures concerning information security with firm value. Therefore, we employ a price-levels model in a cross-sectional pooled regression as our primary model.[16]

The research model used in our study is a modified version of the model proposed by Ohlson (1995). This model has been widely used in the literature and is shown in equation (1) below:[17]

$$P_{it} = \beta_0 \times \text{Intercept} + \beta_1 \times \text{Dis}_{it} + \beta_2 \times \text{BVPS}_{it} + \beta_3 \times \text{EPS}_{it} + \beta_4 \times \text{LnAst}_{it} + \beta_5 \times \text{NEG}_{it} + \Sigma\beta_k \times \text{Year}_{it} + \Sigma\beta_j \times \text{Indus}_{it} + \varepsilon_{it} \quad (1)$$

where

P_{it} = Stock price of firm *i* for year *t*, 90 days after fiscal year close

Dis_{it} = Proxy variable for generic disclosure concerning information security. We estimate two regression specifications as follows:
1) Base model without any disclosure variable
2) Generic security disclosure, where Dis = 1 if any disclosure concerning information security, 0 otherwise

EPS_{it} = Earnings per share (basic excluding special items) for firm *i* for year *t*, year-end

BVPS_{it} = Book value of equity divided by number of shares outstanding for firm *i* for year *t*, year-end

LogAst_{it} = Log of total assets of firm *i* for year *t*

NEG_{it} = 1 if EPS is negative for firm *i* for year *t*, 0 otherwise

Year = 1 if current year, 0 otherwise

Ind = 1 if firm is in a particular industry, 0 otherwise

Price, earnings, and the book value of equity were calculated for each firm *i* for each time period *t*. All of the financial data were gathered from the CRSP/Compustat merged annual database for year 2004 and are fiscal year-end values, with the exception of stock price. Book value of the firm is defined as stockholder's equity (Compustat # 216), earnings are basic earnings per share excluding extra items (Compustat # 58) and shares outstanding are proxied by common shares outstanding (Compustat # 25).[18] Market value (MV) for a firm is the price per share multiplied by the number of shares outstanding. Since companies have up to 90 days to "officially" file the annual filings with the SEC, we used a three-month lead price. This lead price is important in our model because the variables of interest (voluntary disclosures concerning information security) are provided in the SEC annual filings. Accordingly, if there were any impact of the voluntary disclosures regarding information security, we needed to select a time when this information was available to the market (i.e., filings with the SEC are publicly available to the investors). Therefore, P_{it} is the price-per-share of the firm three months after the fiscal year-end. Since the data includes the year 2004, we used COMPUSTAT industrial quarterly database (Q1) 2005 to get P_{t+Q1} prices for all firms. Furthermore, we restricted our sample to firms with a fiscal year-end of December. By restricting the sample to those with a December fiscal year end, we easily generated a natural control sample of the firms that did not disclose from all the firms in the CRSP/Compustat database.

As noted previously, the above model is a variant of Ohlson's valuation model, where price, earnings, and book value of equity are scaled by shares outstanding at time *t*. Outstanding shares are used as deflators to minimize the scale effect, since this specification performs the best regardless of the type of scale effect (Barth and Clinch 2009).[19] Even though we used an appropriate deflator to mitigate the scale effect, Christie (1987) documents that scale still could be an issue in the

[15]Specifically, the returns are derived as follows: $(P_t - P_{t-1} + D_t)/(P_{t-1})$, where P_t and P_{t-1} are stock prices at time, *t* and *t-1*, respectively, and D_t is dividend payment at time *t*.

[16]For completeness, however, a returns model was also considered as discussed in the fifth section, "Additional Analysis," of this paper.

[17]As discussed in the fifth section, we also analyze the returns model and find qualitatively similar results.

[18]All of the per share data is adjusted for stock splits and stock dividends.

[19]It should be noted that the suggested deflator is specific to the Ohlson model (Barth and Clinch 2009, see footnote 5).

price-levels model. In this regard, Barth and Kallapur (1996) suggest that "the most effective remedy [to control for scale] is to include a scale proxy as an independent variable" (p. 556). Therefore, we used the log of assets as an additional control for scale effect.

One of the main constraints in using the price-levels model, and more specifically for the cross-sectional pooled research design, is the assumption that coefficients are constant across years and are the same for each firm (Lang and Lundholm 1996). Nevertheless, one of the advantages for panel data (cross-sectional over time) is that dummy variables can be employed to control for the "omitted" variables. Thus, we used time dummy variables to control for temporal effects that might have an impact on the earnings of firms (i.e., exogenous growth in the economy as a whole [see Collins and Kothari 1989]). We also employ industry dummy variables to control for industry specific effects (Aboody et al. 2004). Finally, we employed a dummy variable equal to 1 if a firm has negative earnings in a year, and 0 otherwise, to control for the possibility that the price multiple for firms with negative earnings could differ from firms with positive earnings (Collins et al. 1999).

Results of Primary Analysis

Descriptive Statistics

Summary statistics for the full sample, disclosing firms, and non-disclosing firms, are shown in Table 3, Panels A, B, and C, respectively. Panel A of Table 3 shows that the mean equity market value of the full sample is roughly $3 billion with a range of $140,000 to approximately $476 billion. The mean (median) net earnings of the firms are 48 (44) cents per share while the mean (median) stock price is $15.63 ($12.16) per share. Even though the mean book value of equity is about $1.21 billion, the median for the sample is only $132.90 million, indicating that the sample includes firms with large book values.

For the disclosing firms (see Table 3, Panel B), mean stock price for the five year period is $15.57 per share, while the stock price of non-disclosing firms is $15.63 per share (see Table 3, Panel C). The mean earnings for disclosing firms are 14 cents per share compared to 51 cents per share for the non-disclosing firms. However, the mean values of equity market price, book value, and number of shares outstanding are all greater for the disclosing firms than the non-disclosing firms.

As shown in the correlation matrix (see Table 4), we find positive and significant correlations between price, market values, earnings, and book values. The disclosure variable is positively and statistically significantly related with book-value, market share, and shares outstanding. However, the disclosure variable is negatively correlated (and statistically significant) with stock price and earnings per share. Thus, large firms with lower than average earnings apparently are providing the most security related disclosures. Even though the mean and standard deviation of stock price for the disclosing and non-disclosing firms are similar, the mean earnings for the disclosing firms are about 37 cents (per share) lower than the non-disclosing firms. Therefore, we checked to see if the disclosing firms versus the non-disclosing firms are statistically different based on the sample characteristics. Additional multivariate tests showed that the two samples are statistically different.[20] The main difference between the multivariate two-sample results (controlling for overall α-level of .05) is due to earnings and number of shares outstanding. Thus, we cannot rule out the possibility that disclosing firms are different from non-disclosing firms (i.e., disclosure could be an endogenous variable for our analysis and this possibility will be considered in the next section).

Main Findings

The main results of the pooled regressions are presented in Table 5. In all of the regressions, the dependent variable is the firm's stock price calculated three months after the fiscal year close. In total, we analyze three different regression models. The base case (Model 1, Table 5) is the simple regression of stock price on book value per share (BVPS), earnings per share (EPS), the log of assets (LogAst), and a dummy variable for firms with negative earnings (NEG), along with year and industry dummy controls. A heteroskedasticity check was performed using White's test and it rejected the null hypothesis that the error terms are homoskedastic (White 1980). Therefore, all reported t-statistics are based on an asymptotically consistent robust covariance matrix. As expected, coefficients on BVPS and EPS are positive and statistically significant in the base case with an R^2 of 0.53. The magnitude of the coefficient and the model fit is similar to the findings from previous studies using price-levels models (see Aboody et al. 2004).

We use a generic disclosure measure to explore the association of information security disclosures with firm value (i.e., a dummy variable set equal to 1 if a firm had any disclosures and 0 otherwise). Model 2 (Table 5) shows the result of re-

[20]The results from these additional tests are available from the authors upon request.

Table 3. Descriptive Statistics

Panel A: Full sample of firms

Variable	Mean	Min	Max	Percentile 25th	Percentile 50th	Percentile 75th	SD	N
PRC-3M	15.63	0.10	140.50	4.88	12.16	22.43	13.87	20,907
EPS	0.48	-10.87	9.31	-0.33	0.44	1.45	1.84	20,907
Mkt Val	3,160.15	0.14	476,115.50	58.49	259.15	1,187.87	14,645.76	20,907
Bok Val	1,217.18	0.07	152,027.00	37.23	132.90	557.12	4,899.55	20,907
Asset	7,375.16	0.16	1,520,140.00	86.94	397.87	1,854.86	51,277.20	20,907
Sharesout	123.46	0.02	10,586.36	9.73	25.52	67.60	429.34	20,907
Ann Ret	0.19	-1.00	53.66	-0.28	0.07	0.41	1.00	20,391
Turnover	0.60	0.01	1.09	0.34	0.62	0.87	0.30	20,907
Volat	0.16	0.00	1.98	0.07	0.12	0.20	0.12	20,361
Analys	5.81	0.00	62.00	0.00	2.00	8.00	8.20	20,907
Inst Hold	0.34	0.00	14.78	0.08	0.27	0.54	0.38	18,976

Panel B: Disclosing firms

Variable	Mean	Min	Max	Percentile 25th	Percentile 50th	Percentile 75th	SD	N
PRC-3M	15.57	0.10	118.13	4.82	11.37	22.03	14.23	1,641
EPS	0.14	-10.33	9.03	-0.55	0.16	1.11	1.89	1,641
Mkt Val	4,594.01	1.17	250,277.90	101.94	381.61	1,646.57	17,388.07	1,641
Bok Val	1,720.83	0.77	109,291.00	47.15	150.98	628.52	7,180.91	1,641
Asset	15,909.52	1.94	1,484,101.00	82.99	337.09	1,809.93	97,805.58	1,641
Sharesout	179.93	0.43	6,253.00	17.88	34.91	85.37	528.89	1,641
Ann Ret	0.23	-1.00	18.93	-0.38	0.03	0.44	1.22	1,621
Turnover	0.70	0.01	1.09	0.49	0.76	0.95	0.28	1,641
Volat	0.19	0.01	1.64	0.09	0.15	0.24	0.14	1,619
Analys	7.45	0.00	57.00	1.00	4.00	11.00	9.02	1,641
Inst Hold	0.39	0.00	4.48	0.12	0.32	0.59	0.37	1,507

Panel C: Non-disclosing firms

Variable	Mean	Min	Max	Percentile 25th	Percentile 50th	Percentile 75th	SD	N
PRC-3M	15.63	0.10	140.50	4.88	12.24	22.46	13.84	19,266
Earn per share	0.51	-10.87	9.31	-0.31	0.48	1.47	1.84	19,266
Mkt Val	3,038.02	0.14	476,115.50	55.72	248.05	1,141.07	14,381.97	19,266
Bok Val	1,174.28	0.07	152,027.00	36.70	131.39	552.43	4,651.58	19,266
Asset	6,648.24	0.16	1,520,140.00	87.41	405.12	1,856.20	45,080.54	19,266
Sharesout	118.65	0.02	10,586.36	9.38	24.58	66.33	419.44	19,266
Ann Ret	0.18	-1.00	53.66	-0.27	0.08	0.41	0.98	18,770
Turnover	0.59	0.01	1.09	0.32	0.60	0.86	0.30	19,266
Volat	0.15	0.00	1.98	0.07	0.12	0.20	0.12	18,742
Analys	5.67	0.00	62.00	0.00	2.00	8.00	8.11	19,266
Inst Hold	0.34	0.00	14.78	0.08	0.27	0.53	0.38	17,469

PRC–3M = Stock price of firm *i* for year *t*, 90 days after fiscal year close - $/share
EPS = Earnings per share (basic excluding special items) for firm *i* for year *t*, at year-end - $/share
Mkt Val = Equity market value of firm *i* for year *t*, at year-end – Price fiscal year end × Number of shares outstanding
Bok Val = Book value of equity for firm *i* for year *t*, at year-end – '000,000
Sharesout = Number of shares outstanding for firm *i* for year *t*, at year-end – '000,000
Asset = Total assets of the firm *i* for year *t* at year-end – '000,000
Annret = Annual return of firm *i* for year *t*, cumulated 9 months before *t* to 3 months after *t*
Turnover = Shares turnover computed as $[1-\Pi_t(1-\text{volume traded}_t/\text{total shares}_t)]$ 9 months before *t* to 3 months after *t*
Volat = Standard deviation of monthly returns, 9 mnths before *t* to 3 mnths after *t*
Analys = Number of analysts following for firm *i* for year *t* from I/B/E/S detail file
Inst Hold = Percentage of shares held by institutions for firm *i* for year *t* over total shares outstanding

Table 4. Correlation Matrix for the Variables

	PRC-3M	EPS	BV	Shares	MV	Assets	Annret	Turnover	Volat	Analys	Hold
EPS	0.60 (0.00)***	1.00									
BV	0.28 (0.00)***	0.17 (0.00)***	1.00								
Shares	0.17 (0.00)***	0.08 (0.00)***	0.77 (0.00)***	1.00							
MV	0.30 (0.00)***	0.16 (0.00)***	0.83 (0.00)***	0.86 (0.00)***	1.00						
Assets	0.18 (0.00)***	0.13 (0.00)***	0.69 (0.00)***	0.50 (0.00)***	0.54 (0.00)***	1.00					
Annret	0.23 (0.00)***	0.21 (0.00)***	-0.01 (0.07)*	-0.03 (0.00)***	-0.01 (0.23)q	-0.00 (0.61)	1.00				
Turnover	0.13 (0.00)***	-0.06 (0.00)***	0.06 (0.00)***	0.09 (0.00)***	0.05 (0.00)***	0.03 (0.00)***	0.04 (0.00)***	1.00			
Volat	-0.43 (0.00)***	-0.44 (0.00)***	-0.13 (0.00)***	-0.09 (0.00)***	-0.12 (0.00)***	-0.08 (0.00)***	-0.11 (0.00)***	0.24 (0.00)***	1.00		
Analys	0.45 (0.00)***	0.21 (0.00)***	0.35 (0.00)***	0.36 (0.00)***	0.38 (0.00)***	0.17 (0.00)***	-0.01 (0.10)*	0.34 (0.00)***	-0.14 (0.00)***	1.00	
Hold	0.43 (0.00)***	0.18 (0.00)***	0.06 (0.00)***	0.03 (0.00)***	0.06 (0.00)***	0.01 (0.06)*	0.04 (0.00)***	0.45 (0.00)***	-0.18 (0.00)***	0.51 (0.00)***	1.00
Dis	-0.02 (0.00)***	-0.05 (0.00)***	0.03 (0.00)***	0.03 (0.00)***	0.03 (0.00)***	0.05 (0.00)***	0.01 (0.35)	0.10 (0.00)***	0.07 (0.00)***	0.06 (0.00)***	0.03 (0.00)***

***Significant at 1%; **Significant at 5%; *Significant at 10%; N = 20,907.

PRC–3M = Stock price of firm *i* for year *t*, 90 days after fiscal year close - $/share
EPS = Earnings per share (basic excluding special items) for firm *i* for year *t*, at year-end - $/share
Mkt Val = Equity market value of firm *i* for year *t*, at year-end – Price fiscal year end × Number of shares outstanding
Bok Val = Book value of equity for firm *i* for year *t*, at year-end – '000,000
Sharesout = Number of shares outstanding for firm *i* for year *t*, at year-end – '000,000
Asset = Total assets of the firm *i* for year *t* at year-end – '000,000
Annret = Annual return of firm *i* for year *t*, cumulated 9 months before *t* to 3 months after *t*
Turnover = Shares turnover computed as $[1-\Pi_t(1\text{-volume traded}_t/\text{total shares}_t)]$ 9 months before *t* to 3 months after *t*
Volat = Standard deviation of monthly returns, 9 mnths before *t* to 3 mnths after *t*
Analys = Number of analysts following for firm *i* for year *t* from I/B/E/S detail file
Inst Hold = Percentage of shares held by institutions for firm *i* for year *t* over total shares outstanding

gressing the generic disclosure measure along with the base model variables. The coefficient on the disclosure dummy has a magnitude of 1.035, which is positive and statistically significant at $p < 0.001$ (see Table 5, Model 2). This supports our basic argument that voluntary disclosures concerning information security are value-relevant (i.e., have an impact on the market value of firms). We re-estimate our primary model by excluding firms from the Banking and Finance industries (i.e., a reduced sample), since these are regulated industries with unique characteristics. Failure to exclude the firms in these two industries would bias the β coefficients. Results for generic security disclosures for the reduced sample are detailed in Model 3 (Table 5).[21] As before, the coefficient is positive and statistically significant at $p < 0.001$, providing further empirical evidence that the generic voluntary disclosure variable concerning information security has a positive association with the firm value.[22]

[21]Panel data models potentially could suffer from auto-serial correlation. Thus, we re-estimated our models using a Newey and West (1987) covariance estimator to account for serial correlation as well as heteroskedasticity. Our results qualitatively remained the same.

[22]Gordon et al. (2006) found a significant increase in voluntary disclosures of items related to information security in the post-Sarbanes-Oxley Act (SOX) time period as compared to the pre-SOX time period. Accordingly, we also tested our main findings concerning the market-value relevance of voluntary disclosures concerning information security occurring during the pre-SOX time period (i.e., 2000-2001) and the post-SOX time period (i.e., 2003-2004). Disclosures in 2002 were omitted, following the Gordon et al. approach. The results of this additional analysis indicated that the impact of voluntary disclosures on the market value of firms was significant for both the pre-SOX and post-SOX time periods.

We also controlled for previous generic disclosure by firms (if any) and our results remain unchanged. This analysis is available on request from the authors.

Table 5. Pooled Cross-Sectional Stock Price Regression on Disclosure Proxies

$$PRC\text{-}3M_{it} = \beta_0 \times Intercept + \beta_1 \times Dis_{it} + \beta_2 \times BVPS_{it} + \beta_3 \times EPS_{it} + \beta_4 \times LnAst_{it} + \beta_5 \times NEG_{it} + \Sigma\beta_k \times Year_{it} + \Sigma\beta_j \times Indus_{it} + \varepsilon_{it}$$

$PRC\text{-}3M_{it}$ = stock price of firm *i* for year *t*, 90 days after fiscal year close
Dis_{it} = 1 for a generic disclosure of information security, 0 otherwise
$BVPS_{it}$ = book value of equity divided by number of shares outstanding for firm *i* for year *t*, year-end
EPS_{it} = earnings per share (basic excluding special items) for firm *i* for year *t*, year-end
$LnAst_{it}$ = log of Assets for firm *i* for year *t*
NEG_{it} = 1 if EPS is negative for firm *i* for year *t*, 0 otherwise
$Year_{it}$ = 1 if current year, 0 otherwise
$Indus_{it}$ = 1 if current industry, 0 otherwise
Coefficient for year and industry variables are suppressed
p-values in parentheses are heteroskedastic corrected values
*Significant at 10%; **Significant at 5%; ***Significant at 1%

	(1) Base Case	(2) Generic Dis	(3) Sample w/o Banks/Fin
Dis		1.035 (0.000)***	1.359 (0.000)***
BVPS	0.757 (0.000)***	0.760 (0.000)***	0.745 (0.000)***
EPS	0.305 (0.000)***	0.307 (0.000)***	0.250 (0.000)***
LnAst	1.996 (0.000)***	1.982 (0.000)***	2.036 (0.000)***
NEG	-4.689 (0.000)***	-4.711 (0.000)***	-4.797 (0.000)***
Intercept	-2.684 (0.000)***	-2.669 (0.000)***	-1.988 (0.000)***
Obs	20,907	20,907	16,432
Adjusted R^2	0.548	0.548	0.540

Additional Analyses

The above results are based on parsimonious models to explore the effects of voluntary disclosures pertaining to information security. To further check the consistency of these results, we conducted a number of additional analyses. These analyses are discussed below.

Bid-Ask Spread Analysis and Results

The basic research design used in this paper is based on the value-relevance research design. An alternative design would be to investigate the change in the bid-ask spread as a way of examining the market-value impact of voluntary disclosures related to information security (Verrecchia and Weber 2006). Thus, we conducted an additional analysis along these lines to check the robustness of our empirical findings.

Jaffe and Winkler (1976) and Stoll (1978) show that the firm's bid-ask spread is related to the extent of information asymmetry between a firm and its investors. The underlying argument is that traders face potential losses when trading against informed investors (insiders). To protect themselves from potential losses, market makers increase bid-ask spreads as the possibility of trading against informed traders increases. Using this argument, Verrecchia and Weber (2006) provide empirical support that firms that redacted material contract information from their 10-K reports have wider bid-ask spreads. Conversely, when firms provide additional disclosures, it should reduce information asymmetry, resulting in narrower bid-ask spreads. Accordingly, as an alternate

research design to the value-relevance approach for analyzing the market impact of voluntarily disclosing items concerning information security, we conducted a bid-ask spread analysis.

To test bid-ask spread, we follow the Verrecchia and Weber methodology. Following their data selection specification, we focus only on firms whose market value is between (US) $50 million and $100 million. The main reason for focusing on this sample is that the number of analysts following these firms is likely to be less than for larger firms. As such, the impact of voluntary disclosures regarding information security for these firms is likely to be larger. The annual spread for firms is calculated as the average of the daily spreads for the first valid transaction during the normal trading hours as available on the Trade and Quote (TAQ) database.[23] Finally, consistent with Verrecchia and Weber, we restrict our attention to firms that trade on the New York Stock Exchange (NYSE), American Stock Exchange (AMEX), or National Association of Securities Dealers Automated Quotation (NASDAQ) exchanges.

The model that we estimate is as follows:

$$\text{Spread} = \beta_0 \times \text{Intercept} + \beta_1 \times \text{Dis} + \beta_2 \times \text{LnMVE} + \beta_3 \times \text{NYSE} + \beta_4 \times \text{AMEX} + \beta_5 \times \text{Price} + \Sigma\gamma_i \times \text{Year}_i + \varepsilon \quad (2)$$

where

Spread	=	annual average absolute value of the first daily bid-ask spread for the sample firms for the 12 month period starting 3 months after the beginning of the fiscal year
Dis	=	generic security disclosure, where Dis = 1 if the firm has any security related disclosure, 0 otherwise
LnMVE	=	log of firm market value of equity, calculated on the fiscal year close (in $ million)
AMEX	=	1 if the stock is traded on AMEX, 0 otherwise
NYSE	=	1 if the stock is traded on NYSE, 0 otherwise
Price	=	median price per share for the 12 month period starting three months after the fiscal year and ending three months after the fiscal year end
Year	=	1 if current year, 0 otherwise[24]

[23]Verrecchia and Weber (2006) estimate an adverse selection measure for their analysis. However, Easley et al. (2002) show that the first bid-ask transaction (for each day) is an adequate proxy for estimating the annual spreads. Hence, we estimate annual spread by identifying a valid transaction for each security in our sample during normal trading hours.

[24]Since multi-period data are used, we control for the year effect, if any, as well.

Our final sample consisted of 1,834 firm-year observations (consisting of 124 firm-years of disclosing firms and 1,710 firm-years of non-disclosing firms). A simple univariate analysis shows that the spread for firms that provide voluntary disclosures of information security is statistically lower than for firms not providing such disclosures at the conventional significance levels.[25] For the multivariate analysis, we estimated the model for the full sample, as well as for a subsample that does not include firms from the Banking and Finance industries (Table 6). For the full sample (Column 1, Table 6), the coefficient on the disclosure variable is negative and statistically significant at p-level < 0.01, meaning that each voluntary disclosure concerning information security decreases the absolute value of the spread. This result also holds for the subsample that excludes the firms of the Banking and Finance industries (i.e., coefficient on disclosure is negative and statistically significant at p-level < 0.01; Column 2, Table 6). Additionally, the R^2 for the full sample and subsample models are 0.53 and 0.32, respectively, providing empirical support that both models are well specified. Overall, the bid-ask spread results confirm that disclosure is related negatively to the spread at a statistically significant level (p value < 0.01). That is, voluntary disclosures about information security result in a decrease of the bid-ask spread, thereby increasing the ability of investors to estimate better the market value of firms.

Additional Checks for Size and Abnormal Earnings

Aboody et al. (2004) suggest using an additional variable in the model to proxy for future earnings potential. In this regard, they recommend using mean year-end analysts' earnings growth forecasts. Therefore, we estimate the model using mean year-end analysts' earnings growth forecasts, as well as growth in sales (unreported results). Results of both these additional tests do not indicate any material difference from our main findings.[26]

Returns Model

For the reasons discussed in the "Empirical Study" section earlier, our basic research design is based on a price-levels model. Although, we use the panel-data structure to account

[25]The results for this analysis are available on request.

[26]The results of these additional tests are available from the authors upon request.

Table 6. Bid–Ask Spread Analysis on Disclosure

$$\text{Spread} = \beta_0 \times \text{Intercept} + \beta_1 \times \text{Dis} + \beta_2 \times \text{LnMVE} + \beta_3 \times \text{NYSE} + \beta_4 \times \text{AMEX} + \beta_5 \times \text{Price} + \Sigma\gamma_i \times \text{Year}_i + \varepsilon$$

Spread = average absolute value of the first daily bid–ask sprad for the firms for 12 month period starting 3 months after the beginning of the fiscal year
Dis = 1 for a generic disclosure of information security, 0 otherwise
LnMVE = log of firm market value of equity, calculated on the fiscal year close
NYSE = 1 if the stock is traded on NYSE, 0 otherwise
AMEX = 1 if the stock is traded on AMEX, 0 otherwise
Price = median price per share for the 12 month period starting 3 months after the fiscal year and ending 3 months after the fiscal year end
Year = 1 if current year, 0 otherwise
Coefficient for year variable is suppressed
p-values in parentheses are heteroskedastic corrected values
*Significant at 10%; **Significant at 5%; ***Significant at 1%

	(1) Generic Dis	(2) Sample w/o Banks/Fin
Dis	-0.057 (0.005)***	-0.053 (0.002)***
LnMVE	-0.094 (0.000)***	-0.039 (0.146)
NYSE	-0.093 (0.000)***	-0.058 (0.000)***
AMEX	-0.194 (0.000)***	-0.133 (0.000)***
Price	0.024 (0.000)***	0.016 (0.000)***
Intercept	0.447 (0.000)***	0.253 (0.027)**
Obs	1,834	1,220
Adjusted R^2	0.533	0.324

for the temporal and industry effects, our results could suffer from a bias due to firm-specific omitted variables. The returns model helps to mitigate the bias related to omitted variables, due to it being based on a first difference approach (Christie 1987; Collins and Kothari 1989). That is, the first difference model is equivalent in estimation to a fixed effect model (see Wooldridge 2002). By subtracting x_{t-1} from x_t, the fixed effects cancels out, thus mitigating the omitted variable bias (see footnote 15).

Using both the price and the returns models has the additional benefit of providing evidence to further corroborate value-relevance results (Kothari and Zimmerman 1995). Following this suggestion, Amir and Lev (1996) and Aboody et al. (2004, p. 255) also use a combined methodology in their studies.[27] Thus, we estimate the following returns model:[28]

$$\text{Annret}_{it} = \beta_0 \times \text{Intercept} + \beta_1 \times \text{Dis}_{it} + \beta_2 \times \text{EPSS}_{it} + \beta_3 \times \Delta\text{EPSS}_{it} + \beta_4 \times \Delta\text{NEG}_{it} + \Sigma\beta_k \times \text{Year}_i + \Sigma\beta_j \times \text{Indus}_i + \varepsilon_{it} \quad (3)$$

[27]However, Aboody and Lev (1998 , p. 170) caution that "an association between unexpected [items] and the contemporaneous annual stock returns indicates the extent to which the information contained in [items] is consistent with that used by investors (such an association test cannot, of course, indicate whether investors actually used [items] data in assessing security values)."

[28]This is a long window analysis, which has a horizon of one-year (i.e., annual returns are cumulated over 12 months).

where

$Annret_{it}$ = market adjusted annual return of firm *i* for year *t*, accumulated 9 months before *t* to 3 months after *t*

Dis_{it} = same as price model—see methodology, research design section for details

$EPSS_{it}$ = earnings per share for firm *i* for year *t*, scaled by previous year-end price

$\Delta EPSS_{it}$ = change in EPS_t-EPS_{t-1} scaled by previous year beginning price for firm *i* for year *t*

ΔNEG_{it} = change in NEG_t-NEG_{t-1} for firm *i* for year *t*

$Year_i$ = 1 if current year, 0 otherwise

$Indus_i$ = 1 if firm is in a particular industry, 0 otherwise

The results of a pooled cross-sectional analysis of the returns model are presented in Table 7. Similar to what is shown in Table 5, we estimate three models. Models 1 and 2 are analyzed using the full sample of 18,863 observations.[29] Model 3 is estimated using a sample that excludes the firms from the Banking and the Finance industries. Consistent with price-levels analysis, we find that the information security disclosure is positive and statistically significant ($p < 0.001$).[30]

Matched-Pair Analysis and Results

To further check the consistency of the results, and to investigate if significance in the model is due to sample size, we reran the price-levels model using a matched-pair design. For this analysis, each disclosing firm is matched with a non-disclosing firm that has the closest size (market value) for a given year and industry. The intuition behind a matched-pair design is that by matching firms from the same time-periods, industries, and size (i.e., market value), the potential problems associated with "correlated omitted variables" (including size and risk characteristics) are mitigated. Another advantage of the matched-pair design is that if the results hold in a "smaller" sample, then the findings are generally considered to be more robust.

The results of the price regression for the matched-pair sample are presented in Table 8. The explanatory variables are similar to the ones included in the main results (i.e., year and industry dummies are also included). For the matched-pair sample, we estimate two separate regressions. Model 1 uses all the matched-pairs. In Model 2 (as before), firms from the Banking and the Finance industries are excluded. The coefficient on the generic disclosure measure is positive and still statistically significant ($p < 0.001$). Overall, our findings remain consistent with the main results reported in Table 5. We also repeat the analysis of the price-levels model by taking random subsamples starting from 5 percent to 50 percent (in 5 percent increments) of the disclosing firms and matching them with a non-disclosing sample. The results from these further analyses are also consistent with the main results reported in Table 5.[31]

Disclosures Endogeneity Analysis and Results

In most disclosures-related studies, disclosure is the dependent variable, with the goal being to find the determinants of the disclosures. In this research study, voluntary disclosure is used as an explanatory (i.e., independent) variable along with other independent variables. However, voluntary disclosures are an *ex ante* commitment or policy to provide information and are determined endogenously by the firm (Core 2001). Thus, there may well be a self-selection bias in our findings discussed thus far. The intuition behind the self-selection bias is that firms choose to voluntarily disclose information based on their own cost–benefit analysis (i.e., the firms self-select to either provide a disclosure or not). Thus, our findings could reflect the problem of spurious inferences. Hence, we refine the model to account for the potential endogenous effect or self-selection issue under the voluntary disclosure regime (Leuz and Verrecchia 2000).

The econometric method employed to account for the potential selection bias, while including the main effect of the variable on which the selection occurs, is referred to as the "treatment effects model" (see Wooldridge 2002). Both Heckman (1978) and Maddala (1983) show that such a model can be consistently estimated by using a two equation system (first stage probit model, followed by second stage OLS model) and employing an inverse Mills ratio (hazard of disclosing) as a proxy variable (accounting for omitted variables) in the main equation of interest.[32]

[29]Total sample size for the returns model is smaller than the price model, since we have missing information for some firm-years (i.e., *t-1* years observations are missing for any one of the variables in the equation).

[30]We also conducted a returns analysis on a sample where we identify the firm's first year of disclosure, and then use the firm's data from the previous year as its control. Our results remain the same and are available from the authors upon request.

[31]The results of these random subsamples are available from the authors upon request.

[32]Since the two equations are correlated, both of the equations need to be estimated simultaneously to ensure that the estimated variances are consistent.

Table 7. Pooled Cross-Sectional Stock Returns Regression on Disclosure Proxies

$$Annret_{it} = \beta_0 \times Intercept + \beta_1 \times Dis_{it} + \beta_2 \times EPSS_{it} + \beta_3 \times \Delta EPSS_{it} + \beta_4 \times \Delta NEG_{it} + \Sigma\beta_k \times Year_{it} + \Sigma\beta_j \times Indus_{it} + \varepsilon_{it}$$

$Annret_{it}$ = annual return of firm *i* for year *t*, cumulated 9 months before *t* to 3 months after *t*
Dis_{it} = 1 for a generic disclosure of information security, 0 otherwise.
$EPSS_{it}$ = earnings per share for firm *i* for year *t*, scaled by previous year-end PRC
$\Delta EPSS_{it}$ = change in EPS_t-$EPS_{t-}1$ scaled by previous year beginning PRC for firm *i* for year *t*
ΔNEG_{it} = change in Neg_t – Neg_{t-1} for firm *i* for year *t*
Year = 1 if current year, 0 otherwise
$Indus_{it}$ = 1 if current industry, 0 otherwise
Coefficient for year and industry variables are suppressed
p-values in parentheses are heteroskedastic corrected values
*Significant at 10%; **Significant at 5%; ***Significant at 1%

	(1) Base Case	(2) Generic Dis	(3) Sample w/o Banks/Fin
Dis		0.872 (0.000)***	0.867 (0.000)***
EPSS	0.086 (0.008)***	0.113 (0.001)***	0.107 (0.004)***
ΔEPSS	0.003 (0.382)	0.002 (0.392)	0.002 (0.404)
ΔNEG	-0.314 (0.000)***	-0.308 (0.000)***	-0.312 (0.000)***
Intercept	0.208 (0.000)***	0.207 (0.000)***	0.107 (0.000)***
Obs	18,863	18,863	14,768
Adjusted R^2	0.064	0.086	0.097

Accordingly, the first step in estimating the treatment model is to identify the variables that affect firms' disclosure choices. In this regard, the extant literature is replete with studies of the cross-sectional determinants of corporate disclosures. We follow the Leuz and Verrecchia (2000) and Field et al. (2005) studies, since both of these studies provide a comprehensive list of variables that determine a firm's disclosures. Based on a review of these two papers, the following additional variables are identified: firm performance – return on assets (operating income before extraordinary items/total assets); financing needs – capital requirement (long term assets/total assets); firm size (log of assets); industry dummy variables (membership of industries affect disclosure); liquidity – stock turnover ($[1-\Pi_t$ (1-volume $traded_t$/total $shares_t)]$); information asymmetry – volatility (standard deviation of stock returns); analyst following (total number of analysts following a firm); and institutional holding (percentage of shares held by institutions/total shares outstanding). The above noted variables would affect voluntary disclosures in general, and should have a similar effect on disclosures that specifically concern information security.

The additional financial variables for the firms were collected from the Annual Combined CRSP/COMPUSTAT database. Stock turnover and volatility were estimated using the monthly CRSP file for volume of shares traded and returns. Analyst following is computed from the I/B/E/S detail file that provides information on the number of analysts issuing forecasts for a firm. Institutional holding is obtained from the Thomson 13f database that provides information on the number of shares held by institutions.

Following Leuz and Verrecchia (2000), the systems of equations estimated for the self-selection analysis is as follows:

$$D_{it} = \gamma_0 \times Intercept + \gamma_1 \times LnAst_{it} + \gamma_2 \times ROA_{it} + \gamma_3 \times CI_{it} + \gamma_4 \times Volat_{it} + \gamma_5 \times Turnover_{it} + \gamma_6 \times Hold_{it} + \gamma_7 \times Anal_{it} + \gamma_8 \times NEG_{it} + \Sigma\gamma_j \times Indus_{it} + \upsilon_{it}$$

$$P_{it} = \beta_0 \times Intercept + \beta_1 \times Dis_{it} + \beta_2 \times BVPS_{it} + \beta_3 \times EPS_{it} + \beta_4 \times LnAst_{it} + \beta_5 \times NEG_{it} + \beta_6 \times Mills_{it} + \Sigma\beta_k \times Year_{it} + \Sigma\beta_j \times Indus_{it} + \varepsilon_{it} \quad (4)$$

Table 8. Pooled Cross-Sectional Matched-Pair Stock Price Regression on Disclosure Proxies

$$PRC\text{-}3M_{it} = \beta_0 \times Intercept + \beta_1 \times Dis_{it} + \beta_2 \times BVPS_{it} + \beta_3 \times EPS_{it} + \beta_4 \times LnAst_{it} + \beta_5 \times Neg_{it} + \Sigma\beta_k \times Year_{it} + \Sigma\beta_j \times Indus_{it} + \varepsilon_{it}$$

$PRC\text{-}3M_{it}$ = stock price of firm *i* for year *t*, 90 days after fiscal year close
Dis_{it} = 1 for a generic disclosure of information security, 0 otherwise
$BVPS_{it}$ = book value of equity divided by No. of shares outstanding for firm *i* for year *t*, year-end
EPS_{it} = earnings per share (basic excluding special items) for firm *i* for year *t*, year-end
$LnAst_{it}$ = log of assets for firm *i* for year *t*
NEG_{it} = 1 if EPS is negative for firm *i* for year *t*, 0 otherwise
$Year_{it}$ = 1 if current year, 0 otherwise
$Industry_{it}$ = 1 if current industry, 0 otherwise
Coefficient for year variable is suppressed
p-values in parentheses are heteroskedastic corrected values
*Significant at 10%; **Significant at 5%; ***Significant at 1%

	(1) Generic Dis	(2) Sample w/o Banks/Fin
Dis	0.990 (0.004)***	1.374 (0.000)***
BVPS	0.884 (0.000)***	0.826 (0.000)***
EPS	0.558 (0.000)***	0.474 (0.000)***
LnAst	1.516 (0.000)***	1.644 (0.000)***
NEG	-5.559 (0.000)***	-5.795 (0.000)***
Intercept	1.411 (0.041)**	(0.091)*
Obs	3,282	2,648
Adjusted R^2	0.565	0.532

The results of regression analysis after controlling for the potential self-selection bias are presented in Table 9. Column 1 (Table 9) details the coefficients of the first stage Probit regression results that are used to estimate the inverse Mills ratio. The price-model's results are listed in Column 3 (coefficients). Column 4 details the associated p-values. The coefficient on the generic disclosure variable is positive and statistically significant at p-level < 0.001 after controlling for selection-bias (Column 3, Table 9). The coefficients on EPS, BVPS, and LnAst are statistically significant at p-level < 0.001. Overall, the results provide support for the prior results that voluntary disclosures concerning information security are associated positively with the market value of firms (Column 3, Table 9).

Disclosures Classification – Types of Disclosures: Analyses and Results

Since voluntary disclosures concerning information security are a strategic decision, one would presume that a firm would not disclose such information unless the firm believed it would be value enhancing. The analysis to this point focused on finding evidence to confirm that presumption by establishing the value-relevance of voluntary information security disclosures in a generic sense. The determination of value-relevance of such disclosures provides an important step in examining firms' more subtle, and perhaps more interesting, strategic choices surrounding particular types of information security disclosures. We now turn to an exploratory analysis

Table 9. Treatment Regression of Stock Price on Generic Disclosure

$$D_{it} = \gamma_0 \times \text{Intercept} + \gamma_1 \times \text{LogAst}_{it} + \gamma_2 \times \text{ROA}_{it} + \gamma_3 \times \text{CI}_{it} + \gamma_4 \times \text{Volat}_{it} + \gamma_5 \times \text{Turnover}_{it} + \gamma_6 \times \text{Hold}_{it} + \gamma_7 \times \text{Anal}_{it} + \gamma_8 \times \text{NEG}_{it} + \Sigma\gamma_j \times \text{Indus}_{it} + \upsilon_{it}$$

$$P_{it} = \beta_0 \times \text{Intercept} + \beta_1 \times \text{Dis}_{it} + \beta_2 \times \text{BVPS}_{it} + \beta_3 \times \text{EPS}_{it} + \beta_4 \times \text{LnAst}_{it} + \beta_5 \times \text{NEG}_{it} + \beta_6 \times \text{Mills}_{it} + \Sigma\beta_k \times \text{Year}_{it} + \Sigma\beta_j \times \text{Indus}_{it} + \varepsilon_{it}$$

Dis_{it} = 1 for a generic disclosure of information security, 0 otherwise
LnAst_{it} = log of total assets of the firm *i* for yeat *t*, at year end
ROA_{it} = operating income before extraordinary items / assets for firm *i* for year *t*
CI_{it} = long terms assets (PPE) / total assets for firm *i* for year *t*, at year end
Volat_{it} = standard deviation of monthly returns, 9 months before *t* to 3 months after *t*
Tunrover_{it} = shares turnover as $[1-\Pi_t(1-\text{volume traded}_t/\text{total shares}_t)]$ 9 months before *t* to 3 months after *t*
Hold_{it} = percentage of shares held by institutions for firm *i* for year *t* over total shares outstanding
Analyt_{it} = number of analysts following for firm *i* for year *t* from I/B/E/S detail file
PRC– 3M = stock price of firm *i* for year *t*, 90 days after fiscal year close
BVPS_{it} = book value of equity divided by number of shares outstanding for firm *i* for year *t*, year-end
EPS_{it} = earnings per share (basic excluding special items) for firm *i* for year *t*, year-end
NEG_{it} = 1 if EPS is negative for firm *i* for year *t*, 0 otherwise
Mills_{it} = inverse Mills ratio for each firm estimated from the first stage (i.e., disclosure equation)
Year_{it} = 1 if current year, 0 otherwise
Indus_{it} = 1 if current industry, 0 otherwise
Coefficient for year variable is suppressed
p-values in parentheses are heteroskedastic corrected values
*Significant at 10%; **Significant at 5%; ***Significant at 1%

	col 1 Dis Model	col 2 p-values	col 3 Price Model	col 4 p-values
LnAst	0.051	0.000***		
ROA	-0.073	0.000***		
CI	-0.475	0.263		
Volat	0.911	0.000***		
Turnover	0.523	0.000***		
Hold	-0.080	0.096*		
Analysis	0.007	0.004***		
NEG	0.156	0.000***		
Dis			2.048	0.000***
EPS			1.029	0.000***
BVPS			0.788	0.000***
LnAst			2.004	0.000***
NEG			-3.542	0.000***
Mills ratio			-1.601	0.009***
Intercept	-3.835	0.000	-4.726	0.000***
Obs		17,640		17,640
LR $\chi^2(46)$	1,922.60			
Prob > χ^2	0.0000			
Pseudo R^2	0.2099			
Log Likelihood	-4,100.88			
Adjusted R^2				0.6435

of which types of information security disclosures, alone or in combination with one another, provide firms with a higher market value.

Although there is no prescribed format or guideline for voluntary disclosures concerning information security, firms do provide a variety of types of information security disclosures in their annual reports filed with the SEC (refer back to Table 1). For example, a firm might detail the steps to protect its information assets, while at the same time it might report that its information systems are vulnerable. Thus, to get a clearer understanding of the implications of different types of disclosures, we conducted an additional exploratory analysis by further splitting our sample of disclosures concerning information security into separate subgroups.

A taxonomy was developed to refine the generic voluntary disclosure measure regarding information security. The coding scheme facilitates identification of the "type" of disclosures across all firms, while minimizing categorization to facilitate cross-sectional comparison. Using the keywords in Table 1, a pilot study was conducted wherein we reviewed all of the annual SEC reports for the telecommunications and utilities industries for years 2001 and 2002. In total there were 302 annual SEC reports that were read as a part of this pilot study. Two reviewers (i.e., two of the authors) independently read the text (200 words) around these keywords. Based on the information in the pilot study report, a consensus was reached to classify the disclosures related to a firm's information security into the following three categories: (1) proactive security activities, (2) potential security vulnerabilities, and (3) actual security breaches.[33] A coding scheme was developed to assign a score of 1 if the firm provided information related to any one of these three categories, and 0 otherwise. Our coding scheme is detailed in Appendix A. Some sample disclosures are provided in Appendix B. These three categories were presented to two independent experts (non-authors) in the field of information security, both of whom agreed on the face-validity of this taxonomy. We also conducted a factor analysis on the keywords of the full sample. The factor analysis provides strong reliability and validity to our three disclosure categories.[34]

The breakdown of security related disclosures according to the three types of disclosures (i.e., proactive security activities, potential security vulnerabilities, or actual security breaches) and their subgrouping is detailed in Table 10, Panel A. As is seen in the table, there are seven distinct subgroups. For example, group 1 consists of those firm-years in which there were disclosures that only dealt with proactive security measures; group 4 consists of firm-years in which there were only joint disclosures of proactive security activities and potential vulnerabilities; while group 7 comprises firm-years in which there were disclosures of all three categories of information security disclosures. It is interesting to note that only 67 out of the 1,641 firm-years include any voluntary disclosures related to actual security breaches.

For our analysis, we first re-estimate our basic price-levels model (Equation 1, methodology section) by replacing the generic disclosure dummy variable with the following seven dummy variables to proxy for the subgroups:

- Disclosure of proactive security activities only, P = 1, 0 otherwise
- Disclosure of potential security vulnerabilities only, V= 1, 0 otherwise
- Disclosure of actual security breaches only, A = 1, 0 otherwise
- Joint disclosure of proactive security activities and potential vulnerabilities, PV = 1, 0 otherwise
- Joint disclosure of potential vulnerabilities and actual security breaches, VA = 1, 0 otherwise
- Joint disclosure of proactive security activities and actual security breaches, PA = 1, 0 otherwise
- Joint disclosure of proactive security activities, potential vulnerabilities and actual security breaches, PVA = 1, 0 otherwise

The results of the price-levels model are detailed in Table 10, Panel B. As before, we estimate the model with the full sample and without the firms from the Banking and Finance industries (Columns 1 and 2, respectively). For the full sample, the coefficient on proactive security activities (P) disclosure is positive and significant at $p < 0.05$. Potential security vulnerabilities (V) has a positive coefficient as well, which is significant at $p < 0.05$, while actual security breaches (A) has a negative coefficient, but is not statistically significant. For PV (i.e., the group of firms that provide joint disclosure of proactive activities and security vulnerabilities), the coefficient is positive and statistically significant ($p < 0.001$). The coefficients on PA and PVA are also positive and significant at $p < 0.001$ and $p < 0.05$, respectively. The coefficient on VA, although positive, is not statistically significant. Almost an identical pattern is observed for the reduced

[33]The two reviewers agreed on 90.3% of the initial classifications of the information security disclosures. Thus, the inter-rater reliability was quite high. For the remaining 9.7% of disclosures, the two reviewers met to discuss the best category to classify these items.

[34]This analysis is available from the authors upon request.

Table 10. Breakdown of Disclosures

Panel A: Number of security disclosures by type

Group	Proactive Security (1)	Potential Security Vulnerability (2)	Actual Breaches (3)	Disclosures (4)
1	Yes			489
2		Yes		226
3			Yes	4
4	Yes	Yes		859
5		Yes	Yes	9
6	Yes		Yes	2
7	Yes	Yes	Yes	52
Total (1) – (7)				1,641

Group 1 = 1 if disclosure of proactive security activities only (P)
Group 2 = 1 if disclosure of potential security vulnerabilities only (V)
Group 3 = 1 if disclosure of actual security breaches only (A)
Group 4 = 1 if joint disclosure of proactive security activities and potential vulnerabilities (i.e., P = 1 and V = 1)
Group 5 = 1 if joint disclosure of potential vulnerabilities and actual security breaches (i.e., V = 1 and A = 1)
Group 6 = 1 if joint disclosure of proactive security activities and actual security breaches (i.e., P = 1 and A = 1), 0 otherwise
Group 7 = 1 if joint disclosure of proactive security activities, potential vulnerabilities, and actual security breaches (i.e., P = 1 and V = 1 and A = 1)

Panel B: Pooled Cross-Sectional Regression on Disclosure Proxies

$$\text{PRC-3M}_{it} = \beta_0 \times \text{Intercept} + \beta_1 \times \text{Dis}_{it} + \beta_2 \times \text{BVPS}_{it} + \beta_3 \times \text{EPS}_{it} + \beta_4 \times \text{LnAst}_{it} + \beta_5 \times \text{NEG}_{it} + \Sigma\beta_k \times \text{Year}_{it} + \Sigma\beta_j \times \text{Indus}_{it} + \varepsilon_{it}$$

$$\text{Annret}_{it} = \beta_0 \times \text{Intercept} + \beta_1 \times \text{Dis}_{it} + \beta_2 \times \text{EPSS}_{it} + \beta_3 \times \Delta\text{EPSS}_{it} + \beta_4 \times \Delta\text{NEG}_{it} + \Sigma\beta_k \times \text{Year}_{it} + \Sigma\beta_j \times \text{Indus}_{it} + \varepsilon_{it}$$

Where Dis:
Pro Msre (P) = 1 for a disclosure of proactive security activities only, 0 otherwise.
Ptn Vul (V) = 1 for a disclosure of potential security vulnerabilities only, 0 otherwise.
Actl Brch (A) = 1 for a disclosure of actual security breaches only, 0 otherwise
PV = 1 for a joint disclosure of proactive security activities and potential vulnerabilities, 0 otherwise
VA = 1 for a joint disclosure of potential vulnerabilities and actual security breaches, 0 otherwise
PA = 1 for a joint disclosure of proactive security activities and actual security breaches, 0 otherwise
PVA = 1 for a joint disclosure of proactive security activities, potential vulnerabilities and actual security breaches, 0 otherwise
Other variables are as defined previously
Coefficient for year and industry variables are suppressed
p-values in parentheses are heteroskedastic corrected values
*Significant at 10%; **Significant at 5%; ***Significant at 1%

	(1) Prc 3m	(2) Prc 3m w/o Banks/Fin	(3) Prc 3m Match Pair	(4) Prc 3m w/o Banks/Fin	(5) Annret	(6) Annret w/o Banks/Fin
Pro Msre (P)	1.236 (0.012)**	1.296 (0.003)***	0.921 (0.002)***	1.065 (0.041)**	0.905 (0.003)***	1.147 (0.008)***
Ptn Vul (V)	1.740 (0.011)**	1.625 (0.005)***	1.362 (0.047)**	1.668 (0.020)**	0.910 (0.007)***	1.009 (0.026)**
Actl Brch (A)	-1.283 (0.823)	-0.695 (0.904)	-1.042 (0.860)	-0.587 (0.922)	-0.010 (0.970)	-0.453 (0.349)

Table 10. Breakdown of Disclosures (Continued)

	(1) Prc 3m	(2) Prc 3m w/o Banks/Fin	(3) Prc 3m Match Pair	(4) Prc 3m w/o Banks/Fin	(5) Annret	(6) Annret w/o Banks/Fin
PV	1.032 (0.003)***	1.468 (0.000)***	1.033 (0.052)*	1.303 (0.027)**	1.318 (0.003)***	0.781 (0.506)
VA	1.094 (0.262)	1.316 (0.165)	0.410 (0.767)	0.628 (0.652)	-0.060 (0.880)	-0.291 (0.517)
PA	1.465 (0.001)***	1.280 (0.000)***	1.033 (0.052)*	1.303 (0.027)**	1.318 (0.003)***	0.781 (0.506)
PVA	1.550 (0.046)**	1.584 (0.027)**	1.745 (0.045)**	1.486 (0.032)**	1.784 (0.000)***	1.609 (0.001)***
BVPS	0.760 (0.000)***	0.745 (0.000)***	0.886 (0.000)***	0.827 (0.000)***		
EPS	0.307 (0.000)***	0.250 (0.000)***	0.557 (0.000)***	0.475 (0.000)***		
LnAst	1.981 (0.000)***	2.035 (0.000)***	1.507 (0.000)***	1.637 (0.000)***		
NEG	-4.709 (0.000)***	-4.796 (0.000)***	-5.548 (0.000)***	-5.794 (0.000)***		
EPSS					0.113 (0.001)***	0.067 (0.109)
ΔEPSS					0.002 (0.393)	0.002 (0.392)
ΔNeg					-0.307 (0.000)***	-0.315 (0.000)***
Intercept	-2.663 (0.000)***	-1.984 (0.000)***	1.461 (0.000)***	1.265 (0.000)***	0.206 (0.000)***	-0.164 (0.000)***
Obs	20,907	16,432	3,282	2,648	18,863	14,768
Adusted R^2	0.548	0.540	0.565	0.531	0.086	0.226

sample (Column 2, Table 10, Panel B), with the coefficient on P being significant at $p < 0.01$-level.[35]

Additionally, we then re-ran the matched pair sample analysis by substituting the generic disclosure measure with its sub-categories as well. The results of the matched-pair sample analysis with and without the firms from the Banking and the Finance industries are tabulated in Columns 3 and 4 of Table 10, Panel B, respectively. The P coefficient is positive and statistically significant at a p-level < 0.01 (Column 3) while the V coefficient is positive and significant ($p < 0.05$). The coefficients on PV, PA, and PVA are positive and significant at the p-value < 0.05. However, the coefficient on VA is positive but not statistically significant, while the coefficient on A is negative but also not statistically significant.

Finally, we conducted an analysis of the types of information security disclosures provided in the returns model. Column 5, in Table 10 (Panel B), shows that proactive security activities (P) and potential vulnerabilities (V) are positive and significant for the full sample ($p < 0.01$). In line with the price models (Columns 1 and 2), PV and PVA are positive and significant ($p < 0.01$) in both samples (i.e., full sample for returns model and reduced sample that does not contain the firms from the Banking and Finance industries). The coefficient on PA is positive and statistically significant in the full sample ($p < 0.01$) but is not statistically significant in the reduced sample (Models 5 and 6, respectively). The coefficient on actual security breaches (A) is negative, while the coefficient on VA is positive, but both are not statistically significant (Columns 5 and 6).

[35]We also conducted statistical tests of pair-wise comparisons of the magnitudes of the coefficients of the different types of disclosures. None of these differences, however, are significant at the 10% level.

In summary, disclosures of proactive security activities have a positive and statistically significant effect on the market value of firms. Additionally, the voluntary disclosures of vulnerabilities are also positive. For the firms with joint disclosures, it seems that whenever there is mention of proactive security activities (PV, PA, and PVA), the market seems to reward these disclosures. Although some of our seven subgroups are small, voluntary disclosures concerning proactive security activities seem to be a key driving force that underlies improvements in the market value of firms.

Given that the differences in the relative magnitudes of the coefficients of the various types of disclosures are not statistically significant, interpretations concerning the relative size of these coefficients would be highly speculative. Nevertheless, at first blush, one may find it unsettling that the relative magnitude of the coefficients makes it appear that investors are willing to forgive an actual breach provided that the firm has taken proactive security measures, and that proactive security measures become more valuable when an actual breach has occurred. Upon further reflection, however, these findings are easily explained without appealing to the issue of statistical significance. Due, in part, to various laws and regulations, actual security breaches are made public long before annual reports, which are made public approximately 90 days after the end of the firm's fiscal year end. Hence, the effect of the news of an information security breach would generally have been impounded in a firm's stock price prior to the release of the annual report. Thus, the relative size of the coefficients may well be due to the fact that the market is reacting to the "new news," *viz*., that the firm is taking proactive security measures. Furthermore, it could certainly be the case that the market values the news of proactive security measures more for firms that have experienced actual breaches in the past. Again, these conjectures are speculative, and would require a new study with a larger data set showing each firm's timing of the announcement and, likely, a new methodology.

As for the returns models, a consistent pattern to the price-levels and matched-pair analyses is also observed. That is, proactive security activities and potential security vulnerabilities have a positive and a statistically significant effect on the market value of firms, while disclosures of actual security breaches do not have such an effect.

Industry Analyses and Results

Previous research has documented that there is often an industry effect related to value-relevance models (see Barth, Clement et al. 1998). Therefore, we conducted an analysis to explore how the effect of information security disclosures on market value varies across industries. These results are shown in Table 11. The generic security disclosure measure and regressions on various types of disclosures are listed in Panel A and Panel B of Table 11, respectively. Since these regressions are for firms in an industry group over the time period 2000–2004, we only included the year dummy variables to control for year-effects.

For the generic security disclosure measure (Panel A), 9 of the 35 industries have either a significant or a marginally significant coefficient. Most notably, in this regard, are the Business Services, Paper, Retail, and Insurance sectors, which are statistically significant at p-level < 0.01. For these industries, the magnitude of the coefficient varies between 1.217 for Business Services and 35.114 for Paper. The Clothes industry group has a significance of p-level < 0.05, while Transportation and Wholesale industries have a statistical significance of $p < 0.10$ with a positive coefficient. However, for the Auto and Construction industries, the disclosure coefficient is significant at $p < 0.001$ and negative. The R^2 for all of the regressions varies between 0.226 and 0.755. Interestingly, as indicated in Panel A, the coefficient on the information security disclosures dummy variable is positive, but not statistically significant, for both the Finance and the Banking industries. This finding provides some empirical support for our disclosure dummy proxy. Both industries are regulated heavily under the Gramm-Leach-Bliley Act 1999 (GLB), which requires firms in these industries to enforce and maintain information security procedures. Accordingly, as these organizations are already regulated, any voluntary disclosures concerning information security would likely not have any effect on the firm's price, since the market expects firms in these industries to pay a high level of attention to information security.

Panel B in Table 11 details the regression analysis on the various types of information security disclosures for the 35 industry segments. Disclosure of proactive security activities (P) is positive and statistically significant at $p < 0.01$ in the Insurance and Retail industries, while for Banking it is significant at $p < 0.10$ and positive. The potential vulnerabilities (V) is positive and significant at $p < 0.001$ for the Paper industry. It is also positive for Clothes and Chips at $p < 0.05$, while Business Services and Wholesale are significant at $p < 0.10$. However, for the Books, Fun, and Building Materials sectors, the coefficient is statistically significant at $p < 0.01$ and negative. The actual security breach variable (A) has mixed signs across industries, but is not statistically significant at p-level < 0.10. Across industries, PV also has mixed signs. It is positive and statistically significant ($p < 0.01$) for the Retail and Insurance industries, while it is marginally sig-

Table 11. Pooled Stock Price Regression by Industry on Disclosures Proxies

$$\text{PRC-3M}_{it} = \beta_0 \times \text{Intercept} + \beta_1 \times \text{Dis}_{it} + \beta_2 \times \text{BVPS}_{it} + \beta_3 \times \text{EPS}_{it} + \beta_4 \times \text{LnAst}_{it} + \beta_5 \times \text{NEG}_{it} + \Sigma\beta_k \times \text{Year}_{it} + \varepsilon_{it}$$

PRC-3M = Stock price of firm *i* for year *t*, 90 days after fiscal year close
Dis_{it} = 1 for a generic disclosure of information security, 0 otherwise
Pro Msre (P) = 1 for a disclosure of proactive security activities only, 0 otherwise
Ptn Vul (V) = 1 for a disclosure of vulnerabilities only, 0 otherwise
Actl Brch (A) = 1 for a disclosure of actual security breaches only, 0 otherwise
PV = 1 for a joint disclosure of proactive security activities and potential security vulnerabilities, 0 otherwise
VA = 1 for a joint disclosure of potential security vulnerabilities and actual security breaches, 0 otherwise
PA = 1 for a joint disclosure of proactive security activities and actual security breaches, 0 otherwise
PVA = 1 for a joint disclosure of proactive security activities, potential security vulnerabilities and actual security breaches, 0 otherwise
BVPS_{it} = Book value of equity divided by No. of shares outstanding for firm *i* for year *t*, year-end
EPS_{it} = Earnings per share (basic excluding special items) for firm *i* for year *t*, year-end
LnAst_{it} = Log of Assets for firm *i* for year *t*
Neg_{it} = 1 if EPS is negative for firm *i* for year *t*, 0 otherwise
Year_{it} = 1 if current year, 0 otherwise
Coefficient for year variable is suppressed for readability
p-values for BVPS, EPS, and Intercept are suppressed and only significance values are shown
p-values in parentheses are heteroskedastic corrected values
*Significant at 10%; **Significant at 5%; ***Significant at 1%; NS = not significant

	Disclosure		BVPS	EPS	LnAst	Intercp	N	Adj R^2
Autos	-15.153	(0.000)***	0.397***	2.931***	2.226***	-3.31**	313	0.568
Banks	0.362	-0.522	1.044***	0.984*	2.037***	-8.347***	3096	0.687
BldMt	-3.266	-0.542	0.806***	0.848***	2.2***	-4.924***	407	0.632
Books	0.947	-0.787	0.966***	0.571	1.758***	5.026	170	0.623
BusSv	1.217	(0.002)***	0.593***	0.167***	2.199***	-0.481	2941	0.455
Chips	2.441	-0.218	1.188***	0.311**	1.127***	0.488	1231	0.586
Clths	7.104	(0.035)**	0.426**	4.962***	2.432***	-5.773***	148	0.755
Cnstr	-4.638	(0.001)***	0.357***	2.771***	2.039***	-4.219**	193	0.648
Coal	-1.485	-0.726	0.606	1.277	-2.276	29.206***	32	0.588
Drugs	-1.677	-0.153	0.605***	-0.454***	3.29***	-2.172**	1716	0.498
Enrgy	1.211	-0.803	1.197***	1.505***	1.155***	-1.686*	828	0.723
Fin	1.571	-0.218	0.519***	0.725**	1.355***	6.061***	1378	0.453
Food	2.884	-0.67	0.524**	4.769**	2.607***	-6.178**	308	0.532
Fun	-1.968	-0.462	0.815***	0.925***	1.114***	4.133*	240	0.517
Gold			0.322	2.177**	2.623***	-8.224***	269	0.485
Hlth	2.138	-0.349	0.899***	0.143	1.995***	0.702	322	0.502
Hshld	-3.744	-0.463	0.212	3.515*	2.795***	-5.23*	63	0.686
Insur	4.28	(0.000)***	0.694***	2.018***	1.305***	-1.575	838	0.625
LabEq	2.32	-0.141	0.864***	-0.003	3.062***	-3.465***	1056	0.568
Mach	-0.1	-0.945	0.727***	0.211**	2.091***	-1.018	921	0.592
Meals	0.286	-0.922	0.434***	2.516***	2.168***	-0.968	331	0.532
Mines			-0.257	4.516***	6.13***	-15.92**	40	0.721
Misc	1,992	-0.922	1.176***	-0.58	0.524	3.089	86	0.578
Not Classified	7.148	-0.119	0.578***	4.185***	1.804***	-4.823***	175	0.708

Table 11. Pooled Stock Price Regression by Industry on Disclosures Proxies (Continued)

	Disclosure		BVPS	EPS	LnAst	Intercp	N	Adj R^2
Paper	35.114	(0.000)***	0.451***	2.013*	2.639***	-6.497**	203	0.388
PerSrv	4.392	-0.374	0.351**	1.119*	1.286*	9.135**	87	0.266
Rtail	5.74	(0.000)***	0.772***	0.781***	1.676***	-1.891	437	0.537
Smoke	-4.952	-0.554	-0.033	6.861*	2.697	-7.746	25	0.618
Steel	-6.538	-0.169	0.716***	0.892***	1.276***	-2.011	263	0.545
Telcm	-0.256	-0.802	0.835***	0.226	1.053***	2.693*	866	0.492
Toys	0.218	-0.882	0.348**	1.239*	2.358***	-3.633***	155	0.547
Trains	3.391	(0.062)*	0.474***	0.723***	2.981***	-8.381***	493	0.54
Txtls			0.785***	2.083	2.478***	-10.812***	56	0.698
Util	0.014	-0.994	0.9***	1.781***	0.765***	2.32**	705	0.642
Whlsl	3.453	(0.065)*	0.654***	0.978	2.5***	-5.391***	514	0.528

Panel B: Stock price regression by industry on various types of security activities related disclosures

Coefficients for BVPS, EPS, NEG, Year, and Intercept are suppressed for readability

	P		V		A		PV		VA		PA		PVA		Obs	Adj R^2
Autos	-14.199	(0.000)***	0	(.)	0	(.)	-16.135	(0.000)***	0	(.)	0	(.)	0	(.)	313	0.567
Banks	1.147	(0.086)*	-2.098	-0.308	0	(.)	-0.598	-0.59	0	(.)	0	(.)	0	(.)	3096	0.688
BldMt	-1.981	-0.761	-8.333	(0.000)***	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	407	0.631
Books	1.439	-0.788	-13.452	(0.005)***	0	(.)	5.074	-0.233	0	(.)	0	(.)	0	(.)	170	0.626
BusSv	2.658	(0.012)**	1.448	(0.082)	-6.455	(0.435)	0.801	(0.086)*	4.221	(0.786)	2.388	(0.000)***	2.191	-0.173	2941	0.455
Chips	5.069	-0.383	5.84	(0.047)**	0	(.)	-0.537	-0.709	0	(.)	0	(.)	6.94	(0.000)***	1231	0.588
Clths	0	(.)	7.104	(0.035)**	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	147	0.755
Cnstr	-4.638	(0.001)***	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	193	0.648
Coal	-1.485	-0.726	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	32	0.588
Drugs	-4.666	(0.005)***	2.583	-0.332	0	(.)	-0.35	-0.827	0	(.)	0	(.)	0	(.)	1716	0.499
Enrgy	1.211	-0.803	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	828	0.723
Fin	0.879	-0.541	5.968	-0.346	0	(.)	-3.028	(0.176)(.)	0	(.)	0	(.)	-3.438	(0.236)	1379	0.454
Food	6.552	-0.355	-0.754	-0.946	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	308	0.531
Fun	1.722	-0.409	-12.681	(0.010)***	0	(.)	-4.861	(0.095)*	0	(.)	0	(.)	1.19	-0.804	240	0.518
Gold	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	269	0.485
Hlth	-4.494	-0.114	1.015	-0.594	0	(.)	6.06	(0.041)**	0	(.)	0	(.)	0	(.)	322	0.508
Hshld	-3.744	-0.463	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	63	0.686
Insur	4.26	(0.005)***	-0.755	-0.512	0	(.)	6.501	(0.003)***	0.929	-0.31	0	(.)	0	(.)	838	0.626
LabEq	-0.533	-0.839	5.097	-0.115	0	(.)	3.24	-0.138	0	(.)	0	(.)	0	(.)	1056	0.568
Mach	-1.19	-0.609	1.936	-0.557	19.097	(0.287)	-0.769	-0.694	0	(.)	0	(.)	-3.189	-0.187	921	0.594
Meals	8.228	(0.039)**	-9.869	(0.000)***	0	(.)	-1.529	-0.287	0	(.)	0	(.)	0	(.)	331	0.534
Mines	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	40	0.721
Misc	0	(.)	0	(.)	0	(.)	1.002	-0.922	0	(.)	0	(.)	0	(.)	86	0.578
Not Classified	-4.407	(0.013)**	12.658	(0.000)***	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	175	0.713
Paper	0	(.)	35.114	(0.000)***	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	203	0.388
PerSrv	0	(.)	0	(.)	0	(.)	5.826	-0.256	-7.913	(0.436)	0	(.)	0	(.)	87	0.267
Rtail	3.868	(0.007)***	3.444	-0.337	0	(.)	6.617	(0.000)***	0	(.)	0	(.)	0	(.)	437	0.536
Smoke	-4.952	-0.554	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	25	0.618
Steel	-0.101	-0.956	0	(.)	0	(.)	-12.83	(0.000)***	0	(.)	0	(.)	0	(.)	263	0.546
Telcm	-1.012	-0.824	-0.89	-0.628	-6.332	(0.417)	0.254	-0.838	-0.171	-0.898	4.02	(0.000)***	0	(.)	866	0.489
Toys	0	(.)	0	(.)	0	(.)	0.218	-0.882	0	(.)	0	(.)	0	(.)	155	0.547
Trans	2.4	-0.214	1.354	-0.63	0	(.)	5.956	-0.211	0	(.)	0	(.)	11.34	(0.000)***	493	0.539
Txtls	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	56	0.539
Util	0.014	-0.994	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	0	(.)	705	0.642
Whlsl	-3.246	-0.123	16.402	(0.095)*	0	(.)	3.452	(0.066)*	5.214	(0.762)	0	(.)	10.805	(0.000)***	514	0.538

nificant ($p < 0.10$) for Wholesale, Healthcare, and Business Services. For Autos, Steel, and Fun, PV is negative and significant ($p < 0.001$). PA is positive and statistically significant for both Business Services and Telecommunication ($p < 0.001$). VA has mixed signs, but is not statistically significant for any industry segments. Finally, PVA is also positive and significant ($p < 0.001$) for the Chips, Transportation, and Wholesale industries.

The overall results of the industry analysis are consistent with the main results (cross-sectional pooled design, Table 5) in that the voluntary disclosures of proactive security activities have the greatest effect on price. Additionally, Business Services, Clothes, Retail, Insurance, and Transportation are the industries in which the information security related disclosures have the most significance. All of these industries rely heavily on e-commerce and interact with sensitive customer data. However, for the Banking and the Finance industries, the market does not seem to be reacting to any disclosures of information security related activities. Thus, the industry analysis seems to corroborate the cross-sectional pooled analysis, and provides support that our proxy for information security disclosures is reliable.

Discussion and Implications of Overall Results

An unintended consequence of the digital economy is that organizations have become much more vulnerable to information security breaches due to the interconnectivity created by computer networks. Thus, firms need to be concerned with the potential negative effects of information security activities (e.g., Campbell et al. 2003). However, disclosures concerning information security issues related to a firm are not required by the SEC. Accordingly, whether or not a firm voluntarily decides to disclose items concerning information security within its annual reports filed with the SEC is a strategic choice. There is, however, clear evidence that an increasing number of firms are making this choice (Gordon et al. 2006).

We can gain insight into the strategic choice concerning voluntary disclosures of information security items by reviewing the findings from this study. Based on a sample of 1,641 disclosing and 19,266 non-disclosing firm-years in a cross-sectional pooled model, the main results provide empirical support for the argument that voluntary disclosures related to information security on reports filed with the SEC are positively and significantly related to stock price. That is, it appears that senior managers within firms have recognized the value-relevance of voluntarily disclosing items related to their information security. These findings provide generic evidence of the signaling argument, which states that managers voluntarily disclose information in their reports filed with the SEC that are consistent with increasing firm value. On average, voluntary disclosure concerning information security affects the stock price of firms by more than 6 percent. The magnitude of this effect is consistent with the magnitude of the effects of other voluntary disclosures found in other studies, such as Botosan (1997).

The above argument notwithstanding, the findings from our study make it clear that not all voluntary disclosures concerning information security are equal in terms of firm value. In fact, our findings show that voluntary disclosures related to proactive security measures by a firm have the greatest impact on the firm's market. Thus, in terms of strategic choices on the part of managers, it appears that managers would be wise to consider emphasizing their firm's proactive security activities when voluntarily disclosing items about information security.

Based on an industry analysis, it is also clear that the market value increases associated with voluntary disclosures related to information security vary across industries. Specifically, firms in industries that rely heavily on e-commerce activities (e.g., business services, retail, etc.) gain more, on average, from voluntary disclosures of items regarding information security than other firms. Of course, this finding is not surprising. However, it does suggest that firms in these types of industries, not already disclosing such information, would be wise to consider reevaluating their disclosure policies.

Another finding regarding our industry analysis pertains to Banking and Finance firms. Based on our study, firms in these industries do not experience a significant market-value increase from voluntarily disclosing items related to information security. Given the existing stringent regulations on firms in these industries concerning the protection of confidential information (e.g., the Gramm Leech Bliley Act), it would appear that these firms have little to gain in terms of market value from voluntarily disclosing items with respect to their information security. In other words, investors have apparently already assumed that these firms are paying significant attention to such issues as a result of the legislation.

In addition, based on our bid-ask spread analysis, it would appear that the market value increase associated with information security disclosures is, at least in part, due to the reduction in asymmetric information between investors and firms. Although beyond the scope of this paper, the finding that voluntary disclosures pertaining to information security

results in a reduction of information asymmetry suggests (although certainly does not prove) that new regulations mandating information security disclosures may not be required.

Concluding Comments

The primary objective of this paper has been to assess empirically the market value of voluntary disclosures concerning information security. Based on an empirical study, we find support for the argument that voluntary disclosures concerning information security are positively and significantly related to the stock price of firms. While support for our main argument is boosted by numerous robustness tests, support does vary depending on the industry in which firms operate.

As with all empirical studies, our study has its limitations. First, our primary analysis is based on the modified Ohlson (1995) model. Although this is the most widely used specification for value-relevance empirical studies, it has known weaknesses (for a discussion, see Holthausen and Watts 2001). However, the model is well grounded theoretically in the tradition of work done by Peasnell (1982) and Edwards and Bell (1961) and has reasonably robust empirical predictive ability (Barth et al. 2001). Furthermore, we also conduct a bid-ask spread analysis that provides further empirical support for our market relevance findings.

A second potential limitation of our study is that our voluntary disclosure variable might be noisy. This could happen because we are focusing on a single source of information (i.e., annual reports filed by firms with the SEC). For example, it could be that there were public disclosures prior to the SEC filings of annual reports. Accordingly, we did check press releases and other public sources for this possibility. We only found a small number of such public disclosures, and these disclosures were essentially related to actual security breaches. The event study literature on the effect of public announcements of actual security breaches shows that such breaches tend to cause a loss in a firm's market value. It then follows that omitting a variable indicating whether or not a firm's breaches were released to the public prior to the filing of the firm's annual report should make it harder to find significance of a positive association between generic voluntary disclosures pertaining to information security and firm valuation. The fact that we did find a positive association between voluntary disclosures and firm value, in spite of the bias against such a finding, adds support to our main finding.

A third potential limitation of our study is related to the relative size of the sample of disclosing firms versus non-disclosing firms. While the sample size of the disclosing firms is itself large, the fact that this percentage is less than 10 percent of the total sample could be of some concern. However, various robustness tests (e.g., random sample matched pair tests) support our main finding.

A fourth potential limitation of our study is the fact that the three voluntary disclosure categories used in the additional analyses section of this paper could be challenged. However, the three disclosure categories were corroborated with experts from the information security field. In addition, factor analysis of the keywords confirms our three categories. Furthermore, the industry analysis provides some empirical support that our voluntary disclosure variable is indeed measuring the anticipated impact of disclosing items related to information security. A fifth potential limitation of our study pertains to the validity of the implicit underlying assumption that the voluntary disclosures are truthful. In other words, there are competitor deterrence models that might view such disclosures as "cheap-talk" (Gigler 1994). However, we believe that both reputational considerations and litigation costs preclude firms (or at least the overwhelming majority of firms) from disclosing untruthful information.

The above limitations notwithstanding, we believe the study reported in this paper adds to our understanding of how voluntary disclosures concerning information security affect the market value of firms. However, more work is needed along the lines of the questions that follow. How do voluntary disclosures about information security affect the risk profile that investors and creditors assign to a firm? How do voluntary disclosures related to information security affect the signal concerning management's talent? Do voluntary disclosures with respect to information security potentially lower litigation costs arising from information security breaches? What is the best theoretical model (e.g., economics-based or behaviorally based) for explaining the way managers make the strategic choice concerning voluntary disclosures of information security? Finally, do voluntary disclosures about information security help a firm gain market share by attracting customers (due to increased comfort and confidence in dealing with the firm)? The above questions provide possible avenues for future research that would help us better understand the role of voluntary disclosures concerning information security.

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SPECIAL ISSUE

MARKET VALUE OF VOLUNTARY DISCLOSURES CONCERNING INFORMATION SECURITY

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Appendix A

Coding Instrument for Information Security Disclosure

Proactive security activities encompass voluntary disclosure concerning information security that firms are taking to improve the security of their information and information systems. Examples of voluntary disclosures falling into this category include discussions about a firm's use of encryption, secure socket layers data transmission, implementation of network security measures, or disclosure of computer security policy. The disclosure is coded as 1 if the firm provides any information, 0 otherwise.

Potential security vulnerabilities includes voluntary disclosures that discuss a firm's vulnerability in infrastructure (i.e., a susceptibility of their computer systems), or report that the firm's infrastructure is at risk of being disrupted by computer viruses or hacking. The disclosure is coded as 1 if the firm discusses any vulnerability, 0 otherwise.

The third category is comprised of voluntary disclosures that report an actual information security breach (i.e., these disclosures explicitly consist of reports that detail "denial-of-service" attacks or hacker penetration of the information system infrastructure). The disclosure is coded as 1 if the firm specifically lists a security breach, 0 otherwise.

Appendix B

Examples of Disclosures of Security Activities

Proactive Security Activites

"…disclose nonpublic personal information to nonaffiliated third parties and affiliates; annual notices of their privacy policies to current customers; and a reasonable method for customers to opt out of disclosures to nonaffiliated third parties. Compliance with these rules was mandatory after July 1, 2001. San Rafael Bancorp and Tamalpais Bank were in full compliance with the rules as of or prior to their respective effective dates. SAFEGUARDING CONFIDENTIAL CUSTOMER INFORMATION. Under Title V, federal banking regulators are required to adopt rules requiring financial institutions to implement a program to protect confidential customer information. In January 2000, the federal banking agencies adopted guidelines requiring financial institutions to establish an information security program. Tamalpais Bank implemented a security program appropriate to its size and complexity and the nature and scope of its operations prior to the July 1, 2001 effective date of the regulatory guidelines, and since initial implementation has, as necessary, updated and improved that program. (PAGE: 27)

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Report: 10-KSB *Period: 12/31/2003*

Potential Security Vulnerabilities Disclosure

Many of our competitors have substantially greater resources to invest in technological improvements. We cannot assure you that we will be able to effectively implement new technology-driven products and services, which could reduce our ability to effectively compete. Our hardware and software systems are vulnerable to damage that could harm our business. We rely upon our existing information systems for operating and monitoring all major aspects of our business, including deposit and loan information, as well as various internal management functions. These systems and our operations are vulnerable to damage or interruption from natural disasters, power loss, network failure, improper operation by our employees, security breaches, computer viruses or intentional attacks by third parties. Any disruption in the operation of our information systems could adversely impact our operations, which may affect our results of operations and financial condition. (PAGE: 9)

Filer: YARDVILLE NATIONAL BANCORP Date Filed: 3/31/2003
Report: 10-K Period: 12/31/2002

Actual Security Breaches

For example, approximately four percent of our customers experienced a brief delay in delivery of services on June 15, 2004 as a result of a denial of service resulting from an attack by hackers on our network. We believe this attack targeted several well-known websites that are customers of Akamai. Although we have taken steps to enhance our ability to prevent the recurrence of such an incident, there can be no assurance that similar attacks will not be attempted in the future, that our enhanced security measures will be effective or that a successful attack would not be more damaging. Any widespread loss or interruption of our network or services would reduce our revenues and could harm our business, financial results and reputation. (PAGE: 10)

Filer: AKAMAI TECHNOLOGIES INC Date Filed: 3/16/2005
Report: 10-K Period: 12/31/2004