Cybersecurity Risk

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1. Introduction

Background & Motivation

- Cybersecurity risk is the risk of financial loss, disruption, or damage to the reputation of a firm as a result of a failure in its information technology systems due to external attacks.
- SolarWinds in 2020
- It is important to have a deeper understanding of individual firms' exposure to cybersecurity risk, its quantification, and its effects on asset prices.
- The idea behind the measure is firms that are actually attacked are more vulnerable to cyberattacks ex-ante, express this heightened risk ex-ante in their risk disclosure, and that firms that use similar words to describe risk exposure and exposure management, exhibit similar levels of cybersecurity risk.

1. Introduction

Question

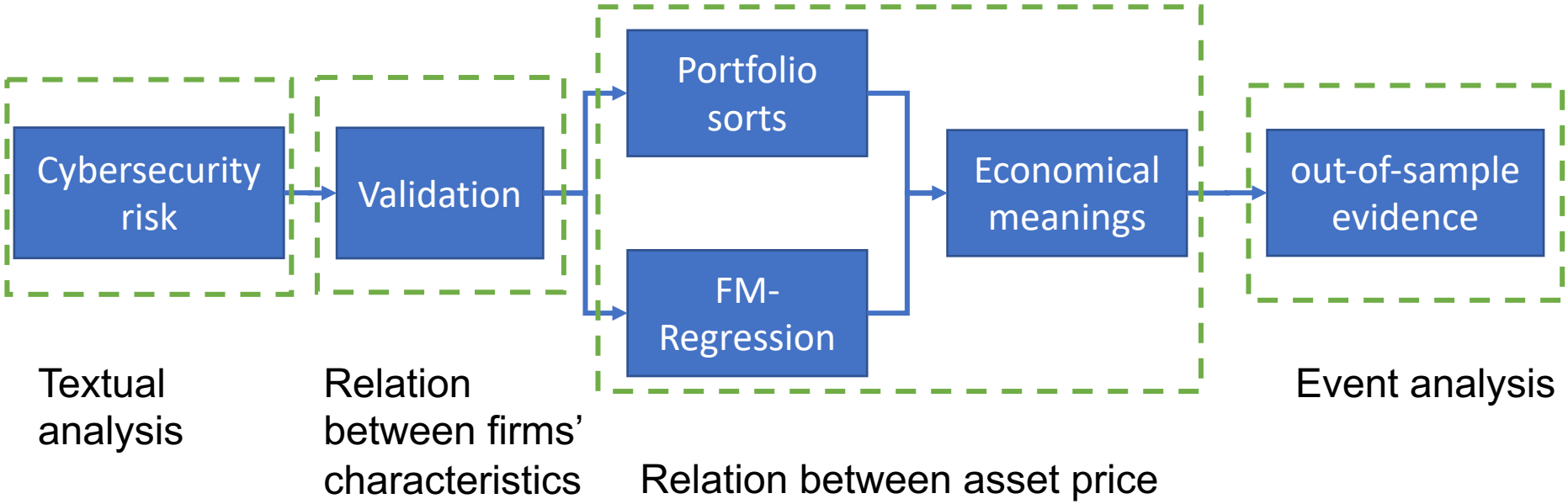
- How can we measure the cybersecurity-risk in firm level?
- Does the stock market price cybersecurity risk in the cross-section of returns?

1. Introduction

Research contents

- We use textual analysis to built a novel firm-level measure of cybersecurity-risk for all US-listed firms and validate our measure in several ways.
- We then examine the cross-sectional relation between cybersecurity risk and stock returns by running stock-level Fama-MacBeth regressions.
- We introduce a cybersecurity-risk factor and test its economic and statistical significance.
- We exploit a recent large-scale cyberattack providing out-of-sample evidence on the validity of our measure, and the effect of cybersecurity risk on stock prices.

1. Introduction



1.Introduction

Related researches

- Textual analysis: Loughran and McDonald (2016) for a review. Use text from financial reports, such as 10-Ks and 10-Qs. *Cohen et al (2020), Hoberg et al (2015), Frésard et al (2020), Campbell et al (2014).*
- Several studies focus on the valuation impact of cyberattacks: *Hilary et al (2016); Johnson et al (2017); Amir et al (2018); Lending et al (2018); Tosun (2020)*
- How firms adjust their financial, investment, governance, and risk-management policies following costly cyberattacks: *Akey et al(2020); Ashraf (2021); Boasiako et al (2021); Kamiya et al. (2021)*
- Jiang, Khanna and Yang (2020) Apply logistic LASSO regressions to estimate the ex-ante likelihood that a firm will experience a cyberattack
- Rey and Tahoun (2021) focus on quarterly earnings calls to construct a text-based measure of cybersecurity risk for a sample of international firms.

1.Introduction

Contribution

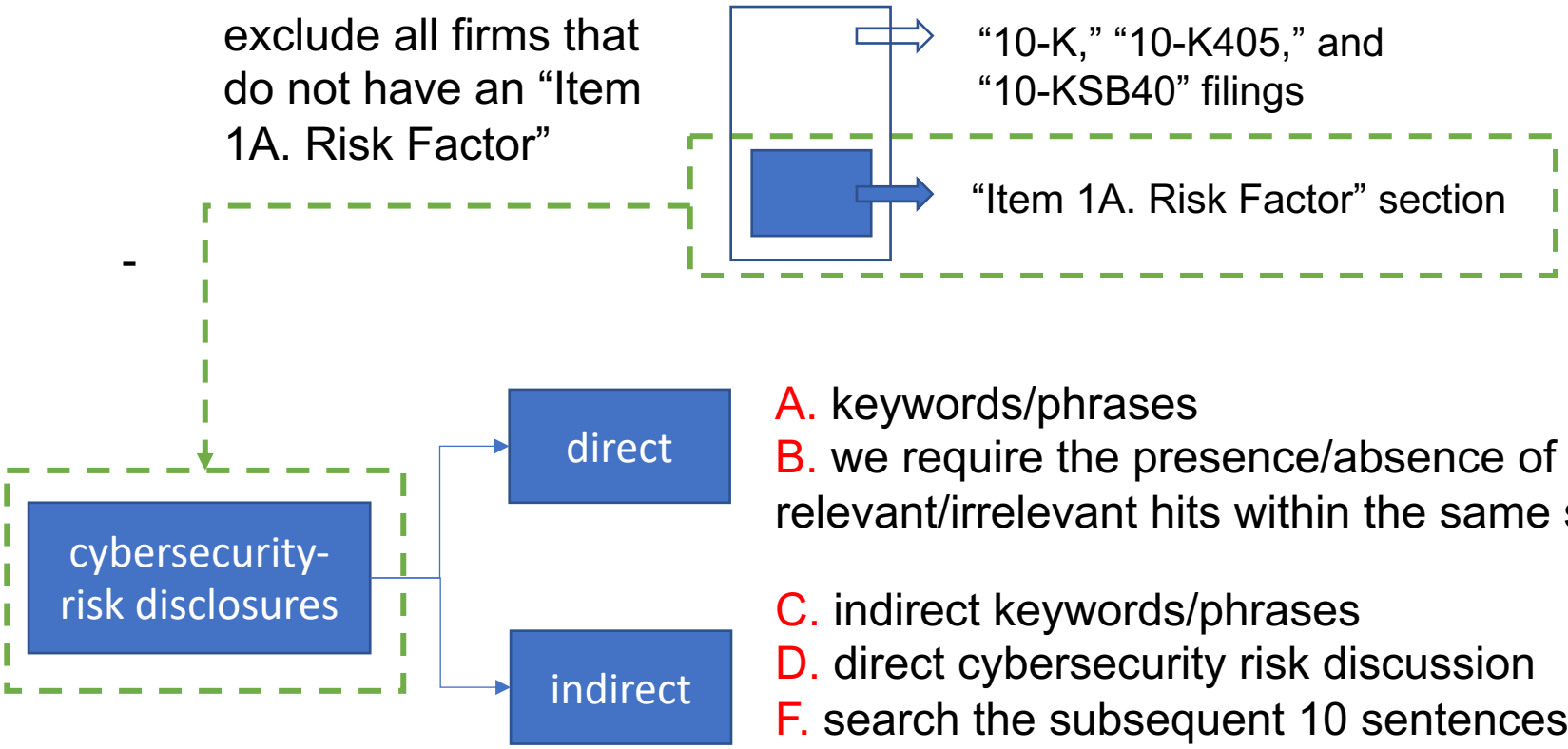
- This study contributes to the literature in several ways. First, it adds to a growing literature extracting important economic information utilizing text as data
- We add to the asset-pricing literature by showing that cybersecurity risk is priced in the cross-section of stocks.
- Finally, we also add to the literature focusing on the implications of cyberattacks on the attacked firms.
- Our study opens several avenues for future research. The cybersecurity-risk measure and its underlying methodology, which is transparent, easily implementable, and comprehensive enables a systematic analysis on cybersecurity risk and its implications for firm value, corporate policies, and firm operations.

2. Data & Variable

数据名称	数据来源
stock returns	CRSP
financial information	Standard and Poor’s Compustat database
institutional ownership	Thomson-Reuters 13F database
governance-related information	BoardEx
annual filings	SEC Edgar
data on cyberattacks	Privacy Rights Clearinghouse (PRC)
global news outlets	Factiva
abnormal institutional investor attention	Bloomberg
Search Volume Index (SVI) data	Google
firms’ key customers	FactSet Revere Supply Chain Relationships

2. Data & Variable

1) Cybersecurity-risk Disclosures



A. keywords/phrases
B. we require the presence/absence of additional relevant/irrelevant hits within the same sentence

C. indirect keywords/phrases
D. direct cybersecurity risk discussion
F. search the subsequent 10 sentences to find indirect keywords/phrases

2. Data & Variable

1) Cybersecurity-risk Disclosures

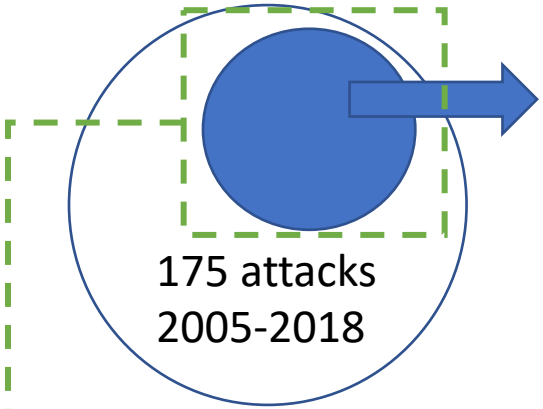
Percentage of Firms with Cyber-related Disclosures by Industry and Year

This table presents the percentage of firms with cyber-related disclosures by (i) year and (ii) Fama and French 12 industry, where: 1- Consumer Non Durables; 2 -Consumer Durables; 3-Manufacturing; 4-Energy Oil and Gas; 5-Chemicals and Allied Products; 6-Business Equipment; 7-Telephone and Television Transmission; 8-Utilities; 9-Wholesale, Retail, and Some Services; 10-Healthcare, Medical Equipment, Drugs; 11-Money Finance and 12-Other.

	Full	*Fama-French Industry Group =*											
Year	Sample	1	2	3	4	5	6	7	8	9	10	11	12
2007	0.29	0.27	0.13	0.12	0.07	0.15	0.41	0.46	0.09	0.36	0.23	0.36	0.25
2008	0.31	0.26	0.11	0.13	0.07	0.22	0.42	0.54	0.10	0.39	0.23	0.41	0.27
2009	0.35	0.27	0.17	0.11	0.07	0.28	0.46	0.55	0.19	0.46	0.26	0.48	0.33
2010	0.39	0.36	0.17	0.15	0.08	0.32	0.49	0.57	0.26	0.53	0.28	0.53	0.36
2011	0.55	0.50	0.35	0.34	0.28	0.54	0.64	0.77	0.70	0.68	0.43	0.65	0.51
2012	0.66	0.60	0.49	0.49	0.42	0.60	0.75	0.81	0.83	0.78	0.52	0.74	0.61
2013	0.73	0.71	0.68	0.57	0.57	0.72	0.79	0.89	0.91	0.86	0.61	0.81	0.68
2014	0.80	0.79	0.80	0.71	0.65	0.75	0.84	0.93	0.94	0.90	0.70	0.86	0.78
2015	0.85	0.83	0.85	0.81	0.72	0.77	0.90	0.96	0.97	0.91	0.78	0.90	0.81
2016	0.88	0.86	0.89	0.85	0.78	0.83	0.91	0.96	0.97	0.94	0.84	0.89	0.86
2017	0.90	0.90	0.93	0.88	0.85	0.88	0.93	0.97	0.95	0.94	0.88	0.91	0.88
2018	0.89	0.95	0.92	0.87	0.60	1.00	0.95	1.00	1.00	0.90	0.82	0.86	0.82

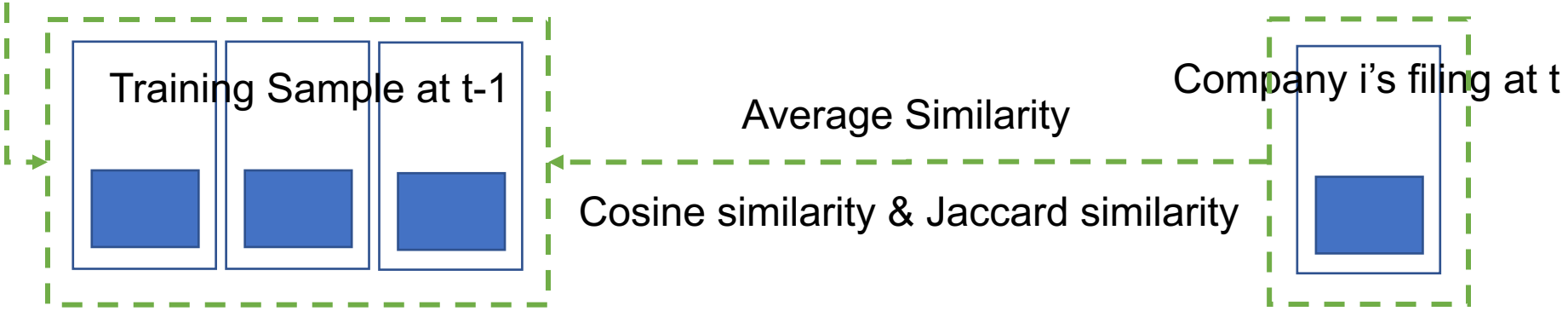
2. Data & Variable

2) Training Sample



Major cyberattacks (69 attacks in 2006-2018): We collect information on all recorded cyberattacks, and manually search news articles from Factiva to cross reference the information and to identify which cyberattacks attracted the attention of global news outlet.

But why?



2. Data & Variable

3) Cybersecurity-risk Measure

- The measure is based on how similar each firm's cybersecurity-risk disclosure is to past cybersecurity-risk disclosures of firms in our training sample
- The idea behind the measure is that firms that use similar words to describe risk exposure and exposure management, exhibit similar levels of cybersecurity risk.

$$Cybersecurity\ Risk_{i,t} = \sum_{n=1}^{N} \frac{CS_{i,n,t}}{N_{t-1}}$$

$$Cybersecurity\ Risk_{Jaccard_{i,t}} = \sum_{n=1}^{N} \frac{JS_{i,n,t}}{N_{t-1}}$$

3. Empirical results

1) Validation: Excerpts from Cybersecurity-risk Disclosures

Panel A: Excerpts for Firms with the Highest Cybersecurity Risk Score

Company Name	Fiscal Year	Cybersecurity Score	Text from Cybersecurity Risk Disclosures
Walgreens Boots Alliance Inc	2018	0.684	Like other global companies, we and businesses we interact with have experienced threats to data and systems, including by perpetrators of random or targeted malicious cyberattacks, computer viruses, worms, bot attacks or other destructive or disruptive software and attempts to misappropriate customer information, including credit card information, and cause system failures and disruptions.

Panel B: Excerpts for Firms with Low Cybersecurity Risk Score

Company Name	Fiscal Year	Cybersecurity Score	Text from Cybersecurity Risk Disclosures
Weyerhaeuser Co	2015	0.036	We and our service providers employ what we believe are adequate security measures.

Firms with high values of our measure indeed discuss threads of cybersecurity-risk extensively in their risk disclosures, whereas firms with low scores manage these risks and threads adequately and face little risk.

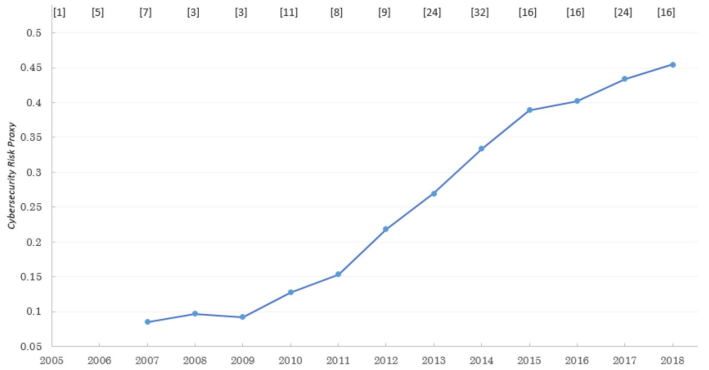
3. Empirical results

1) Validation: Cybersecurity-risk-disclosure Language

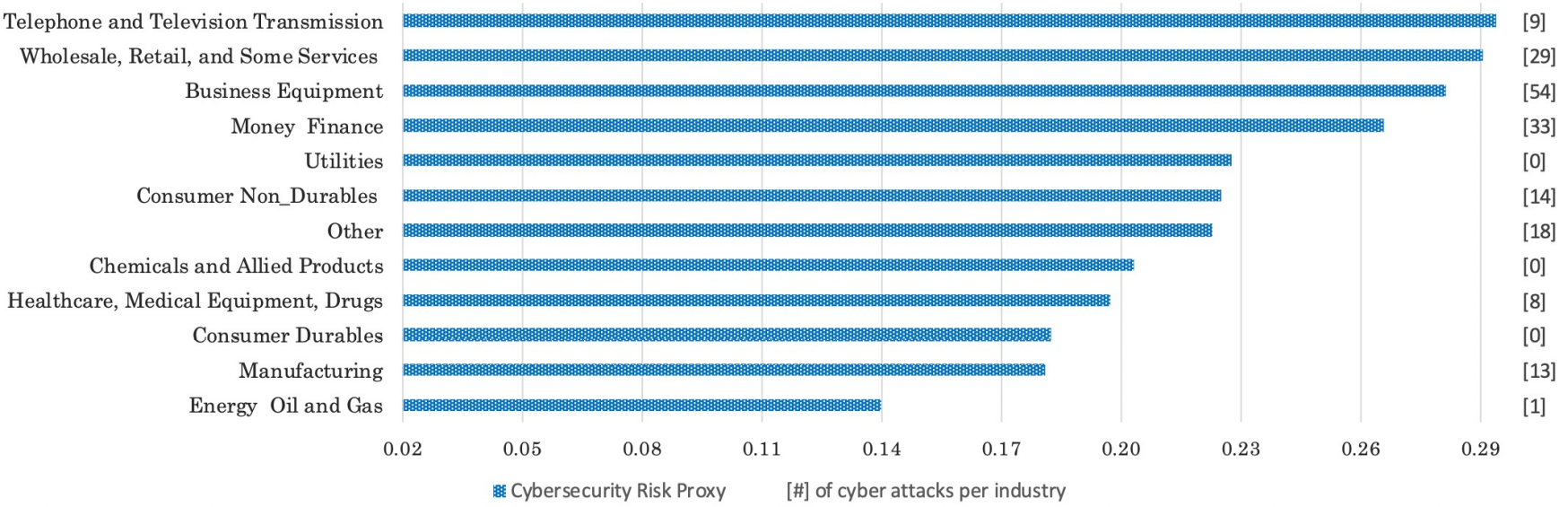
		(i)		(ii)		(iii)		(iv)		(v)		(vi)		(vii)
(i)	*Cybersecurity Risk*	1.000												
(ii)	*CRD Sentences (#)*	0.569	***	1.000										
(iii)	*CRD sentences (ratio)*	0.443	***	0.717	***	1.000								
(iv)	*Negative Words (ratio)*	0.033	***	-0.215	***	-0.133	***	1.000						
(v)	*Precise Words (ratio)*	0.084	***	0.071	***	0.016	***	-0.145	***	1.000				
(vi)	*Litigious Words (ratio)*	0.127	***	0.049	***	0.042	***	0.263	***	-0.071	***	1.000		
(vii)	*Cyber Insurance*	0.169	***	0.369	***	0.266	***	-0.115	***	0.003		0.004		1.000

Overall, these associations provide additional evidence that our measures likely captures exposure to cybersecurity risk

3. Empirical results



1) Validation: Time-series and Industry Properties



The average exposure and the number of firms exposed to cybersecurity risk increases over time, and firms in industries that are more reliant on information technology are more exposed to cybersecurity risk than other firms.

3. Empirical results

1) Validation: Firm and 10-K Characteristics

	Model 1		Model 2	
Firm Size (ln)	**0.014**	***	**0.016**	***
	[13.28]		[4.70]	
Firm Age (ln)	**-0.003**		**-0.041**	***
	[-1.29]		[-5.84]	
Tobin's Q	**0.008**	***	**0.003**	***
	[6.73]		[3.36]	
ROA	**0.062**	***	**0.033**	***
	[6.57]		[3.47]	
Tanginility	**-0.085**	***	**-0.012**	
	[-8.51]		[-0.58]	
R&D Expenditures	**-0.006**		**0.090**	***
	[-0.32]		[4.27]	
Secrets	**0.017**	***	**0.029**	***
	[4.16]		[4.24]	
Cash Flow Volatility (Industry)	**-0.247**	***	**0.025**	
	[-6.94]		[0.67]	
Risk Section Length (ln)	**0.057**	***	**0.051**	***
	[40.80]		[20.59]	
Readability (ln)	**0.007**	***	**0.004**	*
	[2.92]		[1.93]	
Institutional Ownership	**0.022**	**	**0.011**	
	[2.34]		[1.01]	
Independent Directors	**0.406**	***	**0.046**	**
	[5.79]		[1.98]	
Risk Committee	**0.013**	**	**-0.011**	
	[2.09]		[-1.08]	
Constant	**-0.461**	***	**-0.301**	***
	[-12.74]		[-6.60]	

The results show a positive association between our measure and firm size (Firm Size (ln)), growth opportunities (Tobin's Q), and profitability (ROA). These results indicate the score is higher for typically more visible firms.

Firms with higher scores are also younger (Firm Age (ln)), have trade secrets (Secrets), and spend more on research and development (R&D Expenditures).

3. Empirical results

1) Validation: Firm Outcomes

	NCSKEW	*EXTR_SIGMA*
	Model 1	Model 2
Cybersecurity Risk Index	**0.110** ***	**0.094** ***
	[3.14]	[2.91]
Firm Size (ln)	**0.048** ***	**0.026** ***
	[5.13]	[3.09]
Firm Age (ln)	**-0.031** ***	**-0.024** ***
	[-4.05]	[-3.36]
Tobin's Q	**-0.085** ***	**-0.075** ***
	[-9.59]	[-10.03]
ROA	**0.022**	**0.036** ***
	[1.48]	[2.70]
Tanginility	**-0.020** **	**-0.033** ***
	[-2.28]	[-4.04]
R&D Expenditures	**0.045** ***	**0.052** ***
	[2.95]	[3.75]
Secrets	**0.020** ***	**0.023** ***
	[2.70]	[3.33]
Cash Flow Volatility (Industry)	**0.005**	**0.002**
	[0.41]	[0.23]
Risk Section Length (ln)	**0.017** ***	**0.010** *
	[2.71]	[1.73]
Readability (ln)	**-0.015** *	**-0.010**
	[-1.89]	[-1.39]
Institutional Ownership	**0.043** ***	**0.030** ***
	[6.86]	[5.08]
Independent Directors	**-0.013** *	**-0.007**
	[-1.95]	[-1.07]
Risk Committee	**-0.033**	**-0.050** **
	[-1.55]	[-2.35]
Constant	**0.212** ***	**2.714** ***
	[9.05]	[116.3]

We expect that firms with high cybersecurity risk should have negative asymmetries in stock returns.

We estimate a linear regression in which the dependent variable is the negative coefficient of skewness of weekly returns and extreme sigma that is the negative of the worst deviation of firm-specific weekly returns from the average firm-specific weekly returns divided by the standard deviation of firm-specific weekly returns

3. Empirical results

1) Validation: Firm Outcomes

	Panel A: All Cyber Attacks		*Panel B: Major Cyber Attacks*		*Panel C: Non-major Cyber Attacks*	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Cybersecurity Risk Index	**0.961** ***	**0.656** ***	**0.749** ***	**0.461** **	**1.129** ***	**0.813** **
	[7.10]	[4.60]	[3.85]	[2.27]	[7.06]	[4.17]
Previous Attack Dummy	-	**1.503** ***	-	**1.694** **	-	**1.122** **
	-	[3.79]	-	[3.07]	-	[2.26]
Firm Size (ln)	-	**1.510** ***	-	**1.867** ***	-	**1.221** ***
	-	[10.53]	-	[8.41]	-	[7.72]
Firm Age (ln)	-	**-0.143**	-	**-0.244**	-	**-0.051**
	-	[-1.30]	-	[-1.53]	-	[-0.38]
Tobin's Q	-	**0.197**	-	**0.321**	-	**0.078**
	-	[1.31]	-	[1.63]	-	[0.39]
ROA	-	**0.483**	-	**0.400**	-	**0.563**
	-	[1.48]	-	[1.02]	-	[1.27]

We estimate a logit regression in which the dependent variable equals 1 if a firm experiences a cyberattack in a given year, and 0 otherwise.

Notably, firms with no major attacks are not part of the training sample. Therefore, this analysis provides “out-of-sample” evidence of the predictability of future cyberattacks.

3. Empirical results

2) Stock Returns: Univariate Portfolio-level Analysis

Panel A: Future (1-month) portfolio returns sorted by our Cybersecurity Risk Index

		Portfolios			
		Low Cyber-Risk [P1]	*Middle Group* [P2]	*High Cyber-Risk* [P3]	[P3]-[P1]
Excess return	ew	**0.169**	**0.710** *	**0.843** **	**0.674** ***
		[0.38]	[1.70]	[2.17]	[4.54]
	vw	**0.508**	**0.831** **	**1.117** ***	**0.609** ***
		[1.25]	[2.40]	[3.32]	[3.02]
CAPM alpha	ew	**-0.727** **	**-0.219**	**-0.054**	**0.673** ***
		[-3.32]	[-0.97]	[-0.37]	[4.69]
	vw	**-0.339** *	**-0.010**	**0.321** ***	**0.660** ***
		[-1.90]	[-0.09]	[4.01]	[3.41]
FFC alpha	ew	**-0.675** ***	**-0.169**	**0.011**	**0.686** ***
		[-4.87]	[-1.54]	[0.13]	[4.80]
	vw	**-0.277** *	**0.020**	**0.282** ***	**0.559** ***
		[-1.87]	[0.18]	[3.43]	[3.30]
Five-factor alpha	ew	**-0.602** ***	**-0.108**	**0.055**	**0.657** ***
		[-3.80]	[-0.72]	[0.74]	[4.38]
	vw	**-0.306** **	**0.016**	**0.268** ***	**0.574** ***
		[-2.30]	[0.12]	[3.23]	[3.58]

3. Empirical results

2) Stock Returns: Bivariate Portfolio-level Analysis

		Equal-weighted portfolios High - Low Cyber Risk Stocks		Value-weighted portfolios High - Low Cyber Risk Stocks	
		Avg. Return	*5-Factor alpha*	*Avg. Return*	*5-Factor alpha*
Panel A: Firm Characteristics					
Market Value	LOW	**0.681** ***	**0.668** ***	**0.418** ***	**0.451** ***
		[4.39]	[3.47]	[2.63]	[2.74]
	HIGH	**0.195** *	**0.284** ***	**0.577** ***	**0.547** ***
		[1.91]	[2.60]	[2.65]	[3.12]
Book-to-Market	LOW	**0.818** ***	**0.758** ***	**0.755** **	**0.725** ***
		[5.82]	[5.71]	[2.51]	[3.01]
	HIGH	**0.463** ***	**0.519** ***	**0.280**	**0.328** *
		[2.71]	[2.87]	[1.49]	[1.88]
ROA	LOW	**0.918** ***	**0.959** ***	**0.589** *	**0.537** *
		[5.01]	[4.72]	[1.90]	[1.68]
	HIGH	**0.287** **	**0.216** *	**0.411** **	**0.412** **
		[2.04]	[1.66]	[2.27]	[2.41]
Institutional Ownership	LOW	**0.770** ***	**0.755** ***	**0.664** ***	**0.589** ***
		[5.22]	[4.86]	[2.62]	[2.99]
	HIGH	**0.285** **	**0.277** ***	**0.170**	**0.272** *
		[2.48]	[2.63]	[1.14]	[1.71]

3. Empirical results

2) Stock Returns: Cross-sectional Regressions

	$Returns_{t+1}$			$Returns_{t+2}$	$Returns_{t+3}$	$Returns_{t+6}$	$Returns_{t+9}$	$Returns_{t+12}$
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Cybersecurity Risk Index	**0.298 *** **	**0.102 ** **	**0.124 *** **	**0.117 *** **	**0.111 *** **	**0.150 *** **	**0.122 *** **	**0.115 *** **
	[6.28]	[2.64]	[2.80]	[2.86]	[2.82]	[3.11]	[2.98]	[2.69]
Beta	-	**0.088**	**0.088**	**0.086**	**0.032**	**0.026**	**0.021**	**0.014**
		[0.81]	[0.84]	[0.76]	[0.29]	[0.26]	[0.22]	[0.15]
Market Value	-	**-0.081**	**-0.056**	**-0.067**	**-0.011**	**-0.018**	**0.042**	**-0.011**
		[-1.22]	[-0.77]	[-0.95]	[-0.15]	[-0.27]	[0.58]	[-0.14]
Book-to-Market	-	**0.067**	**0.067**	**0.063**	**0.056**	**0.070**	**0.078**	**0.078 ***
		[1.25]	[1.31]	[1.24]	[1.09]	[1.44]	[1.61]	[1.79]
Momentum	-	**0.153 ***	**0.148 ***	**0.103**	**0.113**	**0.079**	**0.164 *** **	**0.147 *** **
		[1.76]	[1.70]	[1.28]	[1.51]	[1.21]	[4.02]	[3.21]
Reversal	-	**-0.117 ** **	**-0.123 ** **	**0.207 *** **	**0.139 ** **	**0.139 *** **	**0.115 ***	**0.067**
		[-2.08]	[-2.22]	[2.87]	[2.47]	[2.97]	[1.89]	[1.03]
Illiquidity	-	**-0.013**	**-0.015**	**0.023**	**0.029**	**0.052 ***	**0.027**	**-0.005**
		[-0.35]	[-0.41]	[0.77]	[0.94]	[1.65]	[0.86]	[-0.14]
CoSkew	-	**-0.029**	**-0.026**	**-0.008**	**-0.022**	**-0.005**	**-0.026**	**0.034**
		[-0.95]	[-0.85]	[-0.29]	[-0.63]	[-0.15]	[-0.78]	[1.03]
Indiosyncratic Volatility	-	**-0.474 *** **	**-0.467 *** **	**-0.385 *** **	**-0.487 *** **	**-0.495 *** **	**-0.405 *** **	**-0.458 *** **
		[-5.76]	[-5.79]	[-4.19]	[-5.53]	[-6.01]	[-4.76]	[-5.67]
Asset Growth	-	**-0.108 *** **	**-0.099 *** **	**-0.070 ***	**-0.042**	**-0.066**	**0.013**	**0.008**
		[-2.75]	[-2.66]	[-1.95]	[-1.20]	[-1.46]	[0.27]	[0.21]
ROA	-	**0.518 *** **	**0.504 *** **	**0.477 *** **	**0.444 *** **	**0.493 *** **	**0.550 *** **	**0.593 *** **
		[7.59]	[8.10]	[7.90]	[6.83]	[7.79]	[11.21]	[11.04]

3. Empirical results

2) Stock Returns: Economical meanings

- To the extent that the higher returns of stocks with high exposure to cybersecurity risk is due to a compensation for risk.
- we should find that high-cybersecurity-risk stocks perform poorly and significantly worse than low-cybersecurity-risk stocks on days of increased attention toward and concerns of cybersecurity risk

$$CRF_t = a + \beta \times High\_Google\_SVI\_dummy_t + \gamma_i \times \boldsymbol{X}_t + error,$$

- CRF is the cybersecurity-risk factor (2*3)
- High_Google_SVI_dummy (hacker and data breach topics)
  - First, we download a series of daily SVI data that and rescaling.
  - We estimate daily abnormal SVI by scaling each daily SVI with the median SVI estimated during the past 2 weeks to adjust for seasonality.
  - Extreme attention days as days when the daily abnormal SVI is greater than the mean abnormal SVI plus n standard deviations, both estimated during the past 2 weeks.

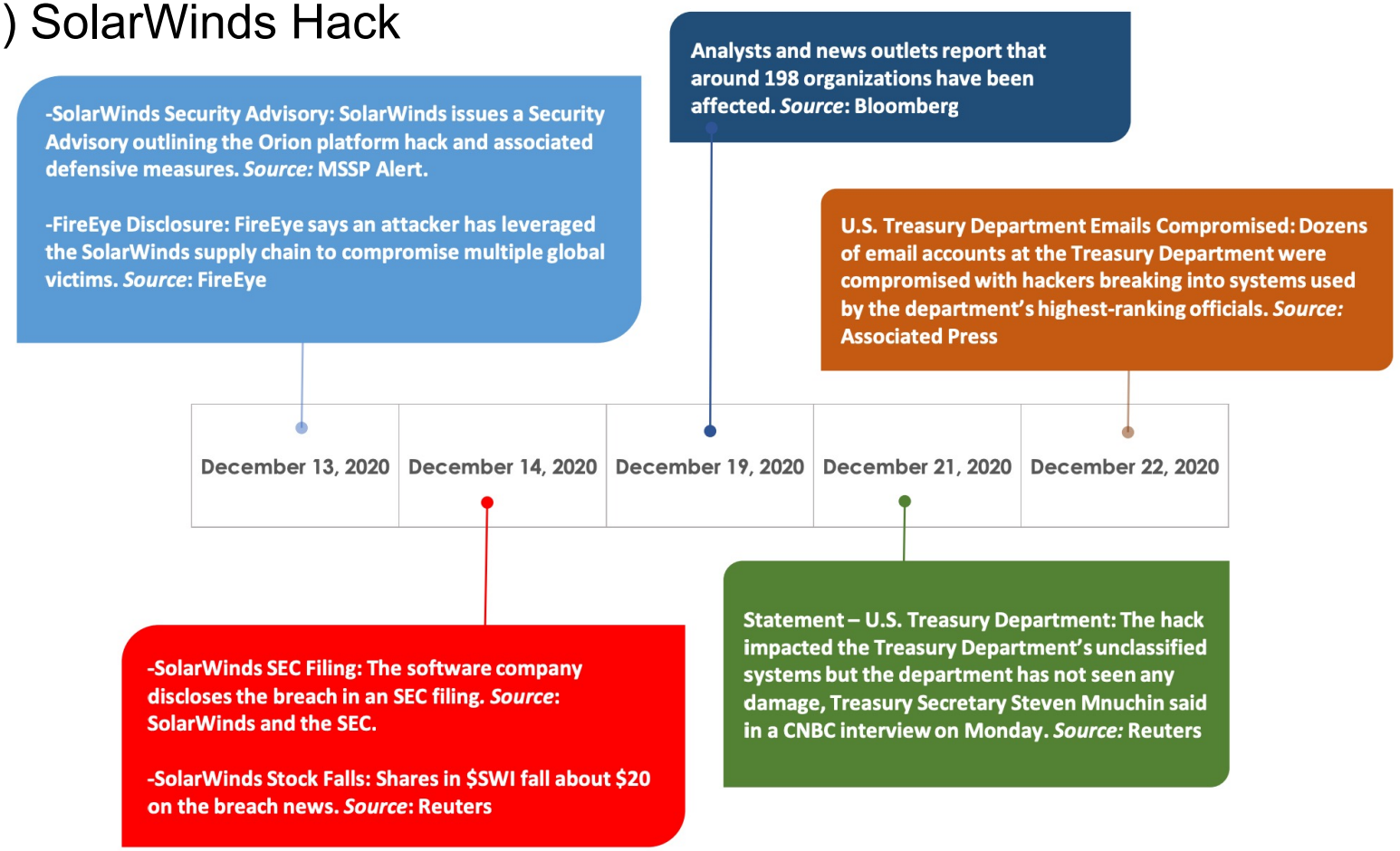
3. Empirical results

2) Stock Returns: Economical meanings

	Cybersecurity Risk Factor $_t$			
	CONTROLS			
	NONE	*CAPM*	*FFC*	*FF-5*
	[1]	[2]	[3]	[4]
Panel A: Benchmark				
Constant	**0.0002** ***	**0.0002** ***	**0.0002** ***	**0.0002** ***
	[3.39]	[3.55]	[3.48]	[3.63]
High Google SVI Dummy	**-0.0004** **	**-0.0004** **	**-0.0004** **	**-0.0004** ***
	[-2.43]	[-2.41]	[-2.46]	[-2.64]
Panel B: Robustness (Alternative Factor)				
Constant	**0.0002** **	**0.0002** **	**0.0002** **	**0.0002** ***
	[2.50]	[2.46]	[2.48]	[2.70]
High Google SVI Dummy	**-0.0005** ***	**-0.0005** ***	**-0.0005** ***	**-0.0005** ***
	[-2.69]	[-2.70]	[-2.64]	[-2.76]
Panel C: Robustness (Alternative Shocks 1)				
Constant	**0.0002** **	**0.0002** **	**0.0002** **	**0.0002** ***
	[2.33]	[2.30]	[2.34]	[2.58]
High Google SVI Dummy	**-0.0005** **	**-0.0005** **	**-0.0005** **	**-0.0006** ***
	[-2.41]	[-2.43]	[-2.42]	[-2.58]
Panel D: Robustness (Alternative Shocks 2)				
Constant	**0.0002** **	**0.0002** **	**0.0002** **	**0.0002** **
	[2.40]	[2.35]	[2.38]	[2.57]
High Google SVI Dummy	**-0.0006** ***	**-0.0006** ***	**-0.0006** ***	**-0.0007** ***
	[-2.78]	[-2.80]	[-2.76]	[-2.86]

3. Empirical results

3) SolarWinds Hack



3. Empirical results

3) SolarWinds Hack

- We first calculate cumulative abnormal returns (CAR[-1,+1] and CAR[-1,+3]) around the event date for all firms in our sample.
- We then check whether our cybersecurity risk measure is correlated with these CARs

Panel A: Average CARs per portfolio	CAR[-1,+1]	CAR[-1,+3]
Low Cybersecurity Risk Portfolio [P1]	0.006	0.004
High Cybersecurity Risk Portfolio [P10]	-0.009	-0.008
High-Low [P10-P1]	-0.015	-0.012
t-test [p-value]	[0.00] ***	[0.01] **

Panel B: Regression Analysis	CAR[-1,+1]			CAR[-1,+3]		
Cybersecurity Risk Index	**-0.011** **	-	-	**-0.011** *	-	-
	[-2.11]	-	-	[-1.66]	-	-
High Cyber Risk Dummy 1	-	**-0.007** ***	-	-	**-0.004**	-
	-	[-3.01]	-	-	[-1.48]	-
High Cyber Risk Dummy 2	-	-	**-0.012** ***	-	-	**-0.010** ***
	-	-	[-3.99]	-	-	[-2.57]
Number of Observations	3,289	3,289	3,289	3,289	3,289	3,289

3. Empirical results

3) SolarWinds Hack

- We then move to the question whether our cybersecurity risk measure can predict which companies, ex post, were most impacted by the SolarWinds hack.

Panel A: Differences in Means	Affected Firms	Non-Affected Firms	*t-test* [p-value]
% of Firms with AIA	64.00	37.13	[0.01] ***
CAR[-1,+1]	-0.012	0.002	[0.01] ***
CAR[-1,+3]	-0.017	0.001	[0.01] ***
Cybersecurity Risk Index	0.491	0.442	[0.03] **
Panel B: Logistic Regression	Prob (1=Affected Firm / 0=Non-Affected Firm)		
Cybersecurity Risk Index	**0.860** ***	-	-
	[2.77]	-	-
High Cyber Risk Dummy 1	-	**0.815** **	-
	-	[2.40]	-
High Cyber Risk Dummy 2	-	-	**0.490**
	-	-	[1.10]
Observations	3,289	3,289	3,289

4. Conclusion

- We find the measure correlates with several characteristics linked to firms hit by cyberattacks. We also find the measure is positively associated with (negative) asymmetries in stock returns and it also predicts the probability of experiencing a future cyberattack.
- Overall, these results support the view that our measure captures exposure to cybersecurity risk.
- In financial markets, cybersecurity risk is priced in the cross-section of stock returns. Using an out-of-sample test, we show that firms with higher ex-ante cybersecurity risk scores based on our measure exhibit negative cumulative abnormal returns around the hack.
- All the results support the idea that investors require compensation for bearing cybersecurity risk.