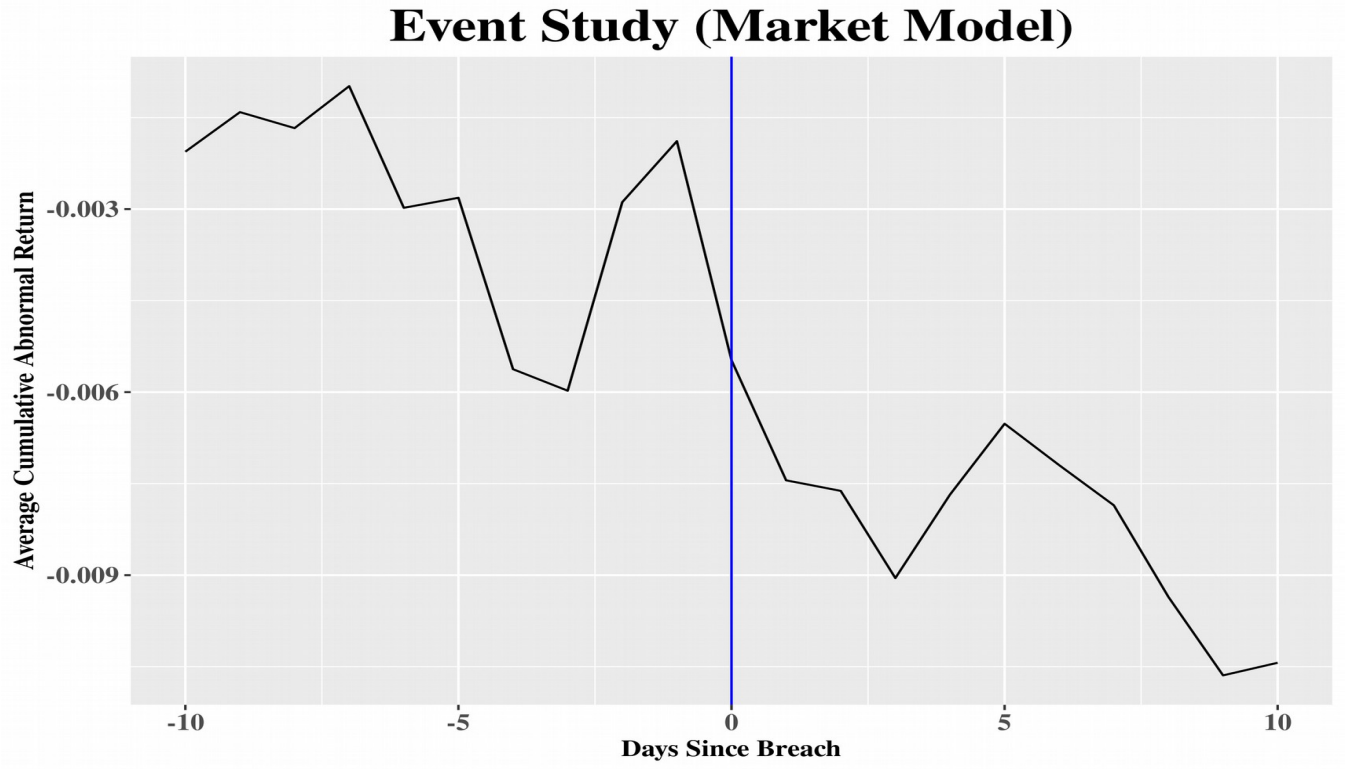
Stock Market Event Study



CAR t-test						
	Market Model			Fama-French Model		
Event Window	2 days	5 days	10 days	2 days	5 days	10 days
N	209	368	468	209	368	468
Mean	-0.77	-0.56	-0.27	-1.09	-0.84	-0.42
SD	0.49	0.27	0.18	0.46	0.27	0.17
t-stat	-1.57	-2.06	-1.54	-2.00	-3.00	-2.00
p	0.06*	0.02**	0.06*	0.01**	0.00***	0.01**
Note: Returns shown as percentages						

- Stock prices decrease significantly after data breaches, robust to many specifications.

- Stock market seems to react more strongly than firm specific variables – but this does not mean it is disproportionate.

Market Impact

What is privacy worth to consumers? information? What other

# of Data Breaches

Do they punish firms for exposing their costs do firms face?

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Firm Event Study (Profits)

	Dependent variable:				
	Net Income				
	(1)	(2)	(3)	(4)	(5)
After Breach	-112.461**	-88.894	-147.039*	-94.395	-137.462
	(54.593)	(56.429)	(77.921)	(191.056)	(194.086)
After Breach x Quarter		-7.289**	-6.648**		
		(3.455)	(3.358)		
Records Leaked (log) x After Breach			-1.076		-2.592
			(4.478)		(4.787)
Google Search Index			-1.113		-0.839
			(1.548)		(1.624)
Google Search Index x After Breach			2.153		2.095
			(1.928)		(1.866)
After x Revenue Quartile 1				-49.332	-68.370
				(204.380)	(213.003)
After x Revenue Quartile 2				-21.165	-44.463
				(200.244)	(203.987)
After x Revenue Quartile 3				6.768	-2.919
				(195.609)	(198.478)
Dependant Mean	398.35	398.35	398.35	398.35	398.35
Dependant SD	1703.73	1703.73	1703.73	398.35	1703.73
Observations	20,288	20,288	19,153	20,288	19,153
R^2	0.291	0.292	0.291	0.291	0.291
Adjusted R^2	0.276	0.277	0.276	0.276	0.276

Note: *p<0.1; **p<0.05; ***p<0.01

Standard errors clustered at the company level

Company and year fixed effects in all specifications

Prediction period is up to 10 years before breach, and event period 10 years after

Firm Event Study (Revenues)

	Dependent variable:				
	Revenue				
	(1)	(2)	(3)	(4)	(5)
After Breach	9.857	227.496	-0.617	175.091	172.559
	(228.820)	(243.690)	(264.276)	(545.346)	(404.608)
After Breach x Quarter		-62.107***	-61.318***		
		(18.785)	(17.707)		
Records Leaked (log) x After Breach			22.490		19.635
			(25.921)		(15.336)
Google Search Index			9.623		-7.636
			(10.067)		(5.714)
Google Search Index x After Breach			14.605		7.376
			(8.973)		(7.259)
After x Revenue Quartile 1				-210.757	23.482
				(546.093)	(527.595)
After x Revenue Quartile 2				-103.552	90.156
				(557.304)	(510.051)
After x Revenue Quartile 3				-380.419	-93.065
				(536.374)	(507.576)
Dependant Mean	5040.16	5040.16	5040.16	5040.16	5040.16
Dependant SD	11480.45	11480.45	11480.45	11480.45	11480.45
Observations	17,451	17,451	16,450	17,451	16,450
R^2	0.928	0.929	0.929	0.967	0.970
Adjusted R^2	0.927	0.927	0.927	0.965	0.968

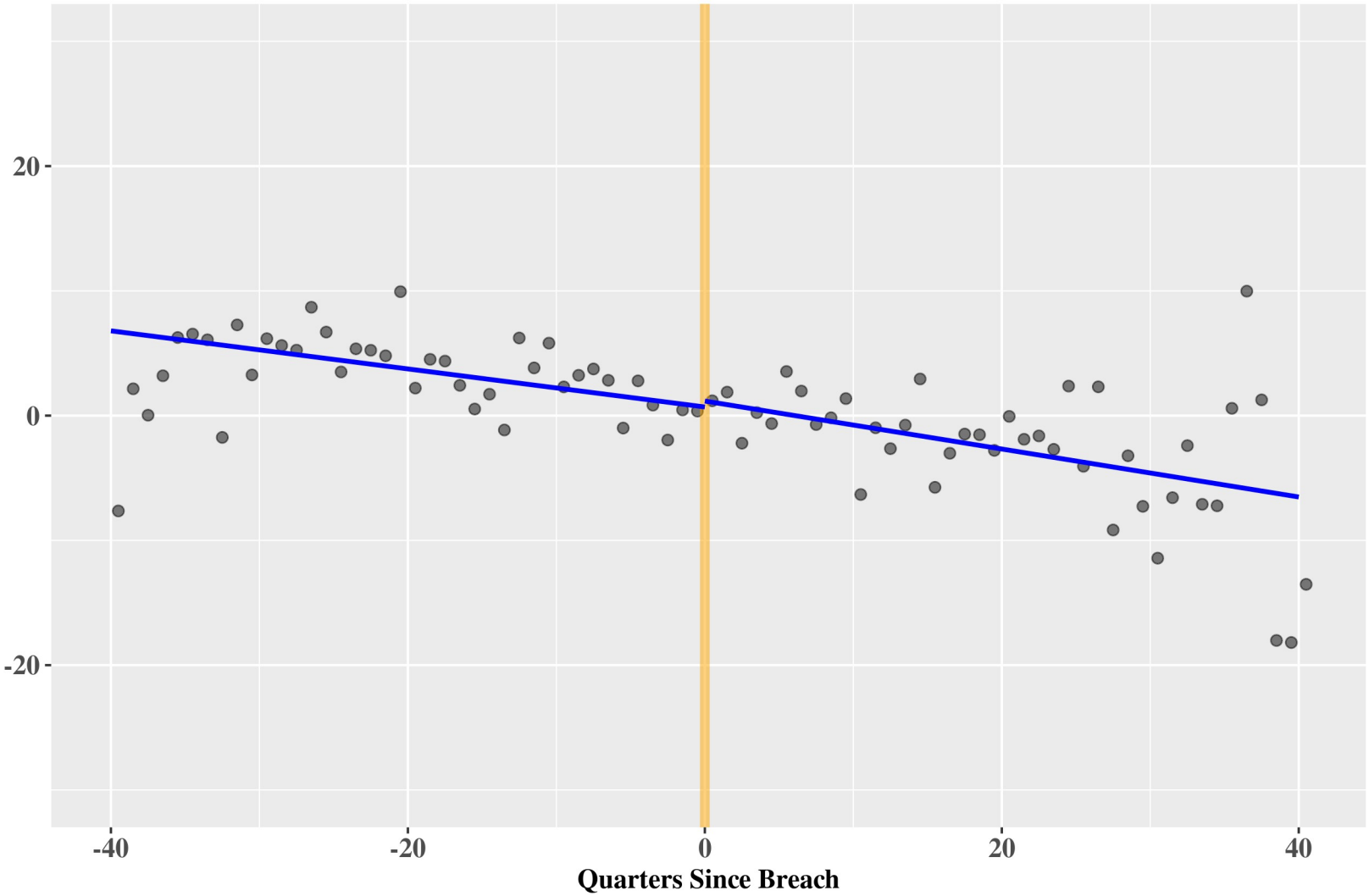
Note: *p<0.1; **p<0.05; ***p<0.01

Standard errors clustered at the company level

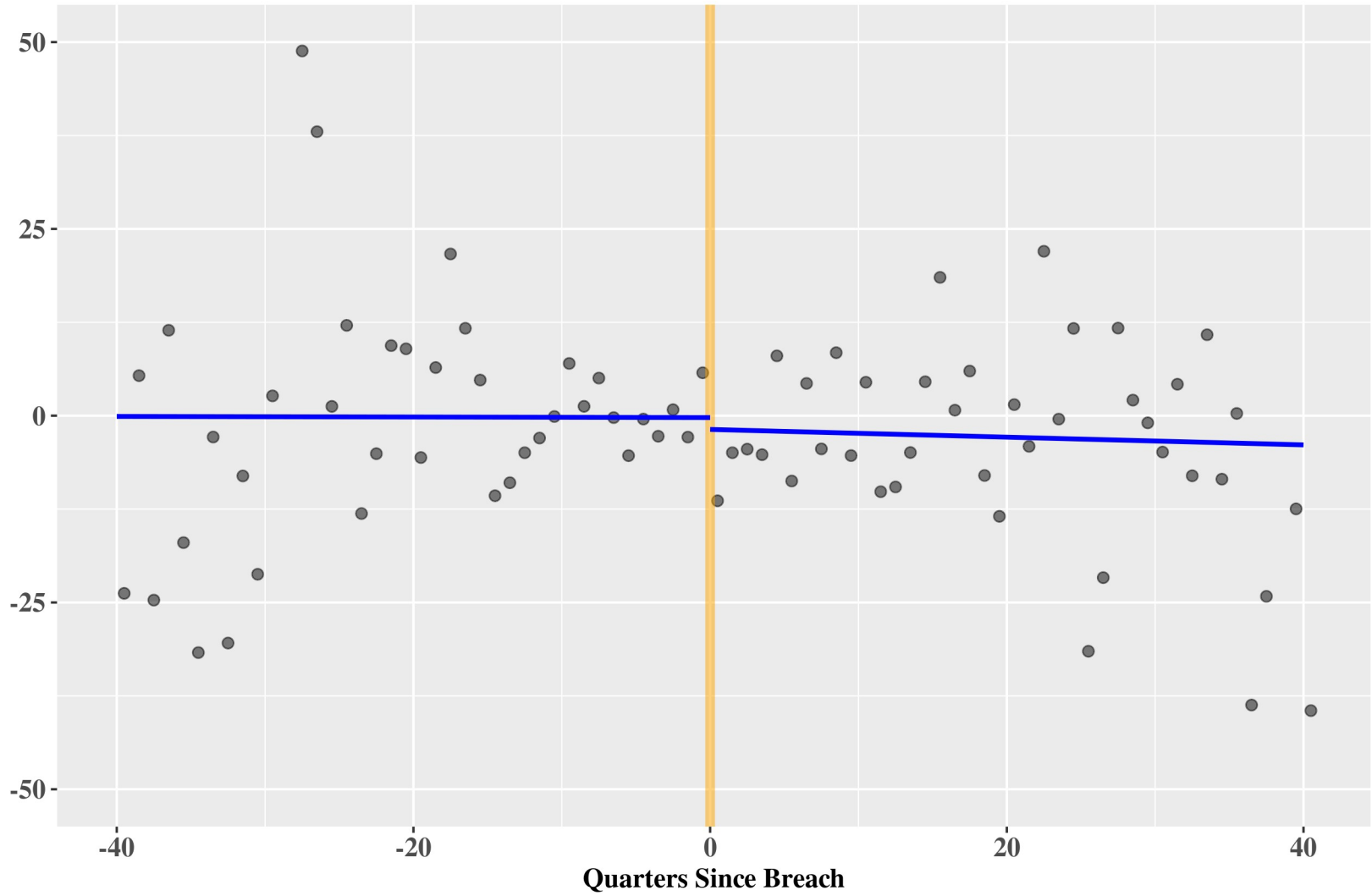
Company and year fixed effects in all specifications

Prediction period is up to 10 years before breach, and event period up to 10 years after

Mean Residual Profit (FE removed)



Mean Residual Revenue (FE removed)



Firm Event Study (Other Outcomes)

	Dependent variable:					
	Operating Expenses	Sales, General and Other Expenses	Total Shareholders' Equity	Number of Employees	Google Searches (Company Name)	Google Searches (Stock Ticker)
	(1)	(2)	(3)	(4)	(5)	(6)
After Breach	145.078	-9.636	-666.146	1.521	-0.445	-0.519
	(180.145)	(42.828)	(778.855)	(1.383)	(0.620)	(0.579)
After Breach x Quarters Since Breach	-43.501***	-12.519***	-183.554**	0.021	-0.121*	-0.008
	(14.359)	(4.192)	(71.694)	(0.168)	(0.068)	(0.072)
Dependant Mean	256.9	247.4	254.9	316.3	299.5	270.6
Observations	20,215	15,864	20,235	13,411	19,211	19,962
R^2	0.931	0.930	0.923	0.982	0.852	0.841
Adjusted R^2	0.930	0.928	0.921	0.982	0.848	0.837

Note: *p<0.1; **p<0.05; ***p<0.01

Standard Errors clustered at the quarter level

Company and quarter fixed effects in all specifications

Prediction period is up to 10 years before breach, and event period 10 years after

- Expenses are expect to rise because profits fall but revenues do not.
  - In fact expenses fall over time alongside revenues, suggesting that the firms are shrinking in size as a result of the data breach

- Google searches do not seem to be affected by data breaches.

Firm Event Study (Type of Data Loss)

	Dependent variable:		
	Net Income	Revenue	Operating Expenses
	(1)	(2)	(3)
After Breach	160.655*	955.432*	721.661*
	(90.238)	(546.363)	(382.472)
After breach x Customer Data Leaked	-229.685***	-1,074.699**	-782.083**
	(88.147)	(499.991)	(363.536)
After breach x Credit Card Leaked	-13.913	100.658	120.620
	(70.024)	(541.215)	(457.011)
After breach x SSN Leaked	-230.552**	-1,017.602*	-682.656*
	(110.068)	(559.643)	(382.480)
After breach x Name Leaked	-0.264	-162.287	-261.992
	(91.040)	(515.084)	(392.443)
After breach x Address Leaked	-117.455	317.929	398.508
	(76.637)	(382.344)	(302.439)
Dependant Mean	398.35	5040.16	3884.7
Dependant SD	1703.73	11480.45	9598.19
Observations	20,288	17,451	20,215
R^2	0.294	0.929	0.931
Adjusted R^2	0.278	0.927	0.930

Note: *p<0.1; **p<0.05; ***p<0.01

Standard errors clustered at the company level

Company and year fixed effects in all specifications

Prediction period is up to 10 years before breach, and event period 10 years after

- Overall we do not observe significant consumer punishment. However, when it is “Consumer Data” (as apposed to for example employee data) that is lost there are stronger negative effects.
    - However, the net effect (subtract row 2 from row 1) is close to zero.
- No evidence that consumers respond to loss of their credit card, name or address.
- Consumer response (lost revenues) is strongest to the loss of social security numbers.
    - This is reasonable considering that consumers likely only give this information to institutions they believe are trustworthy.

Summary Statistics

Table 1A: Summary Statistics for Fincial Variables

Statistic	N	Mean	St. Dev.
Net income (Millions USD)	20,736	392.4	1,690.8
Revenue (Millions USD)	17,855	4,991.9	11,374.3
Operation Expenses (Millions USD)	20,663	3,848.5	9,512.7
Sales, General, and Administrative Expenses (Millions USD)	16,219	959.8	2,158.2
Google Trends Index (Company Name)	19,596	24.8	27.7
Google Trends Index (Company Ticker)	20,359	31.1	28.5

Table 1B: Types of Data Loss

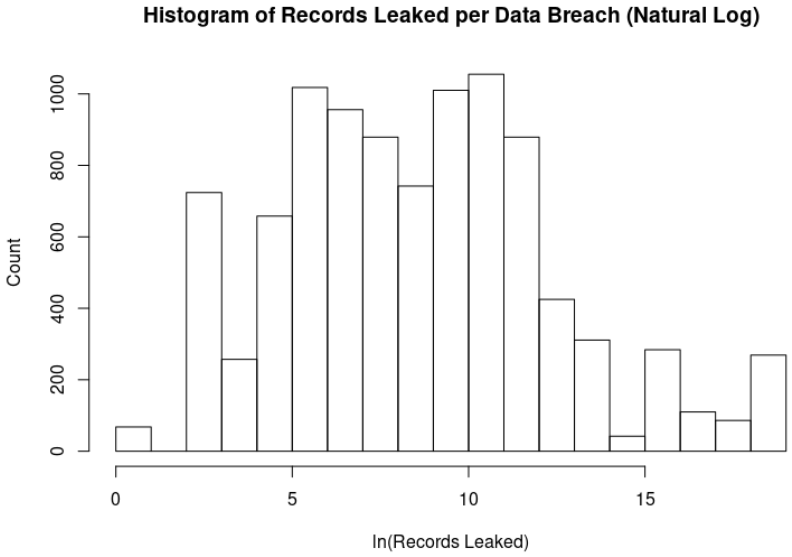
Statistic	Mean
Customer	320
Credit Card	148
Social Security Number	353
Name	423
Address	268
Total Breaches	759

Table 1C: Magnitude of Data Loss

Statistic	N	Mean	Min	Max	St. Dev.
Records leaked per breach	20,796	1,889,737	0	167,000,000	13,959,847

Table 1D: Summary Stock Market Data

Statistic	N	Mean	St. Dev.
Daily Firm Return	936,151	0.0005	0.03
Value Weighted Market Return	936,404	0.0003	0.01
Risk Free Market Return	936,404	0.04	1.19
SMB factor	936,404	0.004	0.57
HML factor	936,404	0.001	0.65



Key Take-Aways

- Firms suffer from lost profits as a result of data breaches, but not at the hands of consumers.
- Effect is not large, average discontinuous drop in profits after a breach are 6.5% of a sd.
- Firms' revenues react weakly, if at all, although there may be more negative effects for smaller businesses.
- Lost profits recover over time (After x Quarter). However, convergence rate is such that they will not obtain previous levels in any reasonable time frame.
- The size of the data breach does not seem to matter (2).
- Consumers react more when it is indeed "consumer data" that was lost, and social security numbers are particularly sensitive (3).
- The stock market reacts strongly to data breaches.

Methodology

- "Firm Event Study" has this functional form:

$$Y_{iq} = \beta_0 + \beta_1 A_{iq} + \beta_2 (Q * A_{iq}) + \alpha_i + \delta_y + \Gamma X_{iq} + \mu_{iq}$$

Where: Y_{iq} is the outcome for firm i in quarter q, A_{iq} is a dummy that indicates whether a firm has had a data breach after quarter q, and Q is the current quarter. α_i and δ_y are firm and year fixed effects.

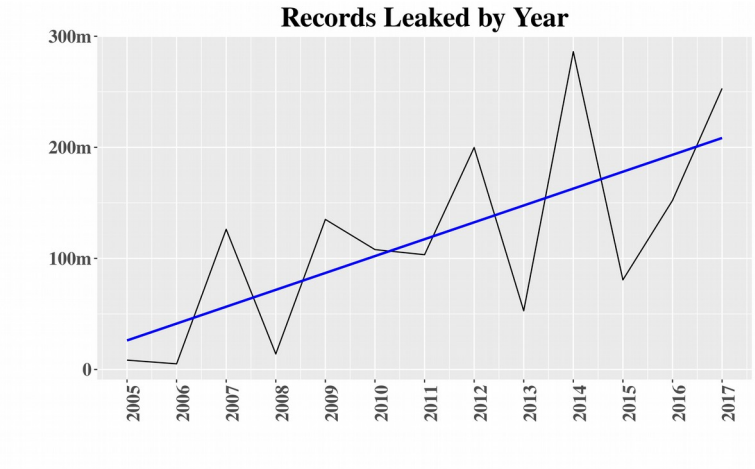
- "Stock Market Event Study" uses standard finance models (Market and Fama-French) to predict returns after the breach.

- These predicted returns are summed over the event period to calculate Cumulative Abnormal Return (CAR), for which a t-stat can be computed.

- Event study the key identifying assumptions:
  - A) The event actually took place when it was recorded.
    - Verified by testing for no effect on placebo event dates.
  - B) No other events happen simultaneously.
    - This is more difficult to confirm. Firms may choose strategically when to admit a data breach.

Motivation

- The frequency and severity of data breaches has been increasing at an alarming rate.



- While much concern is expressed in the media and by privacy experts, little is known about the true costs of data breaches.
- Do consumers “punish” firms for leaking their information by boycotting, resulting in reduced sales?
- If not consumer reaction, what other costs do firms face?
- Are stock market reactions in line with actual business effects?

Data

- Data were combined from a number of sources for this paper:
  - Privacy Rights Clearinghouse: Registry of all publicly announced data breaches. Firms in the United States are legally mandated to publicly announce data breaches.
  - COMPUSTAT: Data on firms' income, revenue and other financial information for the "Firm Event Study."
  - CRSP: Data on daily stock returns for the "Stock Market Event Study."
  - Kenneth French: Data for model factors for the "Stock Market Event Study."
  - Google Trends: Data on Google Searches of companies was collected using an (unofficial) API for Google Trends.

Stock Market Event Study

	Dependent variable:		
	Mkt Model CAR (2 day)	Mkt Model CAR (5 day)	Mkt Model CAR (10 day)
	(1)	(2)	(3)
Records Leaked (log)	-0.034*	-0.016	-0.014
	(0.020)	(0.030)	(0.056)
Customer Data Leaked	-0.112	-0.462	-0.019
	(0.400)	(0.607)	(1.130)
Credit Card Leaked	-1.353***	-1.407*	-3.085**
	(0.465)	(0.717)	(1.470)
SSN Leaked	0.437	0.824	0.026
	(0.433)	(0.658)	(1.241)
Name Leaked	-0.933**	-0.945	-1.966
	(0.434)	(0.674)	(1.317)
Address Leaked	0.018	-0.359	0.517
	(0.415)	(0.643)	(1.198)
Observations	472	372	210
R^2	0.056	0.076	0.078
Adjusted R^2	0.019	0.028	-0.009
Note:			*p<0.1; **p<0.05; ***p<0.01
			Year fixed effects in all specifications

- Regress CARs on characteristics of breach to determine what is associated with response.
- Results are correlations only.
- As in Firm Event Study number of records leaked not a strong predictor.
- Surprisingly, stock market seems responsive to credit card leaks but not social security number leaks, but reverse / confounding causality possible.