Incentivizing Firms to Protect Consumer Data: Can Reputation Play a (Bigger) Role?

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Digital Workshop
Toulouse School of Economics
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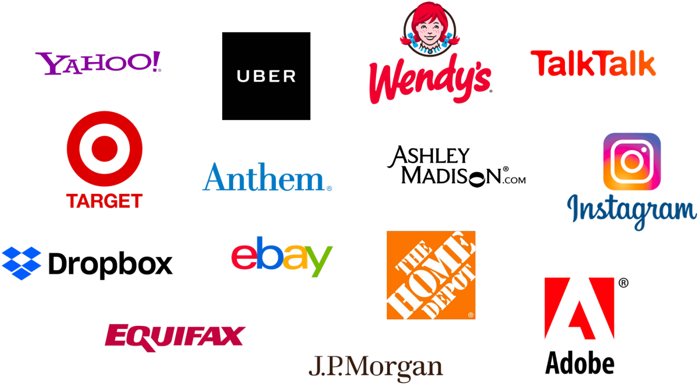
Motivation

What do all of these firms have in common?



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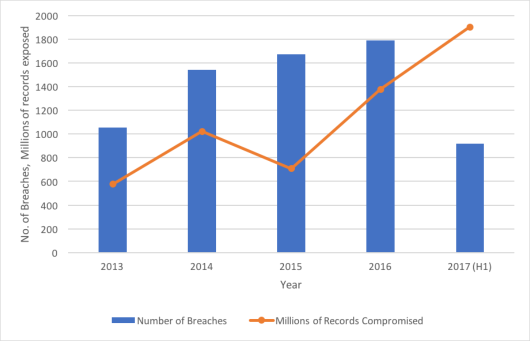
Data breaches are becoming increasingly prevalent.



Source: Breach Level Index

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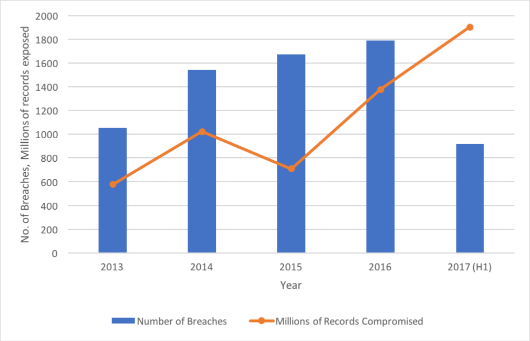

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Data breach victims may suffer costly consequences such as identity thefts and payment fraud.

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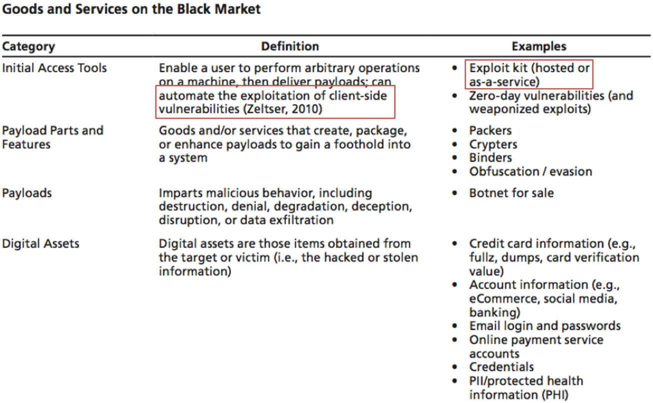
Increasingly hostile cyber-threat landscape, thanks to the emergence of dark-net marketplaces...

Motivation

...where criminals can buy hacking tools



Goods and Services on the Black Market

Category	Definition	Examples
Initial Access Tools	Enable a user to perform arbitrary operations on a machine, then deliver payloads; can automate the exploitation of client-side vulnerabilities (Zeltser, 2010)	• Exploit kit (hosted or as-a-service) • Zero-day vulnerabilities (and weaponized exploits)
Payload Parts and Features	Goods and/or services that create, package, or enhance payloads to gain a foothold into a system	• Packers • Crypters • Binders • Obfuscation / evasion
Payloads	Imparts malicious behavior, including destruction, denial, degradation, deception, disruption, or data exfiltration	• Botnet for sale
Digital Assets	Digital assets are those items obtained from the target or victim (i.e., the hacked or stolen information)	• Credit card information (e.g., fullz, dumps, card verification value) • Account information (e.g., eCommerce, social media, banking) • Email login and passwords • Online payment service accounts • Credentials • PII/protected health information (PHI)

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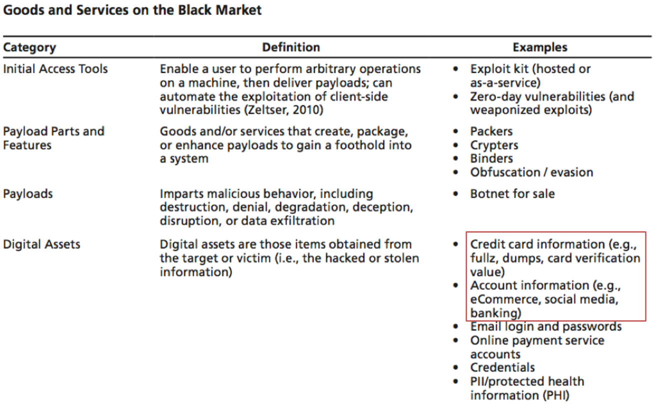
...where criminals can buy hacking tools and sell stolen data.



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- Can reputation concerns play a role in incentivizing security investment? If so, how big a role does it play?
- How can we further improve investment incentives?

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  - **Externalities**: losses to consumer and bank not internalized by website
  - **Imperfect Information**: website's security level not observed by consumer
  - **Customer turnover**: data breaches signal poor security; consumer may leave upon learning that website was breached → Reputation mechanism

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- Its effectiveness depends on the consumer's willingness and ability to punish a breached firm, which may be limited in practice.
  - Difficulty in detecting breaches.
  - Limited consumer losses due to bank's fraud prevention and liability protection policy.
- Policies aimed at raising investment via the reputation mechanism can make the consumer worse off.

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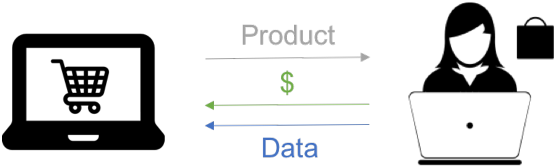

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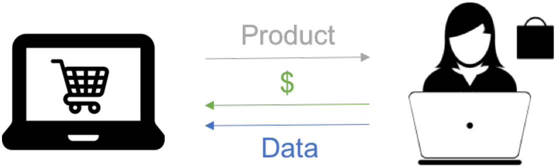
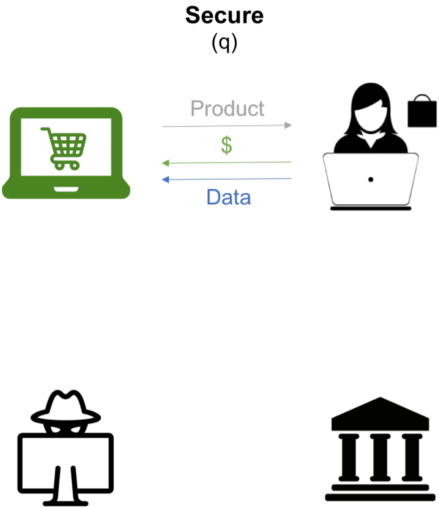


Website makes a one-time investment, $c(q)$, to protect consumer data at the start.

Theoretical Framework



Secure

(q)

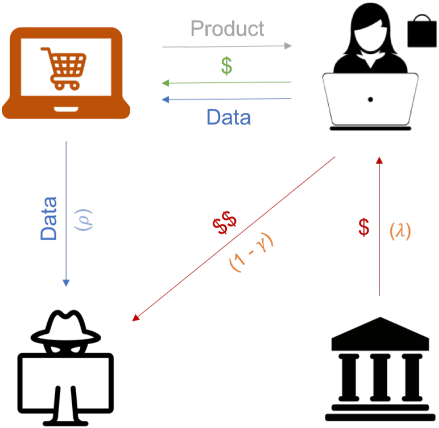
Product

$

Data

Theoretical Framework

Vulnerable
(1 - q)



Information

What do the players know?

Amount invested	Yes.	No, but has rational beliefs over *q* (website's reputation).
State of security	No.	No.
Data breaches	Yes.	With probability $\lambda\ (1 - \gamma)$.

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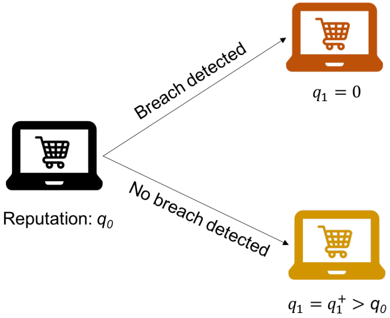


Payoffs

At every period, when the consumer buys from a *secure* website

Sales revenue: *r*

Gross utility: *v*
Expected losses: 0

Financial gains: 0

Expected liability: 0

Payoffs

At every period, when the consumer buys from a *vulnerable* website

Sales revenue: r

Gross utility: v
Fraud losses:
$-\rho(1-\gamma)(1-\lambda\alpha)l$

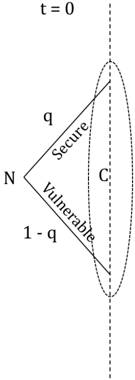
Financial gains:
$\rho(1-\gamma)l$

Fraud liability:
$-\rho(1-\gamma)\lambda\alpha l$

α: Fraud liability protection offered by the bank.

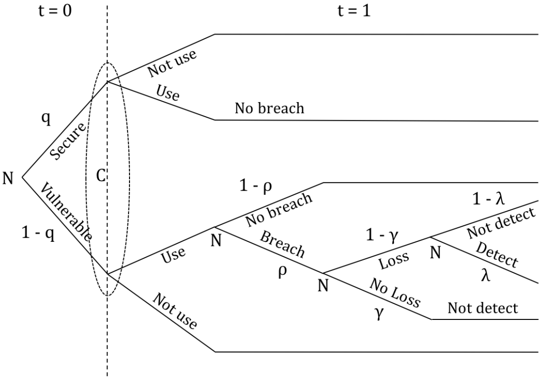
Timing

$t = 0$: Website invests $c(q)$ in security. With probability q, it is secure against cyber-attacks.



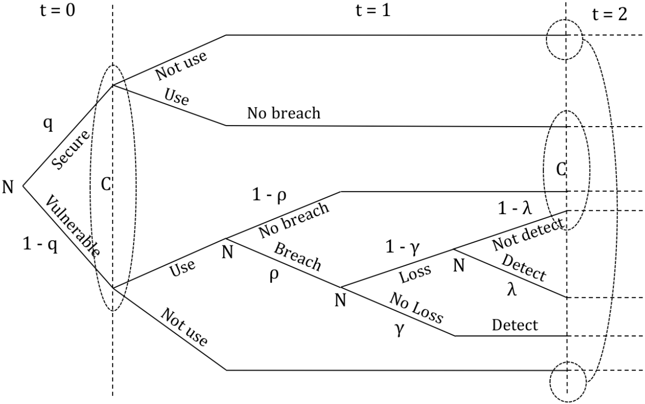
Timing

$t = 1$: Consumer makes purchase decision given website's initial reputation. If website is vulnerable, breach may occur and be detected. Beliefs are updated.



Timing

$t = 2$: Consumer makes purchase decision given website's updated reputation...



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Expected within-period utility from purchasing is

$$E(U(q_{t-1})) = v - \underbrace{(1 - q_{t-1})\rho(1-\gamma)(1-\lambda\alpha)I}_{\text{Expected fraud losses from breach}}.$$

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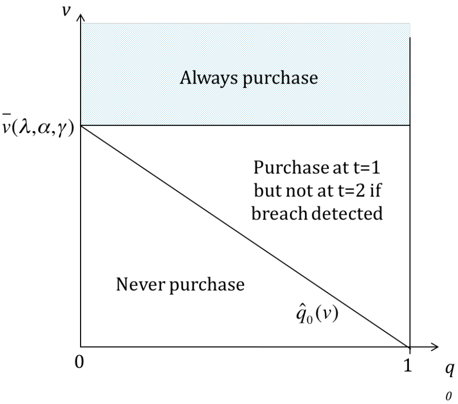
Her decision depends on:

1. Her valuation for the product v
2. Her expected fraud losses → depends on website's reputation $q_{t-1}(q_0)$

Consumer's Strategy

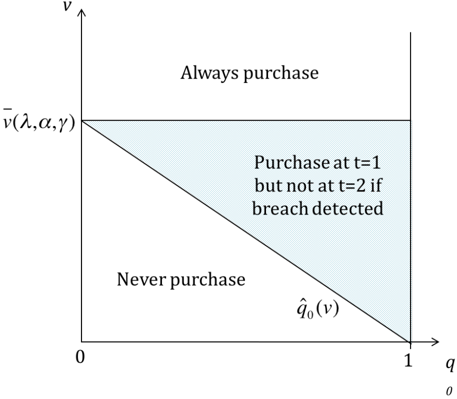
1) Consumer always buys from website regardless of its reputation.



$\overline{v}(\lambda, \alpha, \gamma)$: Max. expected losses
$\hat{q}_0(v)$: Min. initial reputation such that $E(U_1) \geq 0$.

Consumer's Strategy

2) Consumer buys given website's initial reputation, but not after learning that it is vulnerable.



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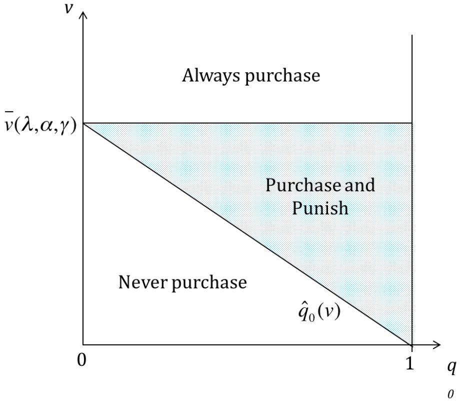

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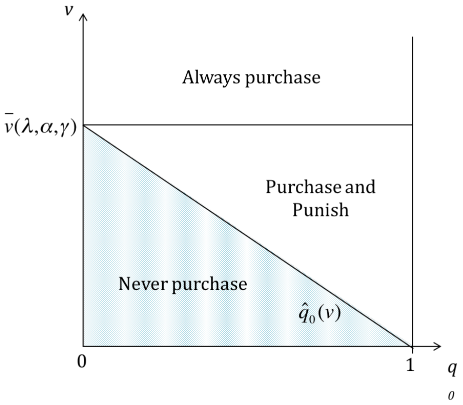
3) Consumer never buys from website.



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Website's Strategy

Website has to decide how much to invest at the start given q_0:

$$\max_{q} \pi(q; q_0, \lambda, \alpha) \equiv \underbrace{R_1(q_0, \lambda, \alpha)}_{\substack{\text{Revenue} \\ \text{at } t=1}} + \delta \underbrace{R_2(q; q_0, \lambda, \alpha)}_{\substack{\text{Expected revenue} \\ \text{at } t=2}} - c(q)$$

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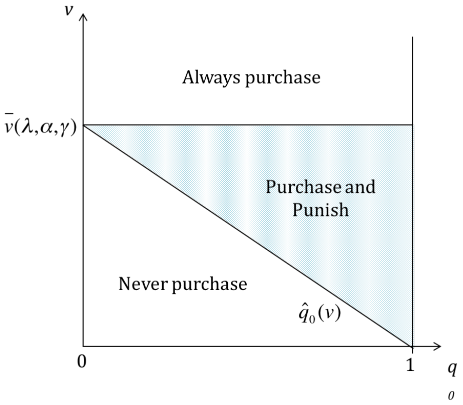

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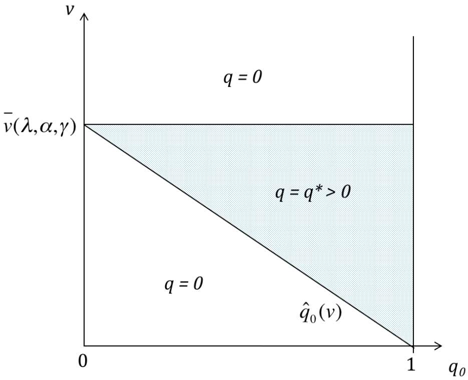

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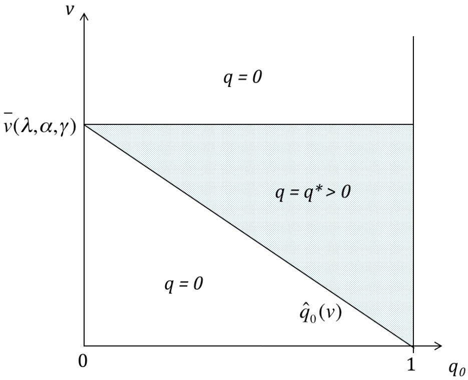

Optimal security level q^* is increasing in consumer's ability to punish.

Website's Strategy

Website's Investment Strategy

1. Website only invests when it expects to be punished by the consumer.

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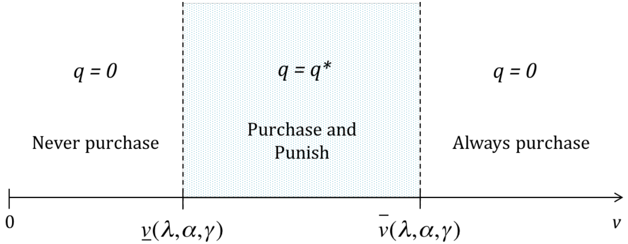
2. It invests more when the consumer is more likely to learn of breaches.

Reputation Mechanism

Bayes-Nash Equilibrium (with Rational Expectations).



Reputation Mechanism

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2. Its role is bigger when the consumer is more *able* to punish the firm.

Reputation Concerns in Practice

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- Only 11% of surveyed consumers terminated business relationship with the affected firm (Ablon et al, 2015).

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     - Micro charges (e.g., the $9.84 scam)
   - Low *ability* to punish the firm → Firm invests little in security

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	Consumer's Maximum Loss
Credit	\$50.
Debit	\$50 if reported within 2 days. \$500 if reported between 2 - 60 days. Unlimited thereafter.

Table: Consumer's liability under the FCBA and EFTA in the U.S.

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   - Many major card networks (e.g., Visa, Mastercard, Amex) even offer a zero-liability policy.

Weak Reputation Effect

Consumer has low *willingness* to punish the firm ...

Weak Reputation Effect

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- Lower expected losses → consumer less willing to punish
- Lower rate of breach detection → consumer less able to punish

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Limited Role of Reputation in Reality

The consumer's *willingness* and *ability* to punish a breached firm in reality limited by:

- a low rate of breach detection
- a high level of liability protection
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Implication:

- Reputation concerns may not provide firms with sufficient investment incentives.

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   - Increasing the direct cost of data breaches: Liability rule

Expulsion from Card Network

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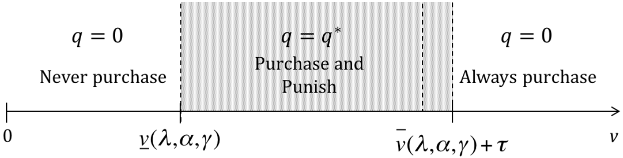
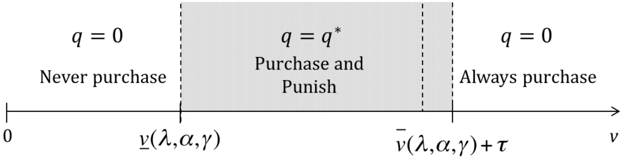
The policy raises the consumer's willingness to punish, but does not affect her ability.

Expulsion from Card Network


$q = 0$
Never purchase
$q = q^*$
Purchase and Punish
$q = 0$
Always purchase
0
$\underline{v}(\lambda, \alpha, \gamma)$
$\bar{v}(\lambda, \alpha, \gamma) + \tau$
v

Expulsion from Card Network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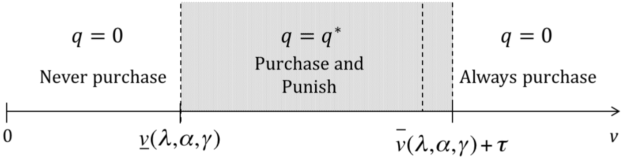

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v

Website's investment level is (weakly) higher.

Consumer surplus is *higher* when her valuation is *sufficiently small* ($v < \hat{v} \in (\overline{v}, \overline{v} + \tau]$) and is lower otherwise.

Active Monitoring by Bank

Bank can prevent fraud by

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  - Neither consumer nor bank learns of breach.
- Active detection: monitoring transactions for suspicious activities (e.g., data analytics)
  - Bank learns of breach and can inform consumer.

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Consumer is better able to punish website under active detection.

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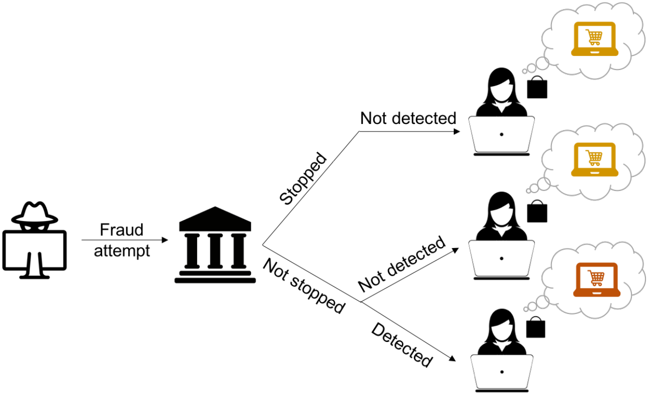

Passive Deterrence

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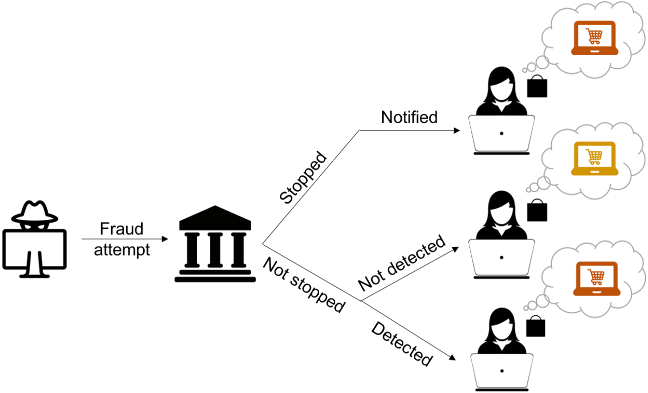

Active Detection

Active Monitoring by Bank

Suppose active detection and passive deterrence are equally effective.

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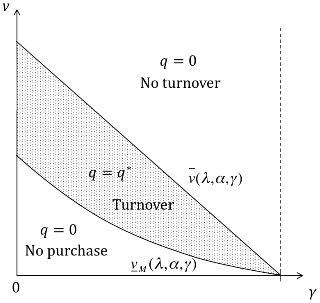
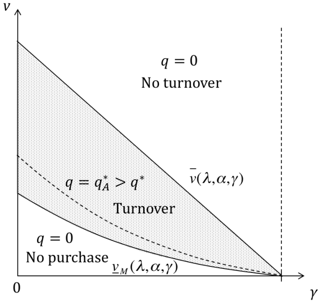
- Website invests (weakly) more under active detection.


v
$q = 0$
No turnover
$q = q^*$
Turnover
$\bar{v}(\lambda,\alpha,\gamma)$
$q = 0$
No purchase
$\underline{v}_M(\lambda,\alpha,\gamma)$
0
γ

Passive deterrence



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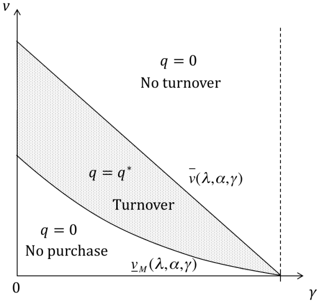
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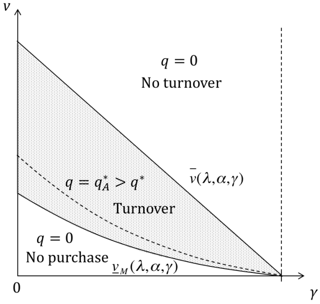

Active detection

- Consumer surplus is always *higher*.

Mandatory Breach Notification

Breach Notification Laws

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- General Data Protection Regulation (GDPR) in the EU
  - Notification must be provided *no later than 72 hours* after data controller becomes aware of the breach, whenever it is likely to "result in a risk for the rights and freedoms of individuals".

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- Failure to comply with regulations will result in high fines or penalties.

Mandatory Breach Notification

Website to notify to consumer whenever breaches occur → raises detection rate from λ to 1.

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Two cited benefits

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But loss mitigation may adversely affect investment incentives

- Lower expected losses from breaches → Less willing to punish the firm.

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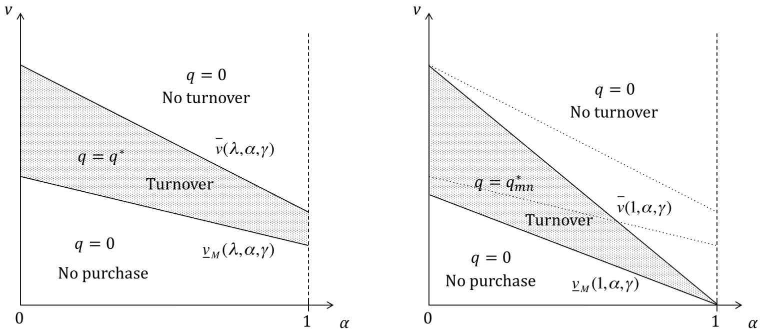
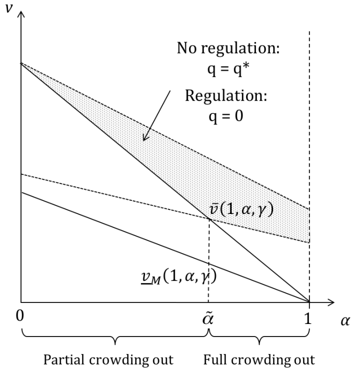


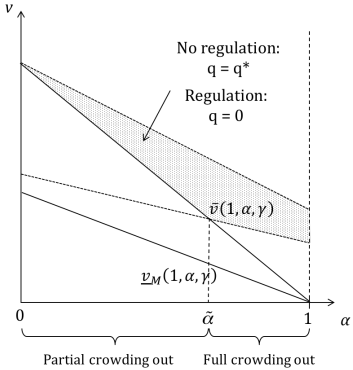
No regulation

Mandatory notification

Mandatory Breach Notification



Mandatory Breach Notification



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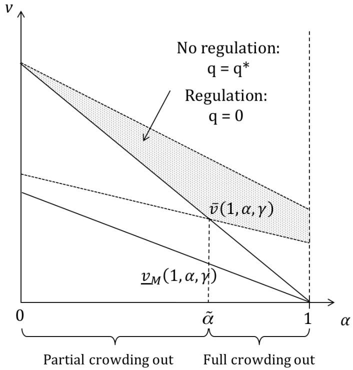

When consumer is initially willing to punish, notification may result in crowding out.

- Larger crowding out effect when α is higher.

Mandatory Breach Notification

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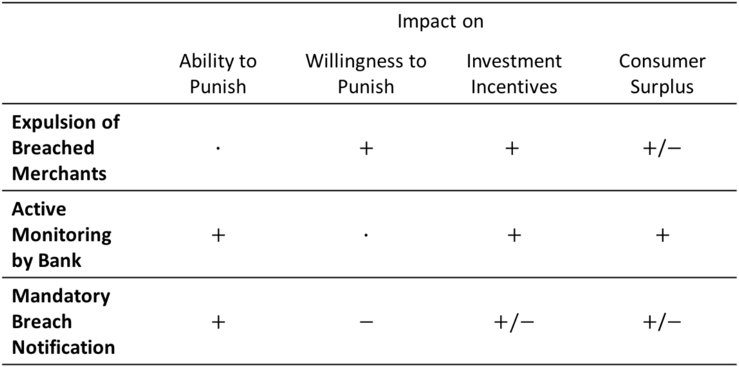
Consumer surplus is *higher* under breach notification if

- the website invests more;
- the website invests less but the loss mitigation benefit is sufficiently big (α is high enough).

Consumer surplus is lower otherwise.

Summary



	Impact on			
	Ability to Punish	Willingness to Punish	Investment Incentives	Consumer Surplus
Expulsion of Breached Merchants	·	+	+	+/−
Active Monitoring by Bank	+	·	+	+
Mandatory Breach Notification	+	−	+/−	+/−

Summary

Policy Implications - Indirect Interventions

- Raising the consumer's *ability* to punish always lead to *higher investment* and *higher consumer surplus*.

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- Ex-post protection of consumers against losses reduces ex-ante investment incentives of firms.

Improving Consumer Information

Consumer information can be improved by obliging website to reveal

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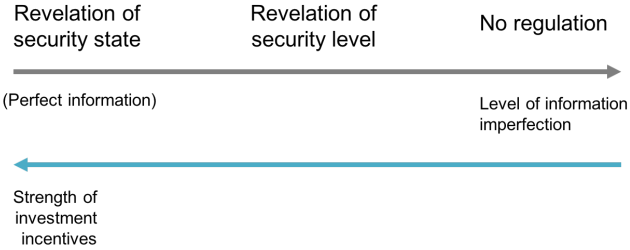

Revelation of security state
Revelation of security level
No regulation
(Perfect information)
Level of information imperfection
Strength of investment incentives

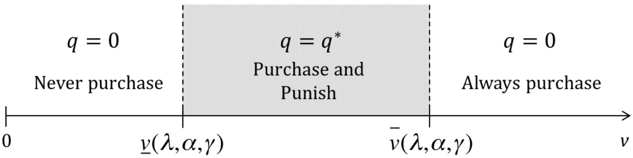
Improving Consumer Information

Comparison Across Regimes

Improving Consumer Information

Comparison Across Regimes

1. No regulation:



Improving Consumer Information

Comparison Across Regimes

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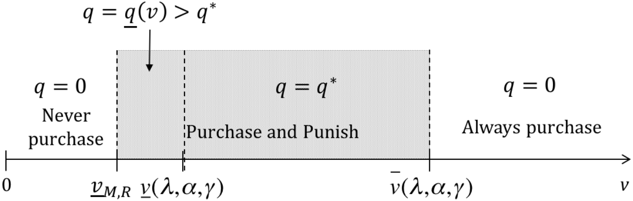
$q = \underline{q}(v) > q^*$
$q = 0$
Never purchase
$q = q^*$
Purchase and Punish
$q = 0$
Always purchase
0
$\underline{v}_{M,R}$
$\underline{v}(\lambda,\alpha,\gamma)$
$\bar{v}(\lambda,\alpha,\gamma)$
v

Improving Consumer Information

Comparison Across Regimes

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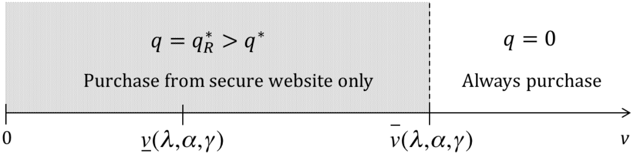
$q = q_R^* > q^*$
Purchase from secure website only
$q = 0$
Always purchase
0
$\underline{v}(\lambda,\alpha,\gamma)$
$\bar{v}(\lambda,\alpha,\gamma)$
v

Increasing the Direct Costs of Breaches

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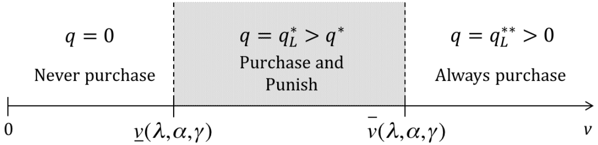

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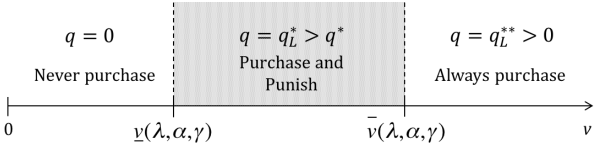

$q = 0$

Never purchase

$q = q_L^* > q^*$

Purchase and Punish

$q = q_L^{**} > 0$

Always purchase

0
$\underline{v}(\lambda,\alpha,\gamma)$
$\bar{v}(\lambda,\alpha,\gamma)$
v

Consumer surplus is (weakly) higher.

Related Literature

Economics of Info Security:
- Probabilistic model of security investment: Gordon and Loeb (2002)
- Public good games: Varian (2004), Grossklags et al. (2008)
- Contagion: Acemoglu et al. (2016), Kunreuther and Heal (2003)
- Composite security model: Riordan (2014)

Reputation and Product Quality:
Board and Meyer-ter Vehn (2013), Allen (1984), Dybvig and Spatt (1983), Rogerson (1983), Shapiro (1982), Shapiro (1983), Klein and Leffler (1981), Smallwood and Conlisk (1979)

Related Literature

Product Safety:
See Daughety and Reinganum (2011) for an overview.

Data Breaches:
- Consumer reactions: Kwon and Johnson (2015), Mikhed and Vogan (2015, 2017), Ablon et al. (2016), Greene and Stavins (2017)
- Stock prices: Campbell et al. (2003), Cavusoglu et al. (2004), Acquisti and Grossklags (2005)
- Breach notification: Romanosky et al. (2010)

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Attention should be paid to how indirect measures affect the consumer's willingness to punish → may lower her surplus.

Thank you.

Feedback and comments are welcomed at
yinglei.toh@gmail.com