Dynamic Privacy Choices

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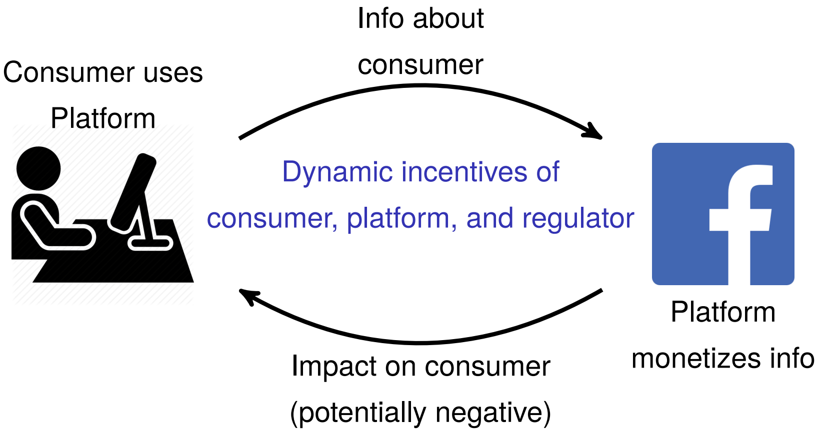
Motivation

This Paper



Consumer uses Platform
Info about consumer
Dynamic incentives of consumer, platform, and regulator
Platform monetizes info
Impact on consumer (potentially negative)

Roadmap

1. Monopoly
   - Model
   - Equilibrium
2. Competition
   - Model
   - Equilibrium

Model

Time $t = 1, 2, \ldots$

Consumer

- Choose an activity level $a_t \geq 0$
- Type $X \sim \mathcal{N}(0, \sigma_0^2)$, fixed over time, unobservable[1]

Platform

- Privately observe $s_t = X + \varepsilon_t$ with $\varepsilon_t \sim \mathcal{N}\left(0, \frac{1}{a_t} + \gamma_t\right)$
- γ_t: privacy level in period t

All random variables are mutually independent

[1] If privately observable, focus on a "pooling" equilib.

Platform Payoffs

Platform's payoff in period t

$$\sigma_0^2 - \sigma_t^2$$

prior variance

conditional variance of X at the end of t

- More info better
- Increasing in $(a_1, \ldots, a_t)$ and decreasing in $(\gamma_1, \ldots, \gamma_t)$
- Take σ_t^2 as a primitive (depends on $a_1, \ldots, a_t$ and $\gamma_1, \ldots, \gamma_t$)
- Discount future payoffs

Consumer Payoffs

Consumer payoff in period t

$$u(a_t) - \overbrace{v \cdot \left(\sigma_0^2 - \sigma_t^2\right)}^{\text{privacy cost}}$$

$u(\cdot)$ strictly concave,

maximized at $a^* > 0$

value of privacy

Consumer myopically chooses $a_1, a_2, \ldots$

Timing

1. Platform chooses a *privacy policy* $(\gamma_1, \gamma_2, \dots) \in \mathbb{R}_+^\infty$
   - $s_t = X + \varepsilon_t$ with $\varepsilon_t \sim \mathcal{N}\left(0, \frac{1}{a_t} + \gamma_t\right)$
   - Higher $\gamma_t \to$ collect less info (for a fixed a_t)
2. Consumer (myopically) chooses a_1, a_2,…

Equilibrium: Consumer myopic best response + Platform optimality

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   - $s_t = X + \varepsilon_t$ with $\varepsilon_t \sim \mathcal{N}\left(0, \frac{1}{a_t} + \gamma_t\right)$
2. Consumer (myopically) chooses a_1, a_2,...

Static Problem

Since myopic, Consumer chooses a_t to maximize

$$u(a_t) - v\left(\sigma_0^2 - \sigma_t^2\right)$$

$$= \; u(a_t) - \; \underbrace{v\left(\sigma_0^2 - \frac{1}{\frac{1}{\sigma_{t-1}^2} + \frac{1}{\frac{1}{a_t}+\gamma_t}}\right)}_{=C_t}$$

Marginal Privacy Cost

Lemma

$\frac{\partial C_t}{\partial a_t}$ is increasing in σ^2_{t-1}.

- Less privacy (lower σ^2_{t-1}) $\rightarrow$ Lower marginal cost
- E.g. if platform knows X, zero marginal cost
- Concave cost of producing info
- Lower payoff $\leftrightarrow$ Higher incentive to use the same platform

Timing

1. Platform chooses a privacy policy $(\gamma_1, \gamma_2, \dots)$
   - $s_t = X + \varepsilon_t$ with $\varepsilon_t \sim \mathcal{N}(0, \frac{1}{a_t} + \gamma_t)$
2. Consumer (myopically) chooses a_1, a_2,...

Timing

1. Platform chooses a privacy policy $(\gamma, \gamma, \dots)$
   - $s_t = X + \varepsilon_t$ with $\varepsilon_t \sim \mathcal{N}(0, \frac{1}{a_t} + \gamma)$
2. Consumer (myopically) chooses a_1, a_2,...

Stationary Privacy Policy

Reminder: $u(a_t) - v \cdot (\sigma_0^2 - \sigma_t^2), \quad a^* := \arg\max_{a \geq 0} u(a)$

Proposition

Suppose $\gamma_t = \gamma$ for all t. There is a $v^*(\gamma) > 0$ such that

1. $v > v^*(\gamma) \Rightarrow a_t^* = 0$ *for all t.*
2. $v < v^*(\gamma) \Rightarrow a_t^*$ *is increasing and converges to a^*, and $\sigma_t^2 \to 0$.*

Moreover, $v^*(\gamma)$ is increasing in γ.

- $a_1 > 0 \to$ lower marginal cost in $t = 2 \to a_2 \geq a_1 \dots$
- High γ may lower the long-run welfare of myopic consumers

Equilibrium

1. Platform chooses a privacy policy $(\gamma_1, \gamma_2, \dots)$
2. Consumer (myopically) chooses a_1, a_2,...

Equilibrium

Reminder: $u(a) - v \cdot (\sigma_0^2 - \sigma_t^2), \quad a^* = \arg\max_{a \geq 0} u(a)$

Proposition

For any $v \in \mathbb{R}$, in any equilibrium, the following holds.

1. $\sigma_t^2 \to 0$ *and* $a_t^* \to a^*$
2. $\forall \tau \in \mathbb{N}$, $\exists v^* > 0$ *s.t.* $\forall v \geq v^*$, $\gamma_t^* > 0$ *for* $t = 1, \ldots, \tau$
3. $\gamma_t^* \to 0$

- Early : high marginal cost $\to$ high γ_t to encourage activity
- Later : low marginal cost $\to$ low γ_t to speed up learning
- Point 1 holds for, e.g., a patient consumer or heterogeneous v

Implication

Two conditions under which

- consumer privacy is difficult to sustain
- collecting and monetizing consumer data is effective

1. Declining marginal privacy cost (concave loss of providing info)
   - Rational addiction: Becker and Murphy (1988)
   - “Privacy paradox”
2. Platform’s ability to commit to “underuse” data

Equilibrium Privacy Policy (characterized in paper)

Platform's trade-off

- Higher γ_t increases activity but reduces the precision of signal

Platform's optimization $=$ static optimization

(set γ_t to maximize the period-t profit)

$$\text{Platform objective} = \underbrace{\text{today's profit}}_{\substack{\text{increasing in}\\ \text{today's info}}} + \underbrace{\text{continuation value}}_{\substack{\text{increasing in}\\ \text{today's info}}}$$

One-period commitment $\rightarrow$ full commitment outcome

Roadmap

1. Monopoly
   - High a_t, privacy loss, potentially negative payoff in the long-run
   - Strong commitment power unnecessary
   - Less privacy $\rightarrow$ lower incentive to protect it
2. Competition
   - Model
   - Equilibrium

Incumbent and Entrant

exogenous, known

$t = 1$ $\qquad$ $t_E \geq 2$

Platform I

Platform E

Before entry:

C chooses a_t^I

After entry:

C chooses (a_t^I, a_t^E)

s.t. $\min(a_t^I, a_t^E) = 0$

i.e. single-homing

Payoffs

- Platform k: $\sigma_0^2 - \sigma_{k,t}^2$
- Consumer before entry: $u(a_t^I) - v \cdot (\sigma_0^2 - \sigma_{I,t}^2)$
- Consumer after entry

$$u(a_t^I) - v \cdot (\sigma_0^2 - \sigma_{I,t}^2) + u(a_t^E) - v \cdot (\sigma_0^2 - \sigma_{E,t}^2)$$

- Privacy cost does not disappear after switching!

  e.g. technical problem, credibility
- Consumer decision based on marginal cost

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Equilibrium

Proposition

There is an equilibrium such that:

- *Consumer only uses I: $a_t^I > 0$ and $a_t^E = 0$ for all t.*
- $\gamma_t^I \to 0$, $\sigma_{I,t}^2 \to 0$, *and* $a_t^I \to a^*$.

For a large t_E, in any equilibrium, I chooses a monopoly strategy.

Intuition

- Incumbent obtains data
- Lower marginal privacy cost $\rightarrow$ cheaper to keep using I
- Switching / entry less likely
- Data as an incumbency advantage
- Market for search engines, Google vs. DuckDuckGo?
- Right to be forgotten (enabling consumer to erase past info)

Literature (not exhaustive!)

Consumer data : Choi et al. (2018), Easley et al. (2018), Acemoglu et al. (2019), Bergemann et al. (2019), Bonatti and Cisternas (2020), Frankel and Kartik (2020), Liang and Madsen (2020)

Competition with data: Cornière and Taylor (2020); Prufer and Schottmüller (2017); Hagiu and Wright (2020)

Switching cost, barrier to entry: Farrell and Shapiro (1988); Klemperer (1995); Fudenberg and Tirole (2000)

Signal-jamming: Holmstrom (1999), Horner and Lambert (2019)

Recap

Less privacy $\Rightarrow$ lower marginal incentive to protect privacy

Monopoly

- Long-run: High activity level & low privacy
- High privacy level only in early periods

Competition

- Lower marginal cost prevents successful entry
- Entry less likely when consumer welfare is low

Regulation

- "Right to be forgotten" might be effective

Total Welfare

Difficult to compare the sum of payoffs

- Different discount factors

For any discount factors, we can calculate long-run welfare

- Without transfer $\rightarrow$ eqm efficient (platform best)
- With transfer $\rightarrow$ efficient iff $v < 1$

Same δ & transfer & compare discounted total surplus

- Inefficiently low activity levels?
- Inefficiently low privacy level?