Competitive Markets for Personal Data

Simone Galperti Jacopo Perego
UCSD Columbia

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Preliminary

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Personal data fuels multi-billion dollar industries and is essential input to the digital economy

Yet, consumers are **imperfectly compensated** for their data, and have **limited control** over their use

Expropriation and barter, common practice in the industry (FTC '15)

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   Price of data needs to depend on its intended use

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We build a competitive economy around this idea and study if/when it leads to market failure

Literature

We know exogenous correlation in consumers' data can lead to externalities

Choi et al. 19, Bergemann et al. 22, Acemoglu et al. 22

Here, we explore novel externality and its consequences in competitive mkts

- It emerges endogenously from how platform uses data even when data are uncorrelated

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Our approach: (GLP22, GP23, and this paper)

- Use tools from information-design literature

  Bergemann and Morris 19, Kamenica 19

- To answer questions about data markets

  Acquisti et al 16, Bergemann and Bonatti 19, Bergemann and Ottaviani 21

Plan for Talk

1. Leading example to illustrate main ideas and results
2. General model, general results, open questions & limitations

leading example

(many consumers, one platform, one merchant)

A Simple Data Economy

A **merchant** sells widgets to consumers and charges fee $a \in A$

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Two periods:

1. Consumers and platform trade data records in a competitive market
2. Platform solves a standard **information-design problem** given acquired data records

First Period

Given prices $p(1)$ and $p(2)$ of data records

- Platform chooses which records to buy $\rightsquigarrow$ **database** $q = (q(1), q(2))$
- Consumer chooses whether to sell her record to platform $\rightsquigarrow$ $\zeta(\omega) \in [0, 1]$

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Platform intermediates merchant with consumers by providing former with info about latter, so to influence merchant's fee a

E.g.: full info $\rightsquigarrow$ discriminatory fee; no info $\rightsquigarrow$ uniform fee

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Gross payoffs:	Merchant:	$\pi(a,\omega) = a\mathbb{1}(\omega \geq a)$
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$$\overbrace{U(q)}^{\text{platform's expected payoff}} = \max_{x:A\times\Omega\to\mathbb{R}_+} \sum_{\omega,a} u(a,\omega)x(a,\omega)$$

such that:

$$\sum_{\omega} \big(\pi(a,\omega) - \pi(\hat{a},\omega)\big)x(a,\omega) \geq 0 \qquad \forall\, a,\hat{a} \in A$$

$$\sum_{a} x(a,\omega) = q(\omega) \qquad \forall\, \omega \in \Omega$$

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Our general model features:

- Many platforms, many merchants, many types, arbitrary objectives, partially informative records

analysis

Efficiency

In equilibrium, **consumers' welfare** is:

$$W(q^*) \quad = \quad \sum_\omega \bar{q}(\omega)\Big((1-\zeta^*(\omega))\varepsilon + \zeta^*(\omega)\Big(\mathbb{E}_{q^*}(g(a,\omega)) + p^*(\omega)\Big)\Big)$$

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To illustrate,

- We will begin from the case $\gamma = 0$, i.e.,

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Efficient Data Allocation

What is the efficient data allocation in this case?

Record Type
$\omega = 1$
$\omega = 2$

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Record Type	**Existing Records**
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Record Type	Existing Records	Records Retained
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Model "enables" this externality, which will lead to inefficiencies

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Two cases to consider, both leading to market failure:

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Let's compute the **competitive equilibrium** of this data economy:

Two cases to consider, both leading to market failure:

1. $\beta < \varepsilon$: **"Too little data"**
2. $\beta > \varepsilon$: "Too much data"

Record Type	**Prices**	**Records Kept**	**Platform's Database**	**Use** (Trivial)	**Welfare**
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Comments:

1. Low-type consumers have no incentive to sell:
   Price $p^*(1) = \beta$ is too low $(\beta < \varepsilon)$

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Comments:

2. High-type consumers have no incentive to sell:
   Price $p^*(2) = 0$ is too low $(\varepsilon > 0)$

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Comments:

3. Platform has no strict incentive to buy at these prices.
   Equilibrium prices = marginal values

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Comments:

4. Equilibrium welfare is inefficiently low $\left(\varepsilon < \frac{1+\beta}{2}\right)$

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Comments:

5. High-type consumers would want to subsidize low-type consumers to sell their data, but market is too incomplete

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Comments:

6. For small ε, consumers welfare would be higher under expropriation!

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\text{Record Type} & \text{Prices} & \text{Records Kept} & \text{Platform's Database} & & \text{Use} \\
\omega = 1 & 0 & 0 & 1 \arrow[r] & s^L \arrow[r] & a = 1 \\
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Comments:

1. Too many high-type consumers sell. Attracted by expected gain $(\frac{1}{2})$, they decrease each other payoffs

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Comments:

2. Welfare is inefficiently low

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Comments:

3. Negative price on high-type consumers? Again, not an equilibrium...

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Equilibrium is generically inefficiency (i.e., for all ε, β)

Consumer welfare can be even lower than under expropriation

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Two kinds of failures:

- "Too little data:" Low-type consumer fails to internalize positive externality of selling
- "Too much data:" High-type consumer fails to internalize negative externality of selling

Both failures originates from same source:

- Platform has incentives to withhold information

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What happens when platform has no incentive to withhold? $\rightsquigarrow$ **Efficiency**

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Suppose that $\beta = 0$ and $\gamma > \varepsilon$: as if platform *is* merchant

$$u(a,\omega) = \beta\, g(a,\omega) + \gamma\, \pi(a,\omega)$$

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Record Type	Prices	Records Kept	Platform's Database	Use (Full Info)	Welfare
$\omega = 1$	γ	0	$1 \longrightarrow s^L \longrightarrow a = 1$		5γ
$\omega = 2$	2γ	0	$2 \longrightarrow s^H \longrightarrow a = 2$		

Comments:

1. Platform does not withhold information from the merchant $\rightsquigarrow$ price discrimination

Equilibrium

What happens when platform has no incentive to withhold? $\rightsquigarrow$ **Efficiency**

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Comments:

2. Crucially, payoff of a consumer is independent of decisions of other consumers. No externalities

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Comments:

3. Consumers get fully compensated: They get payoff that platform makes with their data. $\rightsquigarrow$ Equilibrium is efficient

Beyond the Example

In multi-sided markets, platforms balance complex objectives

In some cases, this leads to information withholding $(\beta > \gamma)$

This generates externalities that **can** make equilibrium in data markets inefficient

In a world without intermediaries, data markets **would be** efficient

remedies

An Economy with Lindhal Prices

How can we fix inefficiencies discussed so far?

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Result. Equilibria in this economy exist and are (first-best) efficient.

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To illustrate, return to case of market unravelling ($\beta < \epsilon$, $\gamma = 0$):

$$u(a, \omega) = \beta \; g(a, \omega) + \gamma \; \pi(a, \omega)$$

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Comments

- High-type consumers subsidize the platform to acquire low-type consumers data
- Previously this was not an equilibrium. Why?

How Realistic?

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It captures a qualitative feature of recent privacy-protection policies

- EU's GDPR: "*The* ***specific purposes*** *for which personal data are processed should be explicit and determined at the time of the collection of the personal data*"

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However, number of markets required is unrealistically large

Open Questions:

1. Intermediate solutions, partial decentralization?
2. "Non-market" solutions: Data Unions?

to conclusions

general model

Model 1/3

There are I competing **platforms**

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A **merchant** is active on platform i and sells product for a_i

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$$\begin{aligned} \text{consumer:} &\quad g_i(a_i, \omega) \\ \text{merchant:} &\quad \pi_i(a_i, \omega) \\ \text{platform:} &\quad u_i(a_i, \omega) \end{aligned}$$

Model 2/3: Data Records

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A collection of data records is called a **database**: denoted $q_i \in \mathbb{R}_+^{\Omega}$

Model 3/3: Platforms

Suppose platform i has acquired database q_i

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\begin{aligned}
\max_{x_i : A \times \Omega \to \mathbb{R}_+} \quad & \sum_{\omega, a} u_i(a,\omega) x_i(a,\omega) & \\
\text{such that:} \quad & \sum_{\omega} \big(\pi_i(a,\omega) - \pi_i(\hat{a},\omega)\big) x_i(a,\omega) \geq 0 & \forall\, a, \hat{a} \in A \\
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Denote by $x^*_{q_i}$ a solution (note: it depends on the entire database)

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Summing Up

platforms

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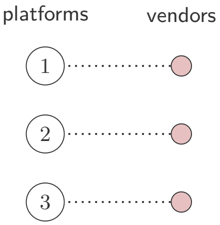

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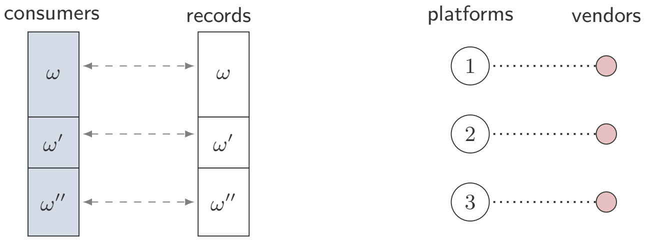
consumers
records
ω
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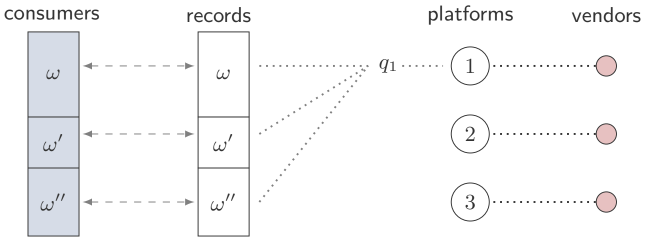
platforms
vendors
1
2
3

Summing Up



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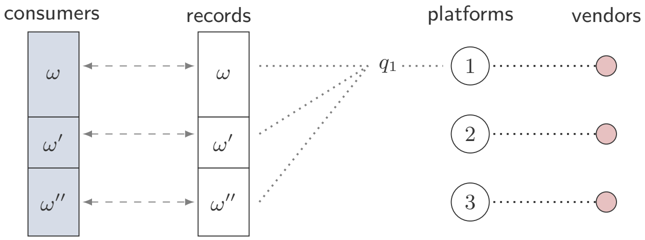

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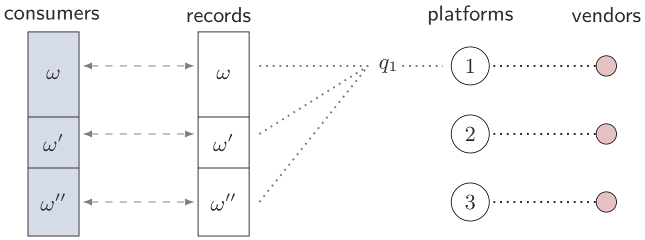

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results

Three Economies

We study the welfare properties of three different economies:

$\mathcal{E}_1$ An economy with expropriation

Platforms own consumers data and can trade

$\mathcal{E}_2$ An economy with data ownership

Consumers own their data and can trade

$\mathcal{E}_3$ An economy with data ownership and Lindhal prices

Data are priced conditional on how it is used

$\mathcal{E}_1$ – An Economy with Expropriation

In this economy:

- Consumers "expropriated" of their records: no control, imperfect compns
- Platforms trade records among each other, taking prices as given

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Definition. Equilibrium in $\mathcal{E}_1$

Prices $p^* \in \mathbb{R}^\Omega$ and a feasible data allocation $q^* \in \mathbb{R}_+^{\Omega \times I}$ are an equilibrium of $\mathcal{E}_1$ if:

1. Platforms maximize given prices $\quad q_i^* \in \arg\max_{q_i} U_i(q_i) - \sum_\omega p^*(\omega) q_i(\omega)$
2. All markets clear $\quad$ for all ω, $p^*(\omega)\left(\bar{q}(\omega) - \sum_i q_i^*(\omega)\right) = 0$

$\mathcal{E}_1$ – An Economy with Expropriation

Platform i's payoff depends only on q_i, not on q_j (exclusivity)

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Proposition. Equilibrium Characterization in $\mathcal{E}_1$

Equilibria of $\mathcal{E}_1$ exist and maximize the sum of platforms' payoffs

Every platform-optimal allocation can be supported as an equilibrium of $\mathcal{E}_1$

Equilibria are solutions of a grand-information design (LP) problem

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Equilibrium in $\mathcal{E}_2$:

Prices $p^* \in \mathbb{R}^{\Omega}$, data allocation $q^* \in \mathbb{R}_+^{\Omega \times (I+1)}$, consumers' decisions $\alpha^* \in (\Delta(I))^{\Omega}$ are an equilibrium if:

1. Given p^*, database q_i^* solves platform i's problem
$$q_i^* \in \arg\max_{q_i} U_i(q_i) - \sum_{\omega} p^*(\omega) q_i(\omega)$$
2. Given p^* and q^*, $\alpha^*(\omega)$ solves ω-consumer's problem
$$\alpha^*(\omega) \in \arg \max_{\alpha(\omega) \in \Delta(I)} (1 - \alpha(0|\omega)) r(\omega) + \sum_i \alpha(i|\omega) \left(p^*(\omega) + \mathbb{E}_{q_i^*}(g_i(a_i, \omega)) \right)$$
3. Markets clear
$$q_i^*(\omega) = \alpha^*(i|\omega) \bar{q}(\omega), \quad \forall \omega, i$$

$\mathcal{E}_2$ – An Economy with Data Ownership

What We Know:

- Equilibrium *can* be inefficient $\rightsquigarrow$ our leading example
- Sufficient conditions for efficiency:

Proposition. No-Intermediation Case

When $u_i = \pi_i$ for all i, equilibria in $\mathcal{E}_2$ exist and are efficient

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What We Don't Know (yet):

- Sufficient conditions for inefficiency beyond examples?
- Sufficient conditions for existence in the intermediation case?

$\mathcal{E}_3$ – An Economy with Lindhal prices

How can we fix inefficiencies discussed so far?

$\mathcal{E}_3$ – An Economy with Lindhal prices

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We enrich our economy by opening "more complete" markets

following e.g. Arrow 69, Laffont 78

- Consumers can sell record for a **specific purpose** (i.e. an action a_i)
- A richer price system: prices $p_i(\omega, a_i)$ depend on record type, on platform identity, and on intended use a_i

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Proposition. Equilibrium Characterization in $\mathcal{E}_3$

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Every (first-best) efficient data allocation can be supported in an eqm

Equilibria are solutions of a grand-information design (LP) problem

Back to Example

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$$u(a,\omega) = \beta\, g(a,\omega) + \gamma\, \pi(a,\omega)$$

Record Type	**Prices**
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	$p^*(1,2) = 0$
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Comments

- High-type consumers subsidize the platform to acquire low-type consumers data
- Previously this was not an equilibrium. Why?

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However, number of markets required is unrealistically large

Open Questions:

1. Intermediate solutions, partial decentralization?
2. "Non-market" solutions: Data Unions?

conclusions

Summary

1. We introduce framework to study competitive markets for personal data and their equilibria
   - Rather general setting: many platforms, many merchants, arbitrary objectives, partially informative records, multiple types
2. We identify a novel externality that can make these markets inefficient
   - The way platforms withhold information creates externalities that can lead to market failures
3. We discuss possible remedies and their limits

thank you