Competitive Markets for Personal Data

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June 2023

Motivation

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

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Key ingredient: Information intermediaries, like platforms

- When withholding information ("pooling"), they create scope for externalities

leading example

(many consumers, one platform, one merchant)

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Two periods:

1. Consumers and platform trade data records in a competitive market
2. Given acquired data records, platform intermediates corresponding consumers with merchant

Period 1

Taking as given the **prices** for data records, $p(1)$ and $p(2)$

- Platform chooses how many records to buy, $q(1)$ and $q(2)$
- Consumer ω chooses whether to sell her record to platform: $\zeta(\omega)$

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Consumer: $u(a, \omega) = \max\{\omega - a, 0\}$

Platform: $v(a, \omega) = \beta\, u(a, \omega) + \gamma\, \pi(a, \omega)$

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

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

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TODAY: $\gamma = 0 \Rightarrow$ Platform: $v(a, \omega) = \beta\, u(a, \omega) + \gamma\, \pi(a, \omega)$

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Remarks:

- Endogenous "prior" q in an otherwise standard ID problem
- More general model in the paper

analysis

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Imagine platform **expropriated** consumers of their records (≈ "status quo")

How would the platform use the implied database?

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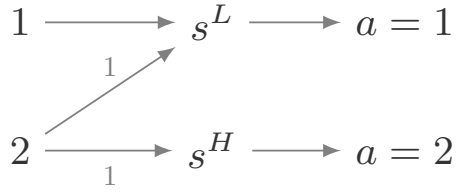

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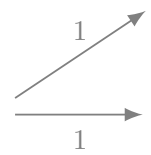

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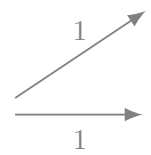

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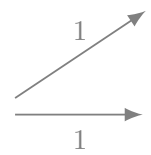

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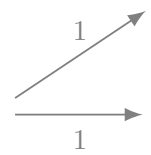

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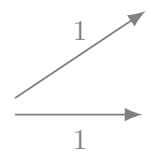

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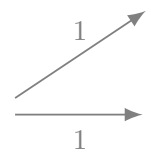

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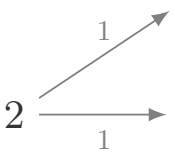

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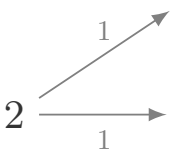

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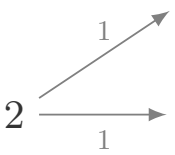

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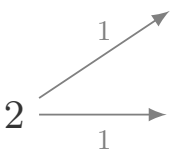

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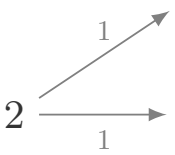

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1. Conflict of interest btw platform and merchant: It is optimal to withhold some information

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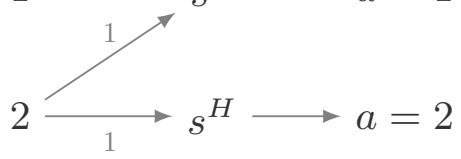

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2. If records are pooled, a consumer's payoff depends on database composition (suppose a low type leaves...)

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3. This will be the root of the inefficiency in our data economy

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Record Type	**Prices**	**Consumers Keep**	**Platform Buys**	**Use** (Trivial)	**Consumer Welfare**
$\omega = 1$	β	1	0	$\longrightarrow s^L \longrightarrow a = 1$	$3\underline{u}$
$\omega = 2$	0	2	0	$\longrightarrow s^H \longrightarrow a = 2$	

Equilibrium: "Too Little Data"

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Comments:

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

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Comments:

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

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Comments:

3. Platform has no strict incentive to buy at these prices.
   $p^* =$ marginal values of data — that's where $(\beta, 0)$ comes from

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Comments:

4. When $\underline{u}$ small, eqm welfare is lower than under expropriation
   Eqm is inefficient more broadly (not shown today)

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Comments:

5. High-type consumers would like to subsidize low-type consumers by paying negative prices, but not an eqm

Equilibrium: "Too Much Data"

Consider now the opposite case: $\beta \geq \underline{u}$ "low" value of privacy

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Let's compute again **competitive equilibrium**:

Record Type	Prices
$\omega = 1$	β
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Record Type	Prices	Consumers Keep	Platform Buys
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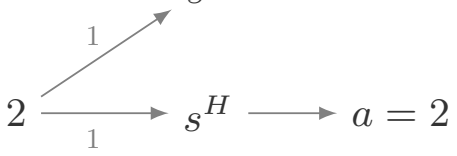

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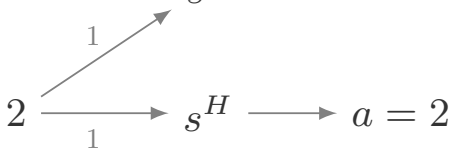

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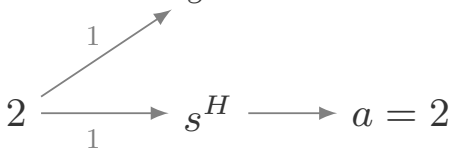

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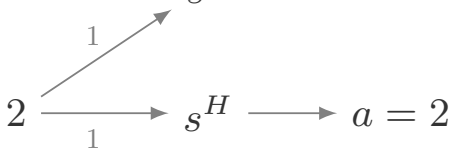

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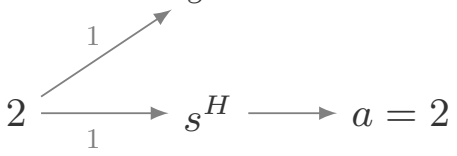

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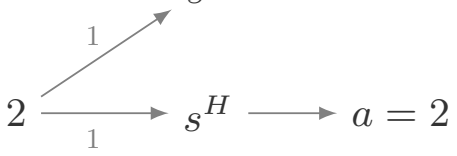

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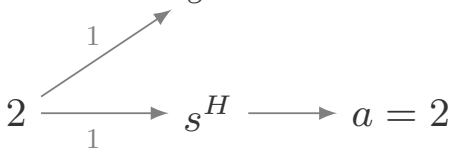

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Comments:

1. Low-types consumers sell, since $p^*(1) = \beta \geq \underline{u}$

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$\omega = 2$	0	0	$2 \to s^H$ (1) / $2 \to s^L$ (1)	$a = 2$	

Comments:

2. High-types consumers sell too, attracted by the possibility of being charged low fee

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Comments:

3. Consumers do better than under expropriation. But eqm still inefficient: Too many high-type consumers sell

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Comments:

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

Takeaways from Example

Competition does not always lead to efficient data allocation (for all $\underline{u}, \beta$)

Welfare can be even lower than under expropriation

- Perverse consequence of empowering consumers

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- Perverse consequence of empowering consumers

Market failure originates from information intermediation:

- Conflict of interest $\rightsquigarrow$ info withholding $\rightsquigarrow$ pooling externalities
- In paper: Necessity result (no COI $\rightsquigarrow$ efficiency)

conclusion

Summary

1. A framework to study competitive markets for personal data and their equilibria

2. We show that **pooling externalities** are a source of market failure

3. In paper, we discuss possible remedies
   - Prices conditional on use (Lindhal Economy)
   - Data unions

remedies

An Economy with Lindhal Prices

How can we fix inefficiencies discussed so far?

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A classic solution: following e.g. Arrow 69, Laffont 78

- Platform has to buy record for a **specific purpose** (i.e. an action recommendation a)
- More complete markets: Prices are $p(\omega, a)$

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- More complete markets: Prices are $p(\omega, a)$

Note: This presumes data use is contractible

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

Back to Example

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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$\omega = 1$	$p^*(1,1) = \beta + 1 - \varepsilon$
	$p^*(1,2) = 0$
$\omega = 2$	$p^*(2,1) = -(1 - \varepsilon)$
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Record Type	Prices	Records Kept	Platform's Database
$\omega = 1$	$p^*(1,1) = \beta + 1 - \varepsilon$ $p^*(1,2) = 0$	0	1
$\omega = 2$	$p^*(2,1) = -(1 - \varepsilon)$ $p^*(2,2) = 0$	1	1

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$\omega = 1$	$p^*(1,1) = \beta + 1 - \varepsilon$ $p^*(1,2) = 0$	0	$1 \longrightarrow s^L$	$\longrightarrow a = 1$
$\omega = 2$	$p^*(2,1) = -(1-\varepsilon)$ $p^*(2,2) = 0$	1	$1 \nearrow s^L$	

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$\omega = 1$	$p^*(1,1) = \beta + 1 - \varepsilon$ $p^*(1,2) = 0$	0	1	$\rightarrow s^L \rightarrow a = 1$	$1 + \beta + \varepsilon$
$\omega = 2$	$p^*(2,1) = -(1-\varepsilon)$ $p^*(2,2) = 0$	1	1		

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$\omega = 2$	$p^*(2,1) = -(1-\varepsilon)$ $p^*(2,2) = 0$	1	1 → s^L → $a = 1$		

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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When a ω-consumer transacts with platform i's vendor, payoffs realize

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

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

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Suppose platform i has acquired database q_i

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$$\max_{x_i : A \times \Omega \to \mathbb{R}_+} \quad \sum_{\omega, a} u_i(a, \omega) x_i(a, \omega)$$

$$\text{such that:} \quad \sum_{\omega} \big(\pi_i(a, \omega) - \pi_i(\hat{a}, \omega)\big) x_i(a, \omega) \geq 0 \qquad \forall\, a, \hat{a} \in A$$

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Suppose platform i has acquired database q_i

i.e., i has exclusive access to consumers whose records belong to q_i

Platform i is an **information designer**: It sends a signal about each consumers's ω to its vendor to influence his price a

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Summing Up

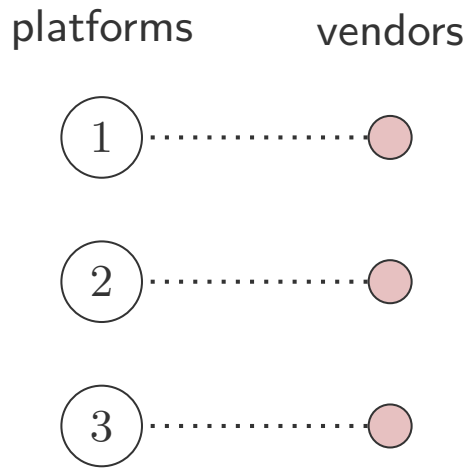
platforms

1

2

3

Summing Up



Summing Up

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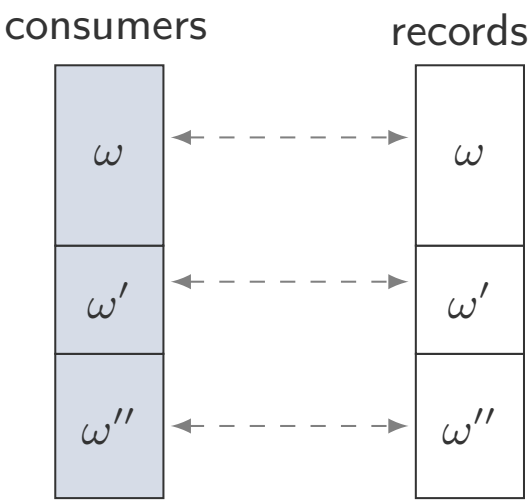
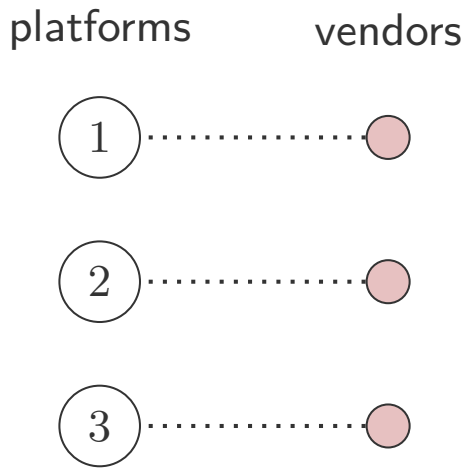

consumers
records
ω
ω'
ω''
ω
ω'
ω''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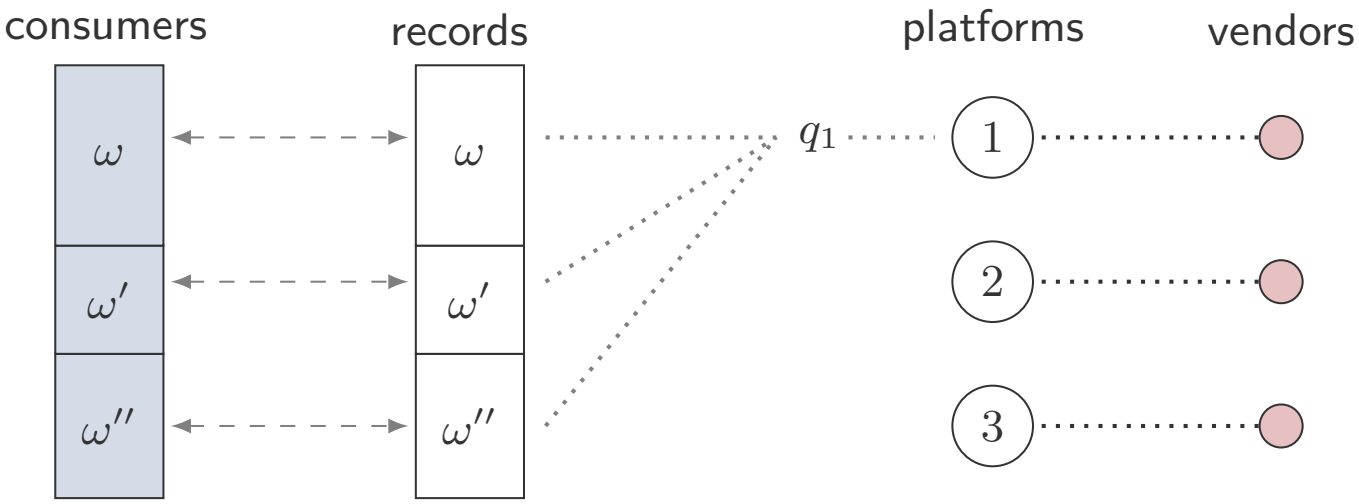

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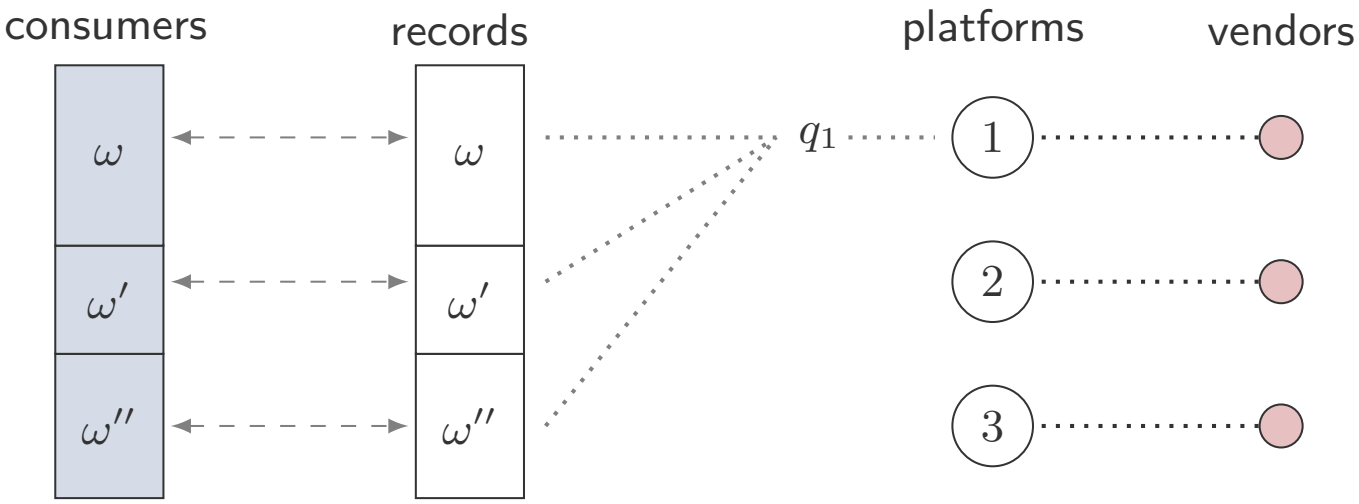

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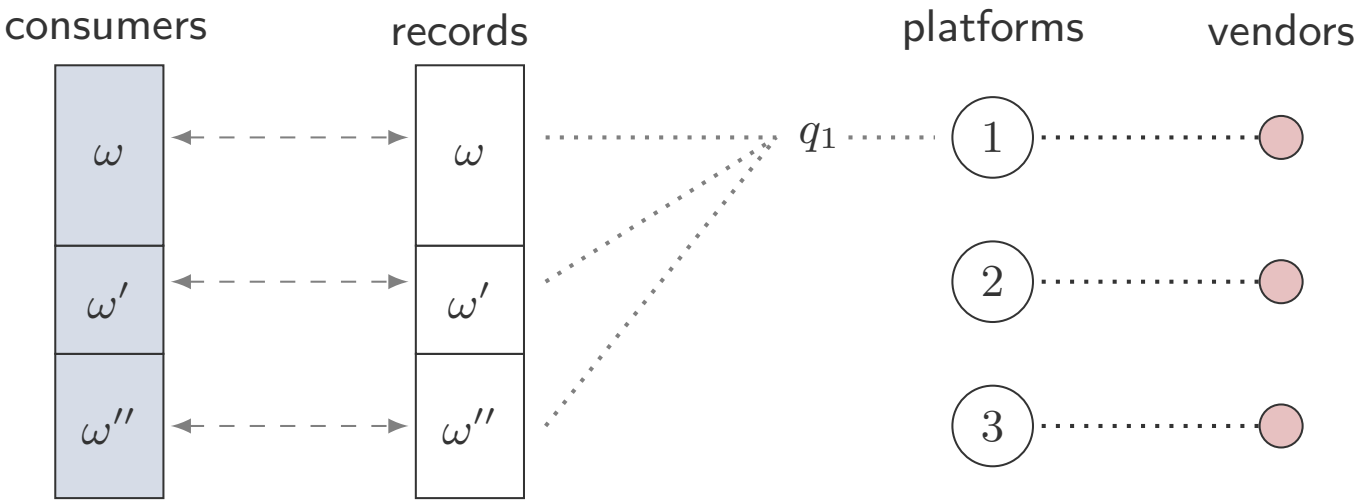

Timing:

1. Platform i acquires q_i in a **competitive market** for data records
2. Given database q_i, platform i chooses $x^*_{q_i}$
3. Payoffs realize

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 $\quad \text{for all } \omega,\ p^*(\omega)\left(\bar{q}(\omega) - \sum_i q_i^*(\omega)\right) = 0$

$\mathcal{E}_1$ – 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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$\mathcal{E}_2$ – An Economy with Data Ownership

$\mathcal{E}_2$ is the economy we analyzed earlier

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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

$$\alpha^*(\omega) \in \arg\max_{\alpha(\omega) \in \Delta(I)} (1 - \alpha(0|\omega)) r(\omega) + \sum_i \alpha(i|\omega) \Big(p^*(\omega) + \mathbb{E}_{q_i^*}(g_i(a_i, \omega)) \Big)$$

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 $\mathcal{E}_3$

Equilibria in $\mathcal{E}_3$ exist and are (first-best) efficient.

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

Illustrate functioning of economy $\mathcal{E}_3$ with our earlier example

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

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

Record Type	
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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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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