Competitive Markets for Personal Data

Simone Galperti   Tianhao Liu   Jacopo Perego

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Motivation

Consumers supply a crucial input for modern economy: their **personal data**

Yet, they often have **limited control** over how and by whom their data is used:

- This may lead to inefficiencies and inequality

New legislation gives consumers more control over their data (GDPR, CCPA, ...)

- Lays foundations upon which **data markets** could emerge

What properties would these markets have, and how should they be designed to promote desirable outcomes?

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Model. A stylized **competitive data market** where

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1. We identify **novel inefficiency** and show it is generated by <u>how intermediaries use data</u>

- If full disclosure $\Rightarrow$ No Externalities $\Rightarrow$ Efficiency
- If some pooling $\Rightarrow$ Externalities $\Rightarrow$ Inefficiencies

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2. Propose three solutions to this market failure:

- Data unions; Data taxes; "Lindahl" pricing for the data

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Exploit progress in info-design to microfound components of data economy:

- How does intermediary use the data? (Bergmann-Morris '19, Kamenica '19)
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Limited knowledge about **data markets**:

- "Correlation" externality Choi et al ('19), BBG ('22), Acemoglu et al. ('22)
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More broadly, we contribute to the growing literature on the economics of platforms, data, & privacy Bergemann and Ottaviani '21, Baley and Veldkamp '24

model

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A unit mass of consumers, one (representative) platform, one merchant

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Two periods: 1. Data markets are open 2. Product market is open

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– If type-ω consumer doesn't sell her record, she gets reservation utility $\bar{r}$

Period 2: Product Market

Given acquired database q, platform acts as **information designer**

- It sends signal to merchant about each consumer in its database
- Given signal, the merchant chooses an action $a \in A$ (finite)
- Together, a and ω determine consumer final purchase decision (left implicit)

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Notation for payoffs in period 2:

Consumer's:	$u(a, \omega)$	e.g., trading surplus
Merchant's:	$\pi(a, \omega)$	e.g., profits
Platform's:	$v(a, \omega)$	

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Remark: Info design problem equivalent to a linear program: (BM '16)

$$V(q) = \max_{x:\Omega \to \Delta(A)} \sum_{\omega, a} v(a,\omega) x(a|\omega) q(\omega)$$

$$\text{s.t. } \forall a, a' \colon \sum_{\omega} \Big(\pi(a,\omega) - \pi(a',\omega)\Big) x(a|\omega) q(\omega) \geq 0$$

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Denote its solutions by $\mathcal{X}(q)$ (standard ID problem, but with endogenous prior)

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$$z^*(\omega) \in \arg\max_{\zeta \in [0,1]} \zeta \Big(p^*(\omega) + \underbrace{\sum_a x^*(a|\omega) u(a, \omega)}_{U(\omega, x^*)} \Big) + (1 - \zeta)\bar{r}$$

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(d). Data markets clear, i.e. $\quad q^*(\omega) = \zeta^*(\omega)\bar{q}(\omega) \qquad \forall \omega$

discussion

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Can accomodate much larger class of **information-intermediation problems**:

- Multiple agents (e.g., competing merchants)
- An arbitrary downstream game (e.g., a second-price auctions, hotelling)
- More than information design (e.g., platform takes a contractible action)

Leading applications: online marketplaces and advertisement auctions

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Substantive assumptions we made:

- A competitive data market
- Platform is a "gate keeper" alt see BB '23
- A data record combines "access" and information alt see ALV '22

analysis

Mantained Assumption

We focus on economies that are “regular:”

Definition

An economy is **regular** if $\mathcal{X}(q)$ is a singleton for almost all q

This is an assumption on v and π

- Regular economies are generic in the space of economies

Efficiency of the Data Market

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$$\begin{aligned} W^\circ = \quad & \max_{q,x} \quad V(q) + \sum_\omega q(\omega) U(\omega, x) + \sum_\omega \Big(\bar{q}(\omega) - q(\omega)\Big)\bar{r} \\ & \text{s.t.} \quad q \leq \bar{q} \ \text{ and } \ x \text{ solves platform' problem } \mathcal{P}_q \end{aligned}$$

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To illustrate failure in data market, this less-demanding benchmark is desirable

(We also study "social" welfare and "unconstrained" efficiency discussion)

Efficiency of the Data Market

To characterize the efficiency of equilibria I will compare:

- How records are allocated by the market
- How records are allocated by the social planner

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The **private gain** for a type-ω consumer when she sells her record is

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Additionally, in eqm, it must hold that consumers optimize

- If $q^*(\omega) > 0$, then $G^*(\omega) \geq \bar{r}$
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For $\psi_q \in \Psi_q$, $\psi_q(\omega)$ captures the social gain of a marginal increase in $q(\omega)$

Constrained-Efficient Allocations

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Fix an allocation (q, x). If (q, x) is constrained efficient, x solves $\mathcal{P}_q$ and there is a $\psi \in \Psi_q$ s.t.

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Thus, eqm efficiency depends on alignement between G^* and ψ_{q^*}

Data Externality

The equilibrium **social benefit** of selling additional ω-record is:

$$\psi_{q^*}(\omega) \cong \frac{\partial V(q^*)}{\partial q^*(\omega)} + U(\omega, x^*) + \sum_{\omega'} q(\omega') \frac{\partial U(\omega', x^*)}{\partial q^*(\omega)}$$

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When selling her data, a consumer does not internalize she affects q, which changes x, which changes the payoff of other consumers $\Rightarrow$ **externality**

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An important class of recommendation mechanisms:

Definition

x_q is a **full-disclosure mechanism** if it recommends only actions the merchant would choose under complete information, i.e., for all ω,

$$q(\omega)x_q(a|\omega) > 0 \qquad \text{only if} \qquad a \in \arg\max_{a \in A} \pi(a, \omega)$$

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Proof Sketch

- If full disclosure is optimal at interior q, full disclosure is optimal at all q
- By regularity, there is an interior q' where full disclosure is uniquely optimal. Then, full disclosure is uniquely optimal at all q's
- Thus, $\sum_{\omega'} q(\omega') \frac{\partial U(\omega', x^*)}{\partial q^*(\omega)} = 0 \quad \Rightarrow \quad$ no data externalities
- Additionally, $\sum_{\omega} q(\omega) U(\omega, x_q)$ is linear in q. Thus, planner's "FOC" is sufficient for efficiency.
- Thus, any eqm is efficient

Bigger Picture

Main insight. The way platform uses data determines whether eqm is efficient

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Thus, substantive question is: When do info intermediaries have incentives to fully disclose info with their agents? And what happens when they don't?

an application

Mediated Price Discrimination

So far, minimal assumptions on the intermediation problem

More structure needed to further characterize equilibrium (in)efficiency

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- Let $\omega \in \mathbb{R}_{++}$ be the consumer's WTP for merchant's product
- Let a denote the merchant's price set for the product
- Players payoffs are

$$\begin{aligned} \text{Consumer's:} \quad & u(a,\omega) = \max\{\omega - a, 0\} \\ \text{Merchant's:} \quad & \pi(a,\omega) = a \, \mathbb{1}(\omega \geq a) \\ \text{Platform's:} \quad & v(a,\omega) = \gamma_u \, u(a,\omega) + \gamma_\pi \, \pi(a,\omega) \end{aligned}$$

Equilibrium Characterization

Proposition

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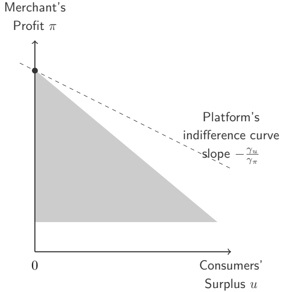

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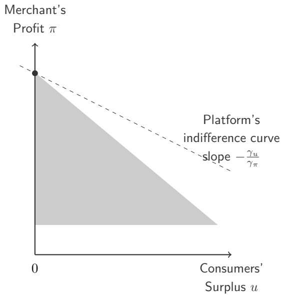

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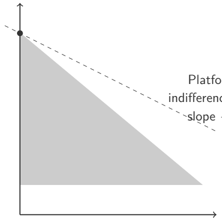

- At all q, **full disclosure** is optimal
- Merchant extracts surplus from all consumers
- Therefore, $x^*(a, \omega)$ does not depend on q
- Therefore, no externality! All equilibria are constrained efficient

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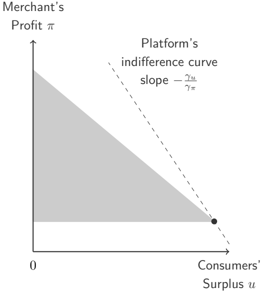

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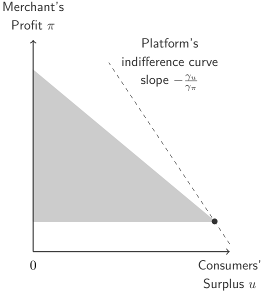

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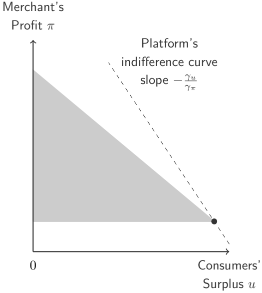

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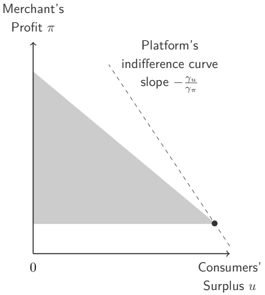

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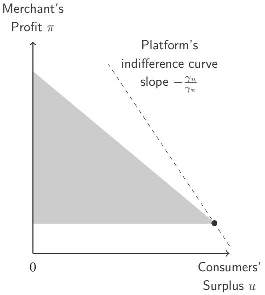

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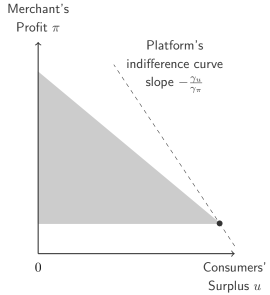

- Platform **withholds information** from merchant
- Pooling types required to keep merchant indifferent at some as
- Thus, x_q depends on q
- Thus, $\sum_{\omega'} q(\omega') \frac{\partial U(\omega', x^*)}{\partial q^*(\omega)}$ can be non-zero: data externality

Bigger Picture

Application shows when there is **no conflict of interest** btw platform and merchant $\Rightarrow$ full disclosure is optimal $\Rightarrow$ data market is efficient

Special case: if platform is merchant $\Rightarrow$ no intermediation

The source of the inefficiency is thus the role platforms play as intermediaries

- Platforms typically balance conflicting interests, which they rarely resolve with full disclosure otw, no info-design literature! :)
- Instead, they often garble the data they have collected

This paper shows how this practice can lead to a failure of the first-welfare theorem in a competitive data market

In the Works

Within application, we are working towards tighter conditions for **inefficiency**

Conjecture

Let $\gamma_u > \gamma_\pi$. An equilibrium is efficient if and only if the platform recommends $a = \min \Omega$ with probability 1.

Therefore, any "nontrivial" use of the database would lead to inefficiencies

example

A Simple Example to Illustrate

Suppose:

- $\gamma_u > \gamma_\pi = 0$, i.e. platform only cares about consumers' surplus
- Only two types of consumers: $\Omega = \{1, 2\}$ with $\bar{q}(1) < \bar{q}(2)$
- Suppose $\bar{r} < \frac{1+\gamma_u}{2}$ so that some trade is efficient

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- All low-type consumers sell: $q^\circ(1) = \bar{q}(1)$
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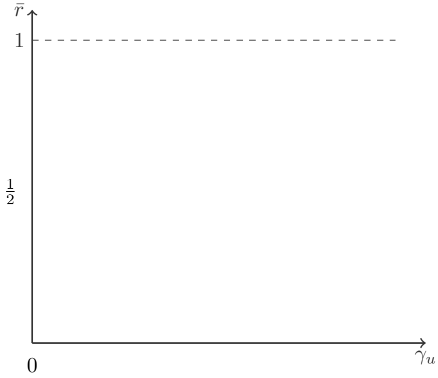
- Market unravels $\rightsquigarrow$ No trade $\rightsquigarrow$ Inefficiency

Example

Complete equilibrium characterization for this example:



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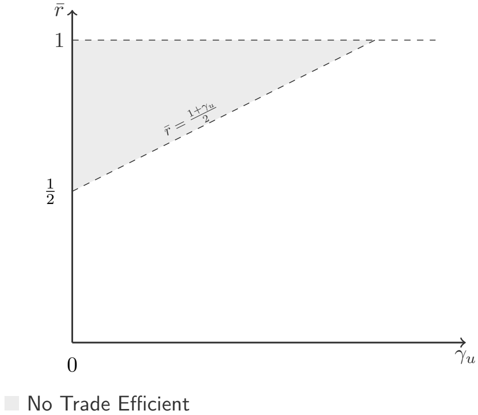

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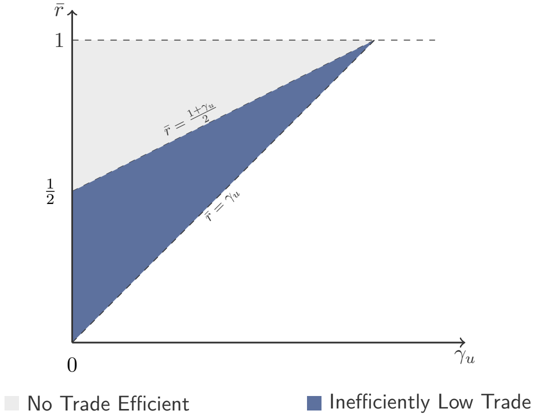

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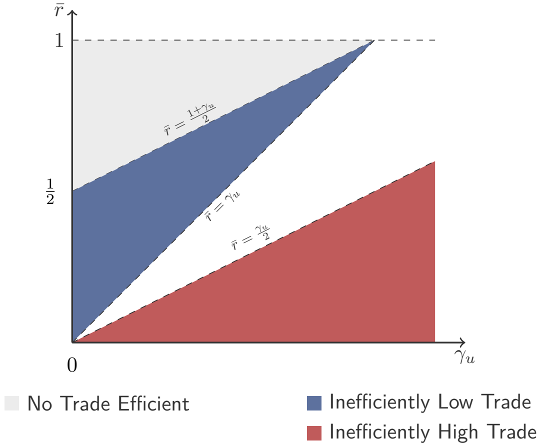

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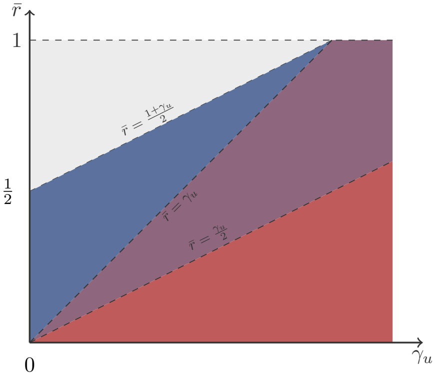

No Trade Efficient | Inefficiently Low Trade
Inefficiently High or Low Trade | Inefficiently High Trade

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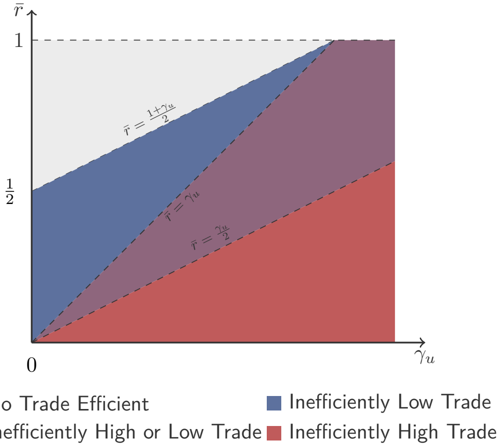

remedies

Remedies

How to fix this market failure?

We explore three alternative market designs:

1. Introducing a **data union**
2. Implementing **data taxes**
3. Making data markets more **complete**

data union

Data Unions

Recent policy proposals for the data economy (Posner-Weyl 18; Bergemann et al 23)

A data union would represent consumers by managing data on their behalf

We offer some theoretical support to these policy proposals

Data Union

How does a data union work?

- Consumers can participate in the union
- If they do, they relinquish their data to the union
- Union sells some of this data to the platform

  Consumers retain reservation utility unless record is sold to platform

- With the proceeds of sale, union compensates all participating consumers (to incentivize their participation)
- Union maximizes welfare of participating consumers

Data Union

Formally, the data union problem is:

$$
\begin{aligned}
\max_{(p,q,x)} \quad & \sum_{\omega} p(\omega)\bar{q}(\omega) + \sum_{a,\omega} u(a,\omega)x(a|\omega)q(\omega) + \sum_{\omega}(\bar{q}(\omega) - q(\omega))\bar{r} \\
\text{such that} \quad & q \leq \bar{q}, \\
\text{and} \quad & \textstyle\sum_{\omega} p(\omega)\bar{q}(\omega) = V(q), \\
\text{and} \quad & x \text{ solves } \mathcal{P}_q, \\
\text{and} \quad & p(\omega) + \tfrac{q(\omega)}{\bar{q}(\omega)} \textstyle\sum_a u(a,\omega)x(a|\omega) + \left(1 - \tfrac{q(\omega)}{\bar{q}(\omega)}\right)\bar{r} \geq \bar{r}.
\end{aligned}
$$

Data Union

Proposition

Equilibria of the data-union economy are constrained efficient and maximize consumers' welfare (and vice versa), regardless of the platform's objective

Some intuition:

Data union coordinates consumers by deciding which records to sell and how to compensate them

By doing so, data union acts as a substitute for the competitive market and avoids market failure

data taxes

Data Taxes

Enrich competitive economy by introducing a simple **data tax**:

- When selling her record, consumer pays tax $\tau(\omega) \in \mathbb{R}$ to the govt

When properly designed, data taxes force consumers to internalize effects that selling their records create on economy

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Proposition

Let (q°, x°) be a constrained-efficient allocation. There exists a profile of taxes τ^*, of prices p^*, and of consumer choices ζ^*, such that $(p^*, \zeta^*, q^\circ, x^\circ)$ is an equilibrium of the economy with taxation τ^* and the government does not run a deficit.

Sketch of the Proof

Let allocation (q°, x°) be constrained efficient

Let p^* be a supergradient of $V(q^\circ)$

Define $\boxed{\tau^*(\omega) \triangleq p^*(\omega) + \sum_a x^\circ(a|\omega)u(a,\omega) - \bar{r}}$

Notice that $U^*(\omega) - \tau^*(\omega) \equiv \bar{r}$

Therefore, all consumers indifferent $\rightsquigarrow$ choose ζ^* to implement q° $\square$

more-complete markets

Lindahl Economy

We let price of data depend not only on its type (i.e., ω) but also on its "intended use" (i.e., a)

> Platform and the consumer trade on **how** record will be used—i.e., which fee a platform will recommend to the merchant

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This is reminiscent of GDPR: "*The **specific purposes** for which personal data are used should be determined at the time of the collection*"

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A market for each (a, ω), where ω-records can be traded for use a at price $p(a, \omega)$

Our equilibrium definition extends naturally to this richer economy

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Proposition

Equilibria of this economy are (unconstrained) efficient and maximize consumers' welfare, regardless of platform's incentives

conclusion

Summary

1. A stylized framework to study competitive markets for personal data

    Rooted in GE tradition but leveraging recent progress in info-design

2. Identify novel inefficiency leading this otherwise perfectly competitive market to fail

    Show how inefficiency critically depends on platform's role as an information intermediary

3. Propose three alternative market designs that fix inefficiency: data unions, data taxes, richer data prices

Competitive Markets for Personal Data

Simone Galperti UCSD
Tianhao Liu Columbia
Jacopo Perego Columbia

Thank You!

Efficiency Benchmark

To illustrate market failure, a less demanding efficiency benchmark is desirable:

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Bonus: In eqm, platform makes not profits. Thus, $W(q^*, x^*)$ equals consumer welfare. Thus, any constrained-efficient eqm maximizes consumer welfare

back