Competitive Markets for Personal Data

Simone Galperti — UCSD
Tianhao Liu — Columbia
Jacopo Perego — Columbia

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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:

- "Expropriation" and barter, common practice in the industry (FTC '15)
- This may lead to inefficiencies and inequality (Seim et al. '23)

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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A stylized model of a **competitive data market**:

- Each **consumer** owns her data and can sell it to a platform
- The **platform** pays her a market price for the data and offers her a "service"
- It gives consumer access to a **merchant**, from whom she can buy a product, and
- Platform uses acquired database to inform merchant about consumer's type

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A canonical info-design problem but platform's database is **endogenous**, pinned down in the equilibrium of the data market

Main Results

1. Identify **novel inefficiency** leading this perfectly competitive market to fail

    Consumers exert an externality on each other, enabled by how the platform endogenously uses the data

    If platform's objective is suff aligned with merchant's, data market is efficient

    If platform's objective is suff aligned with consumers', data market can be inefficient (and, in some case, unravels entirely)

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2. We then propose three solutions to this market failure:

    Introducing a **data union**; Implementing **data taxes**; and making data markets "more complete"

Related Work

Model rooted in a GE tradition but leverages on progress in info-design literature, which offers microfoundation for key components of a data economy:

- E.g., how data is used (BBM '15); How data is valued (GLP '23); How data is priced (this paper)

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We contribute to a recent literature that studies data markets:

- "Learning" externality Choi et al ('19), BBG ('22), Acemoglu et al. ('22)
- Our inefficiency: Not due to exogenous correlation, but to platform's role as info intermediary
- Idea builds on GLP '23, who characterized how much platform values the data of a single consumer in a larger database

model

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

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– If a type-ω consumer sells her record, she obtains reservation utility $r(\omega)$

Period 2: Product Market

Given acquired database q, platform acts as **information designer**: (as in BBM)

- It sends merchant signal about each consumer in database
- Given signal, merchant charges each consumer a fee a
- Given a, type-ω consumer purchases product if $\omega \geq a$

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The **payoffs** in period 2 are:

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

Merchant's: $\pi(a, \omega) = a \, \mathbb{1}(\omega \geq a)$

Platform's: $v(a, \omega) = \gamma_u \, u(a, \omega) + \gamma_\pi \, \pi(a, \omega)$

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Info-design problem equiv to platform choosing mechanism $x : \Omega \to \Delta(A)$ s.t.

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

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

(canonical ID problem with endogenous q)

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(c). Given p^* and x^*, ζ^* solves consumers' problem, i.e.,

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

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

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Three aspects of the consumer problem have been simplified:

- Record fully reveals underlying type — alt see GLP '23
- Record bundles access and information — alt see ALV '22
- Reservation utility $r(\omega)$ is exogenous — alt see BB '23

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An allocation (q°, x°) is **constrained efficient** if it solves

$$\begin{aligned} W^\circ = \quad & \max_{q,x} \quad \mathcal{W}(q,x) \\ & \text{s.t.} \quad q \le \bar{q} \ \text{ and } \ x \text{ solves platform' problem } \mathcal{P}_q \end{aligned}$$

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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

inefficiency of the data economy

Roadmap for the Analysis

Goal: Identify necessary and sufficient conditions for eqm efficiency

1. Characterize constrained efficiency of equilibrium allocations
2. Identify an externality that can lead to market failure
3. State our main result and its intuition

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- Fix any q. Consider the following maximization problem:

$$\begin{aligned} W(q) \triangleq \quad & \max_{x:\Omega\to\Delta(A)} \quad \sum_{a,\omega}(v(a,\omega)+u(a,\omega))x(a|\omega)q(\omega) \\ & \text{s.t.} \qquad x \text{ solves } \mathcal{P}_q \end{aligned}$$

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and denote by $\Psi_q \subset \mathbb{R}_+^{\Omega}$ the **supergradients** of $W(q)$ (a.s. a singleton)

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$\psi_q(\omega)$ is change in $W(q)$ from adding a ω-record to q $\rightsquigarrow$ **social benefit**

Constrained-Efficient Allocations

Using these two concepts, we characterize constrained-efficient allocations

Proposition

An allocation (q, x) is constrained efficient **if and only if** x solves $\mathcal{P}_q$ and there is a $\psi \in \Psi_q$ s.t.

- If $q(\omega) > 0$, then $\psi(\omega) \geq r(\omega)$
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Simple cost-benefit analysis: Necessity is obvious, sufficiency less so, but crucial for what comes next

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$$U^*(\omega) \triangleq p^*(\omega) + \sum_a x^*(a, \omega) u(a, \omega)$$

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In equilibrium, the optimality of consumer behavior requires that:

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Alignment of Social vs Private Benefits

Thus, an equilibrium is constrained-efficient if and only if the social (ψ_{q^*}) and private (U^*) benefit of data records are sufficiently **aligned**

– i.e., $U^*(\omega) \geq r(\omega) \Rightarrow \psi_{q^*}(\omega) \geq r(\omega)$ and $U^*(\omega) \leq r(\omega) \Rightarrow \psi_{q^*}(\omega) \leq r(\omega)$

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Thus, key question is: When are ψ_{q^*} and U^* aligned?

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$$\psi_{q^*}(\omega) = \underbrace{p^*(\omega)}_{\substack{\text{change in platform's} \\ \text{gross payoff}}} + \underbrace{\xi^*(\omega)}_{\substack{\text{change in trading} \\ \text{surplus of \textbf{all consumers}}}}$$

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Discrepancy between $\sum_a x^*(a,\omega)u(a,\omega)$ and $\xi^*(\omega)$ captures an **externality** that type-ω consumer exerts on others when selling her record to the platform

Main Characterization

This externality, and thus the eqm efficiency, depends on how platform uses the data, i.e., on its objective

Recall: $v(a, \omega) = \gamma_u \, u(a, \omega) + \gamma_\pi \, \pi(a, \omega)$

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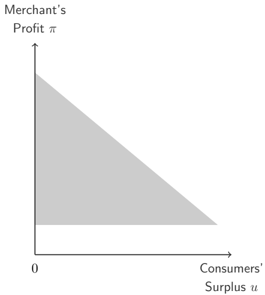
Equilibrium efficient when platform cares more about merchant $\rightsquigarrow$ **Why?**

Intuition for Efficiency

If $\gamma_u < \gamma_\pi$



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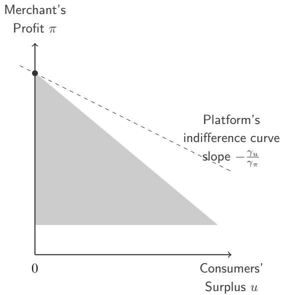

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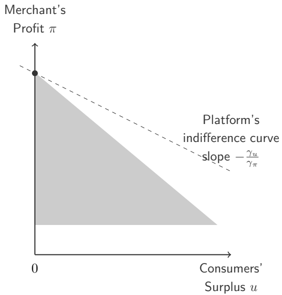

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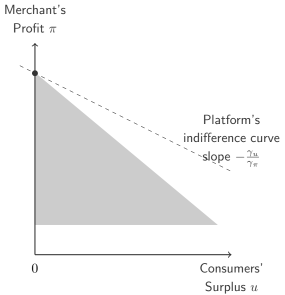

- At all q, **full disclosure** is optimal
- Merchant extracts surplus from all consumers
- Therefore, $\xi^*(\omega) = \sum_a x^*(a,\omega)u(a,\omega) = 0$
- Therefore, $\psi_q^* = U^*$, perfect alignement
- Therefore, all equilibria are constrained efficient

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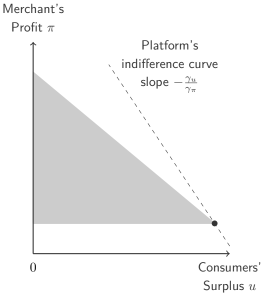

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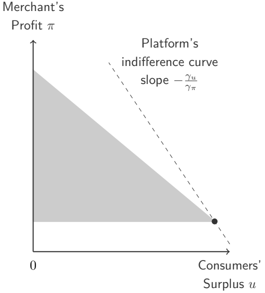

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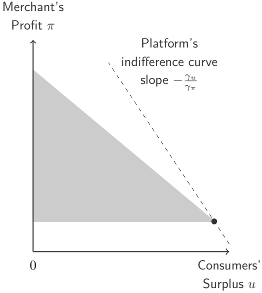

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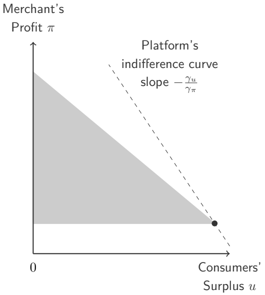

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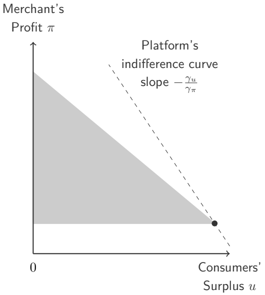

- Platform **withholds information** from merchant
- Pooling different consumers together makes their payoff inter-dependent
- Thus, $\xi^*(\omega) \neq \sum_a x^*(a,\omega)u(a,\omega)$
- Example: think of lowest-type consumer

A Stronger Negative Result

We can sharpen the negative part of the previous result:

To avoid trivial cases, focus on economies where the constrained efficient allocation requires some trade, i.e., $W^\circ > \sum_\omega \bar{q}(\omega) r(\omega)$

Corollary

Let $\gamma_\pi \leq \gamma_u$. Additionally, suppose $\gamma_u \underline{\omega} < r(\underline{\omega}) < (1 + \gamma_u)\underline{\omega}$.
Then, **all equilibria** are inefficient.

Stepping Back

In many digital industries, information intermediaries play a ubiquitous role
Acquisti et al. '16

A defining feature of these intermediaries is that they balance interests of conflicting agents (sellers-buyers; drivers-riders, etc.)

Typically, in theory and in practice, intermediaries manage these conflicts by optimally withholding some information from the agents

This paper illustrates how this practice can create market failures

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 $\bar{q}(1) < \bar{q}(2)$
- Same reservation utility: $r(\omega) = \bar{r} \in (0, \frac{1+\gamma_u}{2})$, for all ω

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There is a **unique** constrained-efficient allocation (q°, x°):

- All low-type consumers sell: $q^\circ(1) = \bar{q}(1)$
- Only some high-type consumers sell: $q^\circ(2) = \bar{q}(1) < \bar{q}(2)$
- Platform provides no info to merchant, who charges lowest fee to all consumers in database: $x^\circ(a = 1|\omega) = 1, \ \forall\omega$

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 $\bar{q}(1) < \bar{q}(2)$
- Same reservation utility: $r(\omega) = \bar{r} \in (0, \frac{1+\gamma_u}{2})$, for all ω

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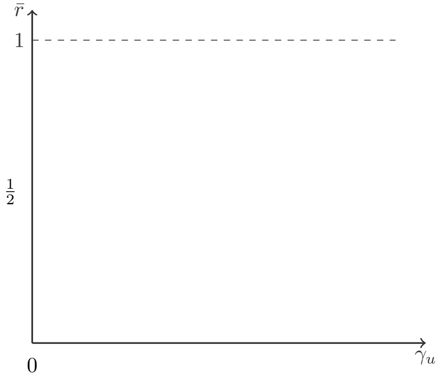
- Market unravels $\rightsquigarrow$ No trade $\rightsquigarrow$ Inefficiency

Example

Complete equilibrium characterization for this example:



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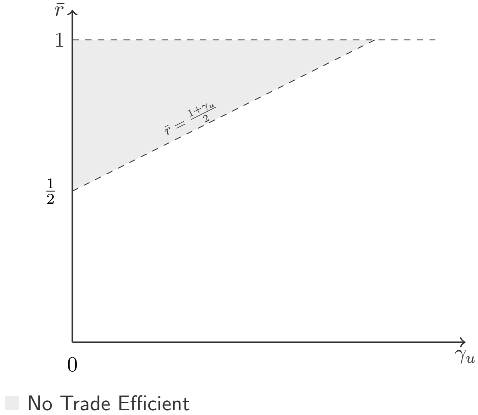

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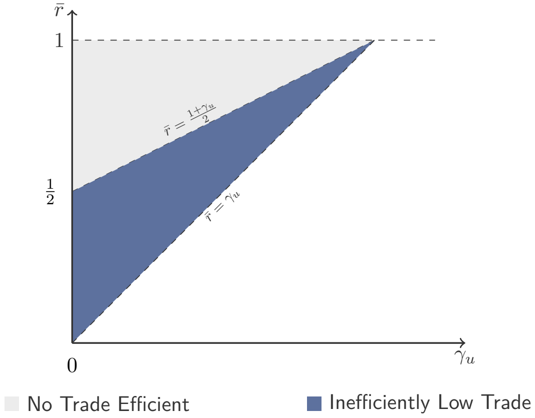

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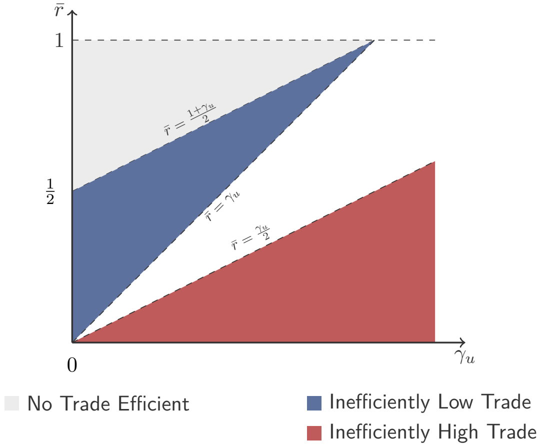

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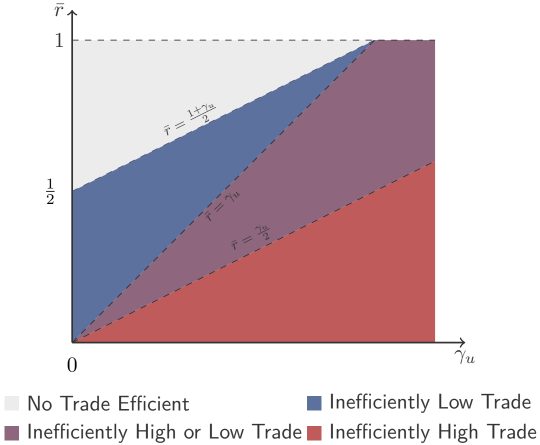

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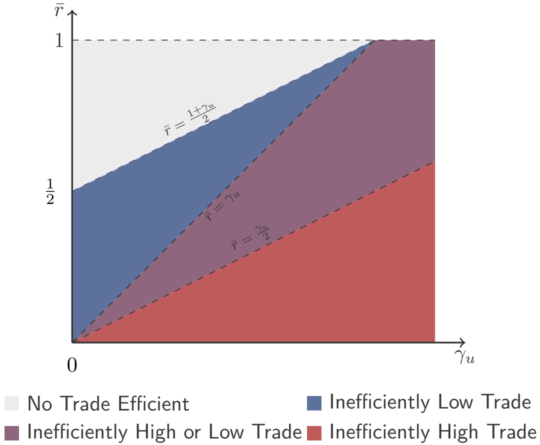

remedies

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 Union

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

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

First model of a data union, we offer theoretical support to these policy proposals

Data Union

How does a data union work?

- Consumers choose whether to become members of 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:

$$\begin{array}{rl}
\max\limits_{(p,q,x)} & \displaystyle\sum_{\omega} p(\omega)\bar{q}(\omega) + \sum_{a,\omega} u(a,\omega)x(a|\omega)q(\omega) + \sum_{\omega}(\bar{q}(\omega) - q(\omega))r(\omega) \\
\text{such that} & q \leq \bar{q}, \\
\text{and} & \sum_{\omega} p(\omega)\bar{q}(\omega) = V(q), \\
\text{and} & x \text{ solves } \mathcal{P}_q, \\
\text{and} & p(\omega) + \frac{q(\omega)}{\bar{q}(\omega)} \sum_a u(a,\omega)x(a|\omega) + \big(1 - \frac{q(\omega)}{\bar{q}(\omega)}\big)r(\omega) \geq r(\omega).
\end{array}$$

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

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

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)

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

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

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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

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