The Value of Data Records

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Motivation

Personal data is an essential input in many modern industries

Markets for data are rapidly developing and raise new questions for policy and regulation (Federal Trade Commission, 2014, Stigler Report, 2019)

Our Goal: better understand **demand side** of data markets, how they work, and how to fairly compensate data sources (Lanier, 2013; Acquisti et al., 2016; Posner and Weyl, 2018)

Basic Question: What is the value of an individual piece of data?

> E.g.: for an e-commerce platform, is one consumer's data more valuable than another's? Why? How much should each be worth/paid?

example

An Illustrative Example

(builds on BBM ’15)

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Suppose there are only two *types* of such records and that

- ω_1 reveals buyer has valuation 1
- ω_2 reveals buyer has valuation 2

Platform's **database** of records composed of $q(\omega_1) = 3M$ and $q(\omega_2) = 6M$

An Illustrative Example

Only platform observes ω; seller only knows database composition

Platform intermediates buyer-seller interaction by giving seller information about ω so as to influence her price p

Seller maximizes profits (MC = 0)

Suppose platform maximizes buyer's surplus

Question. What is the value of a type-ω record for the platform?

An Illustrative Example

An optimal way to use the database the following:

$$\text{Record of type } \omega_1 \longrightarrow s^L$$

$$\begin{tikzcd}
 & s^L \\
\text{Record of type } \omega_2 \arrow[ur, "\frac{1}{2}"] \arrow[dr, "\frac{1}{2}"'] & \\
 & s^H
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An optimal way to use the database the following:

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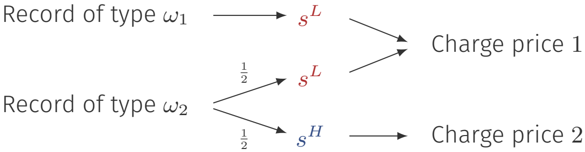

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Record of type $\omega_1 \longrightarrow s^L \longrightarrow$ Charge price 1

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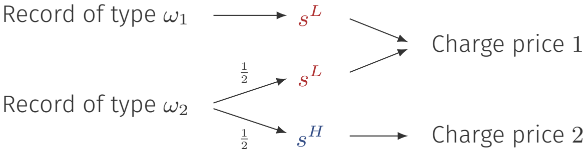

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1. Most valuable records are those yielding lowest payoff
2. ω_1 generates no direct payoff but "helps" ω_2 earn positive surplus
3. Payoff u_q^* gives biased account of the value created by a record

this paper

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We address two main questions

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   – For *more* records — Marketing Lists

     E.g., Platform obtains access to *new* buyers

   – For *better* records — Data Appends

     E.g., Platform obtains more information about *existing* buyers

Related Literature

Two strands of the literature on **data markets** Bergemann and Ottaviani (21)

1. Use of a database — how to design and sell information e.g., Admati and Pfleiderer (86, 90), Bergemann and Bonatti (15), Bergemann et al. (18), Yang (20)
   - Focus is not on use; but on inputs to the database (upstream market)
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   - Features of *data records*: access + information; valued ex post

2. Consumers' incentives to disclose — social dimension of data, learning externalities Choi et al. (19), Bergemann et al. (20), Acemoglu et al. (21), and Ichihashi (21)

   - Ann's record uninformative about Bob's $\rightsquigarrow$ new data externality
   - No disclosure, platform already owns the database

See paper for connections to mechanism/information design literature and duality model

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Buyer's valuation θ for seller's product is i.i.d

A buyer's record is of type $\omega \in \Omega$ and is (partially) informative about her θ

Database composition $q \in \mathbb{R}_{+}^{\Omega}$ is common knowledge

For $i \in \{0, 1\}$, $u_i : A \times \Omega \to \mathbb{R}$ denotes i's expected payoff function

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Information-Design Problem $\mathcal{U}_q$: Bergemann and Morris '16

$$\max_x \sum_{\omega, a} u_0(a,\omega) x(a|\omega) q(\omega)$$

s.t. for all a, a',

$$\sum_{\omega} \Big(u_1(a,\omega) - u_1(a',\omega) \Big) x(a|\omega) q(\omega) \geq 0$$

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Letting x_q^* be a solution of $\mathcal{U}_q$, denote

- $u_q^*(\omega) \triangleq \sum_a x_q^*(a|\omega)u_0(a,\omega)$ the **direct payoff** of a record
- $U^*(q) \triangleq \sum_\omega u_q^*(\omega)q(\omega)$ the **total payoff** of the database

the value of a single data record

The Value Problem

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Value Problem:

$$\mathcal{V}_q : \qquad \min_{v, \lambda} \sum_{\omega} v(\omega) q(\omega)$$

s.t. for all $\omega \in \Omega$,

$$v(\omega) = \max_{a \in A} \Big\{ u_0(a, \omega) + t(a, \omega) \Big\}$$

Lemma (Duality)

$\mathcal{V}_q$ is the dual of $\mathcal{U}_q$.

For every optimal solution v_q^* and x_q^*,

$$\sum_{\omega\in\Omega} v_q^*(\omega)q(\omega) = U^*(q) \triangleq \sum_{\omega,a} u_q^*(\omega)q(\omega)$$

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Basic Step

Lemma (Duality)

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- Formally, $v_q^*(\omega)$ is multiplier of feasibility constraint, thus $v_q^*(\omega)$ captures effect of marginal change in $q(\omega)$ on $U^*(q)$
- $v_q^*(\omega)$ is the **unit value** of a record of type ω (Gale '89)
- The goal of the paper is to characterize properties of $v_q^*(\omega)$

Decomposing the Value of a Record

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$$u_q^*(\omega) \triangleq \sum_a u_0(a,\omega) x_q^*(a|\omega) \qquad \text{direct payoff}$$

- $u_q^*(\omega)$ captures the payoff that platform earns directly from record

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- Clarfies why $u_q^*(\omega)$ is biased measure of value

Externality

Externalities arise because platform may withhold information by pooling data records together

- Specific to **intermediation problems**, as opposed to decision problems

  Ubiquitous due to rise of "info-mediaries" Acquisti et al. (16)

- They arise even if records are statistically independent between buyers

  Unrelated to "learning" externalities in literature (e.g. Acemoglu et al. 2021, Bergemann et al. 2020, Ichihashi (2021))

Example

$\Omega = \{\omega_1, \dots, \omega_K\}$ and record of type ω_k fully reveals that $\theta = \omega_k$

Platform maximizes

$$u_0(a, \omega) = \pi\Big(\underbrace{a\mathbb{1}\{\omega \geq a\}}_{\text{seller's profit}}\Big) + (1-\pi)\Big(\underbrace{\max\{\omega - a, 0\}}_{\text{buyer's surplus}}\Big) \qquad \text{for } \pi \in [0, 1]$$

Notation: a_q = uniform monopoly price

Proposition

Suppose $\pi < 1/2$.

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If $\pi < 1/2$, u_q^* provides biased account of the value of each record

Ignoring externality may lead to:

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Suppose $\pi \geq 1/2$.

- $t_q^*(\omega) = 0$ for all ω

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changing the database

Having More Data?

What is the platform's **willingness to pay** for more data?

We study two cases ($\approx$ kinds of information products):

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There is finite collection $\{Q_1, \ldots, Q_N\} \subseteq \mathbb{R}_+^\Omega$ of open, convex, disjoint sets s.t. $\bigcup Q_n$ has full measure and v_q^* is **constant** in $q \in Q_n$ for each n

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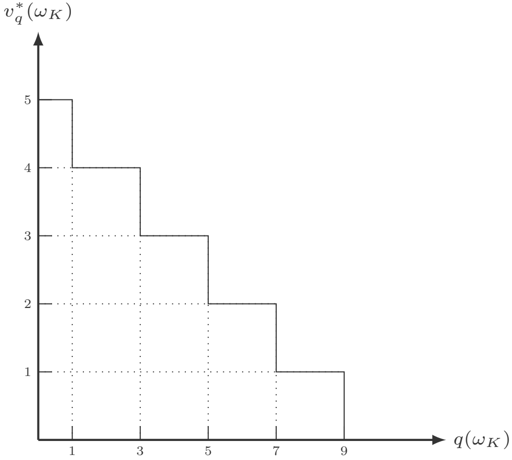
An example of a **demand curve** for records of type ω_K



Fix $\pi = 0$, $K = 10$, $q(\omega_k) = 1$, $\forall k < K$

Data records exhibits complementarities iff platform withholds information

Proposition

Records are **perfect** substitutes iff for **some** (interior) q it is optimal to **fully disclose** every record. In this case, full disclosure is optimal for every q.

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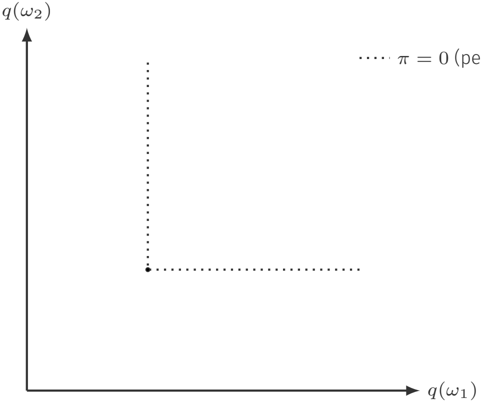

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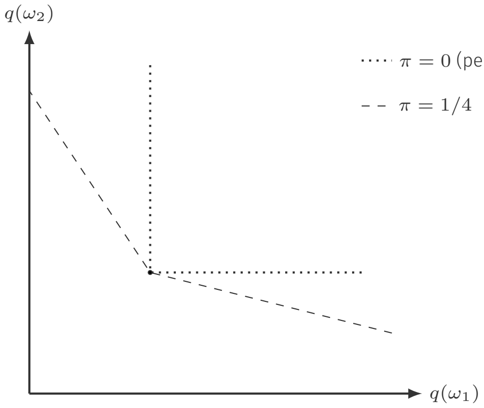

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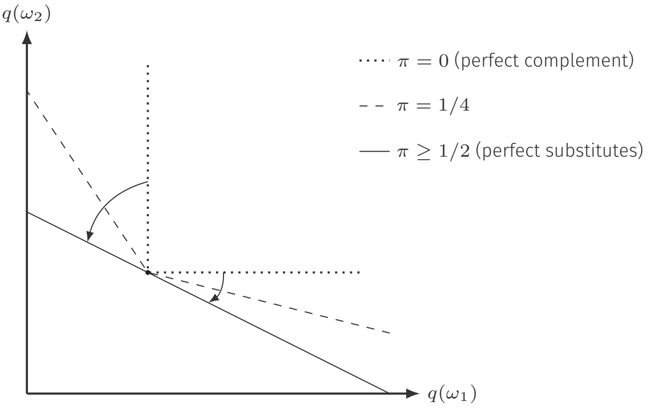

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Refining Existing Records

Records are often only partially informative about θ and platform can **learn** more about them $\rightsquigarrow$ **refine records**

Example

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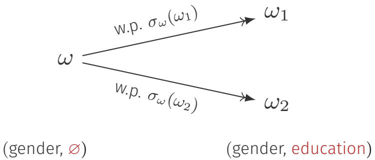

Definition. A **refinement** independently refines a share α of type-ω records wrt σ_ω

It transforms the original database $q \rightsquigarrow q_\alpha$ such that:

$$q_\alpha(\omega) < q(\omega) \qquad \text{and} \qquad q_\alpha(\omega') > q(\omega') \qquad \forall \omega' \in \operatorname{supp} \sigma_\omega$$

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Corollary:

Direct Effects. The value of each *refined* record increases:

$$\sum_{\omega' \in \Omega} v^*_{q_\alpha}(\omega')\sigma_\omega(\omega') \geq v^*_q(\omega)$$

Indirect Effects. The value of *unrefined* records changes as well

$$v^*_{q_\alpha}(\omega) \geq v^*_q(\omega) \qquad \text{and} \qquad v^*_{q_\alpha}(\omega') \leq v^*_q(\omega') \qquad \forall \omega' \in \operatorname{supp} \sigma_\omega$$

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Indirect Effects. The value of *unrefined* records changes as well

$$v^*_{q_\alpha}(\omega) \geq v^*_q(\omega) \qquad \text{and} \qquad v^*_{q_\alpha}(\omega') \leq v^*_q(\omega') \qquad \forall \omega' \in \operatorname{supp} \sigma_\omega$$

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WTP for Better Records

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- Marginally **decreasing** in α

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summary

Summary

We characterize **unit value** of a buyer's specific data record using duality

- Direct payoff from a record gives biased account of its value
- Novel data externalities, platform withholds information by pooling records

We study the platform's WTP for more data

- *"More"* records: demand for records, complements vs substitutes
- *"Better"* records: Refinements, effects on values, WTP $= 0$

Overall, a study of the **demand side** of data markets

$\rightsquigarrow$ Welfare effects of policy intervention; demand estimation

Future Directions: Privacy

With the same framework, we can study effects of **privacy** on the value of data

In a richer version of today's model:

- Buyer is an agent $(i = 2)$ and ω is her **private** information
- Platform must elicit such information in IC ways in order to use it

Still a LP problem, same approach as today applies.

Preliminary findings show that

- Privacy decreases the overall value of the database (of course!)
- But it can **increase** the value of some of types of record

How does v_q^* depend on q?

Stability

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v_q^* goes beyond a *marginal* interpretation $\rightsquigarrow$ WTP for discrete changes in q

Proposition (Stability)

There exists finite collection $\{Q_1, \ldots, Q_K\}$ of open sets in $\mathbb{R}_+^\Omega$ s.t.:

- $\bigcup Q_k$ has full measure
- (v_q^*, λ_q^*) is **unique** and **constant** in $q \in Q_k$ for each k

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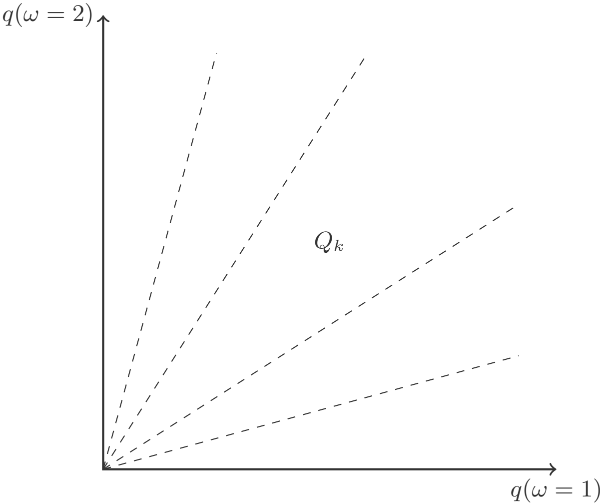
Note : v_q^* constant in Q_k even though x_q^* changes

Proof idea : algebraic representation of extreme points & optimality

Example



Proposition

For $\pi \leq \frac{1}{2}$,

$$v_q^*(\omega) = \begin{cases} (1-\pi)\omega & \text{if } \omega < a_q \\ \pi a_q + (1-\pi)(\omega - a_q) & \text{if } \omega \geq a_q; \end{cases}$$

Moreover, $t_q^*(\omega) > 0$ for $\omega < a_q$ and $t_q^*(\omega) \leq 0$ for $\omega \geq a_q$

For $\pi \geq \frac{1}{2}$ we have $v_q^*(\omega) = u_q^*(\omega) = \pi\omega$ for all ω