Privacy as a Public Good: A Case for Electronic Cash[1]

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Models of Cryptocurrencies: Pricing and Design

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[1] *Views expressed do not necessarily reflect official positions of the Bank of Canada.*

Trends

Privacy in payments is a feature inherent to cash but its survival is threatened.

- Decreasing cash share at the point of sale
  - Declined to 33 per cent of volume in Canada, 31 percent in US
- Increasing share in online payments

- Data collection and data sharing between commercial payments providers and other companies (Google/Mastercard)
- R&D of commercial payment providers in predicting behaviour for marketing purposes based on payments data in combination with other data sources
- Corporations with data-intensive business models outside the realm of payments seek to expand into payments (Facebook)

Patents and Patent Applications

Mastercard (2011): "Systems and methods for analyzing and segregating payment card account profiles into clusters and targeting offers to cardholders. (...) *Customers who have no transaction history with a merchant may be selected for offers based on similarities with respect to other customers of the merchant.*"

Mastercard (2018): "Disclosed herein are systems and methods of individual level learning that include receiving purchase event data from a merchant device that indicates that a purchase event occurred by a user on a user device, and transmitting the purchase event data to an analytics server. The methods may also include processing the purchase event data. (...) When the purchase hazard probability is above a threshold, the system may push a message to the user device."

Research Questions

1. What could be adverse economic consequences of losing privacy in payments?
2. Might individuals make sub-optimal choices when it comes to preserving privacy in payments?
3. Is there a role for government and/or central bank action?

The Privacy Externality

General point
Your information and choices reveal something about you, and also others

- Individuals may not be properly incentivized to protect their private information
- Do not bear the full social cost of failing to protect privacy
- Privacy lost through actions of others regardless of what you do
- Leads to sub-optimal choices and role for government action

Related literature

Money is Privacy (Kahn, McAndrews and Roberds, 2005)

- Allows consumers to purchase goods without revealing their identities
- Protects them from theft

Privacy Paradox (Norberg et al., 2007; Athey et al., 2017)

- Observed dichotomy between attitudes toward privacy and behavior
- Potential explanations in the literature:
  - Information disclosure based on optimal trade-off
  - Unawareness of cost of information disclosure by consumers
- Explanation in this paper
  - A public good aspect of privacy in payments

Modeling Approaches

One-period model

- 3 types of agents
- Money in the utility function

Dynamic model

- Overlapping generations model, agents live 3 periods
- Full monetary equilibrium

Both models deliver the **same result** regarding the public good aspect of privacy in payments.

Dynamic model endogenizes/rationalizes assumptions of the static model.

Model: Setup

Three cohorts, each consisting of n agents indexed by i:

- Young merchants (y)
  - Endowed with two units of a consumable good
  - Wish to sell goods for money
  - $U_y(m_{iy}) = \underbrace{m_{iy}}_{\text{Amount of money}}$
- Middle-aged ($a = m$) and old ($a = o$) consumers
  - Endowed with money, interested in consuming 1 unit of the good
  - Two types: Fraction z of consumers are willing to pay a high price (r_H) and the others are willing to pay a low price (r_L), depending on their unobservable type $s \in \{H, L\}$
  - $U_a(c_{ia}, m_{ia}, e_{ia}; s) = \underbrace{c_{ia} r_s}_{\text{Consumption}} + \underbrace{m_{ia}}_{\text{Amount of money}} + \underbrace{e_{ia}(\beta - \delta)}_{\text{Personal net benefit of privacy in payments}}$

Model: Observable characteristic

Consumers have an observable characteristic $h_{ia} \in \{X, Y\}$

- For example, address information, online profile, etc
- Simple relationship with consumer type:
  - Perfectly correlated with type of middle-aged consumers
  - Imperfectly correlated with type of old consumers: fraction ε of old consumers have the "wrong" observable characteristic
- Merchants do not know the sign of the relationship

Model: Timeline

Start — Meet middle-aged — Meet old — End

· Middle-aged and old consumers randomly adopt observable characteristic h_{ia} based on their type s_{ia}

· Merchant meets a random middle-aged consumer

· Makes a take-it-or-leave-it offer

· If accepted, the merchant sells a unit of the good to the middle-aged consumer

· Merchant meets a random old consumer

· Makes a take-it-or-leave-it offer

· If accepted, the merchant sells a unit of the good to the old consumer

Outcome without price discrimination

- Merchants quote a low price r_L to all consumers
- All consumers accept the offers made by the merchants

- Consumers protect their privacy in payments if the net personal benefit is positive

- Total welfare (ignoring aggregate money holding) equals

$$W^* = \underbrace{2zn}_{\substack{\text{Consumers}\\ \text{with high}\\ \text{valuations}}} r_H + \underbrace{2(1-z)n}_{\substack{\text{Consumers}\\ \text{with low}\\ \text{valuations}}} r_L + 2en(\beta - \delta),$$

where $e = 1$ when $\beta \geq \delta$ and $e = 0$ otherwise.

Outcome with price discrimination

- we assume $zr_H < r_L$
- to be willing to price discriminate, merchants need to learn something about the relationship between consumer characteristics (observable) and consumer types (unobservable).
- when $\beta \geq \delta$ this requires experimentation with high reserve prices
- when $\beta < \delta$ can use information obtained from consumers paying without protecting their privacy

Price Discrimination when $\beta \geq \delta$

Consumers protect their privacy in payments

- Meet middle-aged: Quote the high price r_H to all consumers.
  - Type H consumers accept the offer
  - Type L consumers reject the offer
- Meet old: Quote high price to consumers with characteristic associated with type H and low price to all others.
  - Type H consumers accept the offer
  - Only correctly classified type L consumers accept the offer
- Not all "win-win" situations lead to transactions.
  - Welfare will be lower than W^*

$$W^{UD} = W^* - n(1+\varepsilon)(1-z)r_L$$

- Price discrimination is optimal for merchants whenever the profiling technique is sufficiently precise: $\varepsilon < \theta^U(z, r_H, r_L)$.

Price Discrimination when $\beta < \delta$

Consumers do not protect their privacy in payments

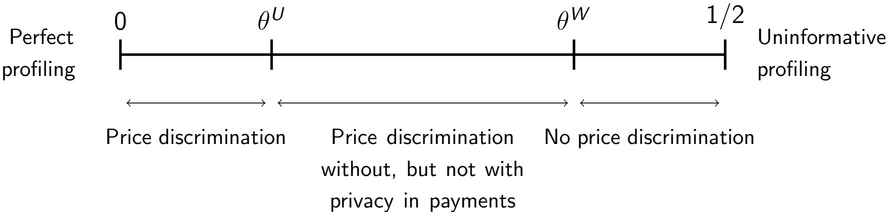
- Meet middle-aged: Quote the low price r_L to all consumers.
  - All consumers accept the offer
- Meet old: Quote high price to consumers with characteristic associated with type H and low price to all others.
  - Type H consumers accept the offer
  - Only correctly classified type L consumers accept the offer

- Not all "win-win" situations lead to transactions.
  - Welfare will be lower than W^*

$$W^{WD} = W^* - n\varepsilon(1-z)r_L.$$

- Price discrimination is optimal for merchants whenever the profiling technique is sufficiently precise: $\varepsilon < \theta^W(z, r_H, r_L)$.

Profiling Accuracy and Price Discrimination



Dynamic Model

Every period, there are n new agents who live three periods

- Agent i starting in generation t
  - can produce up to three perishable consumable goods when young
  - meets random middle-aged agent and two random old agents
  - wishes to consume when middle-aged (meeting A) and when old (meetings B and C)
  - has utility function

$$u(c_{it}^A, c_{it}^B, c_{it}^C, Q_{it}, e_{it}) = \underbrace{c_{it}^A + c_{it}^B b + c_{it}^C c}_{\text{Consumption}} - \underbrace{Q_{it} f}_{\text{Production}} + \underbrace{e_{it}(\beta - \delta)}_{\text{Personal net benefit of privacy in payments}},$$

where $\frac{1}{3} < c < 1 < b$ and the production cost $f < 1/3$

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- Agents can carry up to 3 units of an indivisible durable asset

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where $\frac{1}{3} < c < 1 < b$ and the production cost $f < 1/3$

- Agents can carry up to 3 units of an indivisible durable asset
- In total $4n$ units of this asset ("money"), no record-keeping

Dynamic: Timeline when Young

t — Meeting A — Meeting B — Meeting C — $t+1$

t

- Young agent it is born
- Middle-aged and old agents randomly adopt observable characteristics $h^t_{i,t-1}$ and $h^t_{i,t-2}$ based on their respective statuses $s_{i,t-1}$ and $s_{i,t-2}$ and the time-specific relationships between $h^t_{i\tau}$ and $s_{i\tau}$, $\tau \in \{t-1, t-2\}$, for period t

Meeting A

- Young agent it randomly meets a middle-aged agent
- Makes a take-it-or-leave-it offer
- If offer is accepted, the young agent produces a unit of the good for the old agent

Meeting B

- Young agent it randomly meets an early old agent
- Makes a take-it-or-leave-it offer
- If offer is accepted, the young agent produces a unit of the good for the old agent

Meeting C

- Young agent it randomly meets a late old agent
- Makes a take-it-or-leave-it offer
- If offer is accepted, the young agent produces a unit of the good for the old agent

$t+1$

- Consumable goods and old agents perish
- Young agent it (potentially) receives inheritance from an old agent
- Young agent it attains lifetime status $s_{it} = \{H, L\}$ based on whether or not she accumulated three units of money
- Young agent it turns middle-aged

Dynamic: Timeline when Young

t	Meeting A	Meeting B	Meeting C	$t+1$
· Young agent *it* is born · Middle-aged and old agents randomly adopt observable characteristics $h^t_{i,t-1}$ and $h^t_{i,t-2}$ based on their respective statuses $s_{i,t-1}$ and $s_{i,t-2}$ and the time-specific relationships between $h^t_{i\tau}$ and $s_{i\tau}$, $\tau \in \{t-1, t-2\}$, for period t	· Young agent *it* randomly meets a middle-aged agent · Makes a take-it-or-leave-it offer · If offer is accepted, the young agent produces a unit of the good for the old agent	· Young agent *it* randomly meets an early old agent · Makes a take-it-or-leave-it offer · If offer is accepted, the young agent produces a unit of the good for the old agent	· Young agent *it* randomly meets a late old agent · Makes a take-it-or-leave-it offer · If offer is accepted, the young agent produces a unit of the good for the old agent	· Consumable goods and old agents perish · Young agent *it* (potentially) receives inheritance from an old agent · Young agent *it* attains lifetime status $s_{it} = \{H, L\}$ based on whether or not she accumulated three units of money · Young agent *it* turns middle-aged

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Dynamic Model: Best Feasible Monetary Equilibrium

Socially optimal allocation

- Young agent always charge a price of one
- They earn 2 or 3 units of money, each with probability $1/2$
- $\mathbb{E}u^* = 1 + b - 2f + \frac{1}{2}(c - f) +$ potential privacy benefit

This is a monetary equilibrium if

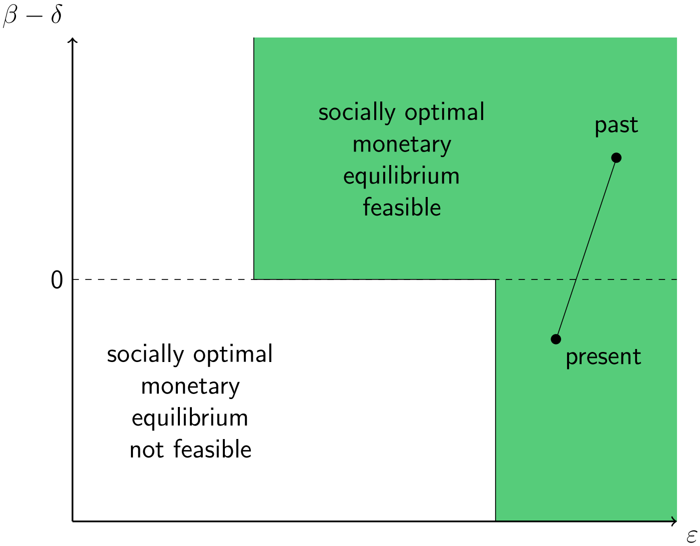
P1 profiling errors $\varepsilon \geq \theta^U$ for $\beta > \delta$ (individuals protect privacy)

P2 profiling errors $\varepsilon \geq \theta^W$ for $\beta < \delta$ (individuals do not protect privacy)

P3 where $\theta^U < \theta^W$ as in the one-period model

Otherwise, young agents optimally price discriminate.

Privacy in Payments and Big Data: Past, Present & Future



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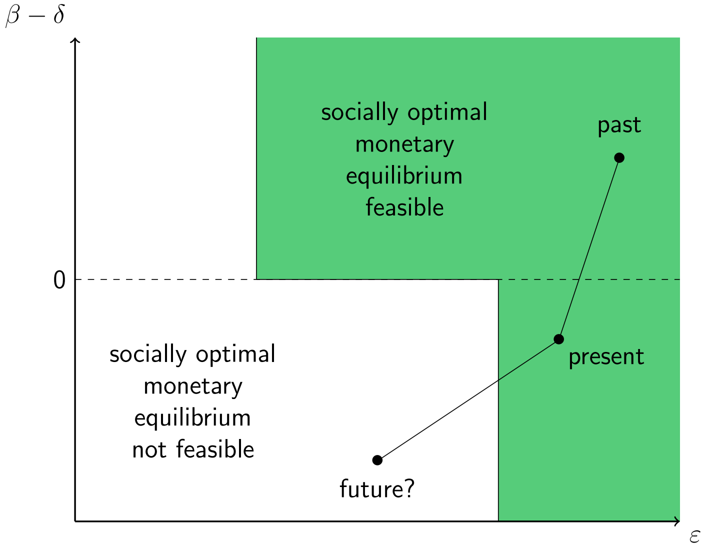

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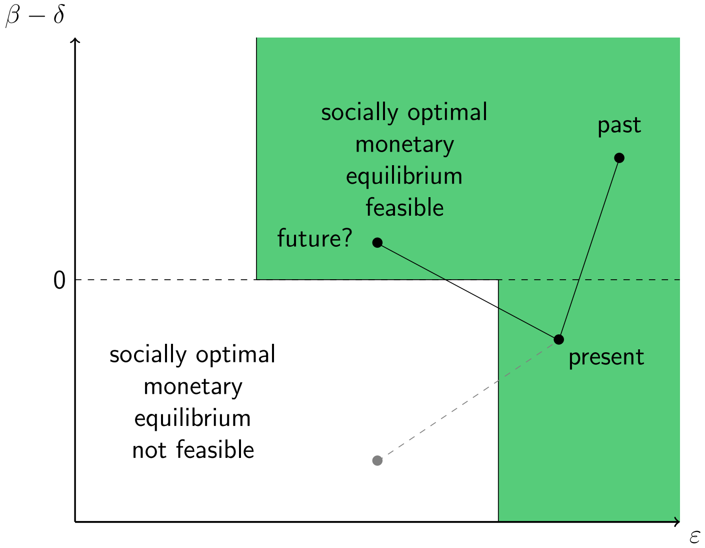

Concluding remarks

Options for promoting privacy in payments

- Encourage/subsidize cash use
  - Does not address increasing share of online payments
- Promotion of electronic cash substitutes
  - CBDC (designed as electronic cash)
  - Privacy preserving cbDC (eg Digicash)
  - Cryptocurrencies (eg Bitcoin)
- Regulation to promote privacy in payments
  - Makes current payment methods more "cash-like"
  - Social optimum not necessarily achieved with consent-based approach (externality)

Advantages of CBDC

- "...(i) financial inclusion, (ii) security and consumer protection; and to provide what the private sector cannot: (iii) privacy in payments." (Christine Lagarde, 2018)

Thank you!