Demand for Payment Services and Consumer Welfare: The Introduction of a Central Bank Digital Currency (CBDC)

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2. The second is where private cryptocurrencies make serious inroads.

Source: Speech to the CFA Montréal FinTech RDV2020 on 25 February 2020. Follow up speech on "*Payments innovation beyond the pandemic*" at the Institute for Data Valorisation on 21 February 2021.

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Nota bene (N.B.): Physical cash (banknotes) has two uses: transactional and non-transactional (store-of-value, etc).

Paper will focus on transactional demand & condition #1!

Motivation: Decline in cash shares at POS
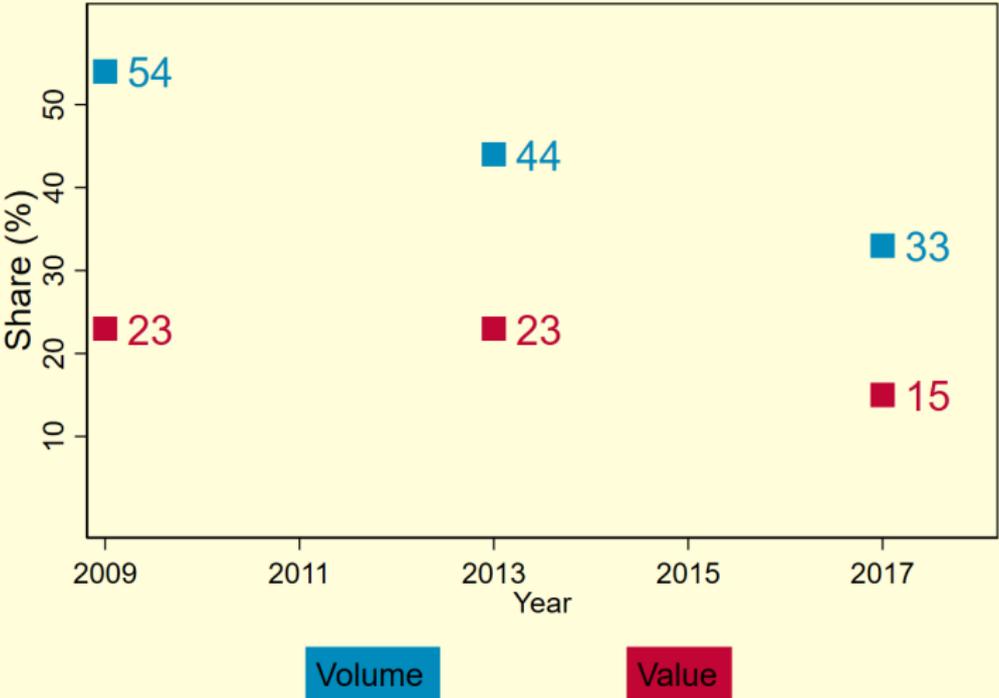
Source: Method-of-Payment survey

Possible reasons for ↓ cash at the POS

1. Consumer demand for cash declines:
   - Demographics and stated preferences
   - Alternative payment methods: debit and credit cards
   - Payment innovations: contactless cards and Interac e-Transfers
2. Increase in merchant acceptance of cards:
   - Cash almost universally accepted by all merchants
   - Cards almost universally accepted at Large Businesses
   - Cards accepted by 2/3 Small-Medium Businesses (SMB)
   - A small number of SMBs not accepting cash

Research on Central Bank Digital Currency

1. Impact on monetary policy
   - Potential new tools: negative interest rate, direct transfer,
   - different interest rates for different accounts
   - Monetary sovereignty: Libra, digital currencies
2. Impact on the payment system:
   - competition for credit card/ payment processing companies
3. Impact on financial stability:
   - stability of deposit funding of retail banks, increased bank runs
4. Impact on consumers:
   - safety, universal access, privacy, resiliency

Research Contribution

1. **What are the main characteristics of consumer demand for usage and adoption of payment methods?**
   - Perceptions: ease of use, affordability of use and security of use
   - Observed characteristics: Reward, transaction cost
   - Demographics: age, income, education, marital status, employment, Canadian born, smartphone ownership
   - Transaction characteristics: type of purchase

2. **What would be the predicted usage of a hypothetical central bank digital currency (CBDC)?**
   - Cash like digital currency (possibly token based)
   - Debit card like digital currency (account based)
   - Mix of cash and debit like digital currency (best features of both)

Results Preview

- **CBDC usage**: 19 to 25 percent market share for baseline CBDC under full adoption and acceptance

- **Consumer welfare**: a maximum $2 per month welfare increase from usage on average under full adoption and acceptance

- **Distribution**: different designs of CBDC will benefit different people

- **CBDC design**: transaction cost, ease of use, acceptance most important

Literature Review

- **New product introduction**: Petrin (2002), Gentzkow (2007), Borzekowski and Kiser (2008)

- **Demand estimation with adoption and usage decisions**: Dubin and McFadden (1984), Hendel (1999), Koulayev et al. (2016)

- **Characteristics based demand estimation for Payment Services**: Borzekowski, Kiser and Ahmed (2008), Zinman (2009),Humphrey (2010), Ching and Hayashi (2010), Cohen and Rysman (2013), Arango, Huynh and Sabetti (2015), Wakamori and Welte (2017)

- **Two-sided models of Payment Services**: Rochet and Tirole (2003), Huynh, Nicholls and Shcherbakov (2019)
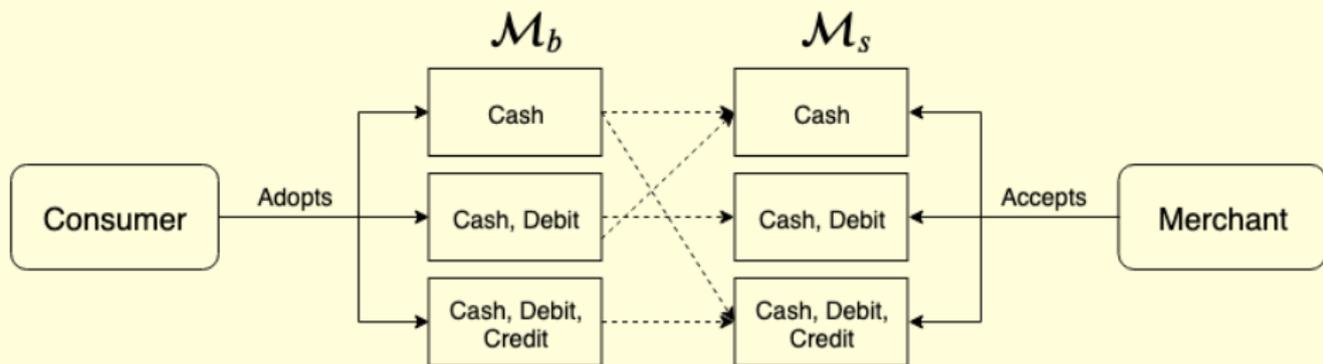
Model: setup

Based on Huynh, Nicholls and Shcherbakov (2019).

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- Buyers: $b = 1, \ldots, N_b$
  - know average acceptance probability by sellers.

- Sellers: $s = 1, \ldots, N_s$
  - know expected adoption decisions for each consumer type.

- Methods of payment:
  - Cash, ca,
  - Debit, dc,
  - Credit, cc.

- Consumer adoption / Merchant acceptance choice set

$$\mathcal{M}_i = \Big(\{ca\}, \{ca, dc\}, \{ca, dc, cc\} \Big)$$

Model: setup

- The interaction is modeled as a two-stage game played every period:
  1. Merchants and consumers simultaneously and independently choose $\mathcal{M}_s$ and $\mathcal{M}_b$, respectively.
  2. Conditional on the acceptance/adoption decisions, merchants and consumers are randomly matched for each transaction.
     - ▶ At a point of sale, consumers make usage decisions.
     - ▶ If a consumer chooses to use $m \in \mathcal{M}_b \cap \mathcal{M}_s$, merchants must accept m.

- We assume $ca \in \mathcal{M}_b$ and $ca \in \mathcal{M}_s$ for all s, b, therefore
  - ○ it is guaranteed that consumers and merchants can trade because

  $$ca \in \mathcal{M}_s \cap \mathcal{M}_b$$

- We focus on consumer demand with heterogeneity

Model: Choice of Payment Method

- Second stage: discrete choice of a payment method (cash, debit, credit) at the POS with heterogenous consumers depending on

    - Payment method specific variables: ease of use, affordability of use, security of use, rewards, transaction cost

    - Transaction specific variables: type of purchase

    - Consumer specific variables: age, gender, income, education, marital status, employment, Canadian born, smartphone ownership

    - Conditional on merchant acceptance ($\mathcal{M}_s$) and consumer adoption ($\mathcal{M}_b$)

Model: Choice of Payment Bundle

- First stage: discrete choice of the payment method bundle:

    - 3 bundles: $\{ca\}, \{ca, dc\}, \{ca, dc, cc\}$

    - The bundle choice is the maximum of the expected sum of usage values of each bundle

    - Conditional on merchant acceptance $\mathcal{M}_s$ with probability $P_{\mathcal{M}_s}$

Model: consumers, usage decisions

- Every consumer b is endowed with a set of transactions, $\mathcal{J}_b$ at a given price, p_{bj}, all of which must be completed:

$$\mathbb{E}[U_{bj}|\mathcal{M}_b] = \sum_{\mathcal{M}_s} P_{\mathcal{M}_s} \times \mathbb{E} \max_{m' \in \mathcal{M}_b \cap \mathcal{M}_s} \{X_{bm'j}\beta + Z_{bj}\gamma_{m'} + \varepsilon_{bm'j}\}$$

$$= \sum_{\mathcal{M}_s} P_{\mathcal{M}_s} \times \mathbb{E} \max_{m' \in \mathcal{M}_b \cap \mathcal{M}_s} \{\delta_{bm'j} + \varepsilon_{bm'j}\}$$

$$= \sum_{\mathcal{M}_s} P_{\mathcal{M}_s} \times \ln\left(\sum_{m' \in \mathcal{M}_b \cap \mathcal{M}_s} \exp(\delta_{bm'j})\right),$$

- Assume inelastic demand — all consumers complete their transactions.

Model: consumers, adoption decisions

- Let $F_{\mathcal{M}_b}$ denote fixed cost (benefit) of adopting combination $\mathcal{M}_b$.
- Then, the first stage decision can be described as

$$EU_{1b}(\mathcal{M}_b) = \sum_{j=1}^{J_b} \mathbb{E}[U_{bj}|\mathcal{M}_b] - F_{\mathcal{M}_b} + \epsilon_{b,\mathcal{M}_b},$$

Assumption 1. *Consumer first stage adoption costs are given by $F_{\mathcal{M}_b}$, s.t.,*

$$\bar{F}_{\mathcal{M}_b} + \epsilon_{b,\mathcal{M}_b}, \qquad \text{if } \mathcal{M}_b = \{ca, dc\} \text{ or } \mathcal{M}_b = \{ca, dc, cc\}$$
$$\epsilon_{b,0}, \qquad \text{if } \mathcal{M}_b = \{ca\}$$

where $\epsilon_{b,\mathcal{M}_b}$ are iid draws from a standard Gumbel distribution.

Model: joint likelihood

- We estimate structural parameters using simulated maximum likelihood:
    1. Observed point-of-sales usage decisions $d_{b,m,j}$, and
    2. Observed consumer adoption decisions $D_{b,\mathcal{M}_b}$ both conditional on merchant acceptance.

$$\mathcal{L}(\beta) = \prod_{b=1}^{N_b} \prod_{j \in \mathcal{J}_b} \Pr(j, ca|M_b)^{d_{b,ca,j}} \Pr(j, dc|M_b)^{d_{b,dc,j}} \Pr(j, cc|M_b)^{d_{b,cc,j}}$$

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$$\prod_{b=1}^{N_b} \Pr(\{ca\} = \underset{\mathcal{M}'_b \subset \mathcal{M}}{\arg\max}\{EU_{1b}(\mathcal{M}'_b)\})^{D_{b,\{ca\}}}$$

$$\times \Pr(\{ca, dc\} = \underset{\mathcal{M}'_b \subset \mathcal{M}}{\arg\max}\{EU_{1b}(\mathcal{M}'_b)\})^{D_{b,\{ca,dc\}}}$$

$$\times \Pr(\{ca, dc, cc\} = \underset{\mathcal{M}'_b \subset \mathcal{M}}{\arg\max}\{EU_{1b}(\mathcal{M}'_b)\})^{D_{b,\{ca,dc,cc\}}}$$

Data: Components of the Methods of Payment Survey (MOP)

1. Survey Questionnaire (SQ):
   - Portfolio of Payment options
   - Perceptions of characteristics of payment methods
   - Typical payment patterns
   - Demographics
2. Diary Survey Instrument (DSI):
   - 3 day recording period
   - POS purchases: value, MOP, business
   - Type of purchase
3. TransUnion credit registry
   - Imputed with nearest neighbour
   - Matched using demographics data

Normalize cash to 1

Table: **Mean perception by MOP bundles in 2017**

Adopted bundle	Variable	Cash	Debit	Credit
$\{ca\}$ (N=42)	Ease of use	**1**	0.88	0.85
	Affordability	**1**	0.78	0.75
	Security	**1**	0.90	0.86
	Acceptance	**1**	0.95	0.94
$\{ca, dc\}$ (N=301)	Ease of use	**1**	0.96	0.83
	Affordability	**1**	0.85	0.65
	Security	**1**	0.95	0.88
	Acceptance	**1**	0.98	0.90
$\{ca, dc, cc\}$ (N=2780)	Ease of use	**1**	0.95	0.96
	Affordability	**1**	0.87	0.80
	Security	**1**	0.96	0.96
	Acceptance	**1**	0.97	0.96

Source: MOP SQ 2017

Table: **Demographics by MOP bundles in 2017**

Variable	$\{ca\}$	$\{ca, dc\}$	$\{ca, dc, cc\}$
Age	45.00	40.65	47.39
Income (1000)	47.14	44.34	76.80
Education	2.88	2.97	3.84
Gender	0.50	0.58	0.51
Urban	0.76	0.88	0.87
Employed	0.26	0.22	0.45
Retired	0.26	0.11	0.26
Smartphone	0.52	0.62	0.73

Source: MOP SQ 2017

Table: **Shares of payment methods usage by transaction type**

| | 2009 | | | 2013 | | | 2017 | | |
Transaction type	Cash	Debit	Credit	Cash	Debit	Credit	Cash	Debit	Credit
Groceries/Drugs	**47**	31	21	**39**	26	34	30	28	42
Gasoline	29	31	40	20	29	51	13	27	60
Personal Attire	28	32	39	25	29	46	20	23	57
Health Care	37	26	37	35	27	38	25	24	51
Hobby/Sporting Goods	**46**	28	26	41	19	40	37	21	42
Professional/Personal Services	**57**	21	22	**45**	16	39	**45**	14	42
Travel/Parking	**83**	7	10	**61**	10	29	**47**	10	42
Entertainment/Meals	**69**	19	12	**59**	18	23	**43**	24	33
Durable Goods	33	27	40	30	26	45	22	20	58
Other	**69**	18	14	**55**	20	25	**47**	21	32
Total	53	25	21	44	23	33	34	25	41

Source: MOP DSI 2009,2013,2017

Model estimates for perception variables

		Conditional logit	Mixed logit			
		(1)	(2)		(3)	
	Variable	coef.	coef.	s.d	coef.	s.d.
Second stage	Ease-of-use (↑ easier)	6.380	7.144	—	7.078	—
	(s.e.)	(0.219)	(0.243)	—	(0.242)	—
	Affordability (↑ cheaper)	2.459	3.058	2.672	3.041	2.590
	(s.e.)	(0.096)	(0.118)	(1.556)	(0.117)	(1.161)
	Security (↑ safer)	0.845	1.059	2.615	1.040	2.497
	(s.e.)	(0.107)	(0.130)	(1.191)	(0.129)	(1.251)
	Reward	1.117	1.384	—	1.323	—
	(s.e.)	(0.025)	(0.030)	—	(0.029)	—
	Transaction Cost	-0.878	-0.964	0.302	-0.959	0.296
	(s.e.)	(0.004)	(0.005)	(0.022)	(0.005)	(0.022)
First stage	$\bar{F}_{ca,dc}$ (cash&debit)	-1.309	-1.326		-1.685	
	(s.e.)	(0.135)	(0.135)		(0.134)	
	$\bar{F}_{ca,dc,cc}$ (all)	-2.249	-2.147		1.450	
	(s.e.)	(0.130)	(0.130)		(0.130)	
	$\gamma_{ca,dc}$ credit score ('00)				0.065	
	(s.e.)				(0.019)	
	$\gamma_{ca,dc,cc}$ credit score('00)				-0.495	
	(s.e.)				(0.018)	
	Demo & trans. controls, Z_{bj}	yes	yes		yes	
	NLL	28,649.06	28,602.62		28,420.03	
	AIC	57,416.12	57,333.24		56,972.06	
	BIC	57,915.72	57,875.18		57,530.94	

Average contribution to the utility of the payment method per month
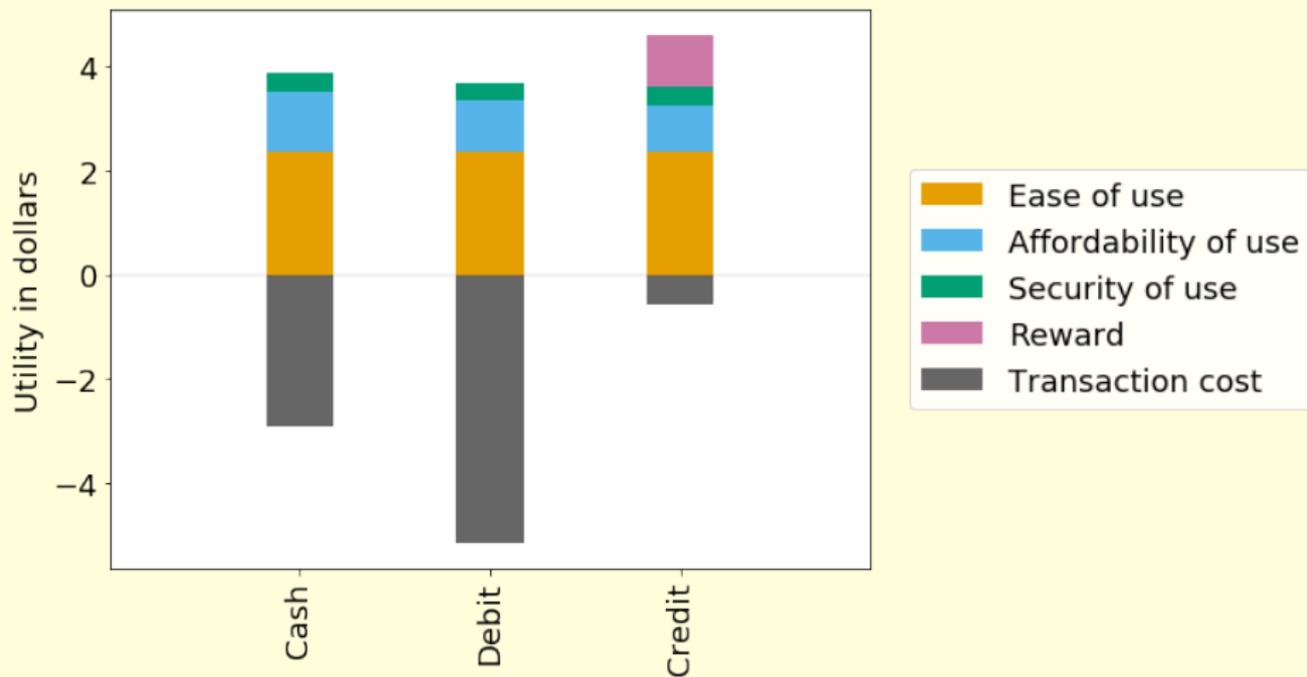
Model estimates for adoption benefits $F_{\mathcal{M}_b}, \gamma_{\mathcal{M}_b}$

For specification 3 we have $\bar{F}_{\mathcal{M}_b} + \gamma_{\mathcal{M}_b}\text{Credit Score}_b/100 + \epsilon_{b,\mathcal{M}_b}$.

Table: **Monthly adoption benefit for each bundles**

	Conditional Logit		Mixed Logit	
	(1)	(2)	(3)	
$\{ca, de\}$	\$1.49	\$1.37	$1.76 - 0.068(\text{Credit Score}/100)$	
$\{ca, de, cr\}$	\$2.56	\$2.21	$-1.51 + 0.516(\text{Credit Score}/100)$	

Counterfactuals: Full Adoption
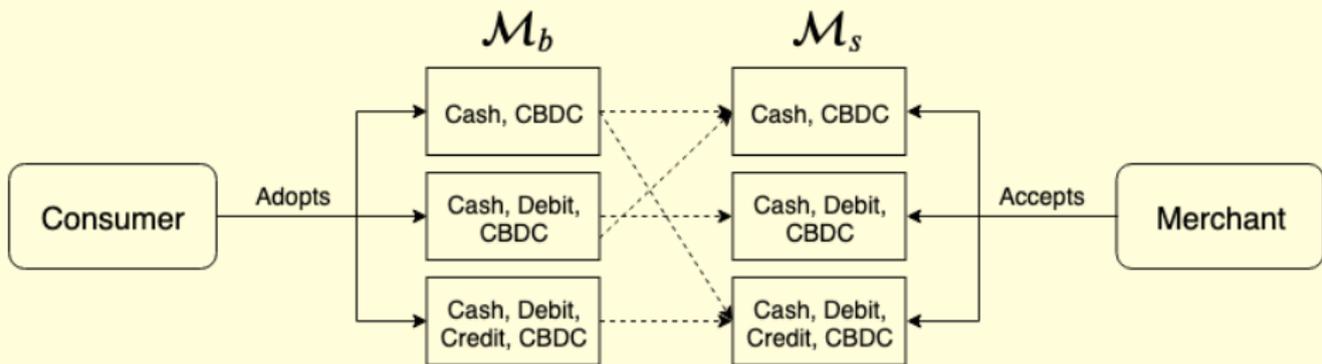
Counterfactuals: No Full Adoption
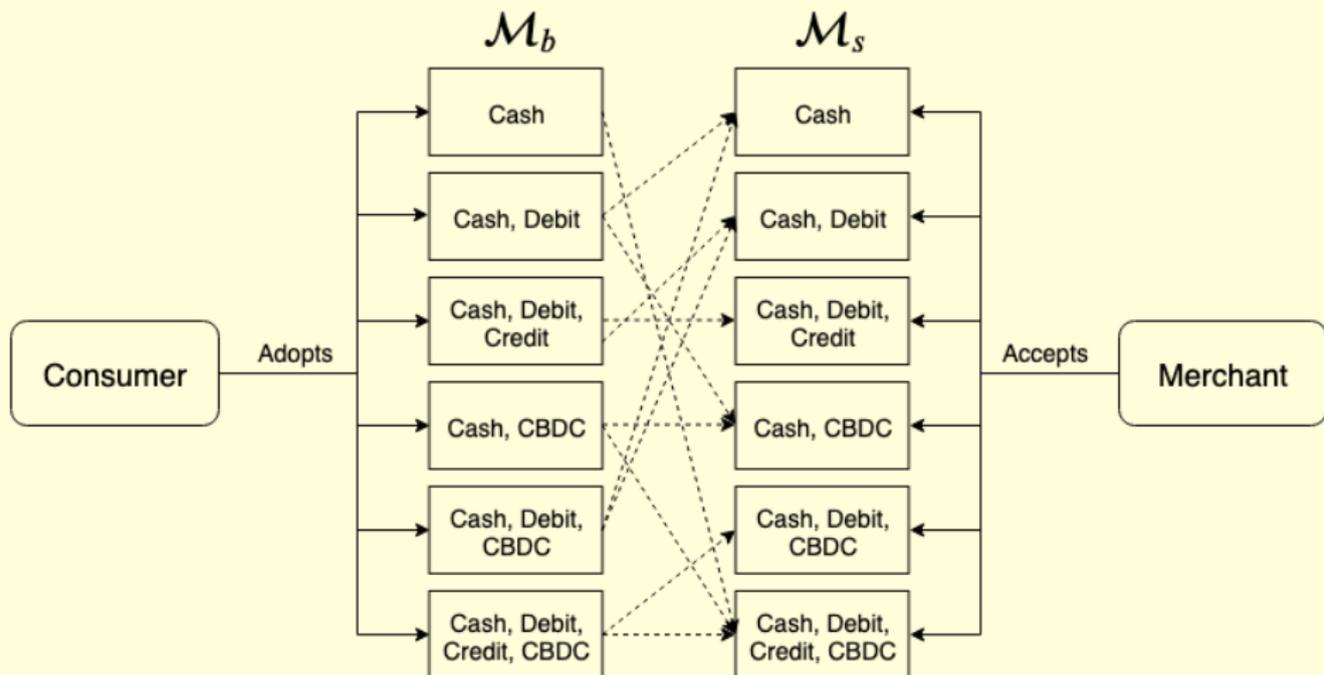
Counterfactuals: with and without full consumer adoption and merchant acceptance

1. Cash-like CBDC — characteristics (ease, affordability, security) are set to cash
   - ○ Market shares
   - ○ Substitution pattern and sensitivity
   - ○ Welfare gain and distribution

2. Debit-like CBDC — characteristics are set to debit

3. Best-feature CBDC — characteristics are set to max of cash and debit

Go to less than full consumer adoption and merchant acceptance

Counterfactuals: Caveats

- Assumes no competitive response from banks and merchants.

- Do not take fully into account possible digital or peer-to-peer usage of CBDC

- Do not consider any potential new applications of CBDC (smart contract, programmable money etc.)

# 1. Cash-like CBDC with full consumer adoption and merchant acceptance
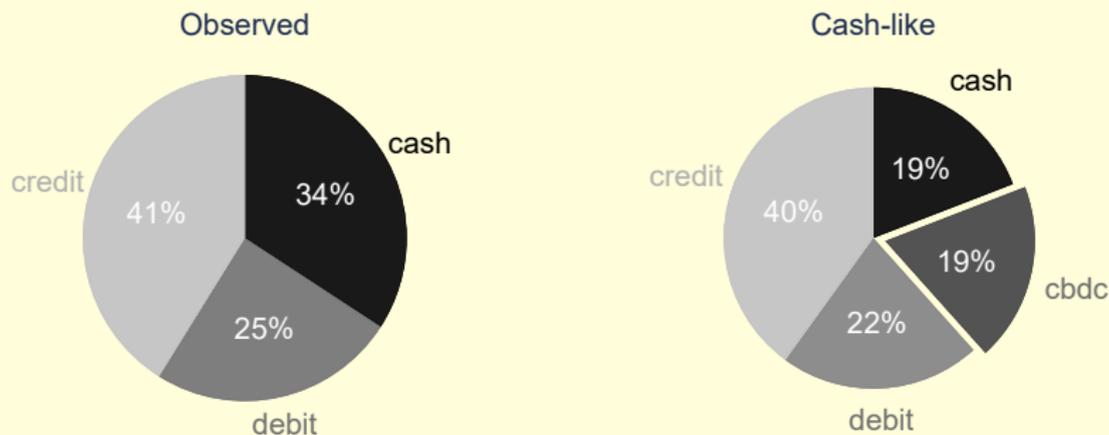
Market shares for observed and counterfactual

1. Cash-like CBDC with full consumer adoption and merchant acceptance
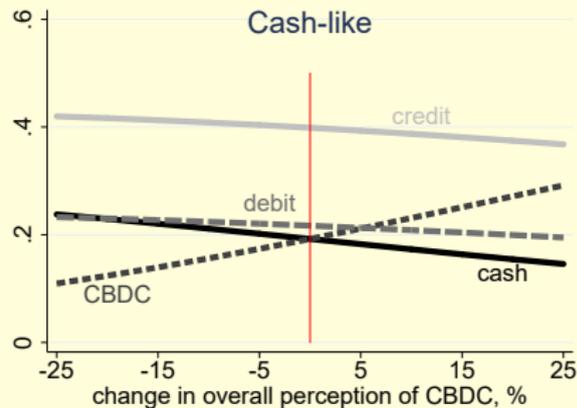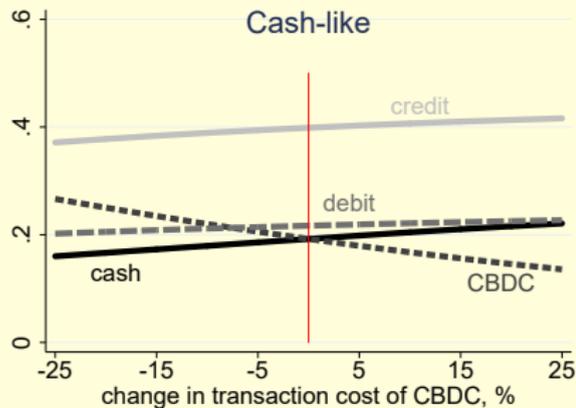
Substitution pattern and sensitivity for cash-like CBDC

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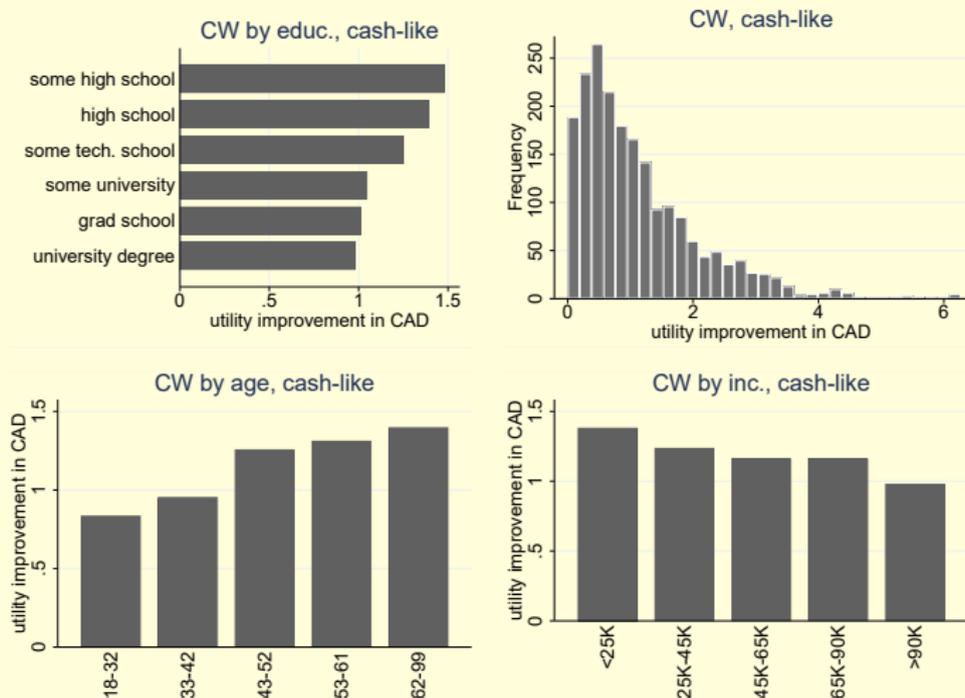
Welfare gain and distribution for cash-like CBDC

2. Debit-like CBDC with full consumer adoption and merchant acceptance
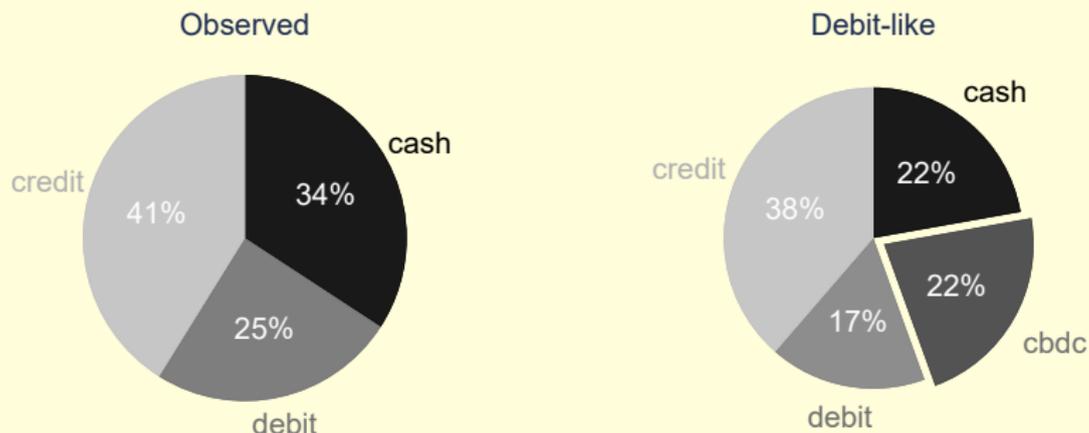
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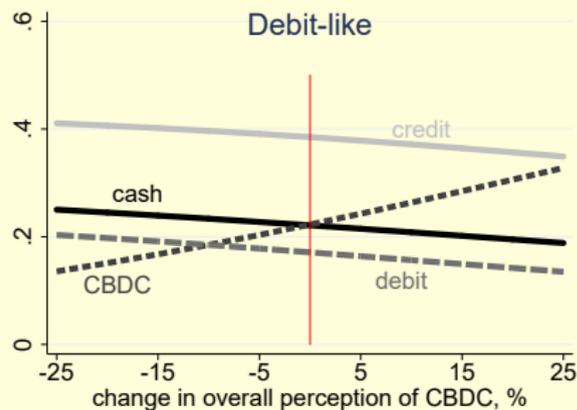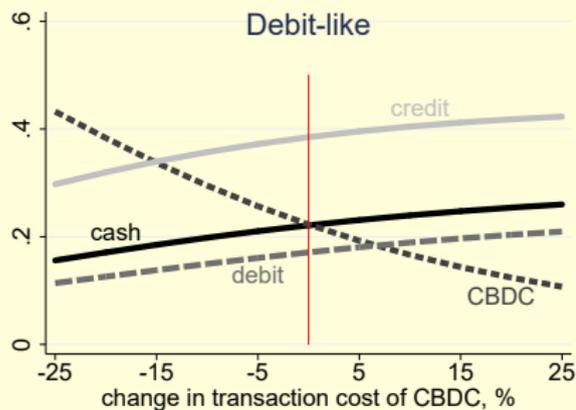
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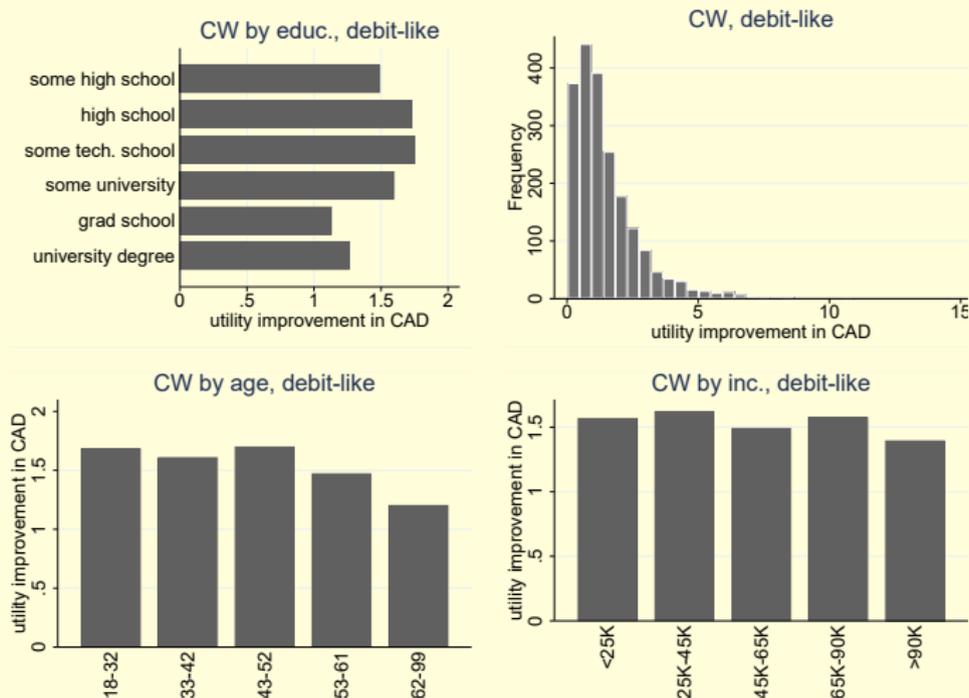

Welfare gain and distribution for best-feature CBDC

3. Best-features CBDC with full consumer adoption and merchant acceptance
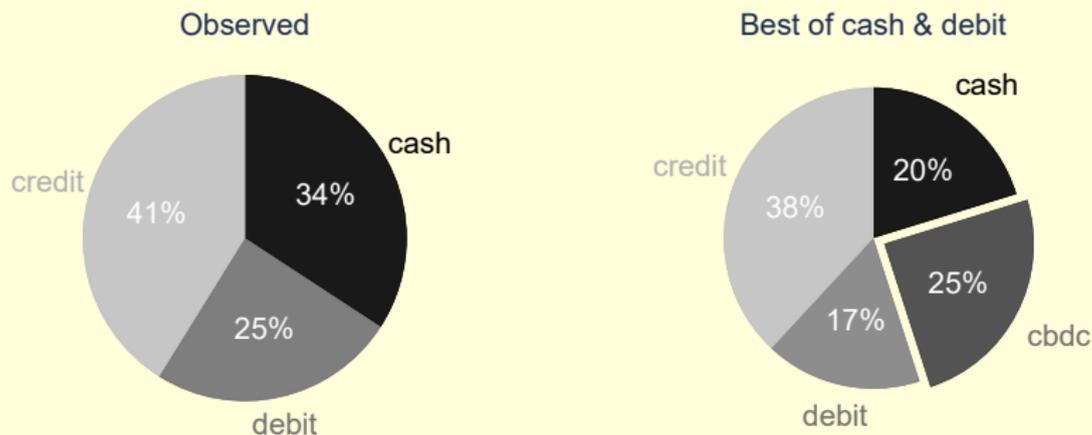
Market shares for observed and counterfactual

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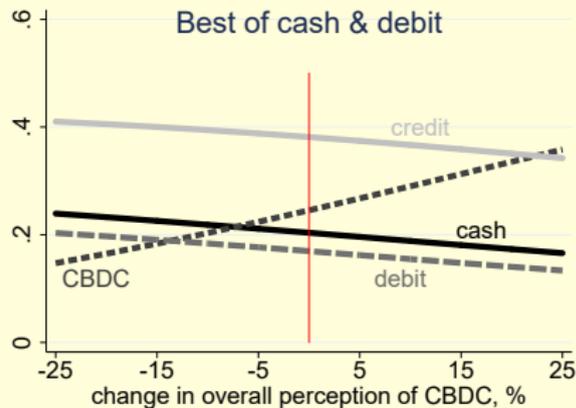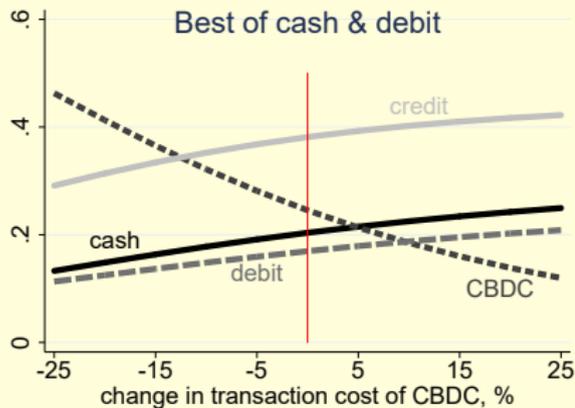
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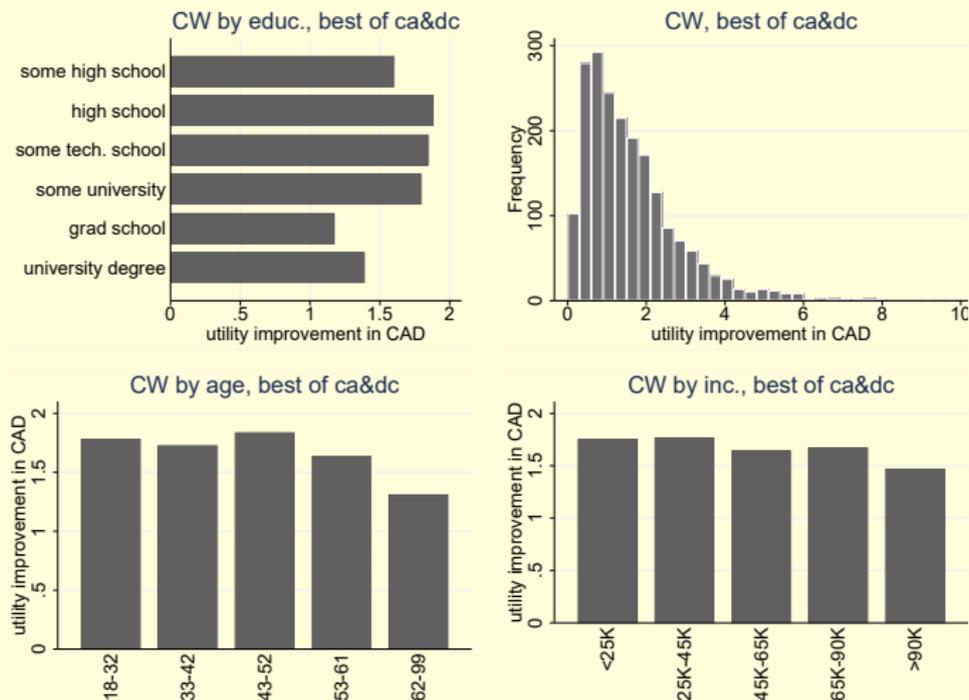
Welfare gain and distribution for best-feature CBDC

Cash-like CBDC with less than full consumer adoption and merchant acceptance
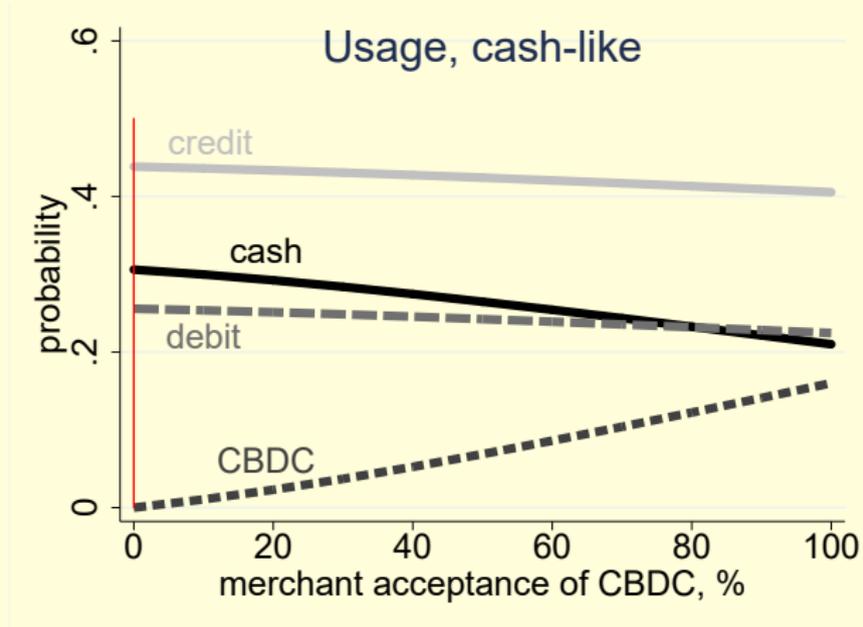
Usage vs acceptance for cash-like CBDC

Consumer welfare

Debit-like CBDC with less than full consumer adoption and merchant acceptance
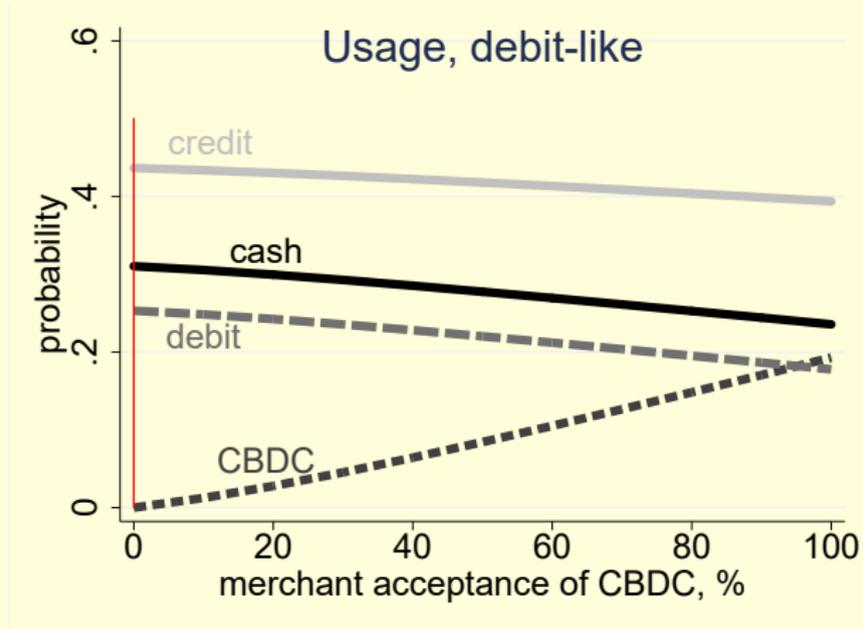
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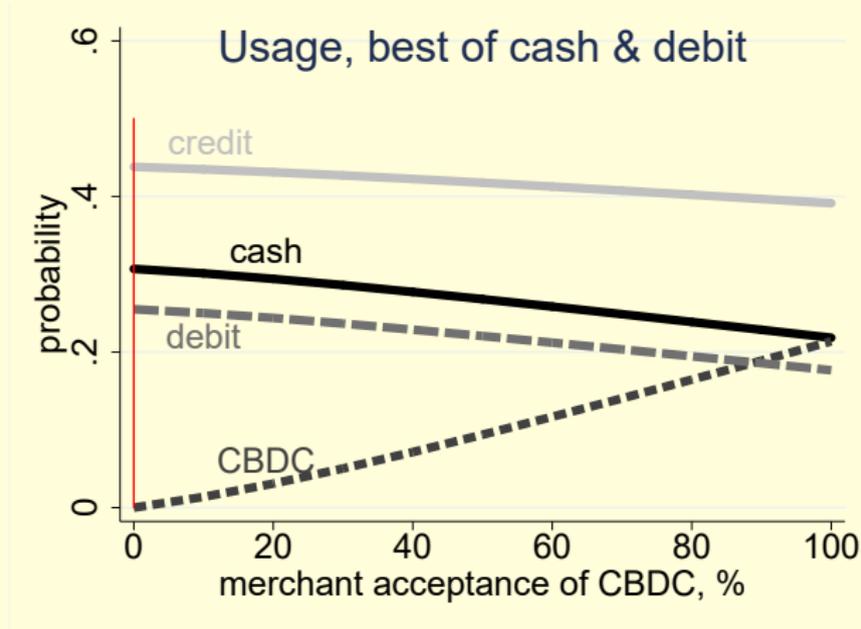
Usage vs acceptance for best-feature CBDC

Consumer welfare

Consumer adoption rates for CBDC with less than full consumer adoption and merchant acceptance
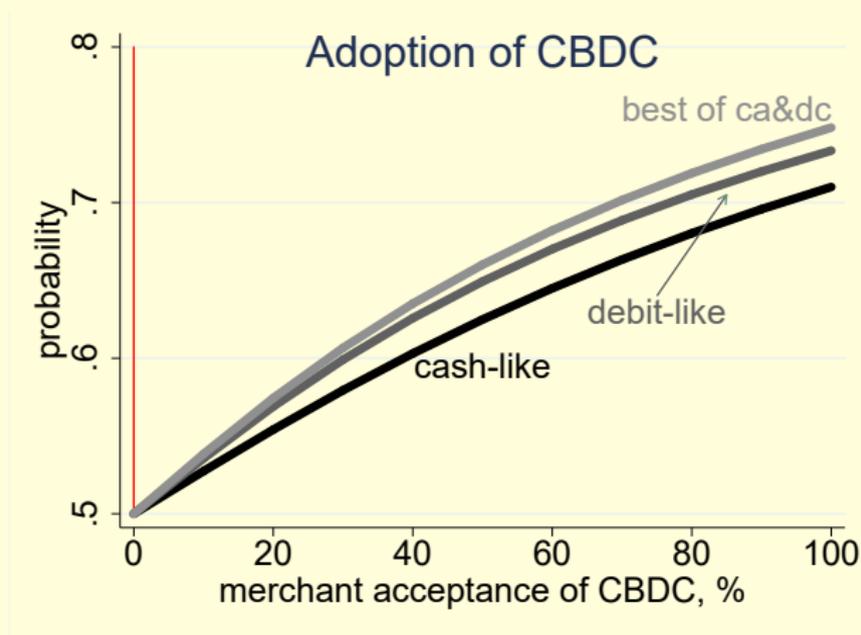
Consumer adoption rate as a function of merchant acceptance rate

Conclusions

- **Cash usage**: cash-only users tend to be lower income, education, employment, and rural.

- **Drivers of payment usage**: transaction cost, ease of use, rewards and merchants acceptance drive majority of welfare from payment

- **CBDC usage with full adoption**: depending on the features, CBDC captures from 19 to 25 percent of payment market share

- **Welfare implications**: Cash-like CBDC provides lowest welfare gain, skewed towards older and less educated. Debit-like and best-feature CBDC benefits the middle class more.

- **Adoption of CBDC**: In the less than fully adopted scenario, adoption rate depends on merchant acceptance, widespread merchant acceptance is necessary for common consumer usage of CBDC. Lower benefits if CBDC is not fully adopted and accepted.

Gracias/Merci/Thanks!

Table: **Share of transactions by MOP bundles in 2017**

| Transaction types	MOP bundles			
	Cash only	Debit	Credit card	Total
Groceries/Drugs	26	46	38	39
Gasoline	3	6	7	7
Personal Attire	5	2	4	4
Health Care	16	2	2	2
Hobby/Sporting Goods	5	2	3	3
Professional/Personal Services	3	1	2	2
Travel/Parking	0	1	2	2
Entertainment/Meals	8	24	25	25
Durable Goods	0	2	3	3
Other	34	14	13	13
Total	100	100	100	100
Average transaction price	23.35	26.63	34.23	33.60

Source: MOP DSI 2017

Cash-like CBDC with less than full consumer adoption and merchant acceptance
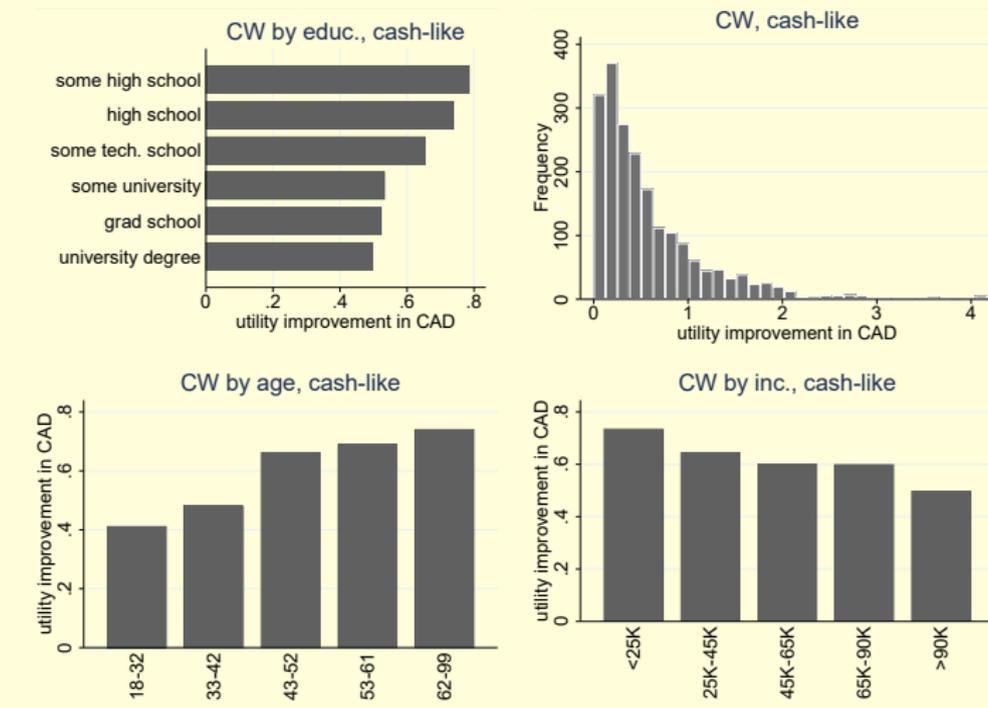
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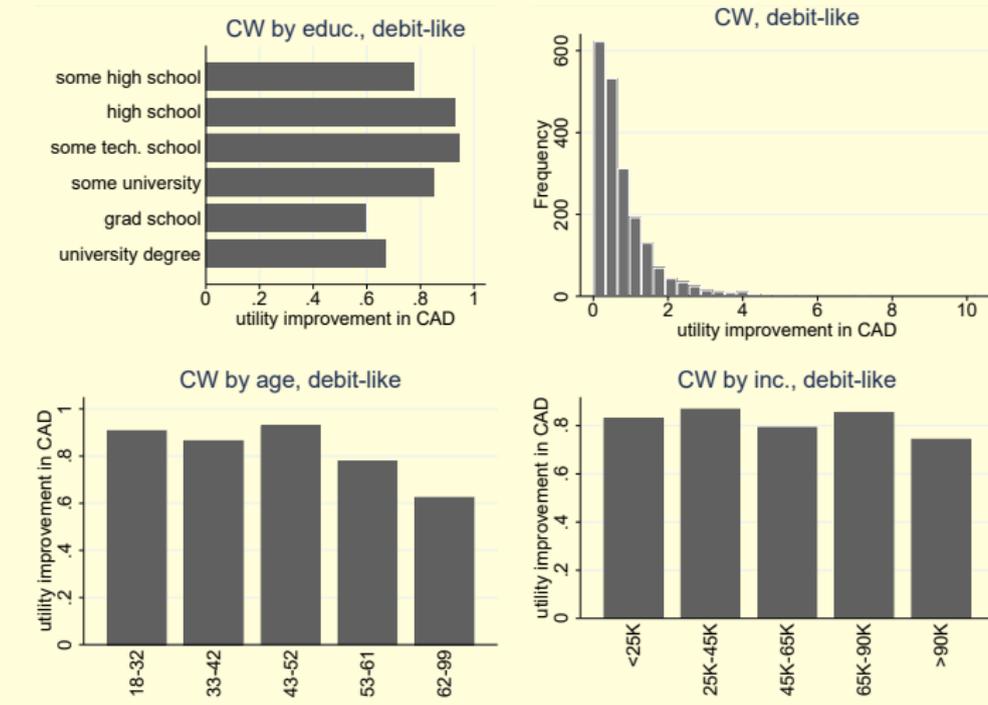
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