Equilibrium in Two-Sided Markets for Payments: Consumer Awareness and the Welfare Cost of the Interchange Fee

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Introduction: Overview

- Study two-sided market for payment instruments.
- Develop an equilibrium structural model.
- Estimate parameters using consumer & merchant survey data.
- Conduct counterfactual simulations to study
  1) effects of an information shock;
  2) what it takes to drive cash out;
  3) effects of the interchange fee on equilibrium and welfare.

Introduction: Why do we care?

- Two important observations about the payment industry
  - declining use of cash at the POS,
  - emergence of private and central bank digital currencies.

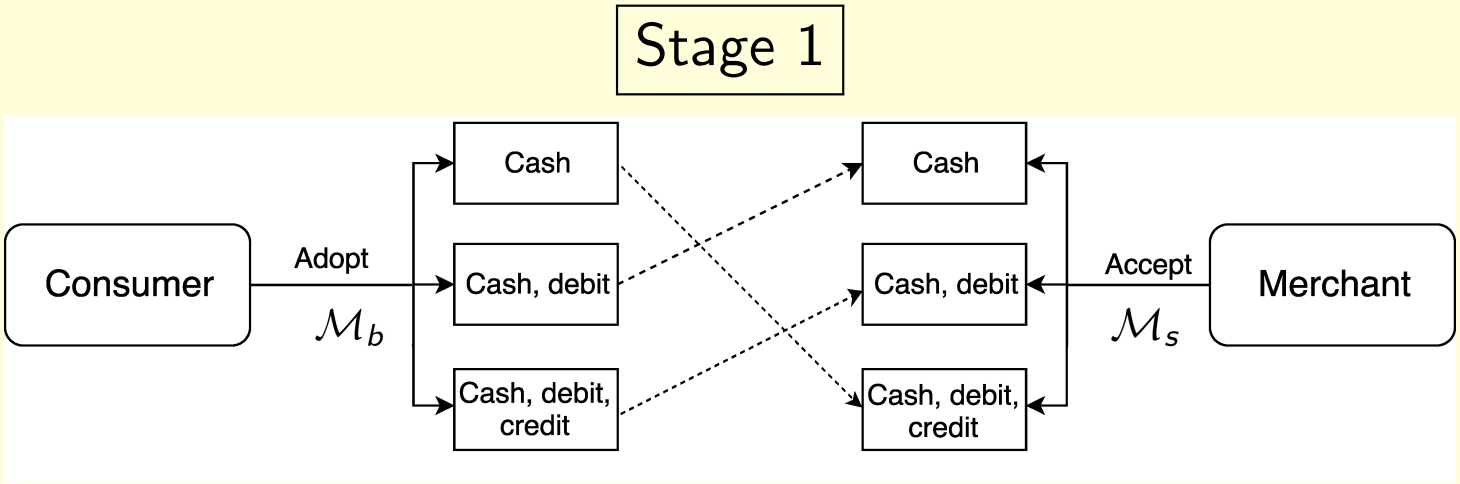
  raise lots of interesting questions about
  - potential transition to a cashless economy,
  - future of cash as a method of payment and financial inclusion,
  - new technologies, platform intermediation and social welfare.
- Theory work on multi-sided markets and platforms
  - Rochet and Tirole (2002; 2003; 2011), Schmalensee (2002), Rochet (2003), Wright (2003; 2004), Belleflamme and Peitz (2019), Anderson and Peitz (2020), Jain and Townsend (2020), Bedre-Defolie and Calvano (2013), Edelman and Wright (2015).
- Empirical models of payment choice
  - Gowrisankaran and Stavins (2004), Rysman (2007; 2009), Loke (2007), Schuh and Stavins (2010), Jonker (2011), Carbó-Valverde et al. (2016), Bounie et al. (2016), Koulayev et al. (2016), Li et al. (2019), Higgins (2020), Vallee et al. (2021), Gupta et al. (2022).

Model: Outline

- Consumers:
  - want to complete a set of exogenously given transactions;
  - can always use cash;
  - can use debit or credit card only if merchants accept them;
  - can be unaware about merchant acceptance choice;
  - choose what to adopt and what to use at the POS.
- Merchants:
  - we do not model supply of real products (assume constant margin);
  - price-takers and maximize profit by choosing what to accept at the POS;
  - accepting more instruments attracts informed consumers.
- Equilibrium:
  - two-stage repeated game played every period:
    (1) adoption & acceptance stage, followed by
    (2) usage stage and payoff realization.
  - depends on the consumer awareness about merchant choice;
  - Subgame Perfect Nash Equilibrium (SPNE) as the solution concept.

Model: Outline

- Two-stage game representation:
  1) consumes and merchants choose what to adopt/accept,
  2) for each transaction a consumer and a merchant are matched: uninformed are randomly matched, informed use directed search,
  3) consumers choose what to use at the POS.



- *Informed* consumers: choose from their adoption set $\mathcal{M}_b$;
- *Uninformed* consumers: choose from an overlap $\mathcal{M}_b \cap \mathcal{M}_s$.

Model: Consumer side

- Every consumer b is endowed with a set of transactions, $\mathcal{J}_b$.
- A transaction is characterized by (p_{bj}, I_{bj}, T_{bj}):
  - p_{bj} is transaction value,
  - I_{bj} is transaction-specific information status (informed or uninformed),
  - T_{bj} is transaction type (e.g., gas, groceries, parking, durable products).
- Consumer per-transaction utility at the POS

$$U_{bjm} = X_{bm}\beta + \alpha\, C_{bm}(p_{bj}) + \xi_m(D_b, T_{bj}) + \epsilon_{bjm},$$

where

  - $m \in \{ca, dc, cc\}$ denotes payment instrument;
  - X_{bm} perceptions of ease-of-use, security, costs;
  - $C_{bm}(p_{bj})$ transaction cost as a function of transaction value;
  - $\xi_m(D_b, T_{bj})$ match value between consumer, transaction type and a payment instrument such that $\xi_{ca,b,j} \equiv 0\ \forall b, j$;
  - ϵ_{bjm} iid innovations at the POS;
  - $(\alpha, \beta, \xi_{mbj})$ are parameters to estimate.

Model: Consumer side

- Expected maximum utility in the second stage,

$$EU_b(\mathcal{M}_b) = \sum_{j \in \mathcal{J}_b} \mathbb{E}_\epsilon \left[I_{bj} \max_{m \in \mathcal{M}_b} U_{bjm} + (1 - I_{bj}) \sum_{\mathcal{M}_s \in \mathcal{M}} \bar{P}_{\mathcal{M}_s} \max_{m \in \mathcal{M}_b \cap \mathcal{M}_s} U_{bjm} \right],$$

  where
  - $\mathcal{M}_b \in \{\{ca\}, \{ca, dc\}, \{ca, dc, cc\}\}$ is adoption combination;
  - $\bar{P}_{\mathcal{M}_s}$ is a vector of probabilities of merchant acceptance choices;

- Adoption probability

$$P_{b,\mathcal{M}_b} = \Pr\left(\mathcal{M}_b = \arg\max_{\mathcal{M}'_b \in \mathcal{M}} \left\{ EU_b(\mathcal{M}'_b) - F_{b,\mathcal{M}'_b} \right\} \right),$$

  where
  - $F_{b,\mathcal{M}_b}$ is combination-specific adoption cost to estimate, which
  - is a function of observable characteristics (perceptions, demographics).

Model: Merchant side

- Incur method-specific usage cost at the POS

$$C_{sm}(p_{bj}) = c_{0sm} + c_{1sm} p_{bj},$$

  where
  - p_{bj} is transaction value, and
  - (c_{0sm}, c_{1sm}) are parameters known from previous studies.
- Every merchant earns constant per-transaction profit margin

$$\gamma_{sbj} \equiv \frac{p_{bj} - mc_{sbj}}{p_{bj}},$$

  where
  - mc_{sbj} is marginal cost of product j offered to buyer b by merchant s,
  - we assume $\gamma_{sbj} = \gamma$ for all s, b, j.
- Acceptance probability

$$P_{s,\mathcal{M}_s} = \Pr\left(\mathcal{M}_s = \arg\max_{\mathcal{M}'_s \in \mathcal{M}} \left\{ \mathrm{E}\Pi_s(\mathcal{M}'_s) - F_{s,\mathcal{M}'_s} \right\}\right).$$

  where $F_{s,\mathcal{M}_s}$ is a function of merchant size.

Model: Summary

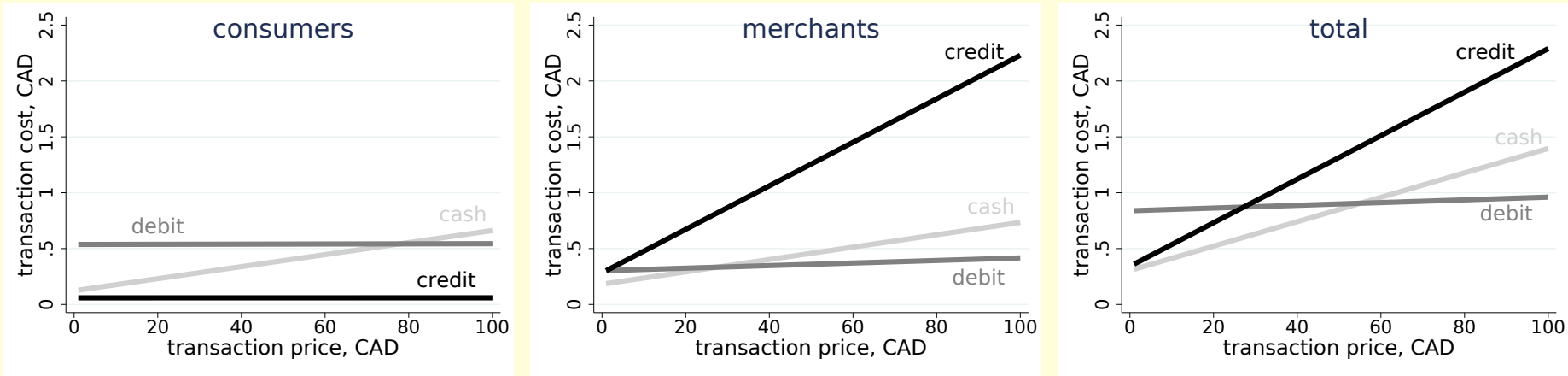
- Consumers
  - make adoption decisions in anticipation of the usage stage,
  - since adoption is costly have to consider
    (1) expected merchant acceptance decisions, and
    (2) own awareness about exact merchant choices.
- Merchants
  - can attract informed consumers by accepting more methods;
  - wider acceptance combinations do not minimize operating costs;
  - due to the fixed acceptance costs have to consider
    (1) expected consumer adoption, and
    (2) consumer awareness about own acceptance choice.
- In equilibrium
  - each side solves a corresponding single-agent maximization problem;
  - consumer expectations are consistent with realized merchant choice;
  - merchant expectations are consistent with realized consumer choice.
- ⏩ Caveats , ⏩ Estimation Method

Data: Sources

- CONSUMERS: Methods-Of-Payments Survey (2013)
  1) Survey Questionnaire ⏩ TTypes , ⏩ Perceptions , and
  2) Diary Survey Instrument (3-day purchases), ⏩ Awareness .
     - Cost functions for each payment instrument from Kosse et al. (2017).

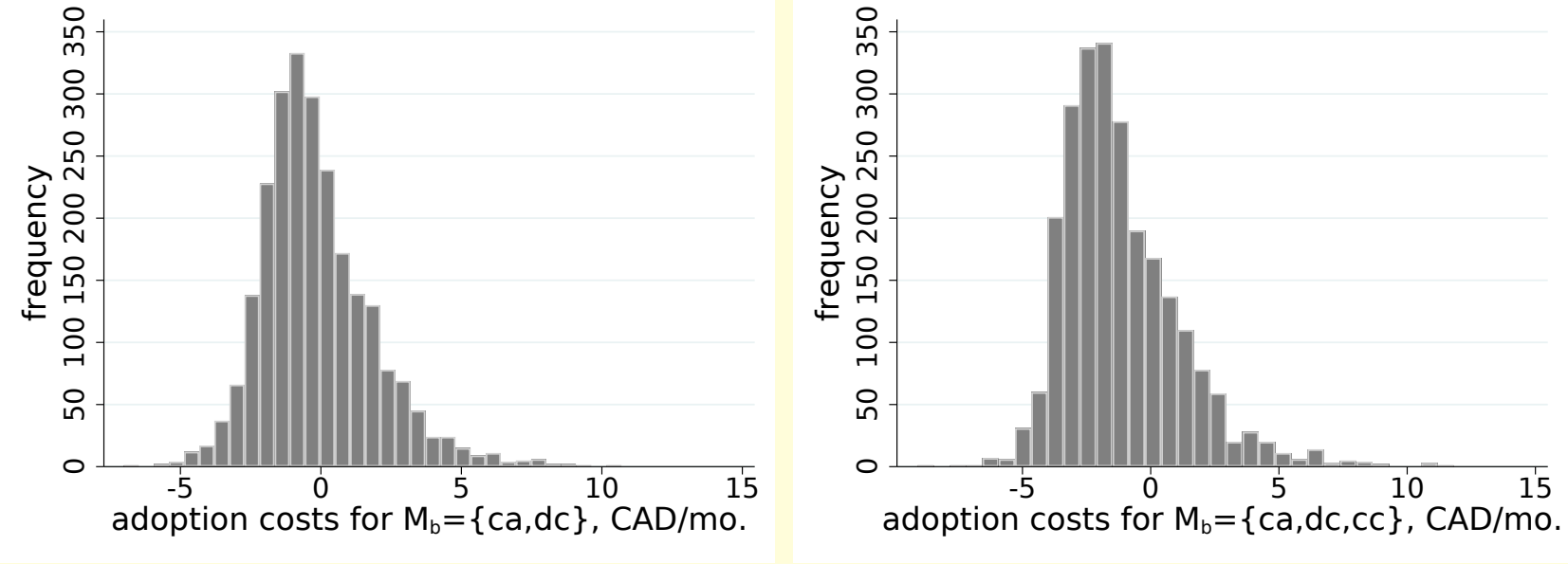
- MERCHANTS: Retailer Survey of Consumer Payment Methods (2014), ⏩ Merchants .
  - Cost functions for each payment instrument from Kosse et al. (2017).

Figure: Linear usage cost functions



Estimation Results: Adoption Costs & Benefits

Figure: Expected adoption costs for $\mathcal{M}_b = \{ca, dc\}$ and $\mathcal{M}_b = \{ca, dc, cc\}$



Adoption costs/benefits	Mean	Median	Min	Max	SD
Cash and debit	-0.15	-0.43	-7.01	10.70	2.01
All payment methods	-1.18	-1.61	-9.09	11.82	2.29

Notes: The left-hand panel is a histogram of adoption costs for the cash and debit combination, while the right-hand panel is a histogram of adoption costs for the combination including all means of payments. All numbers are in Canadian dollars per month.

Estimation Results: Estimates of Match Values

- Match values: consumer $\times$ transaction type $\times$ payment instruments
  - unobserved factors (e.g., fees/rewards, nonpecuniary costs), which are
  - not explained by the observed covariates, e.g.,
  - Costco members (high income&consumption) have 3% cashback on gas.

- Estimated as FEs (cash values normalized to zero) ⏩ Estimates :
  - all else equal, consumers Debit $\succ$ Cash $\succ$ Credit;
  - older consumers don't like electronic payment instruments;
  - preference for credit transactions increases with income and education;
  - strong positive correlation in the "quality" of debit & credit cards;
  - ⏩ Projection

Estimation Results: Merchant-side Parameters

- We estimate gross profit margin at 5.2 percent of price.
- After banking fees are paid it reduces to 3.4 percent.
- Net of acceptance costs the margin drops to 1.6 percent.

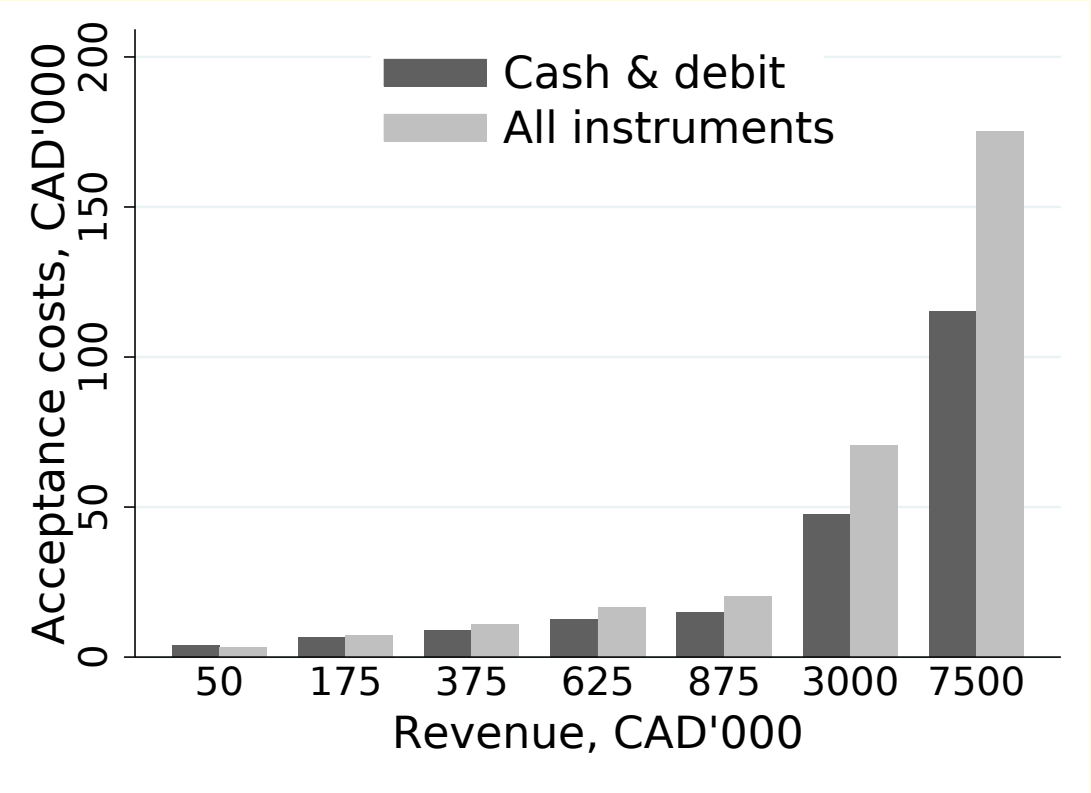
Table: Merchant profit measures (thousands of Canadian dollars)

Revenue, R_s	Gross as given by $\gamma \times R_s$	Net of banking fees		Net of acceptance cost	
		profit	margin, %	profit	margin, %
50	2.58	1.67	3.34	1.00	2.01
175	9.02	5.89	3.37	3.10	1.77
375	19.32	12.84	3.42	5.23	1.40
625	32.20	21.00	3.36	8.96	1.43
875	45.08	29.75	3.40	11.92	1.36
3000	154.55	100.54	3.35	41.77	1.39
7500	386.37	248.80	3.32	105.09	1.40
Average	68.22	44.35	3.37	18.64	1.58

Estimation Results: Merchant-side Parameters

- Merchants accept more instruments to attract informed consumers.
- Difference in acceptance costs increases with firm size.
- Rental cost of terminals is very small relative to total costs.

Figure: Merchant acceptance costs by revenue



Estimation Results: Network Effects

- How to measure various network effects, and
  - can we avoid making ad hoc assumptions on cross-method substitution?
- Adoption, acceptance and usage and cost shocks:
  - how does usage respond to cost shocks on each side? Let
    - $P^*_{b,j,cc}$: equilibrium usage probability for CC,
    - $\Pr(\mathcal{M}_s)$: merchant acceptance probability for CC,
    - $\Pr(\mathcal{M}_b)$: consumer adoption probability for CC,

$$E^{usage}_{C_{b,cc}} = \mathbb{E}_{b,j}\left[\frac{\partial P^*_{b,j,cc}}{\partial C_{b,j,cc}}\frac{C_{b,j,cc}}{P^*_{b,j,cc}}\right]$$

elasticity of usage probabilities w.r.t. consumer usage cost.

  - Cross-elasticities of adoption and acceptance w.r.t. costs of other side

$$E^{\text{merch. acceptance}}_{\text{cons. costs}} = \mathbb{E}_s\left[\frac{\partial \Pr(\mathcal{M}_s = \{ca, dc, cc\})}{\partial \text{ consumer costs}}\frac{\text{costs}}{\Pr(\cdot)}\right]$$

merchant acceptance w.r.t. consumer adoption costs;

$$E^{\text{cons. adoption}}_{\text{merch. costs}} = \mathbb{E}_b\left[\frac{\partial \Pr(\mathcal{M}_b = \{ca, dc, cc\})}{\partial \text{merchant costs}}\frac{\text{costs}}{\Pr(\cdot)}\right]$$

consumer adoption w.r.t. merchant acceptance costs.

Estimation Results: Network Effects

- Equilibrium usage probabilities w.r.t. usage costs
  - inelastic: $E^{usage}_{C_b,cc} = -0.33$ (cons.) vs $E^{usage}_{C_s,cc} = -0.07$ (merch.), and
  - respond more to shocks to the consumer usage cost.
- Cross-elasticities of adoption and acceptance:

	w.r.t. merchant acceptance costs	w.r.t. consumer adoption costs
merchant acceptance	-3.708	**0.036**
consumer adoption	-0.013	-0.178

  - lower consumer adoption of CC $\implies$ higher merchant acceptance!
- Heterogeneity in merchant response:
  - stats for $E^{\text{merch. acceptance}}_{cons.costs}$: $min = -0.62, max = 0.46, sd = 0.11$;
  - share of merchants with positive elasticity is 0.54.

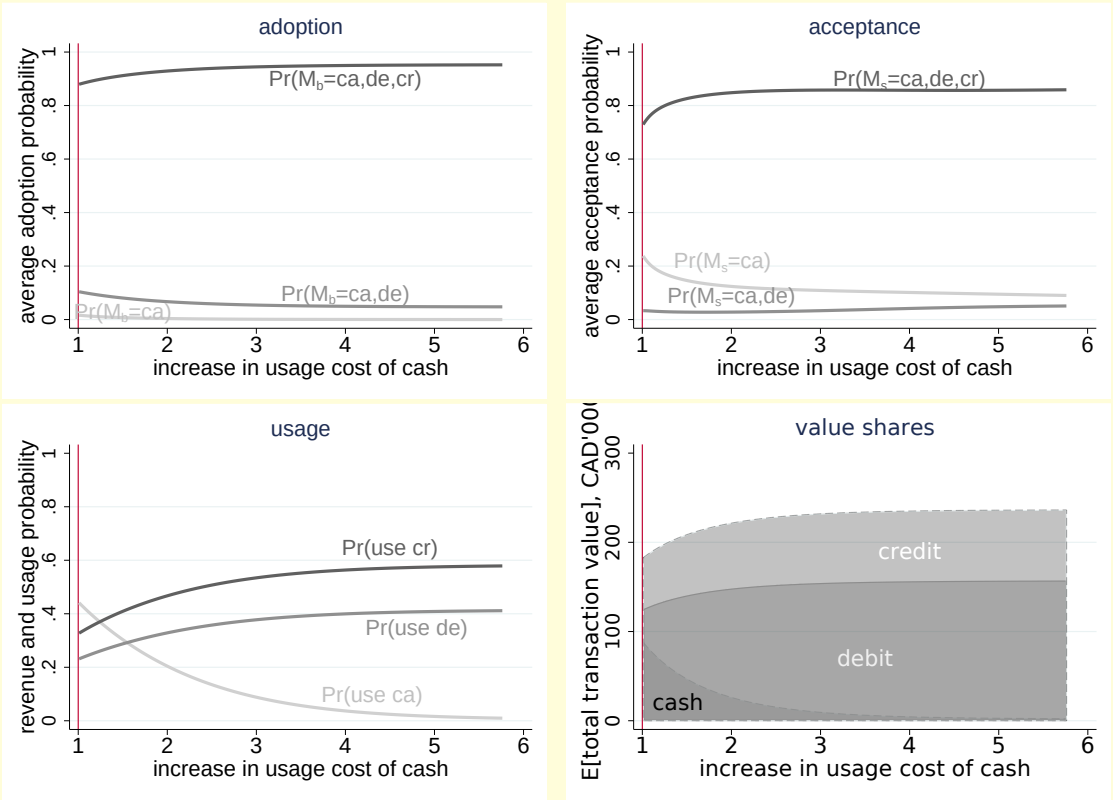
Estimation Results: Network Effects

- Main drivers of $\Uparrow$ acceptance response to $\Downarrow$ adoption are:
  1) relative merchant costs of instruments (CC is most expensive),
  2) inelastic consumer demand for transactions,
  3) larger bundles include all instruments from smaller ones.
- When cash or debit is used instead of CC
  - positive surplus is generated for merchants due to (1).
- Extra surplus is distributed across acceptance bundles such that
  - substitution to cash doesn't change relative values of bundles, since cash belongs to every bundle, but
  - substitution to debit $\Uparrow$ value of $\{ca, dc\}$ and $\{ca, dc, cc\}$ relative to $\{ca\}$
    $\Rightarrow$ $\Pr(\mathcal{M}_s = \{ca, dc\}$ and $\Pr(\mathcal{M}_s = \{ca, dc, cc\})$ increase,
    $\Rightarrow$ $\Pr(\mathcal{M}_s = \{ca\})$ decrease.
- Intuition: if consumers substitute more expensive CC by debit, merchant incentives to adopt bundles containing debit increase.

Counterfactuals: Cashless Society

- It takes almost a 6-fold $\Uparrow$ in usage cost of cash for both sides
  - to drive its equilibrium usage probability to below 1%;
  - e.g., a 5-minute withdrawal trip becomes a 30-minute journey.

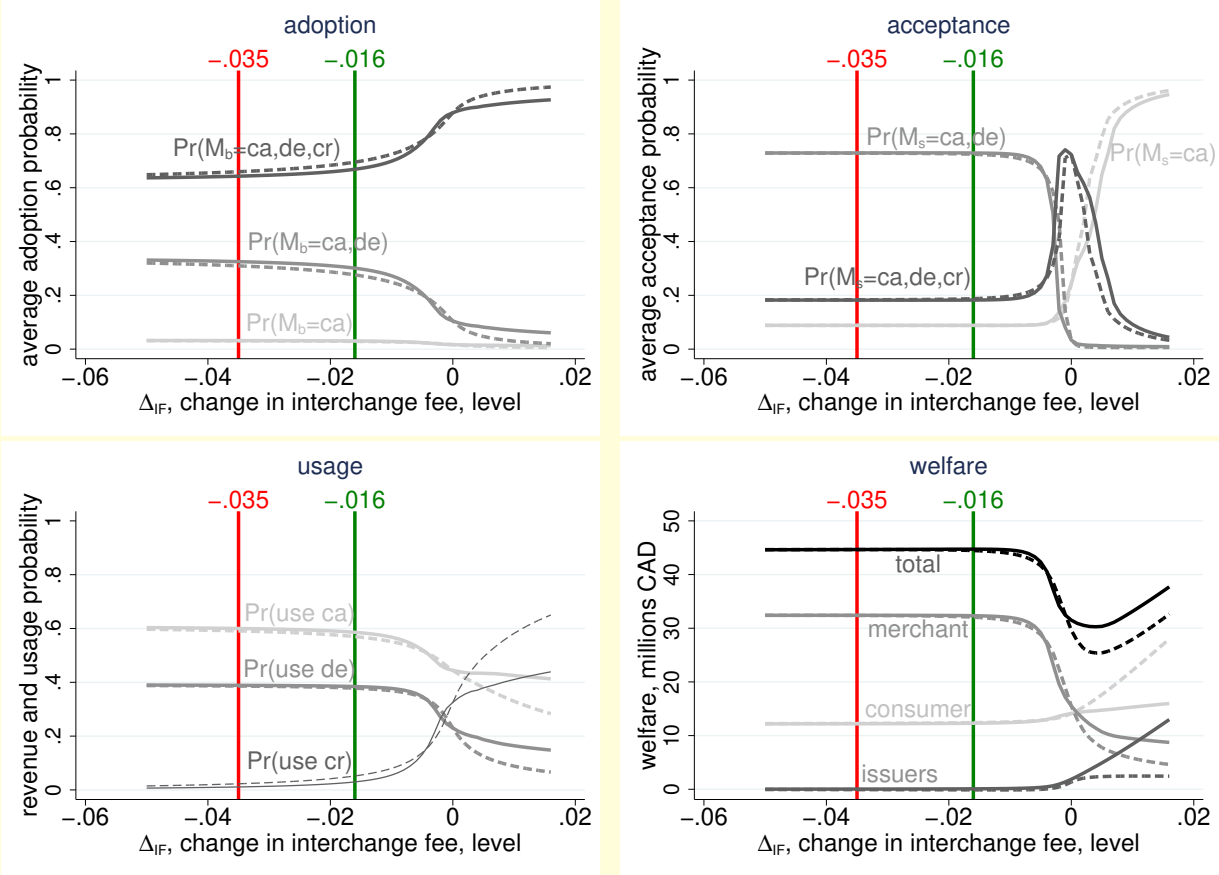
Figure: Equilibrium response to an increase in the usage cost of cash



Counterfactuals: Interchange fee & welfare

- When a monopoly issuer responds to a change in IF
  - by full pass-through, total welfare is maximized at red line ($\Delta^{*}\mathrm{IF} = -0.035$);
  - by optimal pass-through, it is at max at green line, i.e., $\Delta^{*}\mathrm{IF} = -0.016$;
  - CC was too costly for society in 2014 (it was overused relative to optimum).

Figure: Equilibrium response to changes in merchants' per-value cost of credit



Conclusions

- Consumers are heterogeneous w.r.t cost and benefits of adoption
  - the costs and benefits rarely exceed \$5/month;
  - adoption benefits increase with the adoption set.
- At the POS, consumers
  - all else equal prefer to use debit over cash and cash over credit;
  - of older age don't like electronic payment instruments;
  - strong positive correlation in quality of debit and credit cards.
- ... merchants
  - earn a slim profit margin;
  - play prisoners'-dilemma-type technology adoption game;
  - pay acceptance costs well beyond the rental cost of terminals.
- Consumer awareness is important for market equilibrium: ⏩ Counterfactual
  - explains why merchants accept wider set of instruments;
  - helps in technology diffusion.
- It is very hard to drive cash out from the market.
- In 2014, the interchange fee was too high to be socially optimal.

Merci/Thanks!

Economics of Payment XI: at the Bank of Canada on 12-14 October 2022
https://www.bankofcanada.ca/2022/10/economics-of-payments-xi

Appendix: Summary Statistics

Table: Summary statistics for the POS transaction types and prices

Transaction type	Frequency of use			Prices		
	Cash	Debit	Credit	Mean	Median	SD
Groceries/drugs	0.39	0.26	0.34	34.34	20.00	41.43
Gasoline	0.20	0.29	0.51	45.32	41.00	24.23
Personal attire	0.25	0.29	0.46	53.59	34.00	51.95
Health care	0.35	0.27	0.38	50.75	32.50	55.46
Hobby/sporting goods	0.41	0.19	0.40	37.70	20.00	47.55
Professional/personal services	0.45	0.16	0.39	55.88	32.00	57.71
Travel/parking	0.61	0.10	0.29	23.46	10.00	37.55
Entertainment/meals	0.59	0.18	0.23	17.43	9.00	26.21
Durable goods	0.30	0.26	0.45	49.27	30.00	57.78
Other	0.55	0.20	0.24	31.77	15.00	45.31
Average	0.44	0.23	0.33	32.95	18.50	41.66

Notes: The number of observations is 12,029. Our sample includes transactions completed at the POS only and, hence, may represent the lower tail of the distribution of consumer expenditures.

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Appendix: Summary Statistics

Table: Summary statistics for perception variables

Characteristic	Method	Mean	Median	Min	Max	SD
Ease of use	cash	4.70	5.00	1.00	5.00	0.64
	debit	4.48	5.00	1.00	5.00	0.72
	credit	4.48	5.00	1.00	5.00	0.73
Affordability	cash	4.58	5.00	1.00	5.00	0.78
	debit	3.74	4.00	1.00	5.00	1.10
	credit	2.97	3.00	1.00	5.00	1.34
Security	cash	4.25	5.00	1.00	5.00	1.01
	debit	3.76	4.00	1.00	5.00	0.91
	credit	3.64	4.00	1.00	5.00	0.95
Acceptance	cash	3.92	4.00	1.00	4.00	0.36
	debit	3.66	4.00	1.00	4.00	0.64
	credit	3.59	4.00	1.00	4.00	0.61

Notes: In estimation, we normalize all perception variables using the formula: $X_m = \hat{X}_m / \left(\hat{X}_{ca} + \hat{X}_{dc} + \hat{X}_{cc}\right)$, *where* $\hat{X}_m$ *denotes the consumer rating on a 4- or 5-point Likert scale, with the larger values denoting higher characteristics.*

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Appendix: Summary Statistics

Table: Consumer awareness, probability of repeated visits, 2017

	Age, years		Income, '000		Gender		University		Price, CAD	
Transaction type	≤ 25	> 25	< 65	≥ 65	male	female	No	Yes	< 100	≥ 100
Groceries/drugs	0.96	0.98	0.97	0.98	0.98	0.97	0.98	0.97	0.98	0.97
Gasoline	0.96	0.96	0.98	0.94	0.95	0.97	0.96	0.96	0.96	0.90
Personal attire	0.91	0.92	0.94	0.90	0.91	0.92	0.92	0.92	0.91	0.94
Health care	0.79	0.92	0.92	0.89	0.87	0.94	0.92	0.89	0.92	0.85
Hobby/sporting goods	0.90	0.91	0.88	0.93	0.86	0.93	0.91	0.90	0.91	0.82
Professional service	0.79	0.84	0.81	0.85	0.84	0.83	0.87	0.81	0.82	0.86
Travel/parking	0.92	0.88	0.90	0.87	0.84	0.94	0.86	0.90	0.89	0.88
Entertainment/meals	0.90	0.92	0.94	0.90	0.93	0.91	0.94	0.90	0.92	0.76
Durable goods	0.96	0.94	0.94	0.95	0.95	0.94	0.95	0.94	0.97	0.87
Other	0.87	0.93	0.94	0.91	0.93	0.92	0.94	0.91	0.93	0.89

Notes: The numbers represent frequencies of consumers' reported return visits to stores by transaction type, age, income, gender, education level and transaction price. These data will be used to impute the probabilities of being aware about combinations of merchant payment acceptances in 2013.

Table: Distribution of merchant by revenue

	Revenue, thousands of CAD							Total
	50	175	375	625	875	3,000	7,500	
Number	149	114	124	72	58	182	34	733
Percent	20.33	15.55	16.92	9.82	7.91	24.83	4.64	100
Cumulative	20.33	35.88	52.8	62.62	70.53	95.36	100	

Notes: The data description can be found in Kosse et al. (2017)

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Appendix: Caveats

- We do not model large merchants and strategic interactions:
  - no data for identification of these;
  - we care about small and medium firms for financial inclusion reasons;
  - cost: ignoring network effects from the choices by large acquirers.
- The role of consumer awareness:
  - accounts for repeated purchases made by consumers over time:
    - returning customers is an empirical fact, very few "tourists".
  - incentivize merchants to accept wider set of instruments
    - no reason to accept costlier instruments otherwise!
  - reduces networks effect from acceptance choice of local stores:
    - consumer can patronize a store accepting their preferred instruments.
- Heterogeneity of merchants:
  - our merchants differ by (1) size, (2) vector of usage costs, and (3) acceptance choice;
  - we assume every merchant sells all the products recorded in the DSI.
  - Why? No data to support further heterogeneity in the model.
- ⏩ back

Appendix: Estimation method

- We construct joint likelihood function

$$\mathcal{L}(\theta_1^b, \theta_2^b, \theta_1^s) = \prod_{b=1}^{N_b} \prod_{\mathcal{M}_b \in \mathcal{M}} P_{b,\mathcal{M}_b}^{*\ A_{b,\mathcal{M}_b}}$$
$$\times \prod_{b=1}^{N_b} \prod_{j \in \mathcal{J}_b} \prod_{m \in \{ca,dc,cc\}} P_{bjm}^{*\ a_{bjm}}$$
$$\times \prod_{s=1}^{N_s} \prod_{\mathcal{M}_s \in \mathcal{M}} P_{s,\mathcal{M}_s}^{*\ A_{s,\mathcal{M}_s}},$$

where the first line matches consumer adoption decisions, the second line is for the equilibrium usage decisions, and the last line is for merchant acceptance choice.

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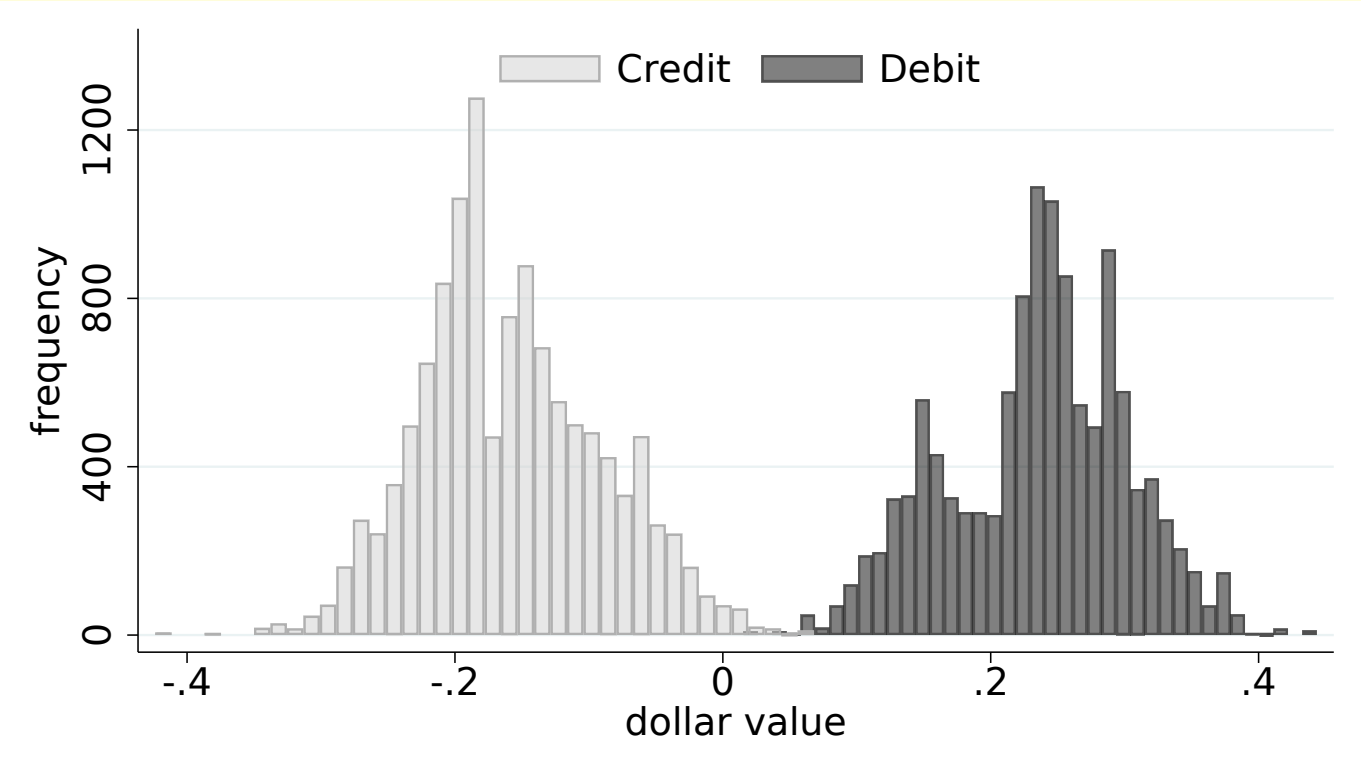
Appendix: Estimates of Match Values

Figure: Match values between consumers, transactions, and payment methods



Fixed effect	Mean	Median	Min	Max	SD
Debit	0.24	0.24	0.02	0.44	0.07
Credit	-0.16	-0.16	-0.42	0.07	0.07

Notes: Match values are estimates as fixed effects. All numbers are in Canadian dollars.

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Appendix: Estimates of Match Values

Table: Explaining consumer-transaction-method match values

Variable	Debit fixed effect		Credit fixed effect	
	coef.	(s.e.)	coef.	(s.e.)
Constant	3.861	(0.078)	-4.218	(0.078)
Age	-0.011	(0.000)	-0.001	(0.000)
Ln(income)	-0.038	(0.005)	0.138	(0.005)
Education	-0.125	(0.003)	0.151	(0.003)
Male	-0.138	(0.007)	0.155	(0.007)
Urban	0.000	(0.010)	-0.004	(0.010)
Married	0.014	(0.008)	0.026	(0.008)
Number of transactions	0.000	(0.001)	-0.010	(0.001)
Value of transactions	-0.006	(0.003)	0.017	(0.003)
Credit score	0.003	(0.008)	-0.007	(0.008)
Credit fixed effects, ξ_{cc}	0.601	(0.007)		
Debit fixed effects, ξ_{dc}			0.625	(0.007)
Observations	12,029		12,029	
R-squared	0.561		0.573	

Note: The estimation method is ordinary least squares.

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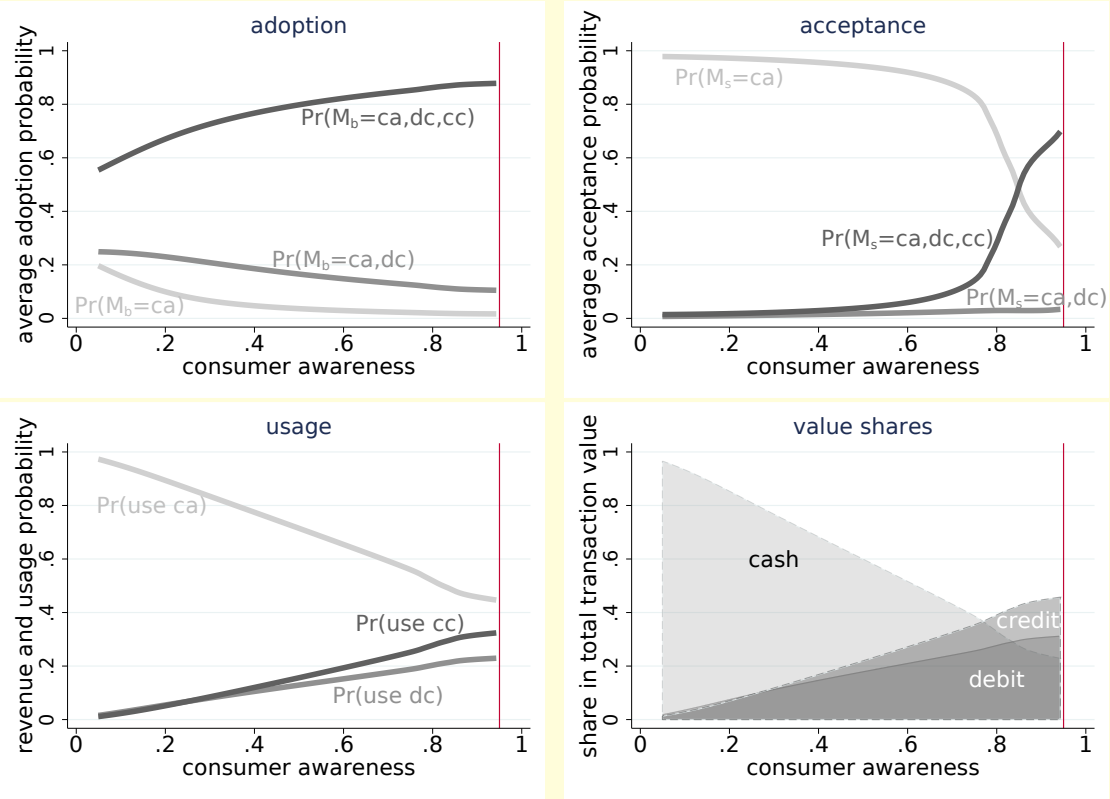
Appendix: Consumer Awareness

- Increase in uncertainty drives equilibrium usage probabilities
  - for debit and credit cards to 0, and for cash to 1.
- Despite low usage probabilities consumers, adopt cards
  - potentially for reasons unrelated to payments at the POS.

Figure: Equilibrium responses to changes in consumer awareness



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