Explaining the interplay between acceptance and usage of payment methods in two-sided markets

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November 16, 2018

Preliminary and Incomplete, Please do not cite!

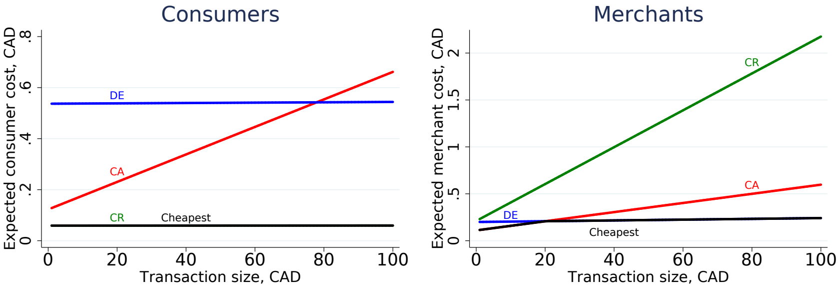
Motivation

- Surveys of consumers and merchants suggest that:
  - Consumers and merchants disagree about the cheapest method.

	Cheapest	Second	Costliest
Consumers	**Credit**	Cash	Debit
Merchants	Cash	Debit	**Credit**

- Most Consumers and Large Businesses adopt/accept credit cards.
- Only 2/3 of Small and Medium Businesses ($<$ than 50 employees) accept credit cards.

Figure 1: Expected Private Costs for Consumers & Merchants



- Consumers find that credit is the cheapest for any transaction value.
- Merchants find cash is the cheapest for transactions values below $24.
- Why do consumers adopt debit and merchants accept credit?
    - Consumers receive pricing incentives/non-pecuniary benefits.
    - Merchants may compete for consumers making repeated purchases.

Research Questions

1. Key determinants of consumer adoption versus merchant acceptance?
   - debit cards cost about $33/mo for consumers, while
   - credit cards generate benefits equivalent to $7/mo (reward programs?);
   - accepting debit cards costs $90/year for a merchant with sales of $375k;
   - accepting credit cards attracts informed consumers, who generate about $12k/year in extra revenue for a merchant with sales of $375k;
   - merchant response to increase in own costs is stronger;
   - consumer react little to innovations in own usage or adoption costs;
   - network effects are important and two sides of the market vary in the strengths of their response.
2. Role of network externalities: which side responds stronger?
   - merchants typically respond stronger to exogenous changes in consumer usage or adoption decisions than vice versa.

Research Questions

3. Extensive vs intensive margins: change in usage vs adoption?
   - immediate (usage) response can be larger or smaller than the long-run response, depending on the reaction on the other side;
   - response of consumer side extensive (adoption) margin is typically very inelastic, i.e., can choose to have but not use if adoption is cheap.
4. Counterfactuals for change in the usage cost of credit card for merchants:
   - consumer adoption decisions do not change much;
   - merchant acceptance decisions can change dramatically:
     - decline in acceptance of credit, and
     - comparable increase in acceptance of cash & debit or cash only;
   - equilibrium usage probabilities:
     - usage of debit is almost unaffected;
     - very strong substitution between credit card and cash usage.

Consumer: 2013 Method-Of-Payments Survey

Henry, Huynh, & Shen (BoC DP, 2015)

- Respondents asked to record their purchases over a three-day period.
- $\sim 13,000$ purchases made by $\sim 2,400$ consumers.
  - The median respondent recorded 7 purchases over three days.
- Over 90% of transactions made using cash (43%), debit (21%), or credit (30%). Other methods were excluded from the analysis.
- Transactions were conducted at the Point-Of-Sale (POS).
- Purchases with price $>$ \$300, were excluded. Remaining purchases had a mean of \$33 and a median of \$18.

2015 Retailer Survey on the Cost of Payment Methods

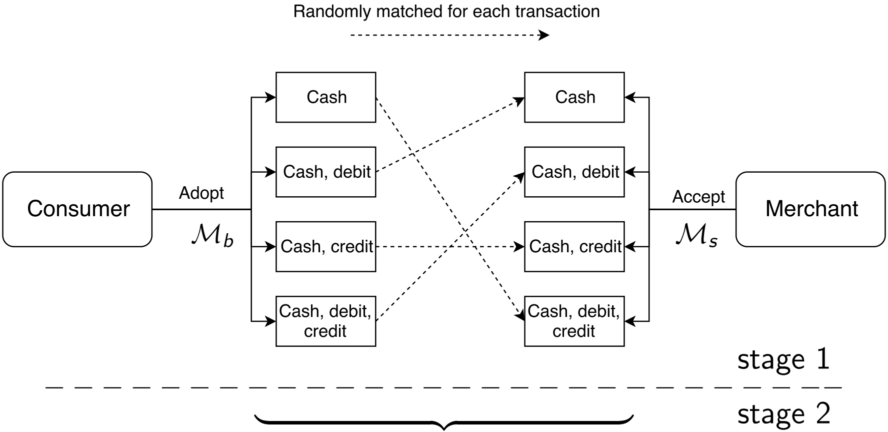
Kosse et al. (BoC DP, 2017)

- 826 small and medium businesses (382 with fewer than 5 employees, 444 with between 5 and 50 employees).
- Businesses from four industry classifications:

Specialized retail stores	32%
General retail stores	11%
Accommodation and food places	20%
Personal service providers	38%

- Almost all (94%) merchants said they accept cash, 67% accept debit cards, and 66% accept credit cards.

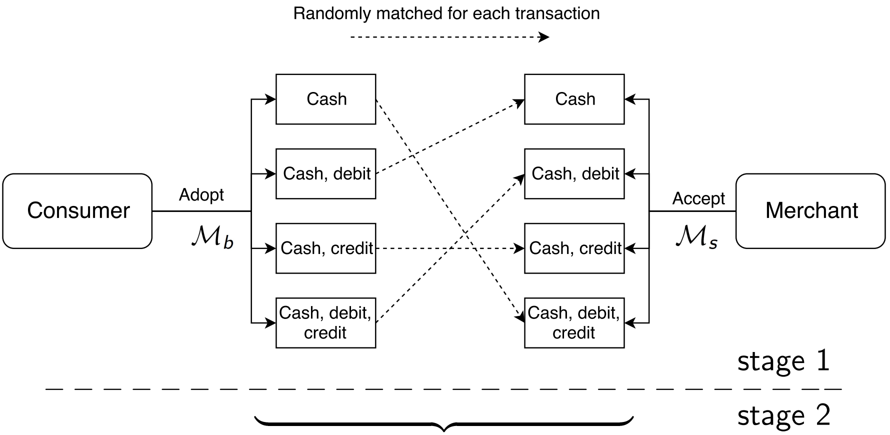
Figure 2: Sketch of Model



$$\min_{m' \in \mathcal{M}_b \cap \mathcal{M}_s} C_{bm'}(p_{bj}),$$

where $C_{bm}(p_{bj})$ is the consumer usage cost of method m for transaction price p_{bj}.

Figure 2: Sketch of Model

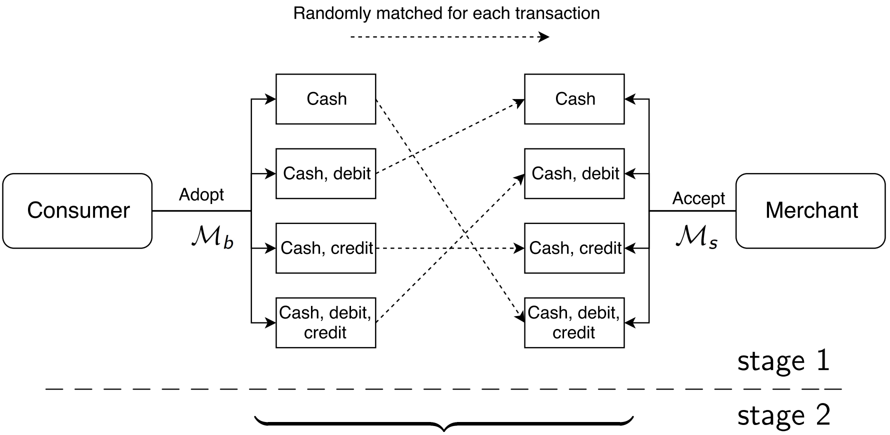


Non-singleton overlap:

if $\mathcal{M}_b$ = (ca,de,cr) and $\mathcal{M}_s$ = (ca,de) $\Longrightarrow \mathcal{M}_b \cap \mathcal{M}_s$ = (ca,de), then consumer in stage 2 for each transaction solves

$$\min \{ C_{b,ca}(p_{bj}), C_{b,de}(p_{bj}) \}$$

Figure 2: Sketch of Model



Singleton overlap:

if $\mathcal{M}_b$ = (CA,CR) and $\mathcal{M}_s$ = (CA,DE) $\Longrightarrow \mathcal{M}_b \cap \mathcal{M}_s$ = (CA), then consumer usage cost is given by $C_{b,CA}(p_{bj})$.

Model: setup

- 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, de,
  - Credit, cr.
- Consumer adoption / Merchant acceptance choice set

$$\mathcal{M} = \Big(\{ca\}, \{ca, de\}, \{ca, de, cr\}\Big)$$

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

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

Model: consumers

- Every consumer b is endowed with a set of transactions, $\mathcal{J}_b$, all of which must be completed:
  - Each transaction is characterized by price, p_{bj}.
  - Transacting is costly and the cost depends on the mean of payment

    $$C_{bmj}(p_{bj}) = c_{0bm} + c_{1bm}p_{bj} + \varepsilon_{bmj},\ \ m \in \{ca, de, cr\}$$

    where c_{0bm} is per-transaction and c_{1bm} is per-value costs, and ε_{bmj} is a cost innovation at the point of sale, s.t.,

    $$\varepsilon_{bmj} \overset{iid}{\sim} F_{b,\varepsilon}(\cdot|\theta).$$

- The number of transactions (cardinality of $\mathcal{J}_b$) and their prices, p_{bj}, are exogenous.

Assumption 1. *Consumers have inelastic demand for transactions.*

Model: consumers

- Let $A_{b\mathcal{M}_b}$ denote fixed cost (benefit) of adopting combination $\mathcal{M}_b$.
- Expected usage cost for consumer type b is

$$EC_b(\mathcal{M}_b) = \sum_{j \in \mathcal{J}_b} \sum_{\mathcal{M}_s \in \mathcal{M}} \mathbb{E}\big[\,\Pr(\mathcal{M}_s)\big] \times \mathbb{E}\big[\min_{m' \in \mathcal{M}_s \cap \mathcal{M}_b} \; C_{b,m'}(p_{bj})\big]$$

- Then, the first stage decision can be described as

$$\min_{\mathcal{M}_b \in \mathcal{M}} EC_b(\mathcal{M}_b) + A_{b\mathcal{M}_b}$$

Assumption 2. *Consumer first stage adoption costs are given by $A_{b\mathcal{M}_b}$, s.t.,*

$$A_{b\mathcal{M}_b} \overset{iid}{\sim} F_{A_b}(\cdot|\theta)$$

Model: merchants

- Second stage usage cost for merchants matched with a consumer for transaction p_{bj} is

$$C_{smj}(p_{bj}) = c_{0sm} + c_{1sm} p_{bj}, \;\; m \in \{\text{ca,de,cr}\}$$

- Total expected usage cost in the 2nd stage as a function of $\mathcal{M}_s$

$$EC_s(\mathcal{M}_s) = \frac{1}{N_s} \sum_b \sum_{j \in \mathcal{J}_b} EC_{bj}(\mathcal{M}_s)$$

where

$$EC_{bj}(\mathcal{M}_s) = \sum_{\mathcal{M}_b \in \mathcal{M}} \mathbb{E}\big[\Pr(M_b)\big] \times C_{smj}(p_{bj}) \times \Pr\Big(m = \operatorname*{arg\,min}_{m' \in \mathcal{M}_s \cap \mathcal{M}_b} C_{b,m'}(p_{bj})\Big)$$

Model: merchants

- Let $A_{s\mathcal{M}_s}$ denote fixed cost of accepting combination $\mathcal{M}_s$.
- Let $\pi^i(\mathcal{M}_s)$ denote benefit from accepting $\mathcal{M}_s$.
- Then, the first stage merchant decision can be written

$$\min_{\mathcal{M}_s \in \mathcal{M}} EC_s(\mathcal{M}_s) + A_{s\mathcal{M}_s} - \pi^i(\mathcal{M}_s) \tag{1}$$

Assumption 3. *Merchant first stage adoption costs are given by $A_{s\mathcal{M}_s}$, s.t.,*

$$A_{s\mathcal{M}_s} \overset{iid}{\sim} F_{A_s}(\cdot|\theta)$$

- We can rewrite minimization problem (1)

$$\min_{\mathcal{M}_s \in \mathcal{M}} EC_s(\mathcal{M}_s) + \tilde{A}_{s\mathcal{M}_s},$$

where we estimate parameters of the distribution of $\tilde{A}_{s\mathcal{M}_s}$.

Model: benefit from informed consumers

- We do not model the informed consumer decisions structurally.
- Instead, we will estimate profits generated by these consumers in reduced form:
  - Let $\Pi(\mathcal{M}_s)$ denote total profit in the market from consumers patronizing combination $\mathcal{M}_s$.
  - If there are $n_{\mathcal{M}_s}$ merchants accepting combination $\mathcal{M}_s$ in equilibrium, each collects profit from the informed consumers equal to

$$\pi^i(\mathcal{M}_s) = \frac{1}{n_{\mathcal{M}_s}} \Pi(\mathcal{M}_s)$$

- We will use estimates of $\Pi(\mathcal{M}_s)$ in our counterfactual simulations to account for
  - increase in per-merchant profit, when less merchants accept $\mathcal{M}_s$, and
  - decrease in per-merchant profit, when more merchants accept $\mathcal{M}_s$.

Model: equilibrium

- Consumer expectations of the merchant acceptance decisions,

$$\mathbb{E}\big[\,\mathrm{Pr}(\mathcal{M}_s)\big]\ \forall \mathcal{M}_s,$$

  are equal to the average of the realized merchants' decisions.
- Merchant expectations of the consumer adoption decisions,

$$\mathbb{E}\big[\,\mathrm{Pr}(\mathcal{M}_b)\big]\ \forall b, \mathcal{M}_b$$

  are consistent with the individual decisions for each consumer type.

Model: equilibrium

- We estimate structural parameters using nested fixed point algorithm:
  - Fix parameter values,
  - Solve for an equilibrium,
  - Evaluate likelihood function using
    1. Observed merchant acceptance decisions,
    2. Observed consumer adoption decisions, and
    3. Observed point-of-sales usage decisions.

$$
\begin{aligned}
\mathcal{L}(\theta) = & \prod_{b=1}^{N_b} \Pr(\mathcal{M}_b)^{M_b \mathcal{M}_b} \times \\
& \prod_{b=1}^{N_b} \times \prod_{j \in \mathcal{J}_b} \prod_{m \in \mathcal{M}_s \cap \mathcal{M}_b} \Pr(c_{bmj} = \min_{m' \in \mathcal{M}_s \cap \mathcal{M}_b} c_{bm'j})^{U_{bjm}} \times \\
& \prod_{s=1}^{N_s} \prod_{\mathcal{M}_s \subset \mathcal{M}} \Pr(\mathcal{M}_s)^{M_s \mathcal{M}_s},
\end{aligned}
$$

  - Iterate to maximize the joint likelihood function above.

Estimation results

- Consumers:
  - debit card costs about CAD 33.00 / mo to have debit card;
  - credit card generates benefits of about CAD 7.00 /mo.
- Merchants (with annual sales of CAD 375k):
  - debit costs CAD 1,230 per year, and

    . . . attracts profit (from informed buyers) of CAD 1,140 /year;
  - credit costs CAD 6,041, and

    . . . attracts profit (from informed buyers) of CAD 12,098 /year.
- Model shows good fit in terms of matching adoption and acceptance decisions.

Results: model fit

Figure 3: Model fit for three acceptence combinations, merchants

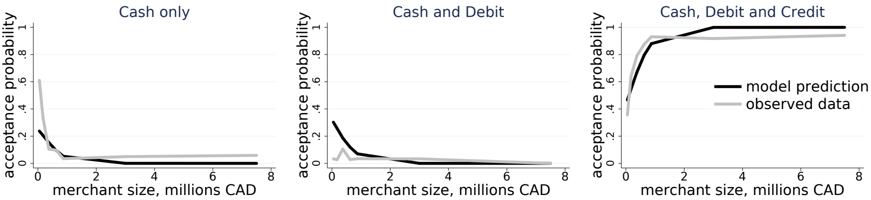
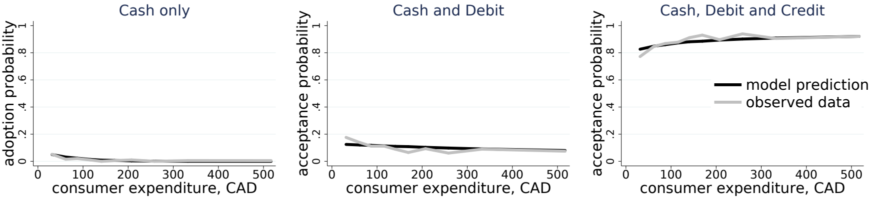
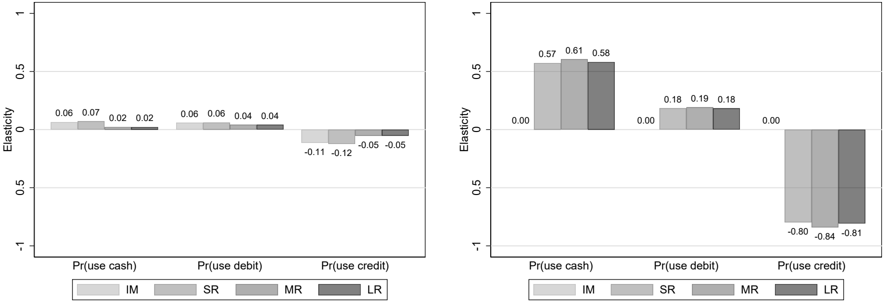


Figure 4: Model fit for three adoption combinations, consumers



Elasticities: short, medium, and long-run

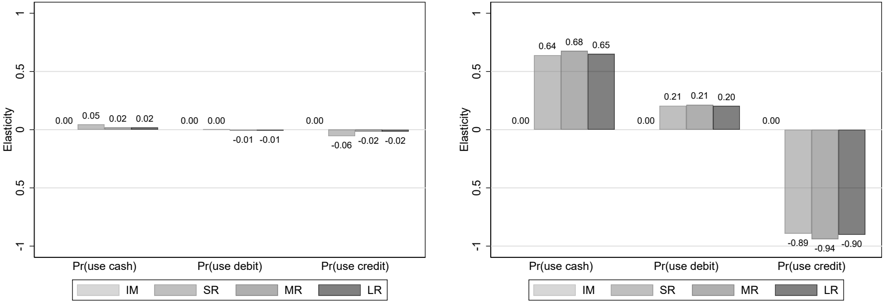
Figure 5: Response of POS usage decisions to an increase in usage cost of credit cards for consumers (left) and merchant (right)



- IR: affects consumer usage choices at a point-of-sale only.
- SR: allows the affected side to adjust its own adoption/acceptance decision.
- MR: each side adjusts its adoption/acceptance decisions once.
- Long-run response measures the difference between two equilibria.

Elasticities: short, medium, and long-run

Figure 6: Response of POS usage to an increase in fixed cost of adopting/accepting all means of payment for consumers (left) and merchant (right)

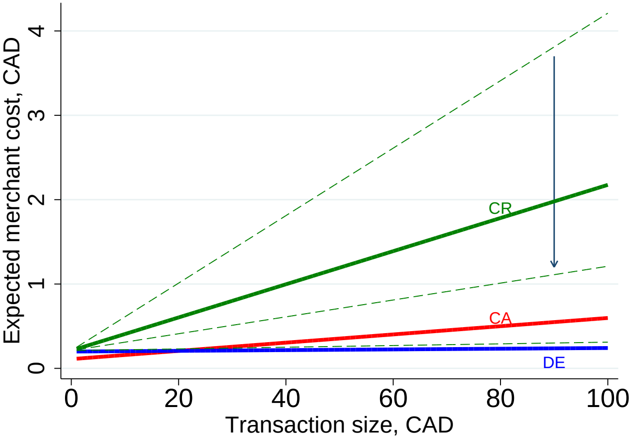


- IR: affects consumer usage choices at a point-of-sale only (no immediate response for either side).
- SR: allows the affected side to adjust its own adoption/acceptance decision.
- MR: each side adjusts its adoption/acceptance decisions once.
- Long-run response measures the difference between two equilibria.

Counterfactual: per-value usage cost of credit

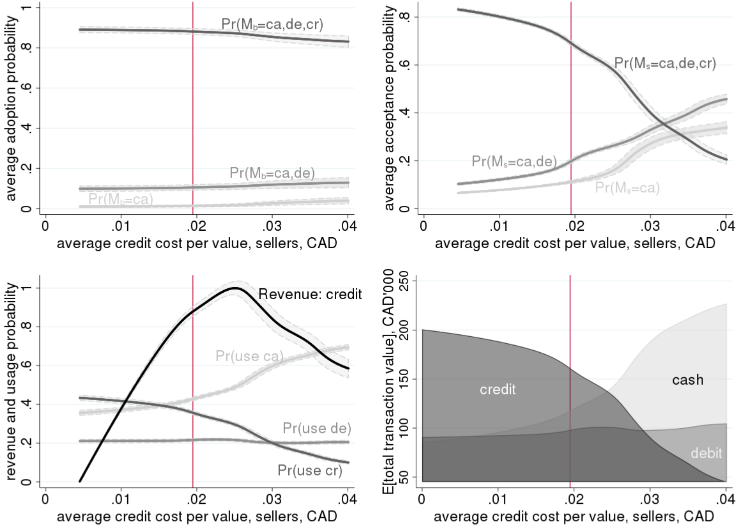
Conduct counterfactual simulations assuming that the *per-value* cost of credit varies from 0.0001 to 0.04 (twice its true value).

Compute equilibria for various levels of slope of the cost function for credit cards:



Counterfactual: per-value usage cost of credit

Figure 7: Equilibrium response to change in merchants' per value cost of credit



Summary

- Estimates of the structural model suggest:
  - Consumers find debit costly, while credit may generate benefits due to loyalty programs.
  - Merchants face moderate net fixed costs when choosing to accept debit, while credit can attract enough consumers to make it profitable.
- Consumers' adoption decision respond very little to the innovations in own usage costs (can choose to have even if not frequently used).
- Network effects originating on the consumer side of the market are typically stronger than those coming from the merchant side.
  - best way to affect equilibrium usage is to apply policies towards consumer side.
- Revenue from total credit card fees is not maximized at the current level of the fees.

Thanks/Merci

Comments and suggestions are much appreciated.

Estimation results

Table 1: Preliminary estimation results, joint estimation

	NN (2)		NN (3)		NN (4)	
Buyers						
mean: ca&de, $F_{b,\{ca,de\}}$	-0.09	(0.47)	0.95	(2.56)	3.29	(1.89)
mean: ca&de&cr, $F_{b,\{ca,de,cr\}}$	-2.56	(0.76)	-3.70	(0.92)	-0.77	(0.15)
var of $F_{b,\{ca,de\}}$	2.54	(3.30)	14.08	(18.69)	13.62	(11.55)
var of $F_{b,\{ca,de,cr\}}$	6.18	(4.38)	6.37	(2.91)	0.84	(0.09)
var of usage cost, cash			0.00		0.10	(0.02)
var of usage cost, debit	0.27	(0.01)	0.34	(0.02)	0.37	(0.02)
var of usage cost, credit			0.13	(0.02)	0.00	(0.02)
Sellers						
mean: ca&de, $F_{s,\{ca,de\}}$	-0.21	(0.04)	0.21	(0.07)	0.09	(0.06)
mean: ca&de&cr, $F_{s,\{ca,de,cr\}}$	-6.07	(0.16)	-5.94	(0.09)	-6.09	(0.10)
var of $F_{s,\{ca,de\}}$	1.86	(0.38)	2.76	(0.78)	2.76	(0.71)
var of $F_{s,\{ca,de,cr\}}$	27.43	(3.18)	14.77	(1.16)	14.33	(1.18)
F-value	-12,634.76		-12,525.05		-12,460.51	

Elasticities: increase in buyer usage costs

Table 2: Consumer and merchant response to increased buyer usage costs

	$\partial C_{b,cash}$	$\partial C_{b,debit}$	$\partial C_{b,credit}$
$\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_b = \{ca\})/\cdots$	-1.701	1.062	0.219
$\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_b = \{ca, de\})/\cdots$	-0.206	-0.171	0.060
$\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_b = \{ca, de, cr\})/\cdots$	0.050	0.004	-0.010
$\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_s = \{ca\})/\cdots$	0.234	0.290	-0.081
$\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_s = \{ca, de\})/\cdots$	0.622	0.672	-0.205
$\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_s = \{ca, de, cr\}/\cdots)$	-0.216	-0.239	0.072

Notes: Each element of the matrix illustrate elasticity of the variable defined in the first column with respect to a variable defined in the first row. For the merchant acceptance probabilities, we compute elasticity using

$$\mathcal{E}_{\mathrm{Pr}(\mathcal{M}_s = x), C_{b,m}} \equiv \left[\sum_{y \in \mathcal{M}} \frac{\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_s = x)}{\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_b = y)} \times \frac{\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_b = y)}{\partial C_{b,m}} \right] \times \frac{C_{b,m}}{\mathbb{E}\,\mathrm{Pr}(\mathcal{M}_s = x)} \;\forall m, \mathcal{M}_s,$$

where the change in $\mathrm{Pr}(\mathcal{M}_b)$ is induced by an increase in buyer usage costs.

Elasticities: increase in seller usage costs

Table 3: Consumer and merchant response to increased merchant usage costs

	$\partial C_{s,cash}$	$\partial C_{s,debit}$	$\partial C_{s,credit}$
$\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_s = \{ca\})/\cdots$	-1.151	0.670	1.101
$\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_s = \{ca, de\})/\cdots$	-0.296	-0.521	2.171
$\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_s = \{ca, de, cr\}/\cdots)$	0.270	0.041	-0.799
$\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_b = \{ca\})/\cdots$	-0.458	0.078	0.991
$\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_b = \{ca, de\})/\cdots$	-0.081	-0.010	0.241
$\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_b = \{ca, de, cr\})/\cdots$	0.017	-0.000	-0.044

Notes: Each element of the matrix illustrate elasticity of the variable defined in the first column with respect to a variable defined in the first row. For the consumer adoption probabilities, we compute elasticity using

$$\mathcal{E}_{\mathrm{Pr}(\mathcal{M}_b = x), C_{s,m}} \equiv \left[\sum_{y \in \mathcal{M}} \frac{\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_b = x)}{\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_s = y)} \times \frac{\partial \mathbb{E}\,\mathrm{Pr}(\mathcal{M}_s = y)}{\partial C_{s,m}} \right] \times \frac{C_{s,m}}{\mathbb{E}\,\mathrm{Pr}(\mathcal{M}_b = x)} \ \forall m, \mathcal{M}_b,$$

where the change in $\mathrm{Pr}(\mathcal{M}_s)$ is induced by an increase in seller usage costs.

Elasticities: increase in adoption costs

Table 4: Consumer and merchant response to increase in consumer adoption costs

	$\partial F_{b,\{ca,de\}}$	$\partial F_{b,\{ca,de,cr\}}$
$\partial\,\Pr(\mathcal{M}_b = \{ca\})/\ldots$	0.34	1.85
$\partial\,\Pr(\mathcal{M}_b = \{ca, de\})/\ldots$	-1.49	0.34
$\partial\,\Pr(\mathcal{M}_b = \{ca, de, cr\})/\ldots$	0.17	-0.07
$\partial\,\Pr(\mathcal{M}_s = \{ca\})/\ldots$	0.14	-0.05
$\partial\,\Pr(\mathcal{M}_s = \{ca, de\})/\ldots$	0.35	-0.11
$\partial\,\Pr(\mathcal{M}_s = \{ca, de, cr\})/\ldots$	-0.12	0.04

Table 5: Consumer and merchant response to increase in merchant acceptance costs

	$\partial F_{s,\{ca,de\}}$	$\partial F_{s,\{ca,de,cr\}}$
$\partial\,\Pr(\mathcal{M}_s = \{ca\})/\ldots$	0.03	1.23
$\partial\,\Pr(\mathcal{M}_s = \{ca, de\})/\ldots$	-0.06	2.42
$\partial\,\Pr(\mathcal{M}_s = \{ca, de, cr\})/\ldots$	0.01	-0.89
$\partial\,\Pr(\mathcal{M}_b = \{ca\})/\ldots$	-0.01	0.02
$\partial\,\Pr(\mathcal{M}_b = \{ca, de\})/\ldots$	-0.00	0.00
$\partial\,\Pr(\mathcal{M}_b = \{ca, de, cr\})/\ldots$	0.00	-0.00